公　開
資料２
（別冊）

Recommendation

The pollution of water environment by microplastics
The Need for Ecological and Health Effects
Research and the Governance of Plastics

April 7, 2020

Science Council of Japan
Joint Committee on Health / Human Life Science and Committee on
Ecology and Environmental Science
Environmental Risk Subcommittee

The original was written in Japanese and SCJ provides English version for non-Japanese readers.

This proposal summarizes and publishes the results of deliberations by the Joint Subcommittee on Environmental Risks of the Committee on Health / Human Life Science and the Committee on Ecology and Environmental Science of the Science Council of Japan.

Joint Subcommittee on Environmental Risk, Committee on Health / Human Life Science and Committee on Ecology and Environmental Science, Science Council of Japan

committee chairman	Tamie Nasu	(Member)	Specially Appointed Professor, College of Life and Health Sciences, Chubu University/ Professor Emeritus,, Nagoya University
vice chairman	Keiko Nakamura	(Member)	Professor, Graduate School of International Health and Medical Business Development, Tokyo Medical and Dental University
manager	Akihiko Kondo	(Member)	Professor, Research Center for Environmental Sensing, Chiba University
manager	Keikoh Nohara	(Member)	Fellow, Environmental Risk and Health Research Center, National Institute for Environmental Studies (NIES)
	Suminori Akiba	(Section Ⅱ Council Member)	Specially Appointed Professor, Hirosaki University / Professor Emeritus, Kagoshima University
	Mayumi Ishizuka	(Section Ⅱ Council Member)	Professor, Graduate School of Veterinary Medicine, Hokkaido University
	Mari Asami	(Section Ⅲ Council Member)	Senior Chief Researcher, Living Environment Research Department, National Institute of Health Sciences
	Keiko Aoshima	(Member)	President of Medical Corporation keiwa-kai, Director of Hagino Hospital
	Tadashi Otsuka	(Member)	Professor, Faculty of Law, Waseda University
	Teruhisa Tsuzuki	(Member)	Professor Emeritus, Kyushu University
	Shigeki Masunaga	(Member)	Professor Emeritus, Yokohama National University
	Katsutaka Murata	(Member)	Professor Emeritus, Akita University
	Chiho Watanabe	(Member)	President, National Institute for Environmental Studies (NIES); Professor Emeritus, University of Tokyo

We would like to express our gratitude to the following people for their cooperation in preparing this proposal and reference materials.

Hideshige Takada	Professor, Department of Environmental and Resource Sciences, Faculty of Agriculture, Tokyo University of Agriculture and Technology
Atsushi	Deputy Director, Resource Recycling and Waste Research Center, National

	Terazono	Institute for Environmental Studies (NIES)

The following staff members were responsible for the administrative work in preparing this proposal.

business	Takashi Inuzuka	Director for Scientific Affairs Ⅱ
	Kurumi Igarashi	Deputy Director for Scientific Affairs Ⅱ
	Marie Yokota	Sub Deliberation Specialist for Scientific AffairsII

Gist

1 Background

Although the ingestion and adverse effects of marine plastics by marine organisms have been reported since the first 1970 decade of the 20th century, two new aspects of marine plastic pollution have emerged since the turn of the 21century. The first is the accumulation of microplastics (plastics smaller than 5 mm) in the ocean surface layer, and their ingestion by marine organisms. The other is that marine microplastics can be carriers of toxic chemicals in marine ecosystems.

Microplastics can be broadly classified into primary microplastics and secondary microplastics. The former are plastics manufactured in the form of particles smaller than 5 mm, such as resin pellets, fertilizer capsules and microbeads in facial cleansers and cosmetics. Secondary microplastics are plastic products released into the environment that have been crushed and shredded by physical forces such as ultraviolet rays, heat, and wind waves, and fibers generated during the washing of synthetic fiber clothes.

2 Current status and problems of marine microplastic pollution

(1) Distribution

The waters surrounding Japan also have high concentrations of microplastics. It is suggested that microplastics are transported from Southeast Asia and southern China by the Kuroshio Current in addition to those discharged from the Japanese archipelago, but quantitative discrimination between the two is a future challenge. Secondary microplastics are more common than primary microplastics along the Japanese coast. Among them, product fragments are more common than fibrous ones. The identification of the product fragments and the rate of fragmentation are essential for effective countermeasures, but little is known about them. In the future, it will be necessary to investigate pollution in Japan's aquatic environment with an eye to understanding secondary microplastic formation and identifying the contribution of chemical fibers. In particular, it has been calculated that the amount of microplastics in sediments is higher than that in seawater. It is necessary to clarify the material dynamics of microplastics by studying the sedimentation rate in sediments, as well as the roll-up and emergence of microplastics from sediments.

(2) Feeding on marine organisms

Laboratory experiments and surveys of captured fish and shellfish have confirmed that a wide variety of organisms (more than 200 species) are currently feeding microplastics. In addition to direct ingestion, microplastic pollution is spreading throughout the ecosystem through transfer through the food chain.

(3) Ecological and health impacts

When considering the ecological effects of microplastics, it is necessary to examine the toxicity of the plastic itself, as well as the toxic effects of additives (plasticizers, UV absorbers, brominated flame retardants, etc.) and the constituent monomers and oligomers. Some additives, such as benzophenones and phthalates, have endocrine disrupting or reproductive toxicity. In addition, nano-sized plastics can pass through cell membranes and damage biological tissues.

In addition to containing additives, microplastics adsorb Persistent Organic Pollutants (POPs), which include substances regulated by the Stockholm Convention, such as hydrophobic DDT. These are sometimes transferred and accumulated in higher trophic organisms such as waterfowl and whales. On the other hand, there have been few studies on the toxic effects of adsorbed and contained toxic substances on living organisms, and no environmental or health risk assessment has been conducted. Rather than assuming that biological effects are not apparent, it is believed that methods for assessing minor effects in the actual environment have not been developed and applied, and that it is necessary to promote surveys and research and take preventive measures.

(4) Microplastics governance of plastics to prevent marine pollution

While the production of plastic products in Japan has remained flat over the past 20years, the production of containers has doubled. Since global production is expected to increase significantly in the future, it is feared that the current situation will lead to more serious pollution of the world's oceans. In response to this situation, the Osaka Blue Ocean Vision, which aims to reduce new ocean pollution caused by plastic to zero by the 2050, was adopted, and the Japanese government has declared its commitment to promote measures against marine plastic litter throughout the world. However, it does not mention what to do with the existing ocean plastic. In Japan, the collection rate of plastic is high, but more than half of the collected plastic is incinerated. Therefore, it is necessary to further strengthen the efforts of the government, industry, and the public to reduce the amount of disposable plastic. At the same time, it is necessary to promote cross-sectoral surveys and basic and epidemiological research to enable risk assessment of the effects of microplastics on ecosystems and human health, and to promote international plastic management based on environmental and health risk assessment of microplastics.

3 Recommendations

In order to achieve the following goals of the Agenda2030 for Sustainable Development (SDGs), the Government of Japan should implement Goal 3 "Health and Welfare for All", Goal 6 "Safe Water and Sanitation for All", Goal 11 "Livable Cities", Goal 12" Responsibility to create and use", Goal 13 "Specifi" measures to combat climate change", Goal 14 "Protect the ocean," and Goal 15 "Protect the land," The following actions should be taken in order to achieve the recommendations

(1) The Government of Japan should urgently investigate the origin of microplastics in the ocean, their dynamics in the aquatic environment, their feeding by marine organisms, and their migration and adverse effects on ecosystems (physical and adverse effects of additives and adsorbed toxic chemicals). At the same time, promote cross-disciplinary basic and epidemiological research on the

toxic effects on organisms and humans and their mechanisms, and hasten the collection of scientific knowledge that will contribute to a comprehensive presentation of scientific findings and to environmental and health risk assessment.

(2) The government should accelerate national, industrial, and citizen efforts to "reduce the total amount of plastic emissions" by reducing the production and use of "disposable plastics.

(3) The government should curb the use of primary microplastics and develop and promptly implement effective methods of collecting marine plastics that are the origin of secondary microplastics.

Table of Contents

1 Introduction

Pollution of the oceans and marine life by marine plastics has been observed since the 1960s [1]. The distribution of plastics in marine surface water and their ingestion by marine organisms such as whales, sea turtles, and seabirds were continuously reported by pioneering researchers throughout the 1970s – 1990s ([2], hereafter references are given only for the major and most recent ones. See Takada and Yamashita [3] for details of references cited). During that time, marine plastic pollution was ongoing. For example, the frequency of plastic ingestion by seabirds increased from the 1970s to the 1990s [2]. However, studies in the second half of the 20th century were still limited.

In the 21st century, marine plastic pollution has taken a new turn on two fronts. The first is the discovery of the so-called "plastic-soup ocean", where microscopic plastic drifts in ocean surface water and accumulates in open ocean gyres [4]. The discovery of the plastic soup itself dates back to the year 1997. , Then, a research showed that even finer plastics of a few hundred μm were present in the sediments of the British coast and that they could be taken up by polychaetes and theropods, i.e., invade the ecosystem [5]. In that paper, Thompson et al. used the term "microscopic plastic" to refer to plastics as small as a few hundred micrometers, which are only visible under a microscope. This later led to the term "microplastics". Another impetus for the term microplastics came from the fact that field adsorption experiments [6] and observations by International Pellet Watch and others have shown that marine plastics are carriers of toxic chemicals in the marine ecosystem. A paper highlighting these new developments was published in *Science* in 2005 [7]. Around that time, there was a great deal of interest from researchers, and in 2008, NOAA held an international workshop in Tacoma, WA, U.S.A., where the definition of microplastics was discussed, and the definition that plastics of 5 mm or less were called microplastics was decided [8]. This definition was inherited by the subsequent UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) [9]. This definition is also followed in this proposal. In addition, although fibers and rubber are excluded from plastics in the Japan Industrial Standards (JIS) definition, this proposal also treats fibers and rubber made of synthetic polymer compounds as plastics, in line with the current international definition of microplastics.

2 Origin of microplastics

The origin of microplastics observed in the marine environment varies, but microplastics can be broadly classified into primary and secondary. Primary microplastics are plastics that were originally manufactured in the form of particles smaller than 5 mm and were used as raw materials for products or blended into products. This category also includes resin pellets (discoid, cylindrical, or spherical plastic grains with a diameter of several millimeters, which are intermediate raw materials for plastic products). Also included in this category are microbeads (plastic scrubs; mainly made of polyethylene) in facial cleansers and cosmetics. After use, the microbeads are transported to sewage treatment plants as domestic wastewater. From observations at sewage treatment plants, it has been reported that more than 99% of the microbeads are removed by going through primary and secondary treatment. In that case, it is considered that the sedimentation and scum treatment have removed them. However, in a combined sewage treatment area, domestic wastewater is not transported to the sewage treatment plant during rainy weather, but is discharged into rivers and the sea along with rainwater from drainage and pumping stations. In this way, it is thought that microbeads are transported to the sea by overflow during rainy weather. However, the amount of microbeads released into public waters by overflow during rain has not been quantitatively determined. In addition, plastic capsules that encase air fresheners in some synthetic laundry detergents and shell-shaped plastics that coat fertilizers in agriculture are also supplied to bodies of water during rainy weather, but their loads and dynamics are largely unknown. The bottleneck lies in the lack of understanding of the actual pollution load itself during rainy weather. Since microbeads have been observed in the coastal areas of Japan, it is necessary to quantitatively understand the amount of microbeads entering the ocean.

Secondary microplastics are plastic products that have entered the ocean after use and have been crushed into small pieces by physical forces such as ultraviolet light, heat, and wind waves. On the Japanese coast, debris from plastic products is considered to be the main source of microplastics [10], but little is known quantitatively, such as the identification of the products that created the debris and the rate of debris formation. The identification of the plastic products from which the debris originates is an essential issue for effective countermeasures. There is a need to develop a scientific approach to link debris to products. The category of secondary microplastics also includes polyester and acrylic fibers that are generated when synthetic clothing is washed. It has been reported that chemical fibers account for a high percentage of microplastics detected in bodies of water in Europe, the United States, Canada, and China, but their contribution is considered to be small in the Japanese aquatic environment [10]. However, since there are only a few examples of investigations of the Japanese aquatic environment, future investigations should be conducted with the identification of the contribution of chemical fibers in mind. Also, sponges used for washing dishes become microplastics when they are worn out.

3 Distribution of microplastics

The global spread of plastic pollution has been revealed in the Arctic, sub-Antarctic and Antarctic regions, as well as on the deep sea floor. It has been revealed that there are accumulation areas in the eastern Mediterranean Sea, the southern coast of Eurasia, and near the center of the ring currents in the North and South Pacific, South and North Atlantic, and Indian Oceans. The marine waters around Japan have also been found to have high concentrations of microplastics [11]. It has been suggested that a large amount of microplastics is discharged from the Japanese islands and transported from Southeast Asia and southern China by the Kuroshio Current, but quantitative discrimination between the two is an issue for the future. A model based on marine observations estimated the amount of plastic floating in the entire ocean to be 270,000 tons [12]. This amount is far less than the estimated amount of plastics entering from land (4,800,000 to 12,600,000 tons per year, an average 8,000,000 tons) [13]. This gap can be attributed to several factors, the first of which is the lack of measurement of microscopic microplastics. Since Newton nets (330 μm mesh for zooplankton) are usually used to measure microplastics in the ocean, only the plastics larger than 330 μm are measured as microplastics in most monitoring. Although there are some reports of actual measurements of plastics smaller than 330 μm, the number of such reports are still limited. The majority of microplastics floating in the ocean are polyethylene and polypropylene, which are lighter than seawater. On the other hand, polystyrene, PET (polyethylene terephthalate), and polyvinyl chloride have densities greater than seawater and accumulate in marine sediments. PET bottles sinking to the bottom of the deep sea in the Mediterranean Sea are well-known examples [14]. Polymers with large densities are deposited on the seafloor as microplastics as well as large plastic fragments [15]. In addition, polyethylene and polypropylene microplastics have also been detected in coastal sediments and on the deep sea floor. The density of polyethylene and polypropylene is lower than that of seawater, so they basically float on the water, but it has been pointed out that organisms may adhere to the surface of the plastic, thereby increasing its sinking power and causing it to settle and accumulate on the seafloor [16]. Along with polyester and polystyrene, microplastics made of polyethylene and polypropylene, which are less dense than water, have been detected in the sediments of Tokyo Bay [15]. In particular, the amount of microplastics per unit area in sediments was calculated to be four orders of magnitude higher than the amount of microplastics in seawater [15]. There is a need to visualize the material dynamics of microplastics by studying their sedimentation rates and also their entrainment and emergence from sediments.

4 Uptake of microplastics by marine organisms

Plastic is taken up by a variety of organisms depending on its size. As of 1997, plastic feeding by marine organisms of 177 species had been reported [17], it is now believed that more than 200 species are feeding on plastic. Plastics ranging from mm to cm in size have been detected in the digestive organs of whales, sea turtles, seabirds, and fish. The accumulation of μm-sized microplastics has been demonstrated in relatively low trophic level organisms such as bivalves and crabs in laboratory experiments and also observed in bivalves in the field. Microplastics have also been detected in the digestive tracts of fish. The detection of microplastics in fish and shellfish has been reported even in those purchased in the market, and has become a major concern for food safety. In Europe and the United States, chemical fibers are reported to account for a large percentage of the microplastics found in fish and shellfish, but in Japan, the percentage of chemical fibers is small, and most of them are fragments of products. However, since polyester has a large density and has been detected in sediments [15], it is necessary to survey a wide variety of fish and shellfish, including benthic fish, in multiple water bodies, taking into account their foraging sites and foraging behavior. In addition, feeding of smaller microplastics by zooplankton such as Daphnia magna and theropods has been confirmed by laboratory experiments and observations in actual marine environments. The transfer of microplastics taken up by these lower trophic level organisms to higher trophic level organisms through the food chain has also been confirmed in laboratory experiments. In addition to direct feeding, migration through the food chain has spread plastic pollution throughout the ecosystem. However, whether these microplastics are being biomagnified through the food chain, that is, whether the amount ingested exceeds the amount excreted, is a subject for future research.

5 Effects of microplastics on living organisms - effects of toxic chemicals

(1) Physical effects

The effects on living organisms are considered from two aspects. One is the effect of the microplastics themselves as physical foreign matter (particle toxicity), and the other is the effect of chemical substances contained in or adsorbed on the microplastics. In reality, these two aspects are considered to be acting simultaneously. For large organisms, physiological effects have been observed due to the physical effects of the relatively large plastics they ingest [19]. As for the particle toxicity of fine plastics (microplastics), a number of laboratory experiments have been conducted since about 2015, and it has been reported that exposure to polystyrene microparticles reduced the reproductive capacity of oysters [20] and induced antioxidant enzymes in rotifers [21]. The results of laboratory experiments on their particle toxicity have been reviewed and thresholds have also been reported [22]. The exposed microplastic concentrations in many laboratory experiments are an order of magnitude higher than the actual microplastic concentrations observed in the environment [23], and it has been reported that at current pollution levels, the area where particle toxicity is occurring is limited [24, 25].

However, when interpreting the results of laboratory experiments on the biological effects of microplastics, it is necessary to consider the effects of the additives and monomers and oligomers that make up the plastic, as discussed below, along with the particle toxicity of the plastic itself. In the case of the decrease in oyster reproduction capacity due to exposure to polystyrene particles described above [20], it is necessary to consider the effects of the additives and styrene monomers and dimers as well as the effects of the particles themselves. In fact, it has been reported that administration of styrene trimers to mice elevates thyroid hormones [26]. In addition, bisphenol A (BPA), which is a raw material for polycarbonate and epoxy resins and is also used as an additive in other polymers, inhibits the expression of steroid synthase and cholesterol transport protein in rat testis and lowers plasma testosterone and luteinizing hormone. These effects are similar to those of estradiol (E2). Microscopically, BPA and E2 reduced testicular Leydig cells and decreased estrogen receptor mRNA expression [27]. Furthermore, it has been suggested that nano-sized (20 nm) plastics can pass through cell membranes and cause damage to biological tissues, albeit at the level of laboratory experiments [28]. The penetration of nano-sized plastics through cell membranes is an important aspect when considering their effects on humans. However, there are few measured examples of nano-sized plastics in the environment. The reason is that nano-sized particles are in the issue of colloidal particles, but the collection and chemical characterization of colloidal particles in environmental water itself is difficult. Analytical chemical methods need to be developed.

(2) Presence and characteristics of additive and adsorbable POPs in marine plastics

In addition to the constituent polymers, various additives such as plasticizers, UV absorbers, antioxidants, release agents, and flame retardants are added to plastics [29, 30]. As constituent additives, not only organic compounds but also compounds containing heavy metals may be added [31]. Some additives have endocrine disrupting or reproductive toxicity, such as nonylphenol, benzotriazoles, benzophenones, and phthalates [29, 30]. Many of the additives are highly hydrophobic and difficult to dissolve in water, and have been found to persist in ocean drift and beach drift plastics [32, 33]. For seabirds, it has also been reported that additives (brominated flame retardants and UV absorbers) were detected by actual measurement of ingested plastics [34, 35]. In the case of fish and shellfish, there are no examples of actual measurement of additives in ingested plastics because the size of ingested plastics is small and it is difficult to analyze the additives in them. The detection of additives in marine drift and coastal drift plastics is also limited to cm-level plastics, and there are only a few examples of measurements of mm-level, or microplastics. It has been reported that BDE209, a brominated flame retardant, was detected at several ng/g to several hundred ng/g in microplastics collected in Tokyo Bay and the Pacific Ocean [36]. However, it is estimated that the rate of leaching of additives with high hydrophobicity and large molecular weight into water is small, and in the case of BDE209, leaching into seawater is almost non-existent [37]. Therefore, it is assumed that BDE209 was also detected in the microplastics collected in the Pacific Ocean. This suggests that other additives with high hydrophobicity and high molecular weight are also present in microplastics. For risk assessment, a wider range of samples and a wider variety of additives need to be measured.

In addition to additives, microplastics drifting in the ocean contain hydrophobic toxic chemicals that have been adsorbed from the surrounding seawater [38, 39]. persistent organic pollutants (POPs) such as PCBs and DDTs, which are regulated by the Stockholm Convention, are also adsorbed on plastics due to their hydrophobic nature. These PCBs and DDTs, also known as legacy pollutants, accumulate in sediments from past uses and return to seawater due to leaching from sediments or sediment upwelling, where they are adsorbed by microplastics. The adsorption power varies among polymers, with polyethylene, which is composed only of hydrocarbons and is amorphous, having the strongest adsorption power [40], and polyester, which contains polar functional groups, having less adsorption power [41]. Depending on the size of the plastic particles and the nature of the target toxic chemical (hydrophobicity), the time required for organic pollutants to reach adsorption equilibrium varies greatly [40]. For example, when PCBs with an octanol-water partition coefficient of more than 6 in log value are adsorbed on small polyethylene particles with a diameter of about 3 mm, it is estimated to take more than a 1year for the PCBs concentration to reach equilibrium with the concentration in the surrounding water [42]. This may be due to the fact that it takes time for contaminants to penetrate from the surface of the polymer to the interior of the polymer, and also because the amount of water in contact with a unit weight of plastic is small due to its small specific surface area. In any case, the fact that the adsorption of POPs on plastics, especially polyethylene, is not a simple surface adsorption [43], but a slow adsorption and desorption dominated by the penetration inside the plastic matrix, makes plastics a unique contaminant transport medium. This explains the sporadic presence of microplastics adsorbing high concentrations of POPs observed in remote areas. For example, in the International Pellet Watch monitoring, pellets collected at the same location are analyzed in five sets and the median value is taken as representative of the location [39]. However, pellets containing orders of magnitude higher concentrations of POPs (microplastics) have often been observed sporadically on remote islands and in remote areas where there are no local sources of POPs contamination [44]. If POPs concentrations reached equilibrium between plastics and seawater, all five sets of plastics should have low POPs concentrations. In reality, however, sporadically high concentrations of pellets are observed. This is explained by the various transport routes and transport rates of microplastics and their slow adsorption/desorption. In other words, this may be due to the fact that pellets with high concentrations of PCBs adsorbed in urban waters with high POPs concentrations are rapidly transported to remote areas without time for POPs to be desorbed. It is conceivable that microplastics may carry adsorbable POPs along with large hydrophobic additives to the organisms in remote ecosystems. On the other hand, in urban waters, POPs accumulated in marine sediments due to their hydrophobic nature may be adsorbed by microplastics in the sediments, and due to the close specific gravity 1of microplastics, they may be resuspended and remigrated, resulting in prolonged legacy pollution. Although the accumulation of microplastics in urban sediments has been clarified [15], their resuspension and remobilization need to be studied in the future.

(3) Transfer and accumulation of chemical substances from ingested plastics to biological tissues and their mechanisms

The manifestation of the effects of chemicals in ingested plastics begins with the leaching of chemicals from ingested plastics and their transfer to biological tissues. Results suggesting the transfer of PCBs from plastic to fat in seabirds have been reported since the early 19801990s [45]. Ryan and Connel [45] conducted a multivariate analysis of the relationship between the amount of plastic in the stomach and the concentration of PCBs in the eggs of the zebra finch on Gough Island in the South Atlantic Ocean and found a positive relationship between the two. Yamashita et al. [46] reported a positive correlation between gastric plastic weight and low-chlorinated PCB homologues in fat for the Bering Sea sandpipers. Tanaka et al. [47] observed individuals with accumulation of high-brominated diphenyl ethers in abdominal fat and detected similar composition of high-brominated diphenyl ethers in the stomach plastic of the same individuals, suggesting that the plastic additive brominated diphenyl ethers (PBDEs) from plastics to organisms was strongly suggested. In addition, the transfer of plastic additives (phthalate esters) was also shown for the Tasmanian bowerbird using tail gland wax [48]. A study that applied this approach of measuring plastic additives in tail gland wax to 150individuals of seabird 35species in the world's 15oceans showed accumulation of plastic additives in adipose in about40 10% of the individuals [49]. A similar study was conducted on whales, and it was reported that metabolites of an additive (phthalate ester) from ingested plastics (MEHP: mono(2-ethylhexyl) phthalate) accumulated in whale tissues [50]. As described above, it is judged that the transfer and accumulation of chemical substances from ingested plastics to biological tissues have been confirmed for organisms in relatively higher trophic levels, such as seabirds, based on examples of field observations.

Although there have been few observations of organisms in the lower trophic levels because of the microscopic nature of the feeding plastic and the difficulty of measuring it, recent years have seen an increase in studies. [51] measured the concentrations of BPA, alkylphenols, alkylphenol polyethoxylates, PCBs, and PBDEs in the tissue of Haddad's beaked eagles in the South Pacific Gyre, and reported that the concentration of high-brominated PBDEs was positively correlated with the plastic density at the sampling site. It is reported that the concentration of high bromine PBDEs is positively correlated with the plastic density at the sampling site. In the coastal area of Korea, hexabromocyclododecane (HBCD), a type of flame retardant, was detected in recycled Styrofoam, and HBCD was detected in bivalves inhabiting the Styrofoam surface [52]. Hermit crabs were examined on beaches with high and low plastic debris drift on a remote island in Okinawa, and the amount of microplastics in the digestive tract of hermit crabs caught on beaches with high plastic debris drift was high, and metabolites of the brominated flame retardant BDE209 (BDE202, BDE179, etc.) were detected in the hepatopancreas of these individuals.) were detected in the hepatopancreas of many individuals [53]. These field observations suggest that the transfer of plastic additives to tissues is occurring even for organisms in lower trophic levels.

The migration of chemicals from plastics has been experimentally demonstrated by feeding and rearing experiments. An increase in the concentration of low-chlorine PCB homologues in tail gland wax was observed when resin pellets with adsorbed PCBs were administered to chicks of the Great Blue Heron [38]. On the other hand, no increase in the concentration of high chlorinated PCB homologous isomers was observed with plastic administration due to the large contribution from the food source. As for plastic additives, when plastics industrially kneaded with benzotriazole and benzophenone UV absorbers and the brominated flame retardant BDE209 were administered to bobwhite chicks, these additives were detected significantly in fat and liver, and the rate of transfer of additives to body tissues was up4 to [54]. These dosing experiments provide direct evidence of the transfer of plastic additives into biological tissues.

For organisms at lower trophic levels, laboratory experiments have shown the transfer of chemicals from ingested plastics to biological tissues [55-57]. However, the chemicals used in these exposure experiments on lower trophic level organisms were all adsorbed on plastics, and it is necessary to conduct exposure experiments on microplastics with additives kneaded into them.

Additives are kneaded into the polymer and have been thought to be difficult to leach out. Especially for additives with large hydrophobicity, leaching into seawater is considered to be almost non-existent [37]. However, when organic solvents and surfactants with hydrophobic properties are mixed, the leaching of chemicals from plastics is dramatically accelerated [42, 58]. For example, the desorption rate from pellets of homologous isomers of PCBs 170(log Kow =7) increased by an

1order of magnitude when methanol was mixed with water in 25% [42]. An example of a study on seabirds and additives showed that the presence of oil in the digestate enhanced the leaching of hydrophobic additives [59]. The digestive juices of seabirds contain stomatal oil, which is the indigestible oil of the fish they eat as food. When experiments were conducted to elute plastics kneaded with the hydrophobic additive BDE209 with seawater, stomack oil, and fish oil, it was confirmed that BDE209 was not eluted in seawater, but several tens of percent of the additive was eluted in stomack oil and fish oil [59]. It is thought that the oil (stomac oil) in the digestive juices acts like a solvent to promote elution. Although stomac oil is unique to seabirds, it is possible that prey fat acts as a solvent in the digestive tract of other organisms as well [42]. Elution experiments under real environmental conditions with fish, shellfish, and humans are needed.

It has been confirmed that the transfer and accumulation of chemicals from plastics to biological tissues occurs, but the next problem is the relative scale of the transfer and accumulation. Organisms are usually exposed to toxic chemicals from their original food sources as well. Assessing exposure to toxic chemicals from plastic feeding is complicated by the need to compare it to exposure from non-plastic pathways. In modeling approaches that assume equilibrium, it has been argued that the contribution of POPs adsorbed on plastics is negligible [60]. However, as mentioned earlier, the adsorption of hydrophobic pollutants on plastics and the presence of additives do not reach equilibrium, and therefore, the global model assuming equilibrium cannot reproduce the actual phenomena occurring. It is necessary to conduct specific evaluations for individual environments and substances. In other words, the exposure of contaminants to organisms via plastics depends on the background contamination, the general contamination level of the environment, as well as the contaminants and species of interest. First of all, because the adsorption and desorption of chemicals on ocean drifting plastics often do not reach equilibrium [42], if plastics with high concentrations of POPs are transported to remote islands or areas with low background pollution and low exposure to toxic chemicals from pathways other than plastics, the plastic It is possible that the contribution of POPs exposure via plastics may increase [36]. As mentioned earlier, sporadic detection of high concentrations of POPs in microplastics from remote islands has been observed [44]. The actual transfer and accumulation of adsorption-derived PCBs from plastics to seabird tissues has also been confirmed in remote areas away from human activities, such as the non-contaminated Bering Sea [46], remote islands [45, 53], and the Atlantic annulus [51]. Conversely, in urban areas where general pollution levels are high, exposure via microplastics is unlikely to be apparent at present. However, if the amount of microplastics increases in the future, their contribution could be significant. In addition, the contaminant and organism of interest, especially the trophic level, should be considered: exposure via microplastics is more likely to occur for constituents for which plastic additives are a major source than for constituents that are supplied from sources other than plastic additives, such as PCBs. In particular, when contaminants that undergo biomagnification in the food chain, such as PCBs, are targeted at higher trophic levels, their concentrations in prey are higher and their effects via microplastics are less apparent [61]. For example, in a study of Pacific sea turtles, no correlation was found between PCBs concentrations in fat and microplastic content in the stomach [62]. On the other hand, in the case of components that are difficult to bioamplify, such as high molecular weight additives with large hydrophobicity, the contribution of exposure via food is relatively small, and the contribution of exposure via plastics is observed [61]. The observed accumulation of BDE209 in seabirds is a typical example of this. It is necessary to have a specific discussion depending on the component, target organism, and target region, rather than a binary discussion of the presence or absence of exposure via microplastics.

As mentioned above, microplastic exposure of some chemicals to some organisms has been confirmed in actual organisms in the environment. The next issue that needs to be considered is the biological effects of chemical exposure mediated by microplastics. In laboratory experiments, exposure of fish and gobi [55, 63] to chemical-adsorbed microplastics has been reported to cause liver dysfunction and tumor formation. However, the amount of microplastics exposed in laboratory experiments where the effects have been observed is considerably (more than one order of magnitude) higher than the amount of microplastics observed in the environment [23]. This can be taken as an alarming sign of the possible effects of increased plastic content in the future. On the other hand, there are very few examples of actual observations of biological effects in the environment. For example, in a study of red-footed boobies in Australia, it was observed that individuals with a high consumption of microplastics had high blood cholesterol levels and low calcium levels [64]. The decrease in blood calcium concentrations is similar to the case of DDT-induced disruption of calcium metabolism in seabirds, which may lead to deformities and thinner eggshells, resulting in reduced hatchability and population decline. Although no morphological abnormality has been confirmed, blood tests have shown abnormalities, so the effects of chemicals from plastic feeding on the red-footed boobies are considered to be one step closer to becoming apparent. Whether similar accumulation and effects of toxic chemicals derived from plastics are occurring in other seabirds and other organisms is still under study, but what is happening in seabirds should be considered a canary in the coal mine, and preventive measures should be taken. As a recognition of the current situation, rather than viewing biological effects as not being apparent, we should view it as the fact that methods for assessing minor effects in the actual environment have not been developed and applied, and that it is necessary to promote surveys and research and take preventive measures.

6 Biological and Human Health Effects of Plastic Additives

Based on the above discussion, we hereby declare the necessity of studies and research on the plastic additive management with respect to their health effects on humans as well as living organisms. Some of the additives added to plastic products such as nonylphenol, bisphenol A, benzotriazoles, benzophenones, and phthalates, have endocrine disrupting and reproductive toxicity., [29, 30]. The health effects of these additives extend not only to the endocrine system but also to the immune system, and have been linked to chronic diseases such as allergy and obesity by research findings [65, 66].

Leaching of these additives into foods and beverages has been a concern for many years, and direct exposure to humans through foods and beverages has been controlled to a certain extent by conducting leaching tests. However, it is necessary to pay attention to the possibility of dissolution depending on the ways of usage and food items cooked with. For example, directly heating oily foods in a plastic container with highly hydrophobic additives in it, such as in a microwave oven, may increase the transfer of the hydrophobic additives from the plastics to the foods or drinks that leads to exposure to humans. Except for these examples, it is generally believed that highly hydrophobic additives are less likely to dissolve in water and therefore less likely to dissolve in foods and drinks from plastic containers, and direct human exposure from plastic products use is small (Fig.1). Therefore, highly hydrophobic additives have been added to plastics. However, highly hydrophobic additives remain in plastic debris drifting in the ocean and on beaches. The fragmented microplastics are taken up by fish and shellfish, and if oil is present in the digestive juices, the hydrophobic additives will leach out from the plastic with increased specific surface area. The leached additives are absorbed from the intestines and accumulate in the fat and liver. The transfer and accumulation of such highly hydrophobic additives in biological tissues has been confirmed in seabirds [54]. Although seabirds are not directly consumed by humans, the transfer and accumulation of hydrophobic additives to fish and shellfish via microplastics may occur, and if the metabolic capacity of these additives in fish and shellfish is low, humans may be exposed through the food chain (Fig.1). In fact, observations of fish and shellfish in the real environment suggest that hydrophobic additives are transferred to and accumulated in biological tissues via microplastics [51-53]. On the other hand, some additives are leached into seawater during the miniaturization process, but they are also exposed to humans through the food chain by adsorption to other microplastics or natural particles (suspended particles and sediments) that do not contain the additives. Although human exposure to additives has only been considered directly from plastics used for food and drink [30], it is possible that hydrophobic additives can be indirectly exposed to humans through environmental plastic miniaturization and uptake into the digestive system of organisms, which is, additives' dissolution into digestive juices containing oil through bioaccumulation and the food chain. Exposure to humans is a new route posed by microplastics, and it is considered to be the most significant aspect in terms of human impact (Fig.1). In other words, the previous estimates of additive exposure based on leaching tests were underestimates, and the overall human exposure to plastic additives may be higher than previously thought. The exposure of humans to plastic additives is likely to be much higher than previously thought. In other words, there is a large possibility that human exposure to plastic additives with low degradability and high hydrophobicity will eventually occur.

The recently reported results of a large epidemiological study in Europe show a serious halving of sperm counts in European adult males in the past 40 years [67]. Although the cause has not been identified, pesticides, insecticides, and chemicals in plastics have been cited as potential factors. In addition, an increase in reproductive diseases, such as an increase in endometriosis, has been observed. There is no doubt that plastics contain additives that affect reproduction. Even if they do not leach into beverages, leaching into oily foods and indirect exposure to humans through plastic micronization and the food chain should be considered. The effects on the endocrine system are not immediate, but may occur over a long period of time, and in some cases over generations. Since there is also an indirect route of exposure, it is extremely difficult to determine causality, but further studies are expected. In addition to the background as a resource issue, the plastic container reduction measures in Canada and the EU also have a chemical pollution perspective.

As mentioned above, the issue of additives is important in considering the effects of plastics and microplastics on living organisms, including humans. The following are some of the studies and researches that are necessary for the future management of additives.

(1) It is necessary to investigate the endocrine disrupting effects of additives in plastic products (including their broad effects on the immune system and reproductive toxicity), to evaluate their effects when exposed to multiple components (plastic products including additives) simultaneously, and to regulate their use based on these effects. Additives include benzotriazole UV absorbers, benzophenone UV absorbers, brominated flame retardants, phosphorus flame retardants, phthalate esters, nonylphenol, bisphenol A, and organic fluoride compounds.

(2) There is a need for comprehensive analysis of additives in plastics in the environment. It is important to measure additives in microplastics, especially in microplastics smaller than 1 mm, and to investigate their content by particle size.

(3) Understanding the relationship between plastic miniaturization and elution characteristics of additives (Does miniaturization facilitate elution? Is elution accelerated by oil in bait or food?) is necessary.

(4) The transfer and accumulation of additives to fish and shellfish via microplastics needs to be examined.

(5) The bioaccumulation of additives through the food chain needs to be examined.

(6) Research is needed to determine the amount of dietary exposure to plastic additives and their effects on humans through total diet studies and analysis of blood and urine. In addition, exposure studies from other exposure sources, such as air (including house dust), water, and soil, should be conducted to collect knowledge for health risk assessment.

(7) As a precautionary measure, it is necessary to switch the regulation of plastic additives from one based on leaching tests to one based on content tests. In other words, since there is a possibility that plastic waste is released into the environment, and then miniaturized and taken up by living organisms, and finally exposed to humans, it is necessary as a precautionary measure to target not only the direct elution from the product, but also the toxicity of the additives contained in the product itself, and the monomers and oligomers that make up the product, and to regulate them based on their content. Therefore, it is necessary as a preventive measure to target not only the direct leaching from products but also the toxicity of additives and constituent monomers/oligomers contained in products themselves, and to implement regulations based on their content.

As mentioned above, there are many issues that need to be resolved, but it is necessary to reduce plastic emissions from a precautionary principle perspective, without underestimating the impact of toxic chemicals contained in plastics.

7 Perspectives of international organizations on microplastics in drinking water and their effects on human health

August 2019, the World Health Organization (WHO) issued a news release calling for further research into microplastics and tighter regulations against plastic pollution [68]. In September of the same year, a report titled "Microplastics in Drinking Water" [69] stated that

Based on current scientific knowledge, microplastics in drinking water are currently of low concern for human health in terms of physical effects, chemicals, and adsorbed microorganisms. Although there is insufficient information about the toxicity of the physical effects of plastic particles, especially nano-sized particles, there is also no information that indicates a credible concern at present.

Microplastics larger than 150 µm are directly excreted in the feces and ingestion of smaller particles is limited. While toxicity studies in rats and mice have reported some effects including liver inflammation. However, these studies were based on exposure to very high concentrations, which is not unlikely to be found in drinking water, and their reliability and relevance have been questioned.

A number of risk assessments have been conducted for chemicals adsorbed on or leached from microplastics in drinking water, finding that the distance between safe estimates of intake and toxicological values for these chemicals is as large as several orders of magnitude. Thus, concern about the chemical effects of microplastics in drinking water is very limited.

The assessment by WHO is reasonable if it is limited to drinking water. However, when it comes to assessing the impact on the entire ecosystem, it is difficult to make an assessment because the current understanding of the actual situation and dynamics of pollution by microplastics and associated chemical substances is yet to grow. In addition to understand the actual situation and dynamics, precautionary approach based on life-cycle assessment from the upstream is necessary.

However, as mentioned in the report [69], international organizations such as International Programme for the Safety of Chemicals (IPCS), International Organization for Standardization (ISO), Joint FAO/WHO Expert Committee on Food Additives (JECFA), United Nations (UN), United Nations Environment Programme (UNEP), United Nations Children's Fund (UNICEF), United States The United Nations (UN), United Nations Environment Programme (UNEP), United Nations Children's Fund (UNICEF), and other international organizations such as United States Environmental Protection Agency (USEPA) and the United Kingdom (UK) have issued reports and policies on (micro)plastics, and there is a need for cross-sectoral knowledge sharing and promotion of countermeasures to plastics and in related fields.

8 Governance of plastics to prevent marine pollution by microplastics

Marine microplastic pollution around Japan is often caused by secondary microplastics, which are formed when plastic products are crushed and shredded by physical forces such as ultraviolet rays, heat and wind waves; for instance, polyester and acrylic fibers generated when washing synthetic clothes, and melamine resin sponges used for washing dishes are worn away.

It is important to note that plastics are petroleum products. In terms of chemistry, they include polyethylene, polypropylene, polyamide, polystyrene, polyethylene terephthalate, polyvinyl chloride resin, epoxy resin, polyurethane, polycarbonate, and many others. In terms of applications, film sheets for containers and packaging account for 1/3 (33.2%), which includes garbage bags, plastic bags, laminates, zipper bags, and shrink films. This is followed by film sheets other than for packaging (22.4%), machinery, equipment, and parts (11.2%), valves and fittings (9.9%), daily necessities and miscellaneous goods (5.0%), construction materials (5.1%), foamed products (4.6%), and other (9.2%) (Japan Plastics Industry Federation, Production Results of Plastic Products: http://www.jpif.gr.jp/3toukei/toukei.htm).

The total output (tons) of plastic products in Japan from 1999 to 2018 is either constant or on a downward trend. By product, however, the production of containers has almost doubled (up by 435,107tons) and that of films has increased by 1.2 times (up by 315,902tons), while the production of other products has either remained flat or shown a downward trend (Figure 2). Among films, those for agricultural use (thickness less than 0.2mm) decreased, but those for packaging (less than 0.2mm, bags for department stores, supermarkets, etc.) showed 1.03 times increase (35,623ton increase), and those for rigid products (less than 0.5mm, used for egg cartons, medicine packaging, cards, etc. as secondary products) 1.8 times (266,274ton increase). There was also a decrease in sheets (those larger than 0.2mm). Although the increase in packaging products is slow, it accounts for 52% of the production in films. Therefore, the key to reducing the volume of plastic products is the production of films (especially packaging and rigid products) and containers, and it is important to reduce this production volume, especially that of one-way (disposable) plastics.

Japan is the world's 0 second largest emitter of *per capita* plastic waste after the United States. Japan, along with the United States, did not sign the Marine Plastics Charter at the G7 summit held in Canada in 2018. The EU has already started efforts to establish cost-effective reuse and recycle of all plastic containers and packaging by 2030. It has also begun to take measures against single-use plastics, such as reducing consumption, reducing markets, expanding producer obligations, and raising awareness [70]. Under these circumstances, Japan was faced with the necessity of appealing its proactive stance as the chair country of the G20 summit held in Osaka in June 2019. To this end, the then Minister of the Environment announced before the G20 that he would enact a law banning the free distribution of plastic bags, making it mandatory to charge for plastic bags from July 1, 2020. The Osaka Blue Ocean Vision, which aims to reduce new pollution caused by marine plastic waste to zero by 2050, was also included in the G20 Summit Declaration. It should be noted, however, that the declaration does not mention what to do with the existing ocean plastic. In order to realize the "Summit Declaration" the government, industry, and the people of Japan must accelerate their efforts to reduce the total amount of plastic waste by reducing the production and use of disposable plastics, which have a large room for reduction, and by considering the use of alternatives.

In Japan, 2000 the Basic Law for Establishing a Sound Material-Cycle Society stipulates that waste treatment and recycling should be carried out in the following order of priority: (1) reduce, (2) reuse, (3) recycle, (4) heat recovery, and (5) proper disposal. In Japan, the effective utilization rate of discarded plastic is estimated to be 84% (the rest is unused waste plastic), but according to the data for 2016, 57.5% of the total plastic waste is largely dependent on "heat recovery," which is the recovery of heat energy from waste plastic when it is burned as solid fuel. Although "reuse as heat energy" by incineration is important as a way to reuse resources, it does not lead to the reduction of CO_2 From the perspective of reducing CO_2 emissions, which are linked to global warming, which is becoming more and more serious, it is necessary to reconsider reuse as heat energy. On the other hand, material recycling accounts for about 2,000,000 tons of 23 recycling per year, and was mainly exported to China. However, China has tightened import restrictions since January 2018, and many of the waste plastics that have lost their way have to be recycled and processed domestically. Therefore, it is necessary to reduce the amount of single-use plastics. In addition, it is necessary to improve logistics and product design to promote material recycling so that the plastics that remain after reduction can be used repeatedly through material recycling. In addition, for plastic products that are difficult to recycle or have a large environmental impact due to recycling, it is necessary to replace them with biomass plastics that are highly biodegradable and can be decomposed by 100 land-based decomposition facilities so that they are not released into the environment. However, the use of these plastics still poses problems such as pressure on food production and deforestation, and it is necessary to make further efforts to reduce consumption. It is necessary for the public and private sectors to work together to promote the governance of plastics, from production to use and disposal.

The governance of plastics needs to be harmonized with the Agenda 2030 for Sustainable Development (SDGs) (Ref. 1) to accelerate the achievement of the goals. Marine plastic pollution is indeed the biggest impediment to Goal 14: "Protect the richness of our oceans," which was commonly recognized at the 2017 UN Conference on the Oceans and has led to the current global movement. The management of plastic waste on land, which is the key to reducing the inflow of plastic into the ocean, needs to be positioned as part of the urban waste issue in Goal 11, "Create livable cities," and harmonized with the management of non-plastic waste. Originally As long as plastic is made from the finite resource of oil, it is incompatible with the sustainable use of resources in Goal 12, "Responsibility to Create and Use". In particular, incineration, which is the main final disposal method for plastic waste in Japan today, generates substantial greenhouse gas emissions as long as the plastic is made from petroleum, which contradicts Goal 13, "Take concrete measures to combat climate change. One way to harmonize with Goals 12 and 13 would be to replace plastics with biomass plastics, but if all the plastics we currently use in large quantities are replaced with biomass plastics and consumed and incinerated in large quantities, this will cause deforestation and competition with food production, making it difficult to achieve Goal 15: "Protect the richness of land. This will make it difficult to achieve Goal 15, "Protect the richness of land. It must be harmonized with the management of forest resources. In addition, microplastics have been detected in river water, which is directly related to Goal 6, "Provide safe water and toilets for all. In the first place, the health effects of plastics, mainly additives, are greatly related to Goal 3: "Health and well-being for all. It is necessary for countries, industries, consumers, and citizens to work together to establish and immediately implement plastic governance that is in harmony with the achievement of all of the SDG goals. Plastic pollution in the oceans is incompatible with a sustainable society, and shows that ESD (Education for Sustainable Development), which we have been working on for many years, is not yet fully successful. More promotion of environmental education is needed.

Even the EU's efforts have not come up with a concrete plan on what to do with the plastics that have already entered the environment. If left unchecked, the number of microplastics will only increase, making it even more difficult to collect them. It is necessary to consider effective measures to collect marine plastic waste and dispose of it appropriately as soon as possible.

9 Recommendations

In order to achieve the following goals of the Agenda2030 for Sustainable Development (SDGs): Goal 3: "Health and well-being for all," Goal 6: "Safe water and sanitation for all," Goal11 7: "Livable cities," Goal12 8: "Responsibility to create, responsibility to use," Goal13 9: "Concrete measures to combat climate change," Goal 10: "Protect the ocean," and Goal 11: "Protect the land. The following actions should be taken in order to achieve the following goals: "Take concrete measures against climate change," 14"Protect the richness of the sea," and 15"Protect the richness of the land.

(1) The Government of Japan should urgently investigate the origin of microplastics in the ocean, their dynamics in the aquatic environment, their feeding by marine organisms, and their migration to and adverse effects on ecosystems (physical and adverse effects of additives and adsorbed toxic chemicals). At the same time, promote cross-disciplinary basic and epidemiological research on the toxic effects on organisms and humans and their mechanisms, and hasten the collection of scientific knowledge that will contribute to a comprehensive presentation of scientific findings and to environmental and health risk assessment.

(2) The government should accelerate national, industrial, and citizen efforts to "reduce total plastic emissions" by reducing the production and use of "disposable plastics.

(3) The government should curb the use of primary microplastics and develop and promptly implement effective methods of collecting marine plastics that are the origin of secondary microplastics.

＜Glossary of terms＞

Primary microplastics

Plastics manufactured in the form of particles smaller than 5 mm, including resin pellets and microbeads in facial cleansers and cosmetics.

SDGs

The Sustainable Development Goals (SDGs) are the international goals for the period from 2016 to 2030 that were set out in the "2030 Agenda for Sustainable Development" adopted at the United Nations Summit in September 2015 as the successor to the Millennium Development Goals (MDGs) set out in 2001. The Agenda consists of 17 goals and 169 targets to achieve a sustainable world, and pledges to leave no one behind on the planet.

Oestradiol

There are three types of oestrogens, oestrone, oestradiol, and oestriol, which are hormones secreted by the ovaries. Of these, oestradiol is the most biologically active.

Osaka Blue Ocean Vision

A vision shared at the G20 Osaka Summit in June 2009. It aims to reduce new pollution caused by marine plastic waste to zero by 2050.

Luteinizing hormone

It is a gonadotropic hormone secreted by gonadotropin-producing cells in the anterior pituitary gland. In males, it acts on the testes to produce testosterone and inhibin, and in females, it acts on the ovaries to produce oestrogen and progesterone.

Governance

It means "governing, ruling, administering countries." It also means "to bring together and govern a country, region, or group.

Substances regulated by the Stockholm Convention

Chemical substances regulated by the Stockholm Convention on Persistent Organic Pollutants (POPs) The POPs Convention stipulates the elimination, restriction and reduction of the production and use of persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and DDT, which are highly toxic to humans and other living organisms due to their persistence in the environment, bioaccumulation, and long-distance mobility.

Testosterone

It is a type of male hormone, and approximately 95% of this substance is produced and secreted by the testes. It acts on multiple organs and plays an important role in maintaining a healthy body.

Total Diet Study

This is a method of estimating the intake of harmful chemical substances such as food additives and pesticides, taking into account the increase or decrease of these substances due to processing and cooking, in order to ascertain the actual level of intake in a wide range of foods sold in the market in light of the diet of the research subjects.

Secondary microplastics

This includes plastic products that have entered the ocean and have been crushed and shredded by physical forces such as ultraviolet rays, heat, and wind waves; and polyester and acrylic fibers generated when washing synthetic fiber clothes, and worn melamine resin sponges used for washing dishes.

Microplastics

Plastics less than 5 mm.

Resin Pellets

These are plastic grains of several millimeters in diameter in the form of disks, cylinders, or spheres, and are used as intermediate raw materials for plastic products.

＜References＞

[1] Rothstein, S. I., Plastic particle pollution of the surface of the Atlantic Ocean: evidence from a seabird. *Condor* 1973, *75*(344), 5.

[2] R. Yamashita, A. Tanaka, H. Takada, Marine plastic pollution: dynamics of plastics in marine ecosystems and effects on organisms. Journal of the Ecological Society of Japan, 2016, 66, 51-68.

[3] H. Takada and R. Yamashita, Introduction to marine plastic pollution : history, dynamics and chemical pollution of research (Special issue on upstream control of plastic pollution). Water and Wastewater, 2018, 60, 29-40.

[4] Moore, C. J.; Moore, S. L.; Leecaster, M. K.; Weisberg, S. B., A Comparison of Plastic and Plankton in the North Pacific Central Gyre. *Mar. Pollut. Bull.* 2001, *42*(12), 1297-1300.

[5] Thompson, R. C.; Olsen, Y.; Mitchell, R. P.; Davis, A.; Rowland, S. J.; John, A. W. G.; McGonigle, D.; Russell, A. E., Lost at sea: where is all the plastic? *Science*2004**,** *304*, 838.

[6] Mato, Y.; Isobe, T.; Takada, H.; Kanehiro, H.; Ohtake, C.; Kaminuma, T., Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. *Environ. Sci. Technol.* 2001, *35*(2), 318-324.

[7] Thompson, R.; Moore, C.; Andrady, A.; Gregory, M.; Takada, H.; Weisberg, S., New directions in plastic debris. *Science*2005**,** *310* , 1117.

[8] Arthur, C.; Baker, J.; Bamford, H., International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris. 2009.

[9] GESAMP, Assessment of microplastics and associated chemicals in marine environments. ii. 2016.

[10] Tanaka, K.; Takada, H., Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. *Scientific Reports Scientific Reports*2016**,** *6*, 34351.

[11] Isobe, A.; Uchida, K.; Tokai, T.; Iwasaki, S., East Asian seas: A hot spot of pelagic microplastics. *Mar. Pollut. Bull.* 2015, *101*(2), 618-623.

[12] Eriksen, M.; Lebreton, L. C. M.; Carson, H. S.; Thiel, M.; Moore, C. J.; Borerro, J. C.; Galgani, F.; Ryan, P. G.; Reisser, J., Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *Plos one* 2014, *9*(12), e111913.

[13] Jambeck, J. R.; Geyer, R.; Wilcox, C.; Siegler, T. R.; Perryman, M.; Andrady, A.; Narayan, R.; Law, K. L., Plastic waste inputs from land into the ocean. *Science* 2015, *347*(6223), 768-771.

[14] Galgani, F.; Souplet, A.; Cadiou, Y., Accumulation of debris on the deep sea floor off the French Mediterranean coast. *Marine Ecology Progress Series* 1996, *142*(1), 225-234.

[15] Matsuguma, Y.; Takada, H.; Kumata, H.; Kanke, H.; Sakurai, S.; Suzuki, T.; Itoh, M.; Okazaki, Y.; Boonyatumanond, R.; Zakaria, M. P.; Weerts, S.; Newman, B., Microplastics in

sediment cores from Asia and Africa as indicators of temporal trends in microplastic pollution. *Arch. Environ. Contam. Toxicol.* 2017, *73*(2), 230-239.

[16] Mincer, T. J.; Zettler, E. R.; Amaral-Zettler, L. A., Biofilms on Plastic Debris and Their Influence on Marine Nutrient Cycling, Productivity, and In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2017; pp 1-13.

[17] Laist, D. W., Impacts of marine debris: entanglement of marine life in debris including a comprehensive list of species with entanglement and ingestion records. In *Marine debris-sources, impacts and solutions*, Coe, J. M.; Rogers, D. B., Eds. Springer: Berlin, 1997; pp. 99-140. 99-140.

[18] Ryan, P. G., Ingestion of Plastics by Marine Organisms. In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2016; pp 1-32.

[19] Wright, S. L.; Thompson, R. C.; Galloway, T. S., The physical impacts of microplastics on marine organisms: a review. *Environ. Pollut.* 2013, *178*(0), 2013, (0), 483-492.

[20] Sussarellu, R.; Suquet, M.; Thomas, Y.; Lambert, C.; Fabioux, C.; Pernet, M. E. J.; Le Goïc, N.; Quillien, V.; Mingant, C.; Epelboin, Y.; Corporeau, C; Guyomarch, J.; Robbens, J.; Paul-Pont, I.; Soudant, P.; Huvet, A., Oyster reproduction is affected by exposure to polystyrene microplastics. *Proceedings of the National Academy of Sciences* 2016, *113*(9), 2430-2435.

[21] Jeong, C.-B.; Won, E.-J.; Kang, H.-M.; Lee, M.-C.; Hwang, D.-S.; Hwang, U.-K.; Zhou, B.; Souissi, S.; Lee, S.-J.; Lee, J.-S., Microplastic Size-Dependent Toxicity, Oxidative Stress Induction, and p-JNK and p-p38 Activation in the Monogonont Rotifer (Brachionus koreanus). *Environ. Sci. Technol.* 2016, *50*(16), 8849-8857.

[22] Besseling, E.; Redondo-Hasselerharm, P.; Foekema, E. M.; Koelmans, A. A., Quantifying the ecological risks of aquatic micro- and nanoplastics. *Reviews in Environmental Science and Technology* 2019, *49*(1), 32-80.

[23] Lenz, R.; Enders, K.; Nielsen, T. G., Microplastic exposure studies should be environmentally realistic. *Proceedings of the National Academy of Sciences* 2016, *113*(29), E4121-E4122.

[24] Everaert, G.; Van Cauwenberghe, L.; De Rijcke, M.; Koelmans, A. A.; Mees, J.; Vandegehuchte, M.; Janssen, C. R., Risk assessment of microplastics in the ocean: modelling approaches and first conclusions. *Environ. Pollut.* 2018, *242*, 1930-1938.

[25] Isobe, A.; Iwasaki, S.; Uchida, K.; Tokai, T., Abundance of non-conservative microplastics in the upper ocean from 1957 to 2066. *Nature Communications* 2019, *10*(1), 417.

[26] Yanagiba, Y., Ito, Y., Tamanoshita, O., Zhang, S.T., Watanabe, G., Taya, K., Li, C.M., Inotsume, Y., Kamijima, M., Gonzalez, F.J., Nakajima, T. Styrene Li, C.M., Inotsume, Y., Kamijima, M., Gonzalez, F.J., Nakajima, T. Styrene trimer may increase thyloid hormone

levels via down-regulation of the aryl hydrocarbon receptor (AHR) target gene UDP-glucronosytransferase. Environ. Health Perspect. 2008, 115 (6), 740-745.

[27] Nakamura, D., Yanagiba, Y., Ito, Y., Okamura, A., Asaeda, N., Tagawa, Y., Li, C., Taya ,K., Zhang, S.Y., Naito, H., Ramdhan, D.H., Kamijima, M, Nakajima, T. Bisphenol A may cause testosterone reduction adversely affecting both testis and pituitary system similar to estradiol. Toxicol. 2010, 194 (1-2), 16-25.

[28] Frohlich, E.; Samberger, C.; Kueznik, T.; Absenger, M.; Roblegg, E.; Zimmer, A.; Pieber, T. R., Cytotoxicity of nanoparticles independent from oxidative stress. *The Journal of Toxicological Sciences* 2009, *34*(4), 363-375.

[29] Andrady, A. L.; Rajapakse, N., Additives and Chemicals in Plastics. In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2017; pp 1-17.

[30] Manoli, E.; Voutsa, D., Food Containers and Packaging Materials as Possible Source of Hazardous Chemicals to Food. In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2017; pp 1-32.

[31] Nakashima, E.; Isobe, A.; Kako, S. i.; Itai, T.; Takahashi, S., Quantification of Toxic Metals Derived from Macroplastic Litter on Ookushi Beach, Japan. *Environ. Sci. Technol.* 2012, , *46*(18), 10099-10105.

[32] Hirai, H.; Takada, H.; Ogata, Y.; Yamashita, R.; Mizukawa, K.; Saha, M.; Kwan, C.; Moore, C.; Gray, H.; Laursen, D.; Zettler, E. R.; Farrington, J. W; Reddy, C. M.; Peacock, E. E.; Ward, M. W., Organic micropollutants in marine plastics debris from the open ocean and remote and urban beaches. *Mar. Pollut. Bull.* 2011, *62*(8), 1683-1692.

[33] Chen, Q.; Reisser, J.; Cunsolo, S.; Kwadijk, C.; Kotterman, M.; Proietti, M.; Slat, B.; Ferrari, F. F.; Schwarz, A.; Levivier, A.; Yin, D.; Hollert, H.; Koelmans, A. A., Pollutants in Plastics within the North Pacific Subtropical Gyre. *Environ. Sci. Technol.* 2018, , *52*(2), 446-456.

[34] Tanaka, K.; Takada, H.; Yamashita, R.; Mizukawa, K.; Fukuwaka, M.-a.; Watanuki, Y., Accumulation of plastic-derived chemicals in tissues of Seabirds ingesting marine plastics. *Mar. Pollut.* 2013.

[35] Tanaka, K.; van Franeker, J. A.; Deguchi, T.; Takada, H., Piece-by-piece analysis of additives and manufacturing byproducts in plastics ingested by seabirds: Implication for risk of exposure to seabirds. *Mar. Pollut. Bull.* 2019, *145*, 36-41.

[36] Yamashita, R.; Tanaka, K.; Yeo, B. G.; Takada, H.; Franeker, J. A. v.; Dalton, M.; Dale, E., Hazardous chemicals in plastics in marine environments: International Pellet Watch. In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2018; pp 163-184.

[37] Sun, B.; Hu, Y.; Cheng, H.; Tao, S., Releases of brominated flame retardants (BFRs) from microplastics in aqueous medium: Kinetics and molecular-size dependence of diffusion. *Water Research* 2019, *151*, 215-225.

[38] Teuten, E. L.; Saquing, J. M.; Knappe, D. R. U.; Barlaz, M. A.; Jonsson, S.; Bjorn, A.; Rowland, S. J.; Thompson, R. C.; Galloway, T. S.; Yamashita, R.; Ochi, D.; Watanuki, Y.; Moore, C.; Pham, H. V.; Tana, T. S.; Prudente, M.; Boonyatumanond, R.; Zakaria, M. P.; Akkhavong, K.; Ogata, Y.; Hirai, H.; Iwasa, S; Mizukawa, K.; Hagino, Y.; Imamura, A.; Saha, M.; Takada, H., Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B-Biological Sciences* 2009, *364*(1526), 2027-2045.

[39] Ogata, Y.; Takada, H.; Mizukawa, K.; Hirai, H.; Iwasa, S.; Endo, S.; Mato, Y.; Saha, M.; Okuda, K.; Nakashima, A.; Murakami, M.; Zurcher, N; Booyatumanondo, R.; Zakaria, M. P.; Dung, L. Q.; Gordon, M.; Miguez, C.; Suzuki, S.; Moore, C.; Karapanagioti, H. K.; Weerts, S.; McClurg, T.; Burres, E; Smith, W.; Van Velkenburg, M.; Lang, J. S.; Lang, R. C.; Laursen, D.; Danner, B.; Stewardson, N.; Thompson, R. C., International Pellet Watch: Global International Pellet Watch: Global monitoring of persistent organic pollutants (POPs) in coastal Waters. 1. Initial phase data on PCBs, DDTs, and HCHs. *Mar. Pollut. Bull.* 2009, *58*(10). 1437-1446, Mar. Pollut. Bull. 2009, (10), 1437-1446.

[40] Endo, S.; Takizawa, R.; Okuda, K.; Takada, H.; Chiba, K.; Kanehiro, H.; Ogi, H.; Yamashita, R.; Date, T., Concentration of Polychlorinated Biphenyls (PCBs) in Beached Resin Pellets: Variability among Individual Particles and Regional Differences. *Mar. Pollut,* Mar. Pollut. Bull. 2005, (10), 1103-1114.

[41] Rochman, C. M.; Hoh, E.; Hentschel, B. T.; Kaye, S., Long-Term Field Measurement of Sorption of Organic Contaminants to Five Types of Plastic Pellets: Implications for Plastic Marine Debris. *Environ. Sci. Technol.* 2013, *47*(3), 1646-1654.

[42] Endo, S.; Yuyama, M.; Takada, H., Desorption kinetics of hydrophobic organic contaminants from marine plastic pellets. *Mar. Pollut. Bull.* 2013, *74* (1), 125-131.

[43] Karapanagioti, H. K.; Klontza, I., Testing phenanthrene distribution properties of virgin plastic pellets and plastic eroded pellets found on Lesvos Marine Environmental Research 2008, (in Japanese). *Marine Environmental Research* 2008, *65*(4), 283-290.

[44] Heskett, M.; Takada, H.; Yamashita, R.; Yuyama, M.; Ito, M.; Geok, Y. B.; Ogata, Y.; Kwan, C.; Heckhausen, A.; Taylor, H.; Powell, T.; Morishige, C; Young, D.; Patterson, H.; Robertson, B.; Bailey, E.; Mermoz, J., Measurement of persistent organic pollutants (POPs) in plastic resin pellets from remote islands: toward establishment of background concentrations for International Pellet Watch. *Mar Pollut Bull* 2012, *64*(2), 445-448.

[45] Ryan, P. G.; Connel, A. D.; Gardner, B. D., Plastic Ingestion and PCBs in Seabirds: Is There a Relationship? *Mar. Pollut. Bull.* 1988, *19*(4), 174-176.

[46] Yamashita, R.; Takada, H.; Fukuwaka, M.-a.; Watanuki, Y., Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, Puffinus tenuirostris, in the North Pacific Ocean. *Mar. Pollut. Bull.* 2011, *62*(12), 2845-2849.

[47] Tanaka, K.; Takada, H.; Yamashita, R.; Mizukawa, K.; Fukuwaka, M.-a.; Watanuki, Y., Accumulation of plastic-derived chemicals in tissues of *Mar. Pollut. Bull.* 2013, *69*(1-2), 219-222.

[48] Hardesty, B. D.; Holdsworth, D.; Revill, A. T.; Wilcox, C., A biochemical approach for identifying plastics exposure in live wildlife: *Methods in Ecology and Evolution* 2015, *6*(1), 92-98.

[49] Hiki, Eiko; Takada, Hideshige; Yamashita, Rei; Sato, Hiroya; Watanuki, Yutaka; Tanaka, Atsusuke, Global surveillance of plastic pollution and persistent organic pollutants (POPs) in seabirds using tail gland wax, 27th Annual Meeting of the Japanese Society of Environmental Chemistry, Okinawa, 2018. Meeting, Okinawa, 2018; Japanese Society for Environmental Chemistry: Okinawa.

[50] Fossi, M. C.; Coppola, D.; Baini, M.; Giannetti, M.; Guerranti, C.; Marsili, L.; Panti, C.; de Sabata, E.; Clò, S., Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: The case studies of the Mediterranean basking shark (Cetorhinus maximus) and fin whale (Balaenoptera physalus). *Marine Environmental Research* 2014, *100*, 17-24.

[51] Rochman, C. M.; Lewison, R. L.; Eriksen, M.; Allen, H.; Cook, A.-M.; Teh, S. J., Polybrominated diphenyl ethers (PBDEs) in fish tissue may be an indicator of plastic contamination in marine habitats. *Science of The Total Environment* 2014, *476-477*, 622-633.

[52] Jang, M.; Shim, W. J.; Han, G. M.; Rani, M.; Song, Y. K.; Hong, S. H., Styrofoam Debris as a Source of Hazardous Additives for Marine Organisms. *Environ. Sci. Technol.* 2016, *50*(10), 4951-4960.

[53] N. Tanaka, H. Takada, K. Mizukawa, N. Takada, T. Ogaki, Exposure and accumulation of toxic chemicals via plastics to Okinawan coastal organisms, The 28th Annual Meeting of the Society for Environmental Chemistry, Saitama, 2019, P-119.

[54] Tanaka, K.; Watanuki, Y.; Takada, H.; Ishizuka, M.; Yamashita, R.; Kazama, M.; Hiki, N.; Kashiwada, F.; Mizukawa, K.; Mizukawa, H.; Hyrenbach, D; Hester, M.; Ikenaka, Y.; Nakayama, S. M., In vivo accumulation of plastics-derived chemicals into seabird tissues. *Current Biology* 2020, 30, (4), Current Biology 2020, 30, (4), 723-728.

[55] Browne, M. A.; Niven, S. J.; Galloway, T. S.; Rowland, S. J.; Thompson, R. C., Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity. *Current Biology* 2013, *23*(23), 2388-2392.

[56] Wardrop, P.; Shimeta, J.; Nugegoda, D.; Morrison, P. D.; Miranda, A.; Tang, M.; Clarke, B. O., Chemical Pollutants Sorbed to Ingested Microbeads from Personal Care Products Accumulate in Fish. *Environ. Sci. Technol.* 2016, *50*(7), 4037-4044.

[57] Rochman, C. M.; Hoh, E.; Kurobe, T.; Teh, S. J., Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Sci. Rep.* 2013, *3*.

[58] Bakir, A.; Rowland, S. J.; Thompson, R. C., Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. *Environ. Pollut.* 2014, *185*, 16-23.

[59] Tanaka, K.; Takada, H.; Yamashita, R.; Mizukawa, K.; Fukuwaka, M.-a.; Watanuki, Y., Facilitated Leaching of Additive-Derived PBDEs from Plastic by Seabirds' Stomach Oil and Accumulation in Tissues. *Environ. Sci. Technol.* 2015, *49*(19), 11799-11807.

[60] Gouin, T.; Roche, N.; Lohmann, R.; Hodges, G., A Thermodynamic Approach for Assessing the Environmental Exposure of Chemicals Absorbed to Microplastic. *Environ. Sci. Technol.* 2011, *45*(4), 1466-1472.

[61] Tanaka, K.; Yamashita, R.; Takada, H., Transfer of hazardous chemicals from ingested plastics to higher-trophic level organisms. In *Hazardous chemicals associated with plastics in the environment*, Takada, H.; Karapanagioti, H. K., Eds. Springer Berlin Heidelberg: Berlin, Heidelberg, 2018; pp. 267-280.

[62] Clukey, K. E.; Lepczyk, C. A.; Balazs, G. H.; Work, T. M.; Li, Q. X.; Bachman, M. J.; Lynch, J. M., Persistent organic pollutants in the fat of three species of Pacific pelagic longline caught sea turtles: Accumulation in relation to ingested plastic marine debris. *Science of The Total Environment* 2018, *610-611*, 402-411.

[63] Rochman, C. M.; Hoh, E.; Kurobe, T.; Teh, S. J., Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports* 2013, *3*, 3263.

[64] Lavers, J. L.; Hutton, I.; Bond, A. L., Clinical Pathology of Plastic Ingestion in Marine Birds and Relationships with Blood Chemistry. *Environ. Sci. Technol.* 2019, *53*(15), 9224-9231.

[65] Kishi, R., Araki, A., Miyashita, C., Ito, S., Minatoya, M., Kobayashi, S., Yamazaki, K., Aitubamai, Y., Miura, R., Tamura, N., The Hokkaido Study of 20,000 birth cohorts and 500 small cohorts: Environment and child health: 15 years of experience and results. Environment and child health: 15 years of experience and results in congenital anomalies, development, and allergy. Japanese Journal of Hygiene, 2018, 73, 164-177.

[66] Soichi Ohta, Chapter 7: Chemical Substances Cause Abnormalities in Immune Mechanisms - Immune Disruption and Allergic Diseases, Inconvenient Substances around the Earth, edited by Japan Society for Environmental Chemistry, Blue Books (Kodansha, Tokyo), 2019, p.190-213.

[67] Levine, H.; Mindlis, I.; Swan, S. H.; Martino-Andrade, A.; Jørgensen, N.; Mendiola, J.; Weksler-Derri, D.; Pinotti, R., Temporal trends in sperm count: a systematic review and meta-regression analysis. *Human Reproduction Update* 2017, *23*(6), 646-659.

[68] WHO, WHO calls for more research into microplastics and a crackdown on plastic pollution, News Release, 22 August 2019, Geneva Available at: https://www.who.int/news-room/detail/22-08-2019-who-calls-for-more-research-into-microplastics-and-a-crackdown-on-plastic-pollution

[69] WHO, Microplastics in drinking-water, 2019 (ISBN: 978-92-4-151619-8)https://www.who.int/water_sanitation_health/publications/microplastics-in-drinking-water/en/

[70] Ministry of the Environment, Domestic situation surrounding plastics. 2018.

<Figures>

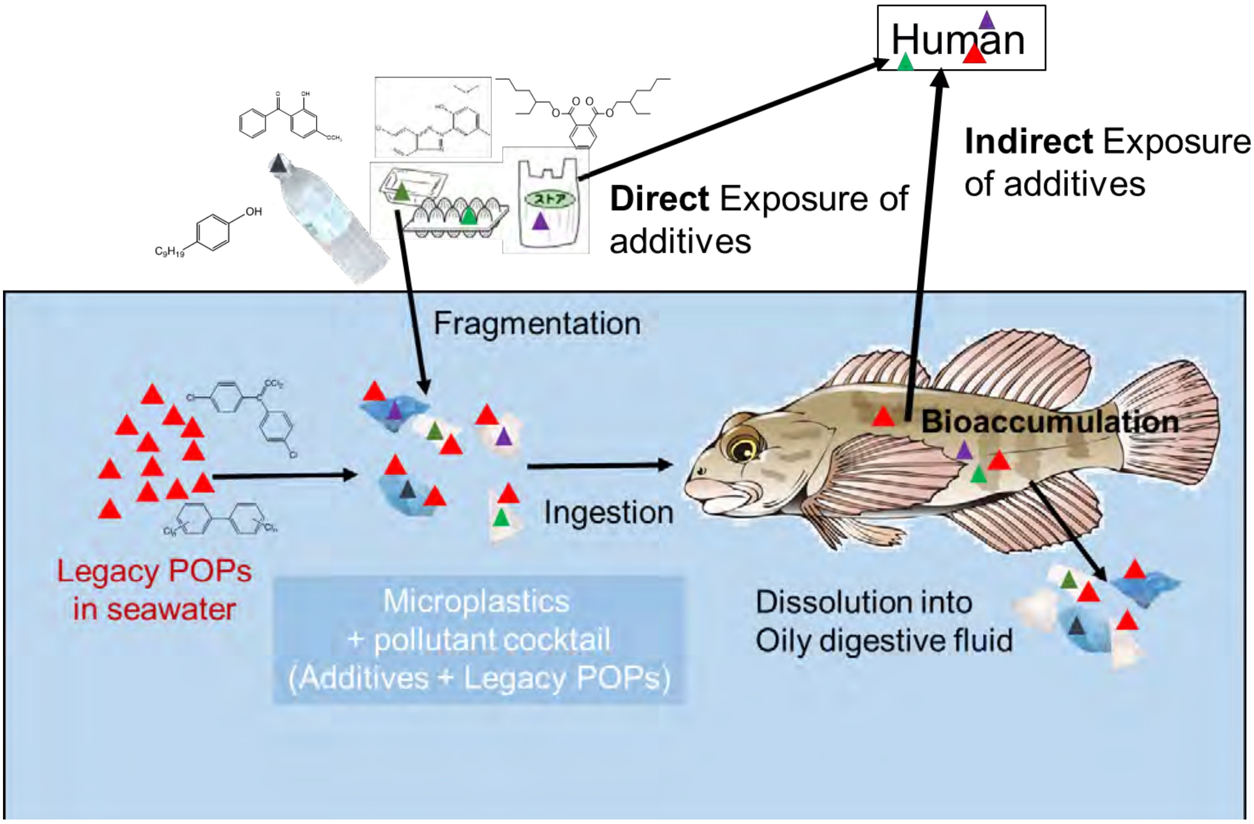

Figure1. Takada, H., Koro, M., Kwan, C.S., 2022. Marine Plastic Pollution: Chemical Aspects and Possible Solutions, In: Nakajima, T., et al. (eds.), Overcoming Environmental Risks to Achieve Sustainable Development Goals: Lessons from the Japanese Experience, pp. 83-92, Springer Singapore, Singapore.

Classification	1999(t)	Change from 2000 to 2017(t)	2018(t)
Films Total	1,995,909		2,311,711
Soft goods Total	1,648,460		1,697,988
Agriculture	126,165		95,191
Packaging	1,174,057		1,209,690
Laminate	129,114		132,999
Other products	219,124		260,108
Rigid products	347,449		613,723
Sheets	336,414		215,415
Plates Total	151,842		119,513
Flat board	109,589		99,277
Corrugated board	42,253		20,236
Synthetic leather	78,422		58,439
Pipe	686,940		394,465
Fittings	66,456		44,892
achinery and equipment parts Total	779,780		683,616
Transportation equipment	356,749		518,568
Telecommunications (including lighting)	287,657		114,134
other products	135,374		50,914
?aily necessities and sundries	349,954		301,071
Containers Total	442,894		868,001
Hollow Molded Containers	364,524		510,028
Other products	78,370		357,973
Building materials Total	312,327		274,138
Gutters and fittings	37,146		29,290
Flooring material	137,406		140,149
other products	137,775		104,699
Foam products Total	377,562		251,866
Planks and boards	93,953		82,633
Molded products	80,102		38,266
Other products	203,507		130,967
Reinforced products Total	84,306		72,080
Plates	8,862		
Molded products	65,938		
Other products	9,506		
Other products Total	385,891		288,084
Deformed extruded products (excluding construction materials)	34,249		29,817
Hoses	46,718		41,540
Disc records	13,485		7,014
Other products	291,439		209,713
Total	6,048,697		5,883,291

Figure 2. Yearly changes in the production of plastic products (Japan Plastics Industry Federation, Plastic Products Production http://www.jpif.gr.jp/3toukei/toukei.htm), prepared by the Environmental Risks Subcommittee. The FY1999 and FY2018 production figures for each component are shown in numerical values, and the changes between the two years are shown in spark lines, where t represents tons of production. Product items and total lines are shown in gray.

<Reference Material 1> SDG goals and targets related to the proposal

Goal 3: Ensure healthy living and promote the well-being of all people of all ages.

3.1 By 2030, reduce the global maternal mortality ratio to below 70 per 100,000 live births.

3.2 Eradicate preventable deaths of newborns and children under five by the 2030year 2020, with the aim that all countries reduce neonatal mortality to at least 12 out of 1,000 live births and under-five mortality to at least 25 out of 1,000 live births Eradicate preventable deaths of newborns and children under five by 2010.

3.3 By 2030, eradicate communicable diseases such as AIDS, tuberculosis, malaria and neglected tropical diseases, and address hepatitis, waterborne diseases and other infectious diseases.

3.4 By 2030, reduce by one-third the youth mortality rate from non-communicable diseases through prevention and treatment, and promote mental health and well-being.

3.5 Strengthen prevention and treatment of substance abuse, including drug abuse and harmful use of alcohol.

3.6 By 2020, halve the number of people killed or injured in road traffic crashes worldwide.

3.7 By 2030, make sexual and reproductive health services available to all, including family planning, information and education, and their inclusion in national strategies and plans for sexual and reproductive health.

3.8 Achieve universal health coverage (UHC), including protection from financial risk, access to quality basic health services, and access to safe, effective, quality and affordable essential medicines and vaccines for all people.

3.9 By 2030, substantially reduce the number of deaths and illnesses caused by hazardous chemicals and air, water and soil pollution.

3.a Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate.

3.b Support research and development of vaccines and medicines for communicable and non-communicable diseases that primarily affect developing countries. It will also provide access to affordable essential medicines and vaccines in accordance with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) and the Doha Declaration on Public Health. The Declaration affirms the right of developing countries to exercise to the fullest extent the flexibility provisions of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) in the protection of public health and, in particular, the provision of access to medicines for all.

3.c Substantially expand health financing and the recruitment, capacity building, training and retention of health personnel in developing countries, especially least developed countries and small island developing states.

3.d Strengthen the capacity of all countries, especially developing countries, for early warning of national and global health risk factors, risk factor mitigation and risk factor management.

Goal 6: Ensure the availability and sustainable management of water and sanitation for all.

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all people.

6.2 By 2030, achieve adequate and equal access for all people to adequate sewage and sanitation facilities and eliminate open defecation. Special attention will be paid to the needs of women and girls, and vulnerable groups.

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing the release of harmful chemicals and substances, halving the proportion of untreated wastewater, and significantly increasing recycling and safe reuse on a global scale.

6.4 By 2030, significantly improve the efficiency of water use in all sectors to ensure sustainable extraction and supply of freshwater and address water scarcity, and significantly reduce the number of people suffering from water scarcity.

6.5 By 2030, implement integrated water resources management at all levels, including appropriate cross-border cooperation.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes.

6.a By 2030, expand international cooperation and capacity-building support to target activities and planning in the water and sanitation sector in developing countries, including water collection, desalination, efficient use of water, wastewater treatment, and recycling and reuse technologies.

6.b Support and strengthen the participation of local communities in improving water and sanitation management.

Goal 11: Achieve inclusive, safe, resilient and sustainable cities and human settlements.

11.1 By 2030, ensure access to decent, safe and affordable housing and basic services for all people and improve slums.

11.2 By 2030, provide all people with access to safe, affordable, easily accessible and sustainable transport systems by improving transport safety, including through the expansion of public transport, with particular attention to the needs of vulnerable groups, women, children, persons with disabilities and older persons.

11.3 By 2030, promote inclusive and sustainable urbanization and strengthen the capacity of all countries for participatory, inclusive, and sustainable human settlements planning and management.

11.4 Strengthen efforts to protect and preserve the world's cultural and natural heritage.

11.5 By 2030, substantially reduce the number of people killed and affected by disasters, including water-related disasters, and substantially reduce direct economic losses as a percentage of global gross domestic product, with a focus on protecting poor and vulnerable populations.

11.6 By 2030, reduce adverse environmental impacts per capita in cities, including through special attention to air quality and general and other waste management.

11.7 By 2030, provide universal access to safe, inclusive and accessible green spaces and public spaces for people, including women, children, older persons and persons with disabilities.
11.a Support good economic, social, and environmental linkages among urban, peri-urban, and rural areas through enhanced country- and region-wide development planning.
11.b By 2020, significantly increase the number of cities and human settlements that have introduced and implemented integrated policies and plans for inclusion, resource efficiency, climate change mitigation and adaptation, and disaster resilience, and develop and implement integrated disaster risk management at all levels, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030. management at all levels, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030.
11.c Support the development of sustainable and resilient buildings using local materials in least developed countries through financial and technical assistance.

Goal 12: Ensure sustainable production and consumption patterns.
12.1 Implement the 10-Year Framework for Sustainable Consumption and Production (10YFP), taking into account the development status and capacities of developing countries, and take measures by all countries under the leadership of developed countries.
12.2 By 2030, achieve sustainable management and efficient use of natural resources.
12.3 Halve global per capita food wastage at retail and consumption levels by 2030, and reduce food losses in production and supply chains, including post-harvest losses.
12.4 By 2020, in accordance with agreed international frameworks, achieve environmentally appropriate management of chemicals and all wastes throughout the product lifecycle, and substantially reduce the release of chemicals and wastes into the air, water and soil to minimize adverse impacts on human health and the environment.
12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
12.6 Encourage companies, particularly large corporations and multinational companies, to adopt sustainable practices and to include sustainability information in their periodic reports.
12.7 Promote sustainable public procurement practices in accordance with national policies and priorities.
12.8 By 2030, ensure that people everywhere have information and awareness of sustainable development and lifestyles in harmony with nature.
12.a Support developing countries in strengthening their scientific and technical capacity to promote more sustainable consumption and production patterns.
12.b Develop and implement methods to measure the impact of sustainable development on sustainable tourism leading to job creation, local cultural promotion and product promotion.
12.c Eliminate market distortions, taking into account the special needs and circumstances of developing countries, while minimizing adverse development impacts in a manner that protects the

poor and communities, through tax reform and the phasing out of harmful subsidies, where they exist, taking into account their environmental impacts, and in accordance with national circumstances Rationalize inefficient subsidies for fossil fuels that encourage wasteful consumption by.

Goal 13: Take urgent measures to mitigate climate change and its impacts*.

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

13.2 Incorporate climate change measures into national policies, strategies and plans.

13.3 Improve education, awareness-raising, human capacity and institutional functions related to climate change mitigation, adaptation, impact reduction and early warning.

13.a Implement the commitment by developed parties to the UNFCCC to jointly mobilize $100 billion per year from all sources by 2020 to address the needs of developing countries in implementing key mitigation actions and ensuring transparency in their implementation, and as soon as possible capital to fully launch the Green Climate Fund.

13.b Promote mechanisms to build capacity for effective climate change-related planning and management in Least Developed Countries and Small Island Developing States, including through a focus on women and youth and on rural and marginalized communities.

*Recognizes that the United Nations Framework Convention on Climate Change (UNFCCC) is the fundamental international and intergovernmental dialogue forum for negotiating a global response to climate change.

Goal 14: Conserve and sustainably use the oceans and marine resources for sustainable development.

14.1 By 2025, prevent and substantially reduce all types of marine pollution, including marine litter and eutrophication, especially pollution from land-based activities.

14.2 By 2020, efforts will be made to restore marine and coastal ecosystems to achieve healthy and productive oceans through sustainable management and protection, including through enhanced resilience, in order to avoid significant adverse impacts on marine and coastal ecosystems.

14.3 Minimize and address the impacts of ocean acidification, including through the promotion of scientific cooperation at all levels.

14.4 By 2020, effectively regulate fishing, end overfishing and illegal, unreported and unregulated (IUU) fishing and destructive fishing practices, and implement scientific management Implement a scientific management plan.

14.5 By 2020, conserve at least 10 percent of coastal and marine areas, based on the best available scientific information, in accordance with national and international law.

14.6 Appropriate, effective, special and different treatment for developing and least developed

countries
Recognizing that subsidies should be an integral part of World Trade Organization (WTO) fisheries subsidies negotiations, by 2020, prohibit fisheries subsidies that lead to overcapacity and overfishing, eliminate subsidies that lead to illegal, unreported and unregulated (IUU) fishing, and discourage the introduction of similar new subsidies**.
14.7 By 2030, increase the economic benefits of sustainable use of marine resources in small island developing States and least developed countries, including through sustainable management of fisheries, aquaculture and tourism.
14.a To improve the health of the oceans and enhance the contribution of marine biodiversity to the development of developing countries, particularly small island developing States and least developed countries, by promoting scientific knowledge, building research capacity and transferring marine technology, taking into account the criteria and guidelines of the UNESCO Intergovernmental Oceanographic Commission on the Transfer of Marine Technology Transfer of marine technology.
14.b Provide small-scale and coastal micro-fishermen with access to marine resources and markets.
14.c Enhance the conservation and sustainable use of the oceans and marine resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea (UNCLOS), which provides a legal framework for the conservation and sustainable use of the oceans and marine resources, as recalled in para. 158 of "The Future We Seek Enhance the conservation and sustainable use of the oceans and marine resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea (UNCLOS), which provides a legal framework for the conservation and sustainable use of the oceans.

**Consider the mandate of the ongoing World Trade Organization (WTO) negotiations and the WTO Doha Development Agenda, as well as the Hong Kong Ministerial Declaration.

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt or reverse land degradation and biodiversity loss.

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial ecosystems, including forests, wetlands, mountains and drylands, and inland freshwater ecosystems and their services, in accordance with its obligations under international agreements.
15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and substantially increase new plantations and reforestation worldwide.
15.3 By 2030, address desertification, restore degraded lands and soils, including lands affected by desertification, drought and floods, and commit to achieving a world unburdened by land degradation.

15.4 Ensure the conservation of mountain ecosystems, including biodiversity, in order to enhance their capacity to deliver essential benefits for sustainable development by 2030.
15.5 Take urgent and meaningful measures to limit the degradation of natural habitats, halt biodiversity loss, protect endangered species, and prevent extinction by 2020.
15.6 Promote the fair and equitable sharing of benefits arising from the utilization of genetic resources, and appropriate access to genetic resources, in accordance with international agreements.
15.7 Take urgent measures to combat poaching and illegal trade in protected animal and plant species, and address both the demand for and supply of illegal wildlife products.
15.8 By 2020, introduce measures to prevent the invasion of alien species and significantly reduce the impact of these species on terrestrial and marine ecosystems, as well as exterminate or eradicate priority species.
15.9 By 2020, integrate the value of ecosystems and biodiversity into national and local planning, development processes and strategies and accounting for poverty reduction.
15.a Mobilize and significantly increase funding from all sources for the conservation and sustainable use of biodiversity and ecosystems.
15.b Mobilize substantial resources from all sources at all levels to finance sustainable forest management and provide adequate incentives to developing countries to promote sustainable forest management, including conservation and reforestation.
15.c Strengthen global support for efforts to address poaching and illegal trade in protected species, including by building the capacity of local communities to pursue sustainable livelihood opportunities.
(Excerpt from the report "The Role of Japanese Academia in Achieving the Sustainable Development Goals (SDGs)," Committee on Environment, Science Council of Japan, September 29, 2017)