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Research Note

Marine Debris Issue and Prevention Practices of Discarded Expanded Polystyrene (EPS) Floats in Japan

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Key words: EPS, Float, Fragment, Marine debris

Abstract

Expanded Polystyrene (EPS) floats are used for various purposes, such as the floating production of marine aquaculture (e.g., floats of net cages and oyster farming rafts), buoys for fishing gear and fenders for boats in the coastal area. However, they cause some environmental impact generating marine debris. In this report, we introduce about the issue of marine debris of discarded EPS floats in Japan and the past prevention practices.

1. Marine debris issue of discarded EPS floats in Japan

Expanded Polystyrene (EPS) floats are used for various purposes, such as the floating production of marine aquaculture (e.g., floats of net cages and oyster farming rafts), buoys for fishing gear and fenders for boats in the coastal area. If the floats are not well maintained and are left exposed to the elements on the seashore, they will disintegrate and will scatter along the beaches after drifting at sea (Fig 1).

Fig.1 Scattered EPS fragments on the sea surface (Left, in harbor; Right, grounded on the coast)

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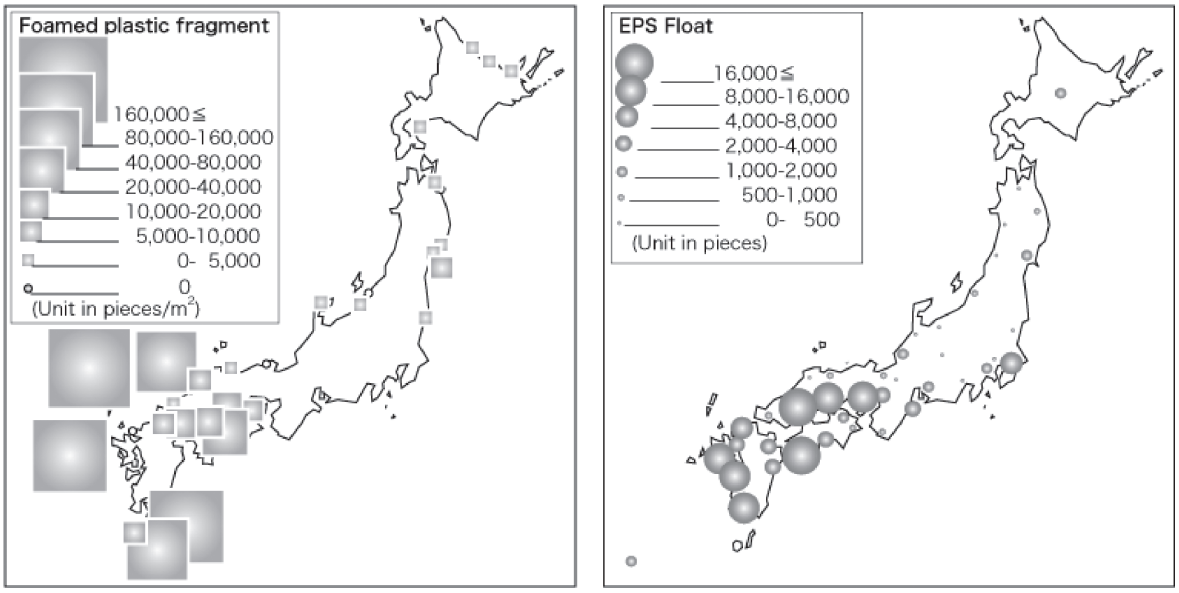

Fig.2 Density of foamed plastic fragments[3] (Left) and production volume of EPS float by prefecture (Right)

The annual production of EPS was 150,000 tons in 2011 in Japan, and 56 % was used for making fish containers[1]. The annual production of EPS floats was 500 tons (155,000 floats)[2], so it was 0.3% of the total production. The density of foamed plastic fragments that had washed up along 30 beaches in Japan from 2004 to 2006[3] and the production volume of the EPS floats by prefecture surveyed by the Japan Foam Styrene Industry Association in 2004[2] are shown in Fig.2. Both results are greater in western than eastern Japan. The density of foamed plastic fragments is related to the

Fig.3 Large amount of EPS floats used on the oyster farms at Geoje Island in South Korea

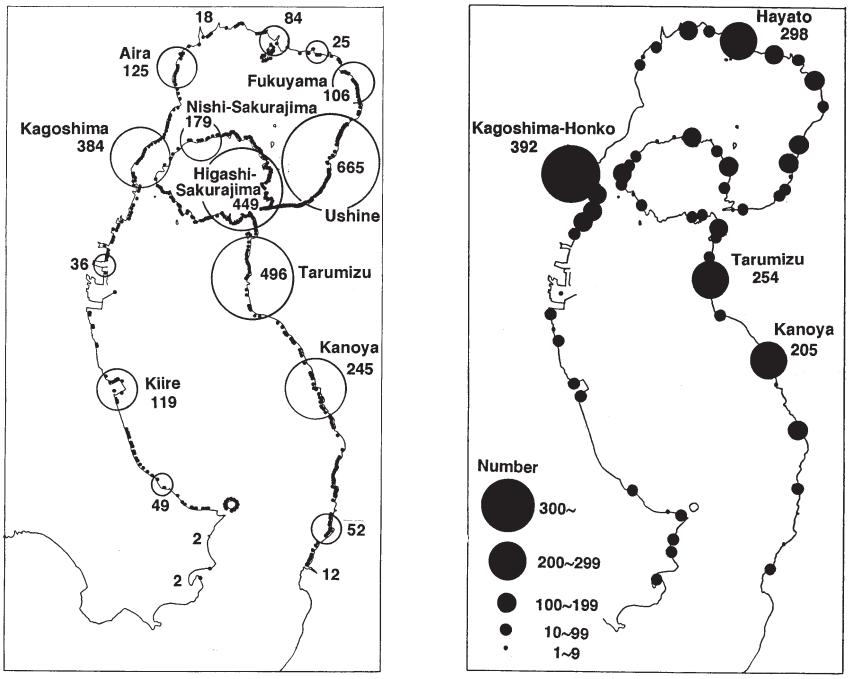

Fig.4 Points where EPS floats were grounded (●) and the number of the floats in each fishing district (○) (Left) and distribution of EPS floats without covers used on the sea as fenders or mooring buoys (Right) [5].

production volume of EPS floats. In the Seto Inland Sea and south Kyushu area, where many of the floats are produced, EPS fragments are scattered along the beaches. These are used as floats for the net cages of aquaculture in Kyushu and rafts for oyster farming in the Seto Inland Sea. However, the highest density area of the fragments was particularly located on the Tsushima island coast in northern Kyushu, where the floats are not produced. This suggests that the origins of the fragments are not Japanese floats. Their origin seems to come from the disintegration of EPS floats originating out of the oyster farms in South Korea (Fig.3).

Fujieda et.al. [4] have conducted surveys on the small plastic fragments along the coast of southern Kyushu since 1998. In their results, foamed plastic fragments accounted for 92.6 % of the total debris and 91.0% of the particles ranged in size from 0.3 to 4.0 mm. Fujieda et.al. [5] visually assessed the use of EPS floats in Kagoshima Bay in 2000 (Fig.4). The left of the figure shows the points where EPS floats were grounded (Fig.1 Right photo.), and the right of the figure the distribution of EPS floats without covers used on the sea as fenders or mooring buoys (Fig.1 Left photo.). We found that 3,043 EPS floats without covers washed up along the coast of Kagoshima Bay. The floats were abundantly found along the east coast of the bay. Floats without covers were also commonly used as fenders in harbors. Distribution of foamed plastic fragments along the coastline of southern Kyushu had the highest density along the east coast of Kagoshima Bay[4]. It had a maximum density of about 70,000 pieces/m^2 (Fig.5), and this is the major aquaculture area in this bay.

Foamed plastic debris is also one of the most popular items in the Seto Inland Sea [6,7]. The EPS floats are commonly used for the floats of oyster farming rafts in Hiroshima Bay. Both the density of the fragments and the amount of the floats without covers were greater than in Kagoshima Bay [6].

Thus the source of EPS fragments was mainly attributed to these wastes coming from the EPS floats. Therefore, we must reduce the amount of EPS floats currently used on the sea. However, the floats are one of the difficult items to dispose off because of their large volume and higher burning calories. They constitute a fire risk when stocked at the storage facilities on land. Additionally, they degrade to smaller fragments when inappropriately reused as boat fenders in the harbor. EPS floats users must comply with the Laws for the proper disposal of their floats. Annual production of EPS floats is 500 tons (155,000 floats), and the number of fish farming companies in Japan is decreasing. Therefore, discarded EPS floats are increasing around the fishing grounds. The discarded EPS floats can be repaired and recycled by wrapping new covers

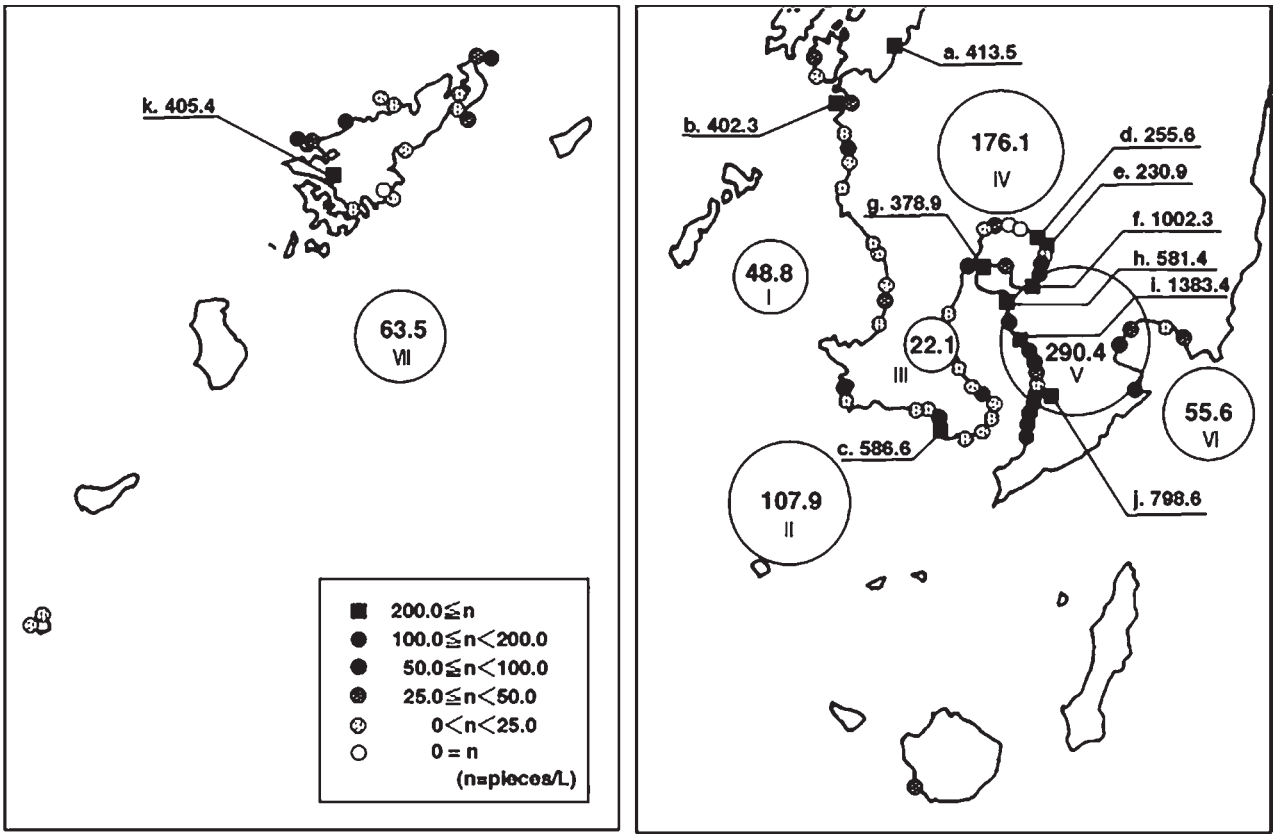

Fig.5 Distribution of foamed-plastic fragments along the coastline of Southern Kyushu[4)]

over them and using them again. However, it is not possible to actually reduce the fragmentation of EPS floats on the sea because the cover degrades very quickly when exposed to sunlight.

EPS Recycling stations are located in over 133 points in Japan[8)], but these are for daily use items, which do not include floats. In 2011, the recycling rate of total EPS production was 85.7 %[1)]. It is the highest rate in all plastics used in Japan. However, the floats can be abundantly found washed up on the coast, because there is no disposal and recycling system in Japan, and because many floats drift and are washed up from other countries along the Japanese coast.

Incineration is prohibited by the current regulations and some groups have demanded for economical disposal or recycling of the floats in Japan. JEAN (Japanese NGO) had a meeting and discussed with all the concerned parties (exp. float makers, recycle associations, experts in marine debris, Fisheries agency and fisheries co-operative associations, etc in 2002[9)]). An improved recycling of EPS floats program was started in 2003 by the government. The method employed involves that the discarded EPS floats are compressed with a portable compressor at the fishing port near the marine aquaculture area.

2. Development of the economical disposal or recycling system of the discarded EPS floats

2.1 Portable compressor for EPS floats

In this section I introduce the development of an economical disposal or recycling system for the discarded EPS floats in Japan. Figure 6 shows the new portable compressor for EPS floats. The mechanism of this compressor is that the EPS is crushed and broken down into small pieces through the crushing zone, and then compressed through a screw press (Patented Product). The volume of the EPS decreases as the gas-containing cells shrink while the polystyrene softens by friction and distortion heat. Bad odors are hardly generated because the polystyrene resin does not reach a high temperature.

The resin does not decrease molecular weight because heating is below the decomposition temperature. Hence, the material processed with this device can be recycled as foam plastic. Because this compressor is a simple and composed

Fig.6 Portable compressor for EPS floats (STYROS BUOY, ELCOM Co. Ltd)

of few parts, its maintenance and management are easy. The supply entry port of the compressor is wide, so that even king-sized buoys used as floats of aquaculture rafts can be processed whole.

2.2 Location of demonstration studies

The demonstration of the portable compressor was carried out at Saiki city (Oita prefecture), Etajima city (Hiroshima prefecture), Minamiise town (Mie prefecture), Sasebo city, Ojika town (Nagasaki prefecture), Nagashima town (Kagoshima prefecture) and Amakusa city (Kumamoto prefecture) from 2009 to 2012. This demonstration was mainly processed by waste generators (fishers) of EPS floats. The target materials were discarded EPS floats. This operation was conducted by "Umi to Nagisa Kankyō Bika Suishin Kikō " (Incorporated association).

2.3 Compacting EPS floats with the portable compressor

Table 1 shows the processing results of discarded EPS floats from 2003 to 2007 (1st term) [2,10-13] and Table 2 those starting from 2010 to 2012 (2nd term) [14]. In the 2nd term, a total of 44,872 floats (183 tons) were processed (Fig.7).

The portable compressor was renewed to a new model in Fig.5 during the 2nd term. In 4 years, 28,358 floats have been recycled in southern Kyusyu and western Shikoku. This new machine had a compacting ratio for floats of 1/5th-1/25th, and a compressing capacity of 50-100 kg/h (14-16 m^3/h) in this trial.

2.4 Recycling of EPS floats by RPF (Refused Paper and Plastic Fuel)

Processed discarded floats were recycled to RPF (Refused

Table 1 Processing results of waste EPS floats since 2003 to 2007

Year	Location	Processed weight (kg)	EPS float number	Memo
2003	Uwajima (Ehime Prefecture)	1,088	240	
	Kokubu (Kagoshima Prefecture)	5,640	1,343	*
2004	Amakusa (Kumamoto Prefecture)	8,360	1,990	*
	Ushine (Hiroshima Prefecture)	7,350	1,751	*
	Nishisakurajima (Kagoshima Prefecture)	1,390	331	*
2005	Uwajima (Ehime Prefecture)	21,130	5,031	*
	Ushine (Kagoshima Prefecture)	12,470	2,969	*
	Azumatyou (Kaghoshima Prefecture)	19,760	4,705	*
2006	Uwajima (Ehime Prefecture)	18,870	4,492	*
	Ushine (Kagoshima Prefecture)	5,290	1,259	*
	Azumatyou (Kaghoshima Prefecture)	8,270	1,968	*
2007	Azumatyou (Kaghoshima Prefecture)	8,990	2,279	
Total		118,608	28,358	

* weight is estimated by 4.2 kg/float.

Table 2 Processing results of waste EPS floats since 2010 to 2012

Year	Location	Processed weight (kg)	EPS float number	Memo
2010	Minamiise (Mie Prefecture)	11,480	3,021	
	Saeki (Ohita Prefecture)	12,460	3,279	
	Sasebo (Nagasaki Prefecture)	6,450	1,696	
2011	Etajima (Hiroshima Prefecture)	3,000	666	4.5kg/float
	Sasebo (Nagasaki Prefecture)	2,300	680	
	Nagashima (Kagoshima Prefecture)	8,761	2,190	
2012	Sasebo (Nagasaki Prefecture)	3,780	945	
	Ojika (Nagasaki Prefecture)	1,600	400	Drifted floats
	Amakusa (Kumamoto Prefecture)	2,430	607	
	Nagashima (Kagoshima Prefecture)	12,114	3,029	
Total		64,375	16,514	

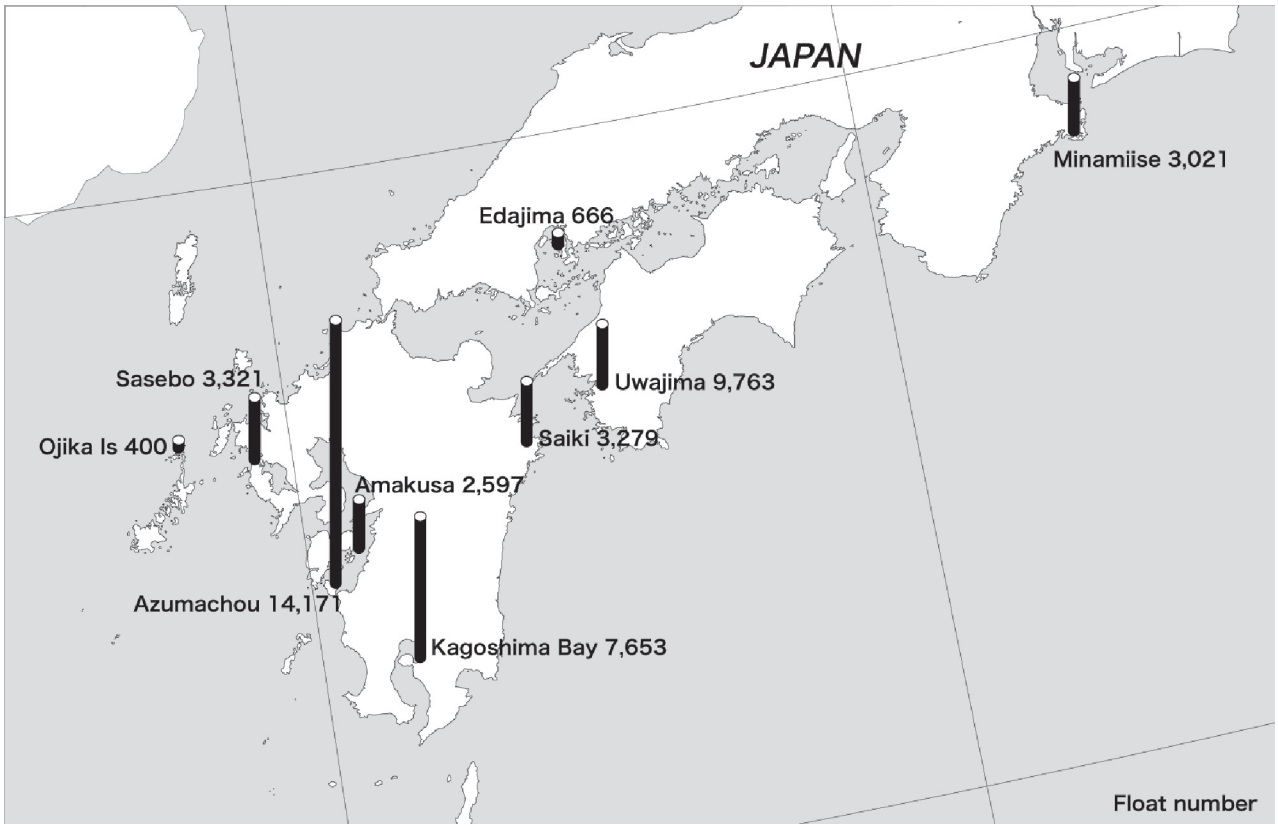

Fig.7 Total number of processed discarded EPS floats (unit in float number) from 2003 to 2012

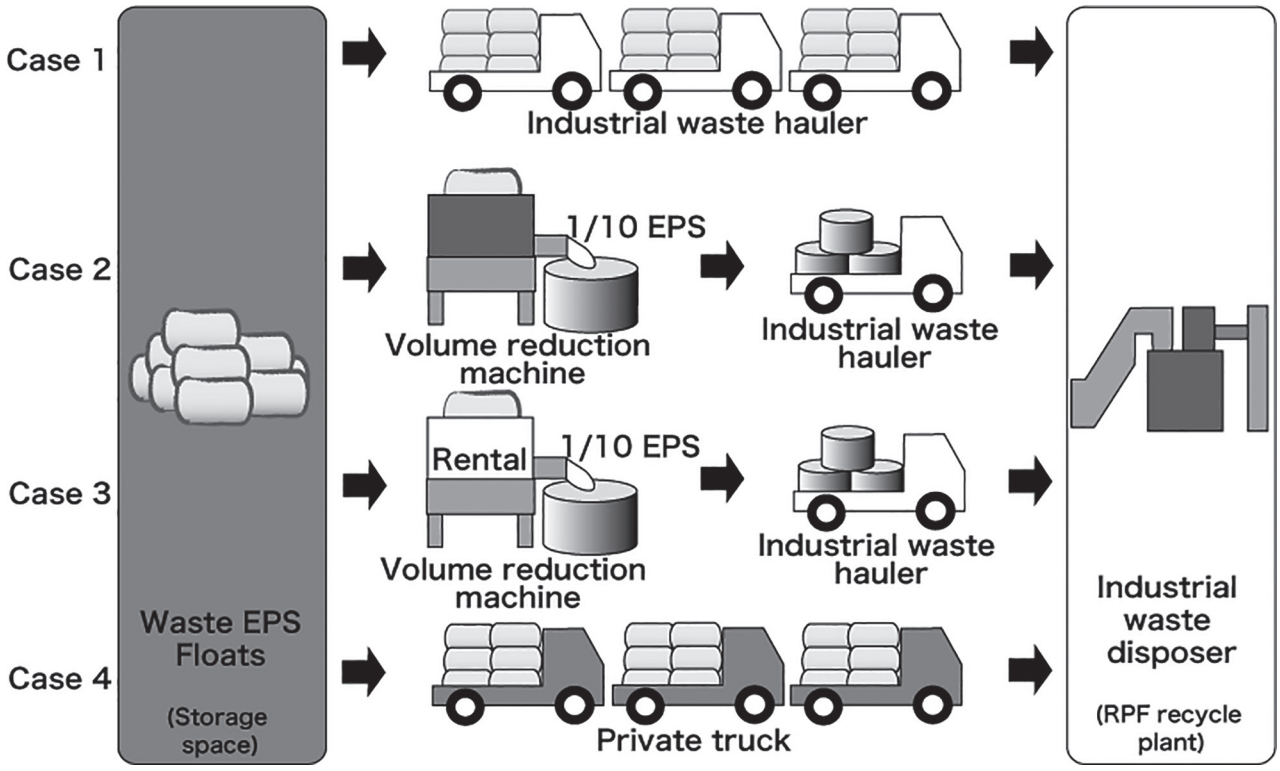

Fig.8 The four methods of disposal of discarded EPS floats showing routes from the storage space to the recycle plant of industrial waste disposal

Paper and Plastic Fuel), which is one of the solid fuels that combines waste paper (low calorie item) and plastic (high calorie item) and where the burning calories can be controlled. This solid fuel is used for heat recovery as recycled fuel for the paper company's boiler instead of Coal. Hereunder are 4 methods (Fig.8) carried out for EPS disposal from the storage space of discarded EPS floats to the recycle plant of industrial waste disposal.

Case 1: Outsourcing the transportation and disposal of discarded EPS floats to the hauler/transporter and bringing them to the recycle plant (Industrial waste disposal). The EPS user covers all the costs.

Case 2: Using a portable compressor for EPS floats. The EPS floats user brings the discarded EPS floats to a stockyard used for volume reduction before disposal. Volume reduction works are carried out by the user of EPS floats. Later the transporter collects the volume reduced EPS and takes it to the recycle plant.

Case 3: Using a rented portable compressor for EPS floats. The EPS floats user brings the discarded EPS floats to a stockyard used for volume reduction before disposal. Volume reduction works are carried out by the user of EPS floats. Later the transporter collects the volume reduced EPS and takes it to the recycle plant.

Case 4: Directly transporting the non-volume reduced EPS floats to the industrial waste disposal plant by the user.

In the 2nd term, we developed an economical disposal and recycling method for the discarded EPS floats. From our results, the most economical method is (4), and it costs more than 300 yen/float (Fig.8). However, this method is confined to where the recycle plant is located near the aquaculture ground and the case is limited to only two areas in Japan.

The second lowest cost is (3), at 300 yen/float if the quantity is over 3,000 floats at a time. However, this method is also confined to where the rental agency is near the aquaculture ground. Currently, there are two rental machines available in Japan. If the disposal is over 10,000 floats / time, the cost of method (2) is the lowest. However, currently there is no user nor area that disposes off over 10,000 floats every year. The highest cost method is (1). The hauling/transportation cost account for a half of total cost.

So the best practice is that the local government or an extended association buys a volume reduction machine and sequentially leases it to areas where over 2,000 floats are

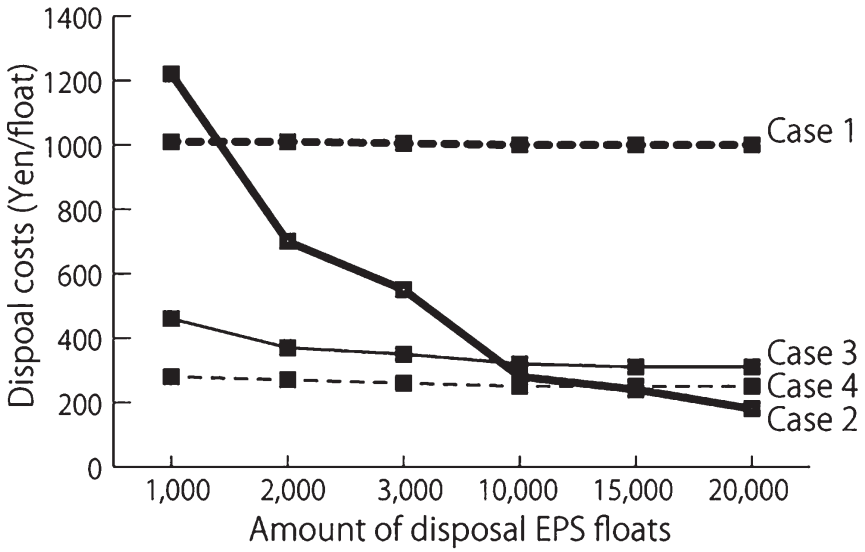

Fig.9 Comparison of disposal costs according to disposal method [14] (Refer to fig.8 for each case)

stocked. Floats users in their areas make their own initiatives and reduce the volume of their own floats.

2.5 Compact Recycle System of EPS floats by E-PEP (EPS Pellet Fuel)

In the past year, we have processed the waste EPS floats to produce RPF. However, there was a problem when producing RPF from compacting EPS wastes, and it is that the generator has to transfer the EPS wastes to the manufacturing plant. Additionally, the calories generated by EPS are higher than those of Coal. If the waste generator can directly recycle EPS fuel, recycling of discarded EPS float will be compact. ELCOM Co. Ltd has developed the E-PEP producing system. This system consists of a portable compressor of EPS floats, a compact Pelletized machine and a Pelletized fuel boiler. If it can make fuel from discarded EPS floats, it contributes to reduce fuel cost and becomes environment-conscious. If pelletized fuel can be used at the compact boiler and if bunker A can be used in it, the running cost of fuel can be reduced.

3. Shift to a high durability float

Tarumizu City is located in the eastern coast of central Kagoshima Bay. The Fisheries Cooperative Association of Tarumizu is a leader for Amberjack production in Japan. In Japan, the Sustainable Aquaculture Production Assurance Act came into force in 1999. The goals of the Fisheries Cooperative Association of Tarumizu are sustainable development of aquaculture and provision of safe production for consumers based on this act. They are trying to reduce the damaging effects on the fishing ground; for example, distinctive inventions on feed, cooperation with agriculture and shifting from conventional EPS float to a high durability float.

It is necessary to change the conventional EPS floats, because they have some defects as follows:

1) Low durability: they brake into many fragments. The PE cover is weak and it is easily broken down by bird-claws and the friction with frames and boats.
2) Low workability: it is difficult to scrape attached fouling organisms because the cover is of low durability, this results in frequent exchange of the covers.
3) Absorption: seawater is absorbed into the EPS beads by direct water contact and the weight increases.
4) Difficulty of recycling material because it includes water and attached fouling organisms.
5) Short period of service: the period of use of conventional EPS floats is 3 years. They generate a huge amount of waste, requires store yards and high disposal costs every year.

When Typhoon 11 hit Kagoshima Bay in the summer of 1989, all the aquaculture rafts in this area were sunk. The causes were that their anchors were moved by the typhoon waves, and were felled into deeper water from the sloping sea floor so that the rafts were sunk. When the EPS floats sunk into the water, the EPS beads were crushed by the water pressure and the floats lost their buoyancy. Consequently, fishers thought that it is necessary to convert the conventional

Fig.10 High durability floats“Power Float” (Yasui Co. Ltd)

EPS floats in order to maintain their buoyancy.

To solve the problem, a new float was developed by the EPS maker (YASUI Co. Ltd) (Fig.10) of Kagoshima in collaboration with the Fisheries Cooperative Association of Tarumizu City. It took 10 years for the shift from using conventional EPS floats to the new floats in the Tarumizu area because they are expensive. This new float consists of a hard plastic cover (5mm thickness Polyethylene) that is evenly filled with foamed PS (Polystyrene) beads using new technology.

Currently, this new float is used by 100% of the aquaculture farmers in the Tarumizu area. Additionally, they also became popular in other aquaculture areas because it has some advantages. The advantages of the new hard plastic & EPS float are as follows:

1) High durability: it can be used for over 10 years because it is a hard plastic float.
2) Easy handling: attached fouling organism can be easily scraped because there is no cover.
3) Easy recycling: water is not absorbed and the attached fouling organisms are not present because the EPS beads are inserted into the hard plastic float.
4) No fragmentation
5) Long period of service: it does not require to stock many new floats.

This is the result of the collaboration between the float maker and the float user that resulted in improvement. In this area, the use of conventional EPS floats with PE covers has started to shift to high durability floats (new PE floats) from the year 2000. This shift was finalized in 2009. Currently, these new floats are predominantly used around this area. This shift was carried out because of the intensive use of floats and the development and improvement by float makers. Unfortunately, this development of the new float and shifting received no support from the government.

4. Future tasks

There are some future tasks. Among them, the most important task is to replace the fenders of pleasure boats from discarded EPS floats to an appropriate substitute. Huge amounts of discarded EPS floats were used as fenders and rafts of pleasure boats in the harbor of Kagoshima Bay. They are reusing discarded EPS floats from aquaculture rafts because these are free. It is more difficult to solve the problem than to shift the floats on the aquaculture because the boats user is personal and the environmental sense lacks.

Acknowledgment

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