Plastic pollution

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Plastic pollution involves the accumulation of plastic products in the environment that adversely affects wildlife, wildlife habitat, or humans.[1] Plastics that act as pollutants are categorized into micro-, meso-, or macrodebris, based on size.[2] The prominence of plastic pollution is correlated with plastics being inexpensive and durable, which lends to high levels of plastics used by humans.[3] However, it is slow to degrade.[4] Plastic pollution can unfavorably affect lands, waterways and oceans. Living organisms, particularly marine animals, can also be affected through entanglement, direct ingestion of plastic waste, or through exposure to chemicals within plastics that cause interruptions in biological functions. Humans are also affected by plastic pollution, such as through the disruption of the thyroid hormone axis or hormone levels. In the UK alone, more than 5 million tonnes of plastic are consumed each year, of which an estimated mere 24% makes it into recycling systems. That leaves a remaining 3.8 million tonnes of waste, destined for landfills.[5][6] Plastic reduction efforts have occurred in some areas in attempts to reduce plastic consumption and pollution and promote plastic recycling.

Plastic waste at Coco Beach in India.

Contents

Types of plastic debris

There are three major forms of plastic that contribute to plastic pollution: microplastics as well as mega- and macro-plastics. Mega- and micro plastics have accumulated in highest densities in the Northern Hemisphere, concentrated around urban centers and water fronts. Plastic can be found off the coast of some islands because of currents carrying the debris. Both mega- and macro-plastics are found in packaging, footwear, and other domestic items that have been washed off of ships or discarded in landfills. Fishing-related items are more likely to be found around remote islands.[7] These may also be referred to as micro-, meso-, and macro debris.

Plastic debris is categorized as either primary or secondary. Primary plastics are in their original form when collected. Examples of these would be bottle caps, cigarette butts, and microbeads. Secondary plastics, on the other hand, account for smaller plastics that have resulted from the degradation of primary plastics.[8]

Microdebris

Microdebris are plastic pieces between 2 μm and 5 mm in size.[7] Plastic debris that starts off as meso- or macrodebris can become microdebris through degradation and collisions that break it down into smaller pieces.[2] Microdebris is more commonly referred to as nurdles.[2] Nurdles are recycled to make new plastic items, but they easily end up released into the environment during production because of their small size. They often end up in ocean waters through rivers and streams.[2] Microdebris that come from cleaning and cosmetic products are also referred to as scrubbers. Because microdebris and scrubbers are so small in size, filter-feeding organisms often consume them.[2] A 2004 study by Richard Thompson from the University of Plymouth, UK, found a great amount of microdebris on the beaches and waters in Europe, the Americas, Australia, Africa, and Antarctica.[4] Thompson and his associates found that plastic pellets from both domestic and industrial sources were being broken down into much smaller plastic pieces, some having a diameter smaller than human hair.[4] If not ingested, this microdebris floats instead of being absorbed into the marine environment. Thompson predicts there may be 300,000 plastic items/km^2 of sea surface and 100,000 plastic particles/km^2 of seabed.[4]

Macrodebris

Plastic debris is categorized as macrodebris when it is larger than 20 mm. These include items such as plastic grocery bags.[2] Macrodebris are often found in ocean waters, and can have a serious impact on the native organisms. Fishing nets have been prime pollutants. Even after they have been abandoned, they continue to trap marine organisms and other plastic debris. Eventually, these abandoned nets become too difficult to remove from the water because they become too heavy, having grown in weight up to 6 tons.[2]

Decomposition of plastics

Plastics themselves contribute to approximately 10% of discarded waste. Many kinds of plastics exist depending on their precursors and the method for their polymerization. Depending on their chemical composition, plastics and resins have varying properties related to contaminant absorption and adsorption. Polymer degradation takes much longer as a result of haline environments and the cooling effect of the sea. These factors contribute to the persistence of plastic debris in certain environments.[7] Recent studies have shown that plastics in the ocean decompose faster than was once thought, due to exposure to sun, rain, and other environmental conditions, resulting in the release of toxic chemicals such as bisphenol A. However, due to the increased volume of plastics in the ocean, decomposition is slowed down.[9] The Marine Conservancy has predicted the decomposition rates of several plastic products. It is estimated that a foam plastic cup will take 50 years, a plastic beverage holder will take 400 years, disposable diaper will take 450 years, and fishing line will take 600 years to degrade.[4]

Persistent organic pollutants

It is estimated that global production of plastics is approximately 225 mt/yr. Their abundance has been found to transport persistent organic pollutants, also known as POPs. These pollutants have been linked to an increased distribution of algae associated with red tides.[7]

Effects on the environment

The distribution of plastic debris is highly variable as a result of certain factors such as wind and ocean currents, coastline geography, urban areas, and trade routes. Human population in certain areas also plays a large role in this. Plastics are more likely to be found in enclosed regions such as the Caribbean. Plastic pollution, more so in the forms of macro- and mega-plastics, potentially serves as a means of distribution of organisms to remote coasts that are not their native environments. This could potentially increase the variability and dispersal of organisms in specific areas that are less biologically diverse. Plastics can also be used as vectors for chemical contaminants such as persistent organic pollutants and heavy metals.[7]

Land

Chlorinated plastic can release harmful chemicals into the surrounding soil, which can then seep into groundwater or other surrounding water sources and also the ecosystem. [10] This can cause serious harm to the species that drink the water.

Landfill areas contain many different types of plastics. In these landfills, there are many microorganisms which speed up the biodegradation of plastics. The microorganisms include bacteria such as Pseudomonas, nylon-eating bacteria, and Flavobacteria. These bacteria break down nylon through the activity of the nylonase enzyme. When biodegradable plastics are broken down, methane is released, which is a very powerful

greenhouse gas that contributes significantly to global warming.[11]

Ocean

In 2012, it was estimated that there was approximately 165 million tons of plastic pollution in the world's oceans.[12] One type of plastic that is of concern in terms of ocean plastic pollution is nurdles. Nurdles are manufactured plastic pellets (a type of microplastic) used in the creation of plastic products and are often shipped via cargo ship.[13] A significant amount of nurdles is spilled into oceans, and it has been estimated that globally, around 10% of beach litter consists of nurdles.[13] Plastics in oceans typically degrade within a year, but not entirely. In the process, toxic chemicals such as bisphenol A and polystyrene can leach into waters from some plastics.[12] Polystyrene pieces and nurdles are the most common types of plastic pollution in oceans, and combined with plastic bags and food containers make up the majority of oceanic debris.[14]

One study estimated that there are more than 5 trillion plastic pieces (defined into the four classes of small microplastics, large microplastics, meso- and macroplastics) afloat at sea.[15]

The litter that is being delivered into the oceans is toxic to marine life, and humans. The toxins that are components of plastic include Diethylhexyl phthalate, which is a toxic carcinogen, as well as lead, cadmium and mercury (Andrews 2012).

Plankton, fish and ultimately the human race through the food chain, ingest these highly toxic carcinogens and chemicals. Consuming the fish that contain these toxins can cause an increase in cancer, immune disorders and birth defects.

The majority of the litter near and in the ocean is made up of plastics. According to Dr. Marcus Eriksen of 5 Gyres, there are 5.25 trillion particles of plastic pollution that weigh as much as 270,000 tons (2016). This plastic is taken by the ocean currents and accumulates in large vortexes known as gyres. The majority of the gyres become pollution dumps filled with plastic.

Ocean-based sources of ocean plastic pollution

Almost 90% of plastic debris that pollutes ocean water, which translates to 5.6 million tons, comes from ocean-based sources. Merchant ships expel cargo, sewage, used medical equipment, and other types of waste that contain plastic into the ocean. Naval and research vessels also eject waste and military equipment that are deemed unnecessary. Pleasure crafts also release fishing gear and other types of waste. These different ships do not have enough storage space to keep these pollutants on the ship, and thus they are discarded. These plastic items can also accidentally end up in the water through negligent handling. The largest ocean-based source of plastic pollution is discarded fishing gear, responsible for up to 90% of plastic debris in some areas. This equipment includes a variety of traps and nets.[2]

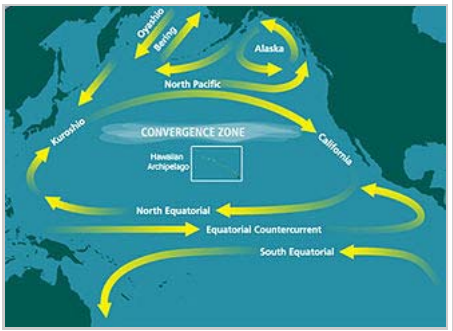
Land-based sources of ocean plastic pollution

A little over 10% of plastic debris in ocean water comes from land-based sources, responsible for 0.8 million tons every year.[2] A source that has caused concern is landfills. Most waste in the form of plastic in landfills are single-use items such as packaging. Discarding plastics this way leads to accumulation.[7] Although disposing of plastic waste in landfills has less of a gas emission risk than disposal through incineration, the former has space limitations. Another concern is that the liners acting as protective layers between the landfill and environment can break, thus leaking toxins and contaminating the nearby soil and water.[16] Landfills

located near oceans often contribute to ocean debris because content is easily swept up and transported to the sea by wind or small waterways like rivers and streams. Marine debris can also result from sewage water that has not been efficiently treated, which is eventually transported to the ocean through rivers. Plastic items that have been improperly discarded can also be carried to oceans through storm waters.[2]

Plastic pollution in the Pacific Gyre

In the Pacific Gyre, specifically 20°N-40°N latitude, large bodies with floating marine debris can be found.[17] Models of wind patterns and ocean currents indicate that the plastic waste in the northern Pacific is particularly dense where the Subtropical Convergence Zone (STCZ), 23°N-37°N latitude, meets a southwest-northeast line, found north of the Hawaiian archipelago.[17]



North Pacific Subtropical Convergence Zone

In the Pacific, there are two mass buildups: the western garbage patch and the eastern garbage patch, the former off the coast of Japan and the latter between Hawaii and California. The two garbage patches are both part of the great Pacific garbage patch, and are connected through a section of plastic debris off the northern coast of the Hawaiian islands. It is approximated that these garbage patches contain 100 million tons of debris.[17] The waste is not compact, and although most of it is near the surface of the pacific, it can be found up to more than 100 feet deep in the water.[17]

Effects on animals

Plastic pollution has the potential to poison animals, which can then adversely affect human food supplies.[18][19] Plastic pollution has been described as being highly detrimental to large marine mammals, described in the book *Introduction to Marine Biology* as posing the "single greatest threat" to them.[20] Some marine species, such as sea turtles, have been found to contain large proportions of plastics in their stomach.[18] When this occurs, the animal typically starves, because the plastic blocks the animal's digestive tract.which block the passage of air and kill them[18] Marine mammals sometimes become entangled in plastic products such as nets, which can harm or kill them.[18]

Entanglement

Entanglement in plastic debris has been responsible for the deaths of many marine organisms, such as fish, seals, turtles, and birds. These animals get caught in the debris and end up suffocating or drowning. Because they are unable to untangle themselves, they also die from starvation or from their inability to escape predators.[2] Being entangled also often results in severe lacerations and ulcers. In a 2006 report known as *Plastic Debris in the World's Oceans*, it was estimated that at least 267 different animal species have suffered from entanglement and ingestion of plastic debris.[4] It has been estimated that over 400,000 marine mammals perish annually due to plastic pollution in oceans.[18] Marine organisms get caught in discarded fishing equipment, such as ghost nets. Ropes and nets used to fish are often made of synthetic materials such as nylon, making fishing equipment more durable and buoyant. These organisms can also get caught in circular plastic packaging materials, and if the animal continues to grow in size, the plastic can cut into their flesh. Equipment such as nets can also drag along the seabed, causing damage to coral reefs.[21]

Ingestion


Sea turtle entangled in a ghost net

Marine animals

Sea turtles are affected by plastic pollution. Some species are consumers of jelly fish, but often mistake plastic bags for their natural prey. This plastic debris can kill the sea turtle by obstructing the esophagus.[21] So too are whales; large amounts of plastics have been found in the stomachs of beached whales[21]

Some of the tiniest bits of plastic are being consumed by small fish, in a part of the pelagic zone in the ocean called the *Mesopelagic zone*, which is 200 to 1000 metres below the ocean surface, and completely dark. Not much is known about these fish, other than that there are many of them. They hide in the darkness of the ocean, avoiding predators and then swimming to the ocean's surface at night to feed.[22] Plastics found in the stomachs of these fish were collected during *Malaspina's circumnavigation*, a research project that studies the impact of global change on the oceans.[23] The most popular mesopelagic fish is the lantern fish. It resides in the central ocean gyres, a large system of rotating ocean currents. Since lantern fish serve as a primary food source for the fish that consumers purchase, including tuna and swordfish, the plastics they ingest become part of the food chain. The lantern fish is one of the main bait fish in the ocean, and it eats large amounts of plastic fragments, which in turn will not make them nutritious enough for other fish to consume.[24]

Birds

Plastic pollution does not only affect animals that live solely in oceans. Seabirds are also greatly affected. In 2004, it was estimated that seagulls in the North Sea had an average of thirty pieces of plastic in their stomachs.[25] Seabird's often mistake trash floating on the ocean's surface as prey. Their food sources often has already ingested plastic debris, thus transferring the plastic from prey to predator. Ingested trash can obstruct and physically damage a bird’s digestive system, reducing its digestive ability and can lead to malnutrition, starvation, and death. Toxic chemicals called *polychlorinated biphenyls* (PCBs) also become concentrated on the surface of plastics at sea and are released after seabirds eat them. These chemicals can accumulate in body tissues and have serious lethal effects on a bird's reproductive ability, immune system, and hormone balance. Floating plastic debris can produce ulcers, infections and lead to death. Marine plastic pollution can even reach birds that have never been at the sea. Parents may accidentally feed their nestlings plastic, mistaking it for food.[26] Seabird chicks are the most vulnerable to plastic ingestion since they can't regurgitate like the adult seabirds.[27]

After the initial observation that many of the beaches in New Zealand had high concentrations of plastic pellets, further studies found that different species of prion ingest the plastic debris. Hungry prions mistook these pellets for food, and these particles were found intact within the birds' gizzards and proventriculi. Pecking marks similar to those made by northern fulmars in cuttlebones have been found in plastic debris, such as styrofoam, on the beaches on the Dutch coast, showing that this species of bird also mistakes plastic debris for food.[21]

An estimate of 1.5 million Laysan albatrosses, which inhabit Midway Atoll, all have plastics in their digestive

system. Midway Atoll is halfway between Asia and North America, and north of the Hawaiian archipelago. It's a remote location, and the plastic blockage has proven deadly to these birds. These seabirds choose red, pink, brown and blue plastic pieces because of the similarities they share with their natural food source. On the shore, thousands of birds corpses can be seen with plastic remaining where the stomach once was. The durability of the plastics is visible amongst the remains. In some instances, the plastic piles are still present while the bird's corpse has decayed.[4] As a result of plastic ingestion, the digestive tract can be blocked resulting in starvation. The windpipe can also be blocked, which results in suffocation.[4] The debris can also accumulate in the animal's gut, and give them a false sense of fullness which would also result in starvation.

Effects on animals

Similar to humans, animals exposed to plasticizers can experience developmental defects. Specifically, sheep have been found to have lower birth weights when prenatally exposed to bisphenol A. Exposure to BPA can shorten the distance between the eyes of a tadpole. It can also stall development in frogs and can result in a decrease in body length. In different species of fish, exposure can stall egg hatching and result in a decrease in body weight, tail length, and body length. [6]

Effects on humans

Due to the use of chemical additives during plastic production, plastics have potentially harmful effects that could prove to be carcinogenic or promote endocrine disruption. Some of the additives are used as phthalate plasticizers and brominated flame retardants.[7] Through biomonitoring, chemicals in plastics, such as BPA and phthalates, have been identified in the human population. Humans can be exposed to these chemicals through the nose, mouth, or skin. Although the level of exposure varies depending on age and geography, most humans experience simultaneous exposure to many of these chemicals. Average levels of daily exposure are below the levels deemed to be safe, but more research needs to be done on the effects of low dose exposure on humans.[28] A lot is unknown on how severely humans are physically affected by these chemicals. Some of the chemicals used in plastic production can cause dermatitis upon contact with human skin.[29] In many plastics, these toxic chemicals are only used in trace amounts, but significant testing is often required to ensure that the toxic elements are contained within the plastic by inert material or polymer.[29]

It can also affect humans in which it may create an eyesore that interferes with enjoyment of the natural environment.[30]

Clinical significance

Due to the pervasiveness of plastic products, most of the human population is constantly exposed to the chemical components of plastics. 95% of adults in the United States have had detectable levels of BPA in their urine. Exposure to chemicals such as BPA have been correlated with disruptions in fertility, reproduction, sexual maturation, and other health effects.[16] Specific phthalates have also resulted in similar biological effects.

Thyroid hormone axis

Bisphenol A affects gene expression related to the thyroid hormone axis, which affects biological functions such as metabolism and development. BPA can decrease thyroid hormone receptor (TR) activity by increasing TR transcriptional corepressor activity. This then decreases the level of thyroid hormone binding proteins that

bind to triiodothyronine. By affecting the thyroid hormone axis, BPA expoure can lead to hypothyroidism.[6]

Sex hormones

BPA can disrupt normal, physiological levels of sex hormones. It does this by binding to globulins that normally bind to sex hormones such as androgens and estrogens, leading to the disruption of the balance between the two. BPA can also affect the metabolism or the catabolism of sex hormones. It often acts as an antiandrogen or as an estrogen, which can cause disruptions in gonadal development and sperm production.[6]

Reduction efforts

Efforts to reduce the use of plastics and to promote plastic recycling have occurred. Some supermarkets charge their customers for plastic bags, and in some places more efficient reusable or biodegradable materials are being used in place of plastics. Some communities and businesses have put a ban on some commonly used plastic items, such as bottled water and plastic bags.[31]

Household items made of various types of plastic.

Biodegradable and degradable plastics

The use of biodegradable plastics has been shown to have many advantages and disadvantages. Biodegradables are biopolymers that degrade in industrial composters. Biodegradables do not degrade as efficiently in domestic composters, and during this slower process, methane gas may be emitted.[28]

There are also other types of degradable materials that are not considered to be biopolymers, because they are oil-based, similar to other conventional plastics. These plastics are made to be more degradable through the use of different additives, which help them degrade when exposed to UV rays or other physical stressors.[28] However, biodegradation-promoting additives for polymers have been shown not to significantly increase biodegradation.[32]

Although biodegradable and degradable plastics have helped reduce plastic pollution, there are some drawbacks. One issue concerning both types of plastics is that they do not break down very efficiently in natural environments. There, degradable plastics that are oil-based may break down into smaller fractions, at which point they do not degrade further.[28]

Incineration

Up to 60% of used, plastic medical equipment is incinerated rather than deposited in a landfill as a precautionary measure to lessen the transmission of disease. This has allowed for a large decrease in the amount of plastic waste that stems from medical equipment. If plastic waste is not incinerated and disposed of properly, a harmful amount of toxins can be released and dispersed as a gas through air or as ash through air and waterways.[16] Many studies have been done concerning the gaseous emissions that result from the incineration process.

Policy

Agencies such as the Environmental Protection Agency and the Food and Drug Administration often do not assess the safety of new chemicals until after a negative side effect is shown. Once they suspect a chemical may be toxic, it is studied to determine the human reference dose, which is determined to be the lowest observable adverse effect level. During these studies, a high dose is tested to see if it causes any adverse health effects, and if it does not, lower doses are considered to be safe as well. This does not take into account the fact that with some chemicals found in plastics, such as BPA, lower doses can have a discernible effect.[33] Even with this often complicated evaluation process, policies have been put into place in order to help alleviate plastic pollution and its effects. Government regulations have been implemented that ban some chemicals from being used in specific plastic products. In Canada, the United States, and the European Union, BPA has been banned from being incorporated in the production of baby bottles and children's cups, due to health concerns and the higher vulnerability of younger children to the effects of BPA.[16] Taxes have been established in order to discourage specific ways of managing plastic waste. The landfill tax, for example, creates an incentive to choose to recycle plastics rather than contain them in landfills, by making the latter more expensive.[28] There has also been a standardization of the types of plastics that can be considered compostable.[28] The European Norm EN 13432, which was set by the European Committee for Standardization (CEN), lists the standards that plastics must meet, in terms of compostability and biodegradability, in order to officially be labeled as compostable.[28][34]

Institutional Arrangements in Canada

The Canadian federal government formed a current institution that protects marine areas; this includes the mitigation of plastic pollution. In 1997, Canada adopted legislation for oceans management and passed the Oceans Act.[35] Federal governance, Regional Governance, and Aboriginal Peoples are the actors involved in the process of decision-making and implementation of the decision. The Regional Governance bodies are federal, provincial, and territorial government agencies that hold responsibilities of the marine environment. Aboriginal Peoples in Canada have treaty and non-treaty rights related to ocean activities. According to the Canadian government, they respect these rights and work with Aboriginal groups in oceans management activities.[35]

With the Oceans Act made legal, Canada made a commitment to conserve and protect the oceans. The Ocean Acts' underlying principle is sustainable development, precautionary and integrated management approach to ensure that there is a comprehensive understanding in protecting marine areas. In the integrated management approach, the Oceans Act designates federal responsibility to the Minister of Fisheries and Oceans Canada for any new and emerging ocean-related activities.[35] The Act encourages collaboration and coordination within the government that unifies interested parties. Moreover, the Oceans Act engages any Canadians who are interested in being informed of the decision-making regarding ocean environment.

In 2005, federal organizations developed the Federal Marine Protected Areas Strategy.[35] This strategy is a collaborative approach implemented by Fisheries and Oceans Canada, Parks Canada, and Environment Canada to plan and manage federal marine protected areas. The federal marine protected areas work with Aboriginal groups, industries, academia, environmental groups, and NGOs to strengthen marine protected areas. The federal marine protected areas network consists of three core programs: Marine Protected Areas, Marine Wildlife Areas, and National Marine Conservation Areas.[35] The MPA is a program to be noted because it is significant in protecting ecosystems from the effects of industrial activities. The MPA guiding principles are Integrated Management, Ecosystem-Based Management approach, Adaptive Management Approach, Precautionary Principle, and Flexible Management Approach.[35] All five guiding principles are used collectively and simultaneously to collaborate and respect legislative mandates of individual departments, to use scientific knowledge and traditional ecological knowledge (TEK) to manage human activities, to monitor

and report on programs to meet conservation objectives of MPAs, to use best available information in the absence of scientific certainty, and to maintain a balance between conservation needs and sustainable development objectives.[35]

Collection

The two common forms of waste collection include curbside collection and the use of drop-off recycling centers. About 87 percent of the population in the U.S.A. (273 million people) have access to curbside and drop-off recycling centers. In curbside collection, which is available to about 63 percent of the U.S.A. population (193 million people), people place designated plastics in a special bin to be picked up by a public or private hauling company.[36] Most curbside programs collect more than one type of plastic resin; usually both PETE and HDPE.[37] At drop-off recycling centers, which are available to 68 percent of the U.S.A. population (213 million people), people take their recyclables to a centrally located facility.[36] Once collected, the plastics are delivered to a materials recovery facility (MRF) or handler for sorting into single-resin streams to increase product value. The sorted plastics are then baled to reduce shipping costs to reclaimers.[37]

There are varying rates of recycling per type of plastic, and in 2011, the overall plastic recycling rate was approximately 8% in the United States.[38] Approximately 2.7 million tons of plastics were recycled in the U.S. in 2011.[38] Some plastics are recycled more than others; in 2011 "29 percent of HDPE bottles and 29 percent of PET bottles and jars were recycled."[38]

Non-Usage/ Reduction in Usage

The Ministry of Drinking Water and Sanitation, Government of India, has requested various governmental departments to avoid the usage of plastic bottles to provide drinking water during governmental meetings etc., and instead, to make arrangements for providing drinking water that do not result in the generation of plastic waste.[39][40][41] The state of Sikkim has restricted the usage of plastic water bottles (in government functions and meetings) and styrofoam products.[42] The state of Bihar has banned the usage of plastic water bottles in governmental meetings.[43] The 2015 National Games of India, organised in Thiruvananthapuram, was associated with green protocols.[44] This was initiated by Suchitwa Mission that aimed for "zero-waste" venues. To make the event "disposable-free", there was ban on the usage of disposable water bottles.[45] The event witnessed the usage of reusable tableware and stainless steel tumblers.[46] Athletes were provided with refillable steel flasks.[47] It is estimated that these green practices stopped the generation of 120 metric tonnes of disposable waste.[48]

Action for creating awareness

On April 11, 2013 in order to create awareness, artist Maria Cristina Finucci founded The Garbage patch state at UNESCO[49] –Paris in front of Director General Irina Bokova . First of a series of events under the patronage of UNESCO and of Italian Ministry of the Environment.[50]

See also

- Great Pacific garbage patch, an area of exceptionally high concentrations of pelagic plastics, chemical sludge and other debris

    - The Ocean Cleanup
- Microplastics
- Plastic particle water pollution
- Plasticulture
- Plastiglomerate
- Plastisphere

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