MARINE-DEGRADABLE PLASTICS PROGRESSING FOR POPULARIZATION UNDER NEW INTERNATIONAL STANDARDS

Reina Ogawa
Consumer Innovation Dept., Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

SUMMARY

- Marine-degradable, biomass-derived plastics are gaining attention as a means of reducing the environmental impact of plastic bags that contribute significantly to marine pollution.
- Many conventional biodegradable plastics do not break down in the ocean because they were originally supposed to degrade in compost or soil. As concerns about marine plastic pollution heightened, a new standard was established and published.
- With the development of biomass-derived, marine-degradable plastic products, it is expected that marine-degradable plastics will become less expensive and be adopted mainly in the EU and China. Nonetheless, it is necessary to monitor how commercial distribution will be affected by costs, regulations in each country, and consumer trends.

BACKDROP TO THE PUBLICATION OF THE NEW INTERNATIONAL STANDARD FOR EVALUATION OF MARINE DEGRADABILITY OF PLASTICS

Plastic Bags and Marine Pollution

Five hundred billion plastic bags are used worldwide every year (from 2018 World Environment Day statement). The use of plastic bags is increasing due to the expansion of the delivery market with the popularization of EC, coupled with the spread of coronavirus infections. From the perspective of preventing infections, people tend to think that disposable plastic bags are safer than reusable bags. The present situation is making it difficult to curb the consumption of plastic bags. Paper bags are often brought up as substitutes, but they produce more carbon emissions, and the difficulty of reuse has been pointed out (from Green Alliance (UK) report[1]).

The fact that the ocean has been contaminated by plastic products, including plastic bags, became widely known throughout society in 2014, when a report on analysis of plastic released into the ocean was published by the International Union for Conservation of Nature and Natural Resources. According to the reported data, polypropylene (PP) used as fishing materials such as ropes and nets and packaging material accounted for 24% of the plastic released into the ocean. Polyethylene (PE) from plastic bags and straws was responsible for 21%. Furthermore, the Ellen MacArthur Foundation conducted a study on global packaging waste in 2016. Its data showed that, of the 78 million tons of packaging plastic waste generated annually, 32% (24.96 million tons) were released in the natural environment, such as forests and the ocean.

[1] In a study conducted by the Northern Ireland Assembly in 2011, it was reported that the amount of energy consumed in the production of paper bags was four times that of plastic bags. Furthermore, according to an investigative report issued by Denmark in 2018, the impact of paper bags on the environment is 43 times that of ordinary plastic bags when comparing the total of the impact such as on the ozone layer, toxicity to the human body and animals, and water and air pollution.

Marine-degradable Plastics and Other Environmentally Friendly Plastics

Under such conditions, marine-degradable biomass-derived plastics are gaining attention. The shift from non-degradable plastics to marine-degradable plastics is currently an important item on the development agenda for resolving the marine pollution problem. Other important items are the expansion of plastic recovery systems in urban waste, and technology for the recovery of plastic released into the ocean. Marine-degradable plastics were defined as follows: Plastics that are degradable in a marine environment regardless of whether the raw materials are petroleum-derived or biologically derived. Being “degradable” refers to being able to break down into carbon dioxide and water by the action of microorganisms, heat, and light in the marine environment.

For plastics with less environmental impact, there have been a variety of definitions created from different backgrounds. These definitions, often confused with one another in environmental measures for plastics, are summarized below for clarity.

(1) Green plastic: Plastic biodegradable in compost (high-temperature soil), as required by the circular economy

(2) Soil-biodegradable plastic: Plastic that is biodegradable in soil at room temperature

(3) Biomass plastic: Plastic fully or partially using biologically derived material, developed in response to the need to prevent global warming

(4) Bioplastic: Biologically derived biodegradable plastic that meets the requirements of both the circular economy and prevention of global warming (defined by Japan Bio Plastics Association)

Plastic is used in a variety of products, including containers and packaging. This paper particularly focuses on plastic bags (not limited to "plastic shopping bags" that have recently been charged in Japan). Plastic bags are most emphasized in evaluation under the new standard on marine-degradable plastics. They are also at the center of attention in that PE and PP, reportedly responsible for marine pollution, should be replaced with marine-degradable plastic.

Figure 1 classifies the plastic bags currently being produced. They are categorized by the main polymer material (petroleum-derived or biomass-derived) and degradability (compost, soil, marine). The types of plastic corresponding to the above definitions are shown by color.

Degradability in the ocean is known to be lower than that in compost or soil.

Figure 1. Types of Polymer Used in Plastic Bags

Main Material		Degradability			Polymer (Plastic bag use)	Product Example (Company Name)
Petroleum-derived	Biomass-derived	Compost	Soil	Ocean		
○	×	×	×	×	Polyethylene (PE) Polypropylene (PP)	T.U.X. (Mitsui Chemicals Tohcello), Suntec-LD (Asahi Kasei), Noblen (Sumitomo Chemical)
×	○	×	×	×	Bio-polyethylene (Bio-PE) Bio-polypropylene (Bio-PP)	Green Polyethylene (Braskem), Bio-PP (Mitsui Chemicals)
×	○	○	×	×	Polylactic acid (PLA)	Terramac (Unitika), Ingeo (NatureWorks), Luminy (Total Corbion)
×	○	○	○	×	Polybutylene succinate (PBS)	Bio-PBS (Mitsubishi Chemical)
×	○	○	○	○	Polyhydroxyalkanoates (PHA), PHA+PLA, thermoplastic starch (TPS)	PHBH (Kaneka), Mirel (Yield10 Bioscience), Biopolymer (MHG)
○	○	○	○	○	Polybutylene adipate terephthalate (PBAT) + TPS	Mater-Bi (Novamont)
○	×	○	○	○	PP or PE + additive	DEGRA-NOVON (Novon)*

Blue box: Marine degradable plastics**
Green box: Green plastics
Yellow box: Soil biodegradable plastics
Orange box: Biomass plastics
Purple box: Bioplastics

Note: *DEGRA-NOVON is the name of the additive (The use of additives in green plastic is discussed below.)
** Marine degradable plastics include products that have not obtained certification.
Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on the web sites of each company

International Standards and International Certification for Plastic Products

In response to the heightened concerns about marine plastic pollution, in 2020 the new standards ISO 22766 (March 20202) and 22403 (April 2020) were established and published successively to evaluate marine degradability correctly.

The performance of plastic products is standardized by international standards such as ISO and ASTM[2]. International certification is granted to products that have passed tests conducted in accordance with international standards by a third-party testing organization with ISO 17025 (Testing and Calibration Laboratories) certification. With regard to the plastics (1) to (4) in the preceding paragraph, each of them has been certified by the evaluation method stipulated in the international standard, which has improved the recognition and quality of the products.

The new standard specified evaluation methods and required performance of marine-degradable plastic. This means there being plastic options capable of reducing the impact more than soil degradable plastic, when released into the environment.

History of Standardization of Marine Degradability Evaluation Methods

In response to the rising awareness of the marine plastic waste problem, the Group of Seven (G7) adopted the “Ocean Plastics Charter” in the summit held in Canada in June 2018. It is a document urging each country to

[2] Standard established by the American Society for Testing and Materials (former name). It is the world’s largest private non-profit international standardization and specification organization. It became an international standard and changed the name of the organization to ASTM International in 2001 aligned to the actual conditions.

take specific measures to address the marine pollution problems caused by plastic wastes. The charter was signed by Canada, France, Germany, Italy, and the United Kingdom—five of the G7 nations, without the US and Japan.[3]

Meanwhile, validation testing was conducted for technology that evaluates the marine degradability of plastics under Open-BIO (Opening bio-based markets via standards, labelling and procurement) from 2013 to 2016, and the results were used to develop a guideline for establishing new standards. As the project name of Open-BIO indicates, it is a project for developing a differentiation strategy to expand the bioplastics market. This study was led by the German marine research institute HYDRA Institute for Marine Sciences (HYDRA) and bioplastics manufacturers Novamont (Italy) and BASF (Germany).

A similar international standard is "OK biodegradation MARINE label" based on ASTM D7081 and D6691, which is certification of "marine biodegradable plastics." However, both of the underlying ASTM standards were withdrawn in 2015 as being inadequate as a method for evaluating marine-degradable plastics based on the Open-BIO validation results.

From the above background, international standardization of evaluation methods related to marine-degradable plastics has been led by the EU from data acquisition to establishment of standards. In the past, Japan took the lead in standardizing the compost and soil degradability of bioplastics and biomass plastics, thereby increasing Japanese products' presence in the market. However, Japan was unable to find the significance of marine degradability because domestic recycling systems were established in advance. This led Japan to a wait-and-see stance to the EU's move to establish standards.

DETAILS OF THE NEW ISO 22403 AND 22766 STANDARDS FOR MARINE-DEGRADABLE PLASTICS

Marine Degradability of Plastics and Positioning of the New Standards

The breakdown of plastics in a marine environment arises through the complex effects of multiple factors. Thus, it is held that the environmental impact of plastics exposed to the marine environment should be evaluated comprehensively based on three main aspects. The three aspects are:

(1) Field evaluation according to the environment in which waste plastic is actually exposed (such as composition of seawater, water depth, concentration of (micro)organisms, and changes in water temperature and sunlight due to the seasons)

(2) Biodegradability evaluation in a laboratory environment (artificially controlled to have the same conditions)

(3) Safety evaluation as a chemical substance

ISO 22766 specifies field testing methods in (1). ISO 22403 specifies the testing method in the laboratory environment in (2) and the criteria for determining biodegradability in the ocean (determination based on data obtained in a laboratory environment). For the safety evaluation in (3), application of the ecotoxicity evaluation method OECD TG202[4] is recommended.

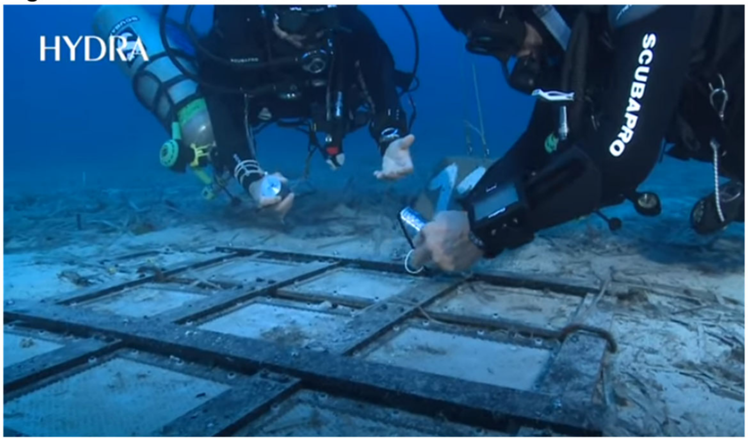
[3] Japanese government officials have stated that the government naturally agreed with the intent to reduce plastic waste but did not sign due to the absence of a valid domestic law and the undetermined degree of impact on society.

[4] Evaluation is performed by placing plastic in a culture for three months, exposed to water fleas (organisms initially preyed upon in the food chain within the water) in it for 48 hours, and evaluating the decline in swimming (inhibition of swimming). If a majority of the water fleas are not affected, it is determined that there is no toxicity.

Overview of ISO 22766: 2020

The evaluation method described in ISO22766 is referred to as a “disintegration” test, which is different from a biodegradation evaluation. A disintegration test is a field evaluation with testing in the littoral zone (coastal area) and sublittoral zone (from the coastline to a depth of 200m), where most waste plastic accumulates. The test is conducted by placing the three types of plastic in the test area: a good reference for testing the degree of disintegration (for example, Kaneka’s PHBH), a reference with a poor degree of disintegration (low-density PE), and the plastic film to be evaluated. The degree of disintegration is measured by the remaining area of the film. The longest test period is three years, but the test is ended if the degree of disintegration reaches 90% or more, in other words, the remaining area is less than 10% of the original film.

Figure 2. HYDRA Field Test



Source: Excerpt from HYDRA YouTube video “Plastic in the Sea - Research Project OPEN-BIO”

Overview of ISO 22403: 2020

Whereas ISO 22766 specifies the method for evaluating the degree of disintegration in the ocean, ISO 22403 defines the evaluation method for “biodegradability” in the ocean. The biodegradability here means plastic being broken down into carbon dioxide and water by marine microorganisms and the like. For this reason, biodegradability is evaluated by measuring the amount of carbon dioxide produced by biodegradation when a powdered sample is sealed in with seawater and sediment.

The required performance of marine biodegradability was specified to be 90% or more of the carbon contained in the sample being broken down into carbon dioxide within two years or having better biodegradability than cellulose, the main component of plant fiber.

Impact of Both Standards on the Development of Marine-degradable Plastics

As mentioned above, determination of evaluations based on the standards requires a long test period of around two to three years. At present, no effective tests with shorter periods have been developed. For this reason, plastics that were already used as reference samples when the marine degradability standard was reviewed can enter into markets with marine degradability requirements. In contrast, for plastics developed in the future, this standard could be a barrier to market entry if the same verification is required. In terms of new development, priority will likely be given to plastics that can break down faster, resulting in a short test period.

VARIOUS COUNTRIES’ RESPONSES TO THE NEW STANDARD

Although there is no opposition to the standard at present, responses have been varied among countries. Some countries are promoting the manufacture and supply of marine-degradable plastics using the other standards, while others are studying evaluation methods for marine environments where degradation cannot be forecast (deep ocean). The United States is waiting and watching the actions taken by other countries.

Response by Japan

Although Japan postponed signing the Ocean Plastics Charter, the prime minister announced in an administrative policy speech to the Diet in 2019 that Japan would aim to realize a world that does not produce new pollution. He also stated that Japan would work with other countries on measures against marine plastic waste by appropriately collecting and disposing of waste, and developing new materials that break down in the ocean. Since then, alongside research and development of marine-degradable plastics, policies for increasing its presence in standardization have been promoted through collaboration among industry, academia, and government. In March 2020, various plastics, including products under development began to be tested by exposing them to seawater at the depth of 5,000m under the Cabinet Office's Strategic Innovation Program. It is a joint project by the Japan Agency for Marine-Earth Science and Technology, the Japan BioPlastics Association, the University of Tokyo, and the National Institute of Advanced Industrial Science and Technology. The water temperature on the deep ocean floor is low at around 4°C throughout the year, and the microorganisms living there differ from any of the currently standardized environments. If a plastic that is degradable in the deep ocean is found, that will provide an added value to the products or those under development.

Response by the EU

Despite having led the establishment of the standard, the EU has not always had advantages in terms of business. The European Bioplastics Association has identified 100% biomass-derived, polyhydroxyalkanoate (PHA)- based biodegradable plastic as the most promising bioplastic through the evaluation tests on marine degradability obtained in the Open-Bio Project. The association estimated that global biodegradable plastic production will increase threefold over the next five years. There are six leading companies manufacturing PHA polymers: BioMatera (Canada), Bio-on (Italy), Danimer Scientific (US), TianAn Biopolymer (China), Tianjin GreenBio Materials (China), and Yield10 Bioscience (US) and North American and Chinese companies are taking the lion's share. While Bio-on (Italy) is increasing its production for the growing demand for PHA, the EU is also seeking to partner with China. The outcome from European Bioplastics was unexpected for Novamont (Italy) and BASF (Germany), which were involved in establishing the standard while centering on non-PHA plastics development. They were unable to shift to PHA development because they had invested in the development of other types of bioplastics. The two companies changed their strategies separately. Novamont decided to expand sales of non-PHA marine-degradable plastics, and BASF shifted to building a robust closed recycling system that does not release plastics into the environment while bringing non-marine-degradable bioplastics to the market.

Response by China

China has maintained a position of forward-looking and active involvement in the establishment of international standards, and a study on the release of plastics into the ocean was conducted with funding by the Chinese government. The study estimated that approximately 30 thousand tons of plastic would be released into the ocean in 2020, even if the import of waste plastic was prohibited, and restrictions were placed on one-way plastic products. It also pointed to the need to strengthen collection in addition to considering measures for reducing the environmental impact of plastic when released. Other than partnering with Europe, China has agreed on a policy to strengthen ties with Japan, through academic exchanges related to marine-degradable plastics (third high-level round table talks between Japan and China held in 2019). China, the biggest producer of both petroleum-derived and biologically derived plastics, has included in its 13th five-year plan the goal of promoting biodegradable plastics. This move by China warrants attention as it is expected to have a significant impact on the market penetration of marine-degradable plastics.

Countries' Measures Related to Plastic Bags

Countries' measures related to plastic bags are shown in Figure 3. The list does not include many countries currently evaluating the impact (such as Canada, and the UK). The trend of establishing measures to promote the reduction of environmental impact is shared worldwide. It is international standards that specifies plastics with a low environmental impact which can be publicly procured or used as an exception. This fact proves the importance of standards for plastic.

Figure 3. Countries and Regions' Measures Related to Plastic Bags

Country/ region	Measures related to plastic bags
France	Disposable containers are banned in principle. Exceptions are plastic containers using 50% biologically derived material that can be composted at home, and this percentage will be raised to 60% by 2025.
Netherlands	Agreement was established between the Netherlands government, industry, and civic groups in 2019 to promote voluntary efforts by companies for plastic containers and plastic products and signed by a total of 75 organizations. One target for 2025 is to use biomass plastic produced as sustainably as possible.
US	Varies by state, but New York plans to ban single-use plastic bags. The US Department of Agriculture operates a bio-preferred program to support the development and expansion of the market for biomass-derived products. The program is made up of two pillars: (1) a mandatory biomass product procurement system for government organizations and (2) a voluntary certification and labeling system for the private sector.
Costa Rica	Declared replacement with products that are recyclable and able to decompose in water within 180 days by 2021.
China	The use in packages (and packaging) in major regions will be banned by the end of 2021. Also considering banning the manufacture and sale of plastic bags with a thickness of less than 0.025mm. Exceptions are biodegradable plastics.
Taiwan	Ban on the provision of free plastic bags in retail stores. Payment of an additional fee for use to be made mandatory in 2025.
Saudi Arabia	Use of government-approved oxidizing biodegradable material is mandatory in plastic products.
South Korea	Bioplastic film is designated in green public procurement system.
Japan	The Ministry of Environment is formulating a roadmap for the introduction of 2 million tons of biomass plastic (not limited to bags) by 2030. Measures such as government procurement and designated bags for combustible waste are also being considered.
Indonesia	Second largest volume of plastic released into the ocean in the world. In 2018, set a target to reduce plastic waste in the ocean by 70%. Established an ordinance banning the use of disposable plastic bags in four cities to ensure the use of environmentally friendly alternatives.
Malaysia	In 2018, announced a policy to totally ban the use of disposable plastic products by 2030 and to tax disposable plastic bags.

Source: Prepared by MGSSI based on various report materials

Market Environment Surrounding Marine-degradable Plastics

The scale of the green plastic market is shown because there are no statistics on market scale separating marine-degradable plastic and green plastic. The movement to reduce CO2 emissions under the Paris Agreement is promoting the departure from fossil fuels for plastic materials, that is, the switch to biomass materials. As a result, the production volume of green plastic is expected to increase from 1.17 million tons in 2019 to 1.33 million tons in 2024 (from European Bioplastics market data). This is less than one-hundredth of the 148 million tons of combined total demand for PE and PP in 2015 (from Plastics Europe report) and is still only a small volume, but there is much potential for it to be used as a substitute.

TECHNICAL ISSUES AND TRENDS IN RESEARCH AND DEVELOPMENT FOR POPULARIZATION

Issues with Existing Products

Details on existing plastic products with marine degradability are shown in Figure 4.

Plastic product	Main material		Advantages	Disadvantages
	Petroleum-derived	Biomass-derived		
PP or PE + additive	Propylene or ethylene decomposition accelerator	-	If Bio-PP and Bio-PE spread, the technical barriers to 100% biomass-derived plastics will be lowered.	Microplastics may remain in the ocean if dispersion of the additive is inadequate.
Mater-Bi (Novamont)	1,4-Butanediol Purified terephthalic acid	Starch	Cheaper than PHA. Can be labeled as biomass plastic because part of the material is biomass-derived.	Difficult to industrialize the use of biomass for the purified terephthalic acid (PTA), a raw material used in PBAT.
PHBH (Kaneka) Mirel (Yield10 Bioscience), etc.	-	Vegetable oil, among others	100% biomass-derived and has a good balance of workability, strength, and degradability.	Expensive.

Source: Prepared by MGSSI based on the web sites of each company and other materials

When limited to the polymers that are the main material used in plastic bags, no petroleum-derived polymers have workability and durability along with marine degradability. Some countries have adopted products that are made degradable by adding a decomposition accelerator (additive) to non-degradable PP and PE. However, the product does not degrade uniformly when the dispersion of the additive is inadequate. Therefore, it has been pointed out that this may result in remaining in the ocean as microplastics. In 2017, more than 150 companies and organizations, including major European corporations and NGOs, signed the "Oxo statement," which is a joint statement demanding the termination of use of plastics with decomposition accelerator added. Mater-Bi is a plastic product being increasingly adopted in plastic bags as a marine-degradable biomass plastic. It balances workability, durability, marine degradability, and price by mixing (compounding) biologically derived TPS and petroleum-derived PBAT. Mater-Bi is somewhat disadvantageous because it partially uses petroleum-derived material to produce polymers that are difficult to substitute with biologically derived materials. Nonetheless, adjusting price and performance through compounding technology could be one direction to take. Meanwhile, the price of 100% biomass-derived PHA plastic is hindering popularization because of the high price that is around double that of conventional PP and PE.

Research and Development Trends

To develop 100% biologically derived, inexpensive marine-degradable plastic, researchers are studying technology that increases strength while retaining the biodegradability of starch-derived polymers, and new synthesis processes for lowering the price of PHA polymers. In addition to these, University of Tokyo Professor Tadahisa Iwata is also developing the ultimate biodegradable plastic with a biodegradation initiation function that commences degradation when released into any environment. With regard to the biodegradation initiation function, he has succeeded in producing a plastic that begins decomposing when placed in water by mixing in an enzyme capable of decomposing PLA in the polylactic acid (PLA) solvent solution. It is anticipated that the studies are proceeding while advancing this technology.

CONCLUSION

The recently established standard on marine-degradable plastic is positioned to complement existing movements to strengthen recycling and measures for restoring the environment. For this reason, the trend that the product design must consider until after use when being commercialized, is the same as for existing plastics. It is believed that some time will be required to achieve a departure from plastic, 100% recycling of plastic, and zero release of plastic into the ocean. However, the use of marine-degradable plastics in plastic bags could rapidly advance as governments strengthen regulations and revise public procurement systems or by a wider awareness that marine-degradable plastics are a better choice than green plastics in reducing the environmental impact due to the release into the environment. Therefore, the relevant companies will be required to quickly and flexibly respond to changes in commercial distribution. It is worth monitoring the actions of the relevant countries, certification organizations, and companies in the future.

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