Research Article

Jong-Seok Song, Yong-Woo Lee, Young-Sik Han, and Young-Kwon Park*

Management status and policy direction of submerged marine debris for improvement of port environment in Korea

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Abstract: As the issue of marine waste is emerging around the world, it is urgent to come up with measures to manage marine waste. This study examined the status of the collection project of submerged marine debris (SMD) undertaken to improve the environment of major ports by the central and local governments of Korea. Approximately, 7,174 and 2,817 tons of SMD have been collected at major trade ports and coastal ports, respectively, over the last 7 years (2014–2020). The projects to collect SMD have achieved effectiveness, reducing marine accidents in the port. For example, entanglement accidents caused by floating debris also decreased by 11% in 2018 compared to the previous year. The results of the sediment environment investigation before and after the collection of SMD also showed that the species of benthos and their population density increased, and the concentration of acid volatile sulfides (AVSs) decreased. To reduce marine accidents in ports and improve the benthic environment, it will be necessary to provide policy support, such as investigating the distribution status of SMD regularly, improving the effectiveness of the collection method, identifying the way to recycle collected debris, maintaining the public–private cooperative system, and establishing a specialized agency for the systematic management of marine debris.

*** Corresponding author: Young-Kwon Park,** School of Environmental Engineering, University of Seoul, Seoul 02504, Korea, e-mail: catalica@uos.ac.kr, tel: +82-2-6490-5484
Jong-Seok Song: Marine Debris Management Department, Korea Marine Environment Management Corporation, Seoul 05718, Korea; School of Environmental Engineering, University of Seoul, Seoul 02504, Korea, e-mail: supersjs@koem.or.kr
Yong-Woo Lee: Marine Environment Monitoring Department, Korea Marine Environment Management Corporation, Busan 49111, Korea, e-mail: wbluesea@koem.or.kr
Young-Sik Han: Marine Debris Management Department, Korea Marine Environment Management Corporation, Seoul 05718, Korea, e-mail: yshan@koem.or.kr

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1 Introduction

As marine debris is emerging as a global social challenge, it is time to manage the debris that flows from the land to the ocean. Land-based sources of marine debris account for more than 60% of total debris, of which plastic is responsible for approximately 73%. This means that annually, 8 million tons of plastics flow into the sea [1,2]. In Korea, the amount of marine debris has been estimated to be approximately 180,000 tons per year, and approximately 73,000 tons of plastic debris is generated annually [3,4].

Marine debris has negative impacts on the marine ecosystem, and marine debris has caused the deaths of 1 million birds and 100,000 mammals and sea turtles every year [5]. In particular, more than 200 species of marine life are threatened by entanglement by plastics or the ingestion of debris [6]. Abandoned fishing equipment, which triggers "Ghost fishing," can negatively impact marine life and fishery resources, devastating fishing activities. In addition, when submerged in the lower layers, marine debris disturbs oxygen exchange between the upper layer of sediment and bottom seawater, damaging the habitat of benthic organisms and affecting the spawning and habitat function of marine life [7–9].

The word "marine debris" is not defined directly in the current domestic law, but "the Marine Environment Management Act" stipulates "a waste is a material that cannot be used as it is if it is discharged into the sea, and has or may have harmful consequences on the marine environment." For the management of marine debris, it is important to establish "the Marine Debris Collection and Treatment Plan" every 5 years in accordance with Article 36 of the Enforcement Decree of the Marine

Environment Management Act. The third Framework Plan for "Marine Debris Management" was concluded (2019–2023), and various measures were implemented [10]. The major tasks in controlling marine debris include "proactive control of marine debris to the sea," "collection of submerged marine debris," and "reinforced management of abandoned styrofoam buoys." Complementing the second Framework Plan, the third Framework Plan seeks to shift the policy from collection to prevention. The cost required to collect and dispose of submerged marine debris (SMD) is approximately seven times more than that of collecting and disposing of land-based waste.

Marine debris can be classified into three types depending on where it is distributed: coastal litter scattered or accumulated on the shore, floating debris floating on the sea, and SMD settled on the seafloor. The "Marine debris and contaminated marine sediment management Act," which was scheduled to take effect in December 2020, comprises of the following: (1) defines marine debris, coastal litter, floating debris, and SMD; (2) requires an investigation of marine debris and its collection; and (3) orders a person producing marine debris to collect the debris. In short, the Act was prepared for the systematic management of marine debris.

Jang et al. [4] estimated that approximately 152,241 tons of marine debris existed in domestic marine areas, of which SMD comprised the majority (approximately 137,761 tons). SMD is largely collected by the central and local governments. Based on the purpose and area of the collection projects, SMD collection projects are divided into the following projects: "cleanup marine debris," "improve the environment of coastal fishing," "enhance the environment of sport fishing," "support the area affected by oil spills," and "remove illegal fishing equipment." SMD collection projects carried out by the central government are largely divided into two categories. (1) The marine debris cleanup project in line with "the Marine Environment Management Act" is designed to remove the materials that are harmful to the marine environment from ports, Environment Management Sea Areas, and Marine Protected Areas, which require nationwide management, to contribute to marine environmental protection and safe navigation of vessels. (2) The project to improve the environment of coastal fishing, pursuant to "the Fishery Resources Management Act," is targeted at important fishery areas where fish spawn, breed, and are caught for commercial purposes, requiring continuous management and protection of fishery resources. These projects are conducted as a part of efforts to maintain and restore fishery resources.

The SMD cleanup project was implemented to collect and remove marine debris settled in ports, fish farms, environment management sea areas, marine protected areas, and exclusive economic zones (EEZs). The project aims to collect abandoned fishing equipment and tires, which deteriorate marine ecosystems, and has been conducted since 1999. This project was entrusted to Korea Marine Environment Management Corporation (KOEM) according to "The Marine Environment Management Act." Since 2015, KOEM has conducted follow-up monitoring to examine the improved effects of seawater and the remediation of coastal sediments before and after an SMD collection project.

In 2007, Kim et al. [11] estimated the cost of surveying the distribution of SMD and collecting the debris. The cost of collecting and disposing of SMD is higher than that of collecting land-based waste, and it is difficult to remove SMD from a technological perspective. Therefore, it is essential to establish a system to study the sources and management status of SMD and build a specialized management institution for the environmentally friendly and systematic management of SMD. Kim and Kang [12] proposed combining the SMD collection project with the marine environment survey to improve the marine environment and achieve cost-effectiveness. The problem of marine waste is emerging, but collection activities, research, and management plan on submerged marine debris are insufficient.

This study (1) examined the status and follow-up monitoring results of SMD collection projects, which have been performed in major ports and coastal seas since 1999 for improvement of the benthic environment and enhancement of ship navigation safety in port areas, and (2) suggested some management actions for improving the environment of ports.

2 Data and methods

The Korean government has been carrying out SMD collection projects since 1999 to improve the benthic environment of the ports. The data of the main projects carried out by KOEM were collected to analyze the collection status of SMD. The reports of "the SMD Cleanup Project" implemented by KOEM were cited to understand the quantity of SMD collected from major ports over the last decade. Since 2015, follow-up monitoring has been conducted to determine if the SMD cleanup project had positively impacted the marine environment and achieved its purposes. The reports of follow-up monitoring activities for the last 5 years (2015–2019) were referenced for this study. The survey method on the distribution status of marine waste and the method of collecting submerged marine debris were referred to the "Standard method for collecting submerged marine debris" published by the KOEM [13]. "The Marine Accident Reports" published annually by "Korean Maritime Safety Tribunal" were used to grasp the relationship between the SMD collection projects and ship accidents.

3 Results and discussion

3.1 Design and method of marine debris (SMD) collection

Figure 1 presents the design and procedure to implement an SMD collection project. The procedure to determine the distribution of SMD was in the following order: field visit, on-site survey, data analysis, and report on implementation design.

The field visit involved collecting and analyzing information related to the fishing conditions and sources of marine debris in sea areas studied through meetings with competent people and fishery cooperatives and compiling information on the distribution and quantity of the debris in each study area based on the analyzed data.

In an on-site survey, the acquired data was analyzed to fill out a field note using various methods: "SSS (Side Scan Sonar)-based research," "towing (lifting frame)-based investigation," "inspection by divers," and "investigation by the naked eye." The quantity of marine debris found by the sample survey recorded in the field notes was combined and saved in a database to set the baseline quantity. The SSS was used to search for abnormalities on the seafloor using sound waves in a short time. This is useful for probing bulky debris, but the error rate is high because it is impossible to detect debris submerged in the floor or small objects. In the case of the towing (lifting frame)-based investigations, the relevant fishers and fisheries cooperatives were interviewed. They filled in questionnaires to reconfirm the sea area to be investigated. Sampling research was then conducted by lifting frames to identify the distribution of debris, the time required for lifting, and the working efficiency of the research ships. A vessel of approximately 6–10 tons under the jurisdiction of the target area was utilized for the sampling research. The vessel was equipped with a roller and a winch used for lifting and towing marine debris. The lifting frames, weights, and ropes of a certain length suitable for the characteristics of the target sites were selected as basic equipment for the survey. In the investigation by divers, divers must observe the nondecompression limit for safety. Before entering the sea, divers shall decide the investigation direction and then swim in the proposed direction using a compass to investigate the distribution of marine debris. The investigated area and diving distance were calculated by entering the coordinates showing the diver's descending and ascending points into the digital chart. Through this process, the quantity of debris in a certain area could be calculated through the ratio between the area of the sample survey and the amount of debris. After completing the investigation, the diver filled out the work log, including the coordinates and distance.

Step1	Field Visit	A public hearing with fishers and interviews with stakeholders
Step2	On-Site Survey	Investigation on towing of lifting frame, two-way sonar probe, and diving survey
Step3	Data Analysis	On-site interview and questionnaires, reconciliation and analysis of data from the on-site survey, and consult on and selection of project sites
Step4	Report on Implementation Design	Calculation of the target quantity of collection, confirmation of target area, design manual, general specifications, special specifications, application criteria, rationale for calculation, preparation of the Project Cost Estimating Guideline, and implementation documents

Figure 1: Procedures of implementation documents on submerged marine debris (SMD).

At the data analysis step, the information collected from various studies was acquired and analyzed to allow additional discussions to select the target site. After the discussion was completed, the research staff made a detailed design statement with the quantity of collected debris, the rationale of the calculation, and the itemized unit cost in line with "the Standardized Design Tablet for SMD Collection" published by KOEM.

The way to collect SMD was divided largely into three: "Collection via Lifting Frames," "Collection via OPG (Organge Peel Grab)," and "Collection by Divers" (Figure 2). In the case of large sea areas and sites where marine debris is scattered, the SMD is collected through lifting frames, while the OPG mounted on the crane barge is used to collect SMD in the case of critical sites in the collection areas. In addition, the divers collect SMD in sensitive sites, such as a floating bridge where OPG

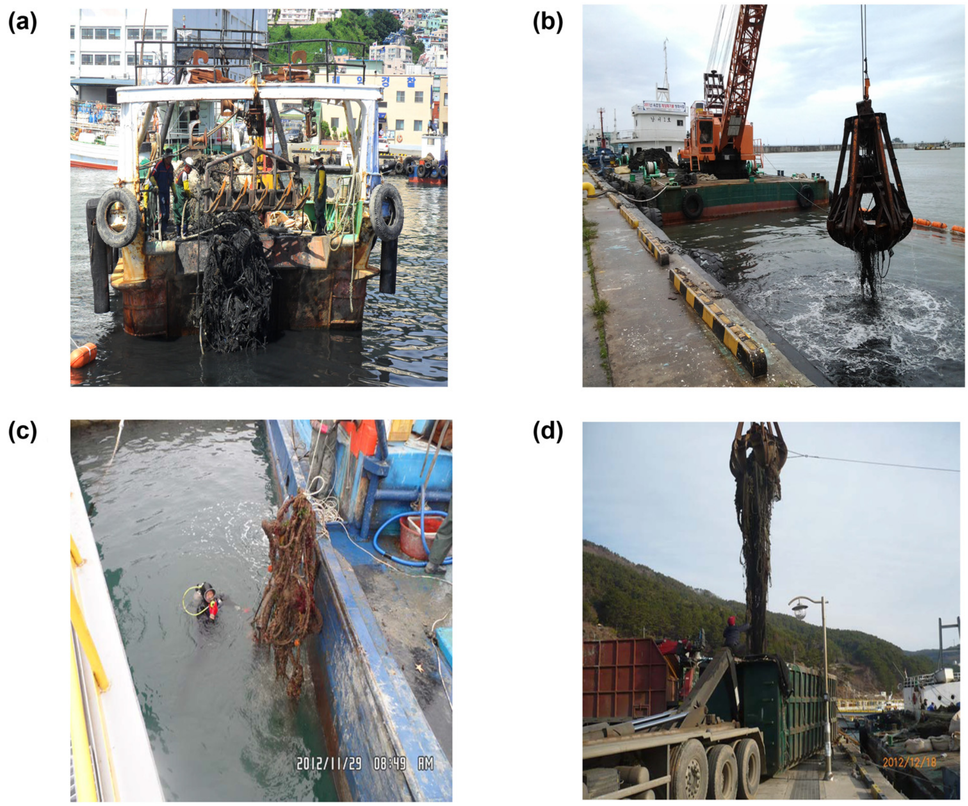

Figure 2: Method to collect submerged marine debris (SMD): (a) collection via lifting frame, (b) collection via OPG, (c) collection by divers, and (d) discharge of waste.

work is difficult, and the intake pipes of sushi restaurants, where many complaints are filed.

The collected debris, including abandoned fishing equipment, waste tires, waste sands, and scrap metal, are stored temporarily in the crane barge. An outsourcing company was entrusted to dispose the abandoned fishing equipment, waste tires, and waste sands, while scrap metals were sold to recycling companies. The sales revenue belongs to the government.

The quantity of SMD is difficult to estimate accurately. For more accurate estimates, it is important to develop a method, during the design, to calculate the amount of marine debris submerged in sediments for a long time. Furthermore, it is desirable to use standardized lifting frames and OPGs in the collection activities and gather SMD intensively in the critical sites, reducing the gap between the intended quantity and the actual quantity of collected SMD.

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3.2 Current status of marine debris collection

3.2.1 Performance of marine debris collection in Korea

Globally, annual data are insufficient to understand how much debris is produced and flown into the coastal and marine environment. In 1997, “the US Academy of Science” presumed that approximately 640 million tons of marine debris per year were flown into the ocean [14]. “Science” magazine published in 2015 argued that 8–12.7 million tons of plastic debris were flown to the sea, which was an overwhelming amount, more than twice the total fish catch (3.74 tons) of Korea in 2017.

Similarly, Korea also lacks national statistics on the amount of marine debris. The Marine Environmental Information Portal (www.meis.go.kr) administered by KOEM is the only tool to collect and provide the data

Table 1: Annual amount of marine debris collected by spatial distribution (unit: ton)

Division	2014	2015	2016	2017	2018	2019	2020	Total
Coastal litters	53,129	48,547	41,998	48,053	48,464	75,131	111,592	426,914
Floating debris	4,454	4,330	4,697	4,461	5,666	7,713	8,558	39,879
SMD	19,353	16,252	24,146	29,662	41,502	25,780	18,212	174,907
Total	76,936	69,129	70,841	82,176	95,632	108,624	138,362	641,700

Table 2: Seven-year (2014–2020) performance of submerged marine debris (SMD) collection by KOEM

Division	2014	2015	2016	2017	2018	2019	2020	Total
Expense (1 million)	5,007	8,178	5,139	4,907	4,736	5,496	6,596	40,059
Collected quantity (ton)	3,432	4,027	3,348	2,997	2,240	2,882	3,191	22,117

on marine debris collected by local governments and relevant agencies. Depending on its spatial distribution, the debris is categorized as coastal litter, floating debris, and submerged marine debris. Over the last 7 years, a total budget of approximately 240 billion won was invested in collecting approximately 641,700 tons of marine debris (Table 1).

3.2.2 Collection of SMD in ports areas

The major ports in Korea consist of 31 trade ports and 29 coastal ports in accordance with the Harbor Act. Focusing on major port areas, KOEM has conducted projects to collect SMD. Table 2 lists the SMD collection projects implemented by KOEM, which had invested 40 billion

Table 3: Amount of submerged marine debris (SMD) collected at the trade ports by KOEM (unit: ton)

Division		2014	2015	2016	2017	2018	2019	2020	Total
Total		607.57	515.83	794.81	972.85	1,487.22	2096.06	699.41	7,173.75
Incheon Gyeonggi	Incheon Port	—	—	—	—	240.99	—	48.77	289.76
	Pyeongtaek Dangjin port	—	9.78	—	60.54	—	—	—	70.32
Chungnam	Daesan Port	—	—	—	—	47.24	—	—	47.24
	Boryeong Port	—	—	—	—	65.59	76.43	61.35	203.37
	Janghang Port	—	—	—	—	88.43	—	—	88.43
	Taean Port	—	—	—	—	39.31	—	—	39.31
Jeonbuk	Gunsan Port	—	91.3	—	—	—	465.79	41.96	599.05
Jeonnam	Gwangyang Port	—	—	—	105.97	—	—	—	105.97
	Mokpo Port	211	—	47.25	81.99	227.65	97.18	158.28	823.35
	Yeosu Port	57.83	—	—	—	—	67.82	—	125.65
	Wando Port	—	—	—	—	20.64	—	—	20.64
Gyeongnam	Gohyeon Port	—	—	—	80.12	—	92.25	—	172.37
	Masan Port	—	—	—	—	51.72	—	—	51.72
	Samcheonpo Port	53.33	—	38.11	—	69.29	—	—	160.73
	Okpo Port	—	—	40.49	—	—	104.7	—	145.19
	Jangseungpo Port	—	118.51	—	—	113.94	—	—	232.45
	Jinhae Port	—	—	—	—	61.6	—	—	61.6
	Tongyeong Port	113.32	—	475.82	644.23	—	868.11	297.15	2,398.63
	Hadong Port						41.78	—	41.78
Busan	Busan Port	—	—	193.14	—	—	149.23	—	342.37
Gangwon	Sokcho Port	25.44	—	—	—	109.81	—	—	135.25
	Samcheok Port						95.29	—	95.29
Gyeongbuk	Pohang Port	146.65	—	—	—	67.75	37.48	—	251.88
Jeju	Seogwipo Port	—	222.12	—	—	174.96	—	28.3	425.38
	Jeju Port	—	74.12	—	—	108.3	—	63.6	246.02

Table 4: Amount of submerged marine debris (SMD) collected at the coastal ports by KOEM (unit: ton)

Division		2014	2015	2016	2017	2018	2019	2020	Total
Total		618.65	289.28	485.69	322.29	272.01	739.84	88.84	2,816.60
Incheon Gyeonggi	Yonggipo Port	—	13.71	—	—	—	—	—	13.71
Chungnam	Daecheon Port	79.49	—	—	59.76	—	—	—	139.25
	Biin Port	—	—	157.04	—	—	84.09	—	241.13
Jeonbuk	Sangwang Deungdo Port						9.52	—	9.52
Jeonnam	Geomundo Port	—	25.2	—	—	—	41.86	—	67.06
	Nokdong New Port	—	—	—	—	8.83	—	—	8.83
	Songkong Port	—	34.8	—	—	—	66.2	—	101.0
	Hongdo Port	30.72	—	—	—	35.63	—	—	66.35
	Heuksando Port	249.63	—	—	—	—	—	—	249.63
	Jindo Port						44.11	—	44.11
Gyeongnam	Jaunghwa Port	—	—	—	—	18.06	—	—	18.06
Gyeongbuk	Guryongpo Port	17.5	—	—	—	—	208.22	—	225.72
	Ulleung Port	—	29.07	—	—	—	—	—	29.07
	Hupo Port						254.86	—	254.86
Busan	Busan Nam Port	—	—	328.65	148.1	—	—	61.11	537.86
Gangwon	Jumunjin Port	—	131.06	—	114.43	47.83	—	—	293.32
Jeju	Seongsanpo Port	38.44	—	—	—	—	—	—	38.44
	Chuja Port	—	55.44	—	—	45.84	—	—	101.28
	Hanrim Port	202.87	—	—	—	115.82	30.98	—	349.67
	Aewol Port						—	27.73	27.73

won for the last 7 years to collect approximately 22,117 tons of SMD [15–21].

As projects collected SMD at trade ports and coastal ports for the past 7 years, approximately 7,174 tons of SMD were collected at trade ports and 2,817 tons of SMD at coastal ports (Tables 3 and 4, respectively) [15–21]. As shown in Table 3, SMD had been collected at 26 trade ports (out of 31) over the past 5 years. Gyeongsangnam-do province came first in terms of the collected quantity, followed by Jeollanamdo-province and Jeju Island. Despite being a trade port, Tongyeong Port and Mokpo Port, where fishing activities were active, accounted for approximately 44.9% of the total collection volume at trade ports. Of 29 coastal ports, 21 had been cleaned up over the last 7 years through projects to collect SMD. In this case, Busan Metropolitan City ranked first in terms of the collected quantity,

Table 5: Types of submerged marine debris (SMD) collected at the trade port by KOEM (unit: ton)

Division	2014	2015	2016	2017	2018	2019	2020	Total
Total	607.57	515.86	794.81	972.85	1,487.22	2,096.06	699.41	7,131.75
Waste fishing gear	537.56	468.55	699.9	938.45	1,106.27	1,740.21	596.91	6,087.85
Waste tire	28.75	—	—	—	125.2	113.64	51.67	319.26
Scrap metal	—	10.03	39.88	27.49	151.46	129.46	11.35	369.67
Others (e.g., polluted sediment)	41.26	37.28	55.03	6.91	104.29	37.85	39.48	369.67

Table 6: Types of submerged marine debris (SMD) collected at the coastal ports by KOEM (unit: ton)

Division	2014	2015	2016	2017	2018	2019	2020	Total
Total	618.65	289.28	485.69	322.29	272.01	739.84	88.84	2,816.60
Waste fishing gear	566.63	280.65	457.38	303.79	243.46	616.24	51.81	2,519.96
Waste tire	—	—	—	—	—	30.54	37.03	67.57
Waste steel	7.18	—	—	0.85	28.55	18.45	—	55.03
Others (e.g., polluted sediment)	44.84	8.63	28.31	17.65	—	—	—	99.43

followed by Jeju Island and Jeollanamdo province (Table 4) [15–21]. Busan Nam Port, Hallim Port, and Heuksando Port, where fishing activities were active, accounted for 40.4% of the total quantity of collected debris at coastal ports.

3.2.3 Types of SMD at ports areas

SMD collected at major trade ports and coastal ports include waste synthetic resin, waste tires, scrap metals, and waste sands. The marine debris is disposed of legally in line with the principles of recycling. Most of the waste synthetic resins are crushed and pulverized to be used as paint, auxiliary fuel, and solid fuel. Waste tires are used for recycled mats, cement kiln (fuels), solid fuel products, and ropes. Waste sands are buried in landfill, and 100% of scrap metals are recycled. Among the SMD collected at trade ports and coastal ports, waste synthetic resin comprises 85% of the trade ports and 89% of the coastal ports, respectively, followed by waste sands, scrap metals, and waste tires (Tables 5 and 6) [15–21].

4 Effects of marine debris collection: ship navigation safety and marine environment improvement

4.1 Enhancement of ship navigation safety in port areas

Marine debris poses a threat to the safe navigations of fishing vessels, boats, large cruise ships, and oil tankers. Abandoned fishing nets, ropes, and waste tires are entangled with the screw of the vessel or clog the cooling water system of a ship, leading to overheating of the engine. One out of 10 accidents of ships in Korea is triggered by marine debris (www.meis.go.kr). In 2015, a boat called “Dolphin” sank in the waters between Chujado Island and Jeju Island because of engine failure caused by abandoned ropes, causing death and injury to the passengers. This is the representative accident triggered by marine debris.

The Ministry of Oceans and Fisheries (MOF) categorizes marine accidents into 12 types according to the cause of the accident: collision, contact, grounding, overturn, fire/explosion, sinking, engine failure, safety accident, entanglement of floating matter, navigation disruption, marine pollution, and others. Others include the statistical data of accidents

Table 7: Marine accident cases by type (unit: case) in Korea (2014–2018)

Year	Collision	Minor collision	Grounding	Overturn	Fire/explosion	Sinking	Malfunc-tion	Human casualty	Entanglement of floating particles	Navigation disruption	Marine pollution	Others	Total
2014	180	19	96	35	97	19	339	113	205	–	–	227	1,330
2015	235	28	84	32	100	31	703	144	331	–	–	413	2,101
2016	209	23	137	49	113	27	755	131	279	–	–	473	2,307
2017	258	25	149	65	96	29	838	160	311	131	–	520	2,582
2018	250	20	142	46	119	38	856	162	278	155	80	525	2,671

Table 8: Entanglement accident cases of floating debris according to vessel type (unit: case)

Year	Passenger ship	Cargo ship	Oil tanker	Tugboat	Other	Fishing boat	Total
2014	11	6	3	11	40	138	209
2015	12	2	4	11	85	219	333
2016	16	3	4	6	83	280	392
2017	6	1	4	6	6	249	272
2018	10	1	3	4	3	222	243

Table 9: Follow-up monitoring indicators

Division	Before and after of collection project	Description
Marine water quality	Water quality index (WQI)	Measurement of marine water quality rating
Marine sediments	Acid volatile sulfide (AVS)	Measurement of oxygen depletion and deficiencies in sediments
Marine organisms	Distribution of benthos (species, population, and body length)	Analysis of species diversity

due to flooding, damage to propeller shafts, errors of steering gear, broken outfits, damage to facilities, and missing.

In the 5 years from 2014 to 2018, there were 1,330–2,671 marine accidents annually; most accidents were caused by engine failure [22]. In 2018, 2,671 accidents occurred, of which approximately 10% were caused by the entanglement of abandoned ropes and fishing equipment, indicating that marine debris caused significant socio-economic damage (Table 7) [22]. Conversely, the project to collect marine debris had been expanded. The accidents in 2018 caused by the entanglement of floating matters decreased by 11% compared to 2017 despite an approximately 3.4% increase in total accidents compared to the previous year (Table 8) [22]. This highlights the effects of marine debris collection projects.

4.2 Marine environment improvement through follow-up monitoring

Since 2015, KOEM has verified where the marine environment is improved or whether the project purposes are achieved. To evaluate the environmental changes, the WQI (Water Quality Index), AVS (Acid Volatile Sulfides), and the distribution of benthic organisms were examined before and after the project (Table 9) [23].

Table 10: 2018 Postmonitoring results of marine organisms (benthos) in sediments of major ports, Korea

Division	Number of species		Population density (ind. m^{-2})	
	Before	After	Before	After
Sihwa Lake/ Incheon Coast	19	34	269	55
Pyeongtaek Dangjin Port	23	45	63	102
Mokpo Port	29	29	169	102
Gwangyang Port	51	50	574	275
Gamakman Bay	11	68	1,183	240
Busan Nam Port	27	44	68	449
Masan Bay	35	45	368	204
Gohyeon Port	12	15	60	46
Jumunjin Port	39	60	580	317

Table 11: 2018 Postmonitoring results of acid volatile sulfides (AVS) concentration in the sediments of major ports, Korea

Division	Before (mg g^{-1} dry wt)	After (mg g^{-1} dry wt)
Sihwa Lake/Incheon Coast	0.210	0.218
Pyeongtaek Dangjin Port	0.181	0.034
Mokpo Port	0.107	0.143
Gwangyang Port	0.131	0.078
Gamakman Bay	0.457	0.397
Busan Nam Port	0.513	1.204
Masan Bay	1.669	0.407
Gohyeon Port	0.161	0.161
Jumunjin Port	0.725	0.213

The collection of marine debris contributed to the improvement and even restoration of the habitat for benthic organisms. Their biodiversity and population density were also enhanced (Table 10) [23]. Overall, the richness and abundance of species tended to increase. In particular, in Busan South Port, the number of benthic species increased by approximately 63%, and the population density grew by approximately 560%. Furthermore, marine debris collection via lifting frames brought the effects of tillage to the sea bed, providing oxygen into seabed sediments and reducing AVS (Table 11) [23]. In particular, AVS declined by 76 and 71% at Masan Bay and Jumunjin Port, respectively, proving that the collection project significantly impacted the benthic environment.

5 Conclusions

This study was carried out to analyze the management status of marine debris, the performance of marine debris collection, and the effect of improving the marine environment in the port areas in Korea. On the basis of these analysis results, we suggest ways to improve the marine environment for the sustainable use of ports.

First, it is necessary to conduct regular surveys on the distribution of marine debris at the main ports of Korea, considering the safety of navigating vessels and port. A systematic survey will be necessary to prioritize ports for collecting marine debris at the main ports of Korea. It is necessary to conduct regular surveys on the distribution of marine debris at each port in Korea, considering the safety of navigating vessels.

To decide on the target site to collect marine debris, the systematic survey is needed to select to be collected within the port.

Korean government KOEM annually surveys the sites requiring the project to collect marine debris and assesses the project period and economic performance. The safety of navigating vessels is critically important in port areas, so it is important to conduct a survey on the distribution of marine debris by region regularly and lay the foundation for implementing the collection project at least once a year. It is also necessary to evaluate the project effectiveness.

Second, it is important to establish an evaluation system to understand and address the socio-economic damage caused by marine debris in port areas. Awareness has been steadily raised on the negative impacts of marine debris on port areas and their seriousness, but there is difficulty in concluding a solution due to insufficient monitoring and evaluation systems. The following are needed: (1) monitoring the characteristics of marine debris by each trade port and coastal port; (2) quantification of the impact of marine debris (converted into the social and economic cost); and (3) developing methods to collect and reduce marine debris in consideration of port characteristics.

Third, it is necessary to build nationwide private–public cooperation systems and increase the awareness of fishers and the relevant organization in port areas on the importance of marine environment conservation and on the policies to collect marine debris. A program connected to the existing education and outreach projects being promoted in relation to marine debris management in Korea is needed. If a public–private cooperation platform for port preservation is developed, it will be able to play a role in implementing the collection project and monitoring the outcomes. Furthermore, it is important to establish an administrative system focusing on the residents' participation as practitioners of coastal protection, such as monitoring the illegal dumping of waste into the sea. Furthermore, increasing attention is being paid to marine debris internationally, and international cooperation bodies, such as UNEP (United Nation Environment Program), share marine debris management plans and policy directions for each country and maintain an international cooperation system [24]. An active response to this is also necessary.

Fourth, it is essential to prepare the measures to manage marine debris, such as the treatment and recycling of SMD that reflects the ecological characteristics of the domestic coasts. The SMD contains salt and foreign substances (e.g., tidal flats), so treatment costs are high. Waste treatment companies are reluctant to deal with marine debris, increasing the difficulty in disposing of the collected marine debris. The expansion and the construction of pretreatment facilities for marine debris, recently promoted by the MOF, will help secure renewable energy sources and increase the durability of landfill by actively utilizing marine debris as a recycling resource, increasing the recycling rate, and lowering the treatment costs.

Fifth, it will be necessary to establish a specialized management institution for the systematic management of marine debris. Complying with the Waste Management Act, the Ministry of Environment has designated laboratories specialized in waste analysis and is promoting a range of policies for waste management in the concept of resource circulation. Therefore, to increase the effectiveness of collection–recycling and support the marine debris management policies, a specialized institution for the integrated management of marine debris at the national level will be established to conduct surveys on the distribution of SMD and the actual condition for collection.

A port is a national facility that plays an important role in multimodal transportation connecting the land and sea. It contributes to the transportation of passengers and cargo, growth of the hinterland, and development of the national economy. Port development is important for the sustainable use of ports, but more efforts are needed to improve the marine environment to allow safe navigation of ships and enhance the environmentally friendly image.

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