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Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

P.O. Box 23, Yuseong, Daejeon 305-600, Republic of Korea
(c/o MOERI/KORDI)
Tel: (+82-42) 866-3638, Fax: (+82-42) 866-3698
E-mail: nowpap@moeri.re.kr
Website: http://merrac.nowpap.org

The Report on the Technologies and Research Outcomes on Prevention, Collection and Treatment of Marine Litter in the NOWPAP Region

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Published in 2010
by Marine Environmental Emergency Preparedness and Response
Regional Activity Centre,
the Northwest Pacific Action Plan (NOWPAP MERRAC)
P.O.Box 23, Yuseong, Daejeon 305-600, Republic of Korea
(c/o MOERI/KORDI)

ISBN 978-89-93604-03-0

For bibliographical purposes, this document may be cited as:
Report on the Technologies and Research Outcomes on Prevention, Collection and Treatment of Marine Litter in the NOWPAP Region, MERRAC, 2010.

Foreword

Marine litter problem has recently been recognized at the national, regional, and global level because it destroys the ecological, economic, cultural, recreational, and aesthetic values of the marine and coastal environment. In acknowledging the problems imposed by marine litter in the Northwest Pacific region, the NOWPAP member states – People's Republic of China, Japan, Republic of Korea, and Russian Federation – have initiated various activities and/ projects related to marine litter issue within the NOWPAP framework.

As a road map to deal with marine litter problems in the NOWPAP region, the project on the Marine Litter Activity (MALITA) was approved by the Tenth NOWPAP Intergovernmental Meeting in November, 2005. MERRAC has been designated to cover marine litter from sea-based sources in close cooperation with United Nations Environment Programme (UNEP), International Maritime Organization (IMO), NOWPAP Regional Coordinating Unit (RCU), other NOWPAP Regional Activity Centres (RACs) and NOWPAP Marine Litter Focal Points. NOWPAP Regional Action Plan on Marine Litter (RAP MALI) was approved for 2008-2009 biennium at the Twelfth NOWPAP Intergovernmental Meeting (Xiamen, China, October 2007), as the next phase of Marine Litter Activity (MALITA) for 2006-2007.

This technical report has been developed by NOWPAP MERRAC as a part of NOWPAP RAP MALI implementation. The Expert Group has contributed to the development of the technical report. The three experts in this group, who were nominated by MERRAC Focal Points, are as follows: Mr. Xiaofeng PENG (China), Mr. Wataru TAKAHASHI (Japan), and Mr. Seon-Dong KIM (Korea, Leading Expert). MERRAC staff (Dr. Seong-Gil Kang, Dr. Jeong-Hwan Oh, and Ms. Hyon-Jeong Noh) finalized and edited the report with technical support from MERRAC Focal Points, Marine Litter Focal Points, NOWPAP Regional Coordinating Unit (RCU), and IMO.

As Director of MERRAC, I would like to thank the MERRAC Focal Points, Marine Litter Focal Points, NOWPAP RCU, IMO, and all the experts devoted to this project for their support and contributions in finalizing the MERRAC Technical Reports.

Seong-Gil Kang
Director of MERRAC

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Chapter 1. Introduction

Marine litter is defined as any persistent, manufactured, or processed solid discarded material, disposed of or abandoned in marine and coastal environment. Marine litter comes from multiple sources, and it can be found both in densely populated regions and in remote islands because of its trans-boundary movement through ocean currents and winds. Since most marine litter consists of non-biodegradable material, a continuous input of marine litter can result in a buildup of marine litter in marine and coastal environment, unless it is removed. To preserve marine and coastal environment from marine litter, many efforts have been taken at global, regional, and national levels. Each member of the NOWPAP region, one of the most highly populated regions in the world, is also faced with marine litter problem and is directly affected by other countries because of regional currents and other oceanographically characteristics of semi-closed sea area.

NOWPAP member states have conducted researches and developed relevant technologies to deal with marine litter efficiently. In other words, NOWPAP member states have investigated on the aspect of marine litter generation and institutional supports needed in order to prevent generation of marine litter, as well as the development of technologies for collection and treatment.

This report is divided into two parts to introduce technologies related to marine litter. The first part is about prevention and collection of marine litter after understanding generation of marine letter. The second part is about proper disposal and treatment technologies of marine litter in environmentally-friendly ways and recycling in accordance with type of marine litter and environment.

For technologies and research outcomes related to prevention and collection of marine litter, this report introduces solid waste collection equipment, submarine equipment that can survey the submerged waste in seabed in real time, and several prevention measures and methods for collecting and processing of the marine litter.

For the treatment technologies of marine litter, waste Fiber Reinforced Plastic (FRP) Vessel melting treatment system developed in Korea will be introduce as an example of proper disposal of FRP vessels. In addition, this report also provides information on the incinerator which is also largely considered for the

treatment of marine litter, especially where the accessibility is poor like remote islands. It will also be introduced the techniques for the recycling waste expanded polystyrene (EPS) floats which are widely used in fisheries. The floats may be compressed for the Refuse Paper and Plastic Fuel (RPF) or supplied as ingot so as to be recycled for plastic products. Especially, it is worthy of notice that different techniques were developed in accordance with circumstances and practical use even if marine litter is the same type.

Various techniques developed according to the circumstance of each country were summarized in this report. Although the reported techniques are just a part of marine litter management, the sharing of each country's experiences will help in improving the NOWPAP area significantly. The effort and cooperation of NOWPAP member states will contribute to providing a solution to keep our sea clean as well as learning how to keep healthy marine environment.

Chapter 2. Technologies and research outcomes related to prevention & collection of marine litter

2.1. Solid Garbage Recovery Equipment in China

Background

In recent years, marine litter pollution has aroused great concern among the coastal states. China Maritime Safety Administration (China MSA) strengthened the management of marine litter from merchant ships. Accordingly, sufficient port reception facilities have been built. Illegal discharging of garbage from ships has been effectively controlled. However, the floating garbage, frequently seen in port areas and in near-shore areas, and the recovery of the floating garbage is still a tough work. The Solid Garbage Recovery Equipment is a mechanical facility that collects the floating garbage with high efficiency and few workers.

Introduction of Solid Garbage Recovery Equipment

Solid garbage recovery equipment (SGRE) is utilized to collect floating solid garbage on open sea area and in port area. SGRE adopts an upward rolling system to move the garbage to a storage tank. Generally, SGRE is fixed on to a barge, catamaran, or other types of ships.

SGRE is composed of four parts, namely, upward rolling system, hydraulic-driven dynamic station, storage tank, and controlling panel. The recovery rate for the SGRE is approximately 5-10M^3/h in relatively calm water. And there are four notable advantages for SGRE, maneuverability, economy, durability, and maintainability.

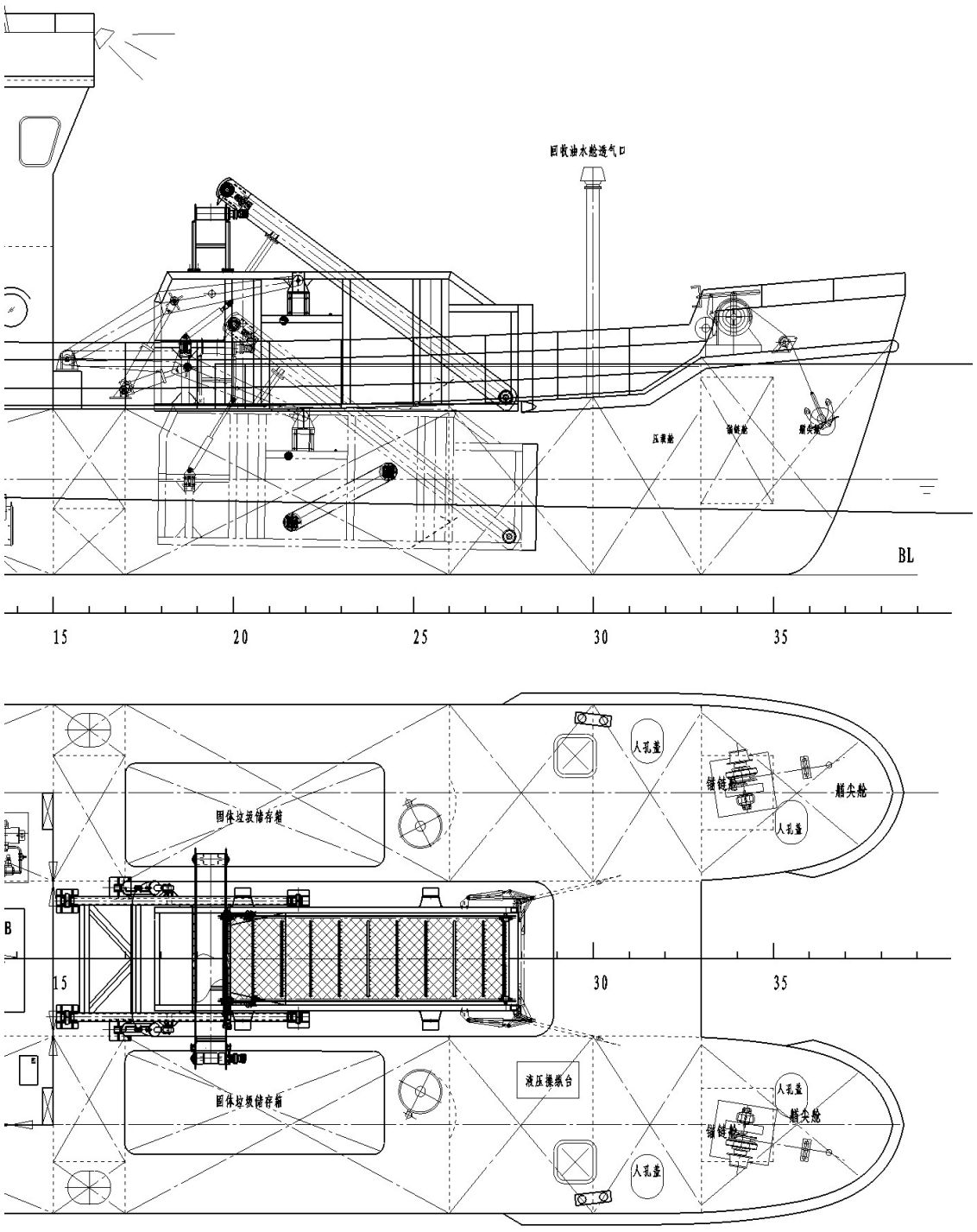


Fig 1. *A blueprint of a SGRE fixed on a catamaran.*

The Upward Rolling System

The upward rolling system is one of the core components of SGRE. There are two functions for the upward rolling system. One is to generate an inward water flow to collect the floating garbage gathered at the entrance of SGRE, and the other is to move the garbage to the storage tank fixed on board the ship. Shown in the graphic below, there is a gate fixed at the entrance of the upward rolling system, which can create a relatively calm water area to increase the water circling speed, produced by the rolling conveyor belt, which uplifts the recovery efficiency.

Fig 2. *Upward rolling system of the SGRE.*

Hydraulic dynamic station

The hydraulic dynamic station is the other core component of the SGRE that is comprised of items like generator, hydraulic pump, bunker tank, hydraulic oil cooler, hydraulic oil tank, filter, and hydraulic control system. Under the control of hydraulic controlling system, the generator in the engine room causes the hydraulic pump to suck the hydraulic oil from filter, and supply hydraulic power.

The hydraulic-driven dynamic system can adjust on the depth and the angle of the rolling surface to water therefore, it can reduce the impact from ship's draft and ship's floating state. These ways made collection of floating litter more effective.

The Application of SGRE

The SGRE was installed on board a newly built multi-function oil spill response vessel in Dongying City, Shandong Province, China. Practically, the SGRE performs well in collecting floating debris especially in the port area.

Fig 3. *SGRE installed on board.*

2.2. Development of real-time underwater acoustic equipment for deep sea survey in Korea

Introduction

Marine litter is one of the major causes of marine pollution that devastates the marine ecosystem and its components. It also hampers vessels and decreases the productivity of fishery. The most serious problem of marine litter is caused by derelict fishing gear abandoned or neglected under the sea, which causes ghost fishing. The impact of ghost fishing depends on the region and fishery. In the Yellow Sea, the productivity of crab began to increase around the early 21st century when the local Korean government began retrieving the derelict nets.

Although the derelict fishing gears devastate the fishing area and the marine ecosystem, it is not easy to survey and recover them particularly from the deep sea area. The depth of the fishing area of the eastern coast of Korea is around 1,000 meters in depth; therefore it is too deep for scuba diving research. In order to survey the deep sea environment around 1,000 meters in depth, KORDI (Korea Ocean Research & Development Institute) developed a deep sea survey system such as ROV that can be economically constructed relative to other underwater investigating systems, in a part of project, ‘Integrated Treatment System for Marine Debris’. This system consists of mainly two parts. The underwater parts consist of a guide frame called Tow-sled, deep-sea cameras, an underwater acoustic modem, position tracking devices, CTD, batteries, a signal controlling unit, lights, buoys, and a steel wire. The deck parts are comprised of notebook computer and another underwater acoustic modem, which can be lowered beneath the sea surface from a ship. All the signals of the deep-sea camera, CTD, and monitoring sensors of controlling unit are transmitted via acoustic modems to the computer on the deck. Therefore, deep sea bottom environments information such as water temperature, salinity, and the image of the habitats of sea life including derelict fishing gears, can be collected in real time.

The size of the Tow-sled is 3.7 meters in length, 2.2 meters in width, and 2 meters in height and it is applied after considering the survey area, the attached systems, and the mother ship. It is made sturdy enough to carry out the underwater bottom survey in towing. The deep-sea camera and the

underwater communication system are protected within the high pressure-resisting can. The bottom images are recorded in the video camera for later examination, and the signals are also transmitted to the computer on the deck via the acoustic modem. The acoustic modem is important to the performance of the entire system so the UWM2000 model of LinkQuest is used. The maximum range of the communication is 1,500 meters so the survey can be made around 1,000 meters in depth. The speed of the transmission is 9600 bps, but it can be controlled to reduce speed and to optimize the image quality. The performance of the camera and the controlling unit can be monitored using sensors inside the high-pressure resisting can. The CTD data can be transmitted to the deck in quasi-real time. In September 2006, the experiment was carried out around the Wang-dong-cho area, off the eastern coast of Korea with the depth of around 700 meters. The images and the data were transmitted successfully, but time delay may occur by depending on the sea condition.

This section aims to introduce the development of equipment and the result of the sea bed survey experiment in deep sea environment that was performed in 2006, around Wang-dol-Cho area in the eastern coast of Korea

Real time underwater acoustic equipment

The first trial to restore marine environments, polluted by marine litter, was to remove the sustained bottom litters in shallow waters in depths of about 30 meters on an average, the depth of which covers nearly most ports and harbors in Korea (Kang et al., 2000, 2001a, 2001b, 2002a, 2002b). In shallow waters, KORDI have many survey techniques and corresponding recovery tools to use. However, the situation becomes completely different in the deep-sea area.

In development of the survey equipment, we are interested in sustained seabed litters in deep-sea bottom that may cause death in fishes and shellfishes. This phenomenon is known as “ghost fishing”, which means that marine lives are caught by lost or discarded nets or traps and die. And to make matters worse, this takes place without end. The original definition of the term is not confined to certain depth range. Due to the semi-permanent durability of fishing gears, we should remove or recover them in order to end the endless chain of death of fishes.

Before proceeding further with our discussion of equipment, we present the previous survey method for seabed for better understanding. In shallow waters, up to 100 meters, it is reported that one can use bottom trawl to investigate the distribution of debris on sea bottom (Galgani et al. (2000), Galil et al. (1995), Stefatos et al. (1999)). Kang et al. (2000, 2001a, 2001b, 2002a, 2002b) combined bottom trawl net, side scan sonar, and grab (or corer). Donohue et al. (2001) conducted debris surveys by towing two snorkel divers behind a small boat in Northwestern Hawaiian Islands. In deep-sea application, Galgani et al. (1995) utilized manned submersibles Cyana and Nautile between 50 and 2,700 meters along European coasts.

Since our goal for bottom survey is 1,000 meter range, we exclude the possibility of using bottom trawl and diver. Furthermore, the use of submersible and ROV or AUV is not regarded as appropriate because of extremely high cost of purchase and management. Another disadvantage is that they are likely to be caught by the sustained fishing nets which then might be impossible to retrieve. Hence, we need to develop a more practical apparatus for economical and safe survey.

Kang et al. (2000, 2001a, 2001b, 2002a, 2002b), and Sung et al. (2003) had developed an equipment that can examine the derelict fishing gear on the deep ocean floor up to the depth range of 500-1,000 meters. The equipment with the name of “Tow-Sled” is to be applied to the deep-sea at the bottom of the eastern coast of Korea. The design prototype of the Tow-Sled is called “DVMSTS”: Deep-sea Video Monitoring System on a Towed Sledge which was developed in order to investigate the population density of the Snow Crab (Watanabe (2002)).

With similar concepts to the DVMSTS of NRIFE, we have developed Tow-Sled of KORDI by redesigning structural members so that it may be applied in more severe environments, such as undulated bottom profile or unexpected rocky tracks, etc. The apparent difference of the two systems is that Tow-Sled of KORDI has a position tracking device and an additional video recording system for wider survey area. The position tracking system is greatly needed to know the correct track of towing with increased efficiency of recovery work for bottom fishing gears. For the position tracking, we used a SBL (Short Base Line) system on Tow-Sled and the support vessel. Due to the DGPS (Differential Global Positioning System), we are able to have reliable track data of Tow-Sled on the sea bottom. Pictures in Fig 2 show one set of the

developed deep-sea survey system and underwater still images taken on the sea bottom along the tracks followed during site experiments in the eastern coast of Korea. The detailed characteristics of video recording systems mounted on Tow-Sled of KORDI are documented in the papers of Sung et al. [7] and Jung et al. (2005), the development of a real-time image transmission system began by utilizing acoustic signal processing techniques in order to observe the sea bottom in real time. In this situation, a slight time lag is expected due to the image treatment and the travel time of acoustic waves. The frame of Tow-Sled are made out of SUS316A, and its size is 3.7 meters in length, 2.2 meters in width, 2 meters in height respectively. The structure was analyzed to confirm the strength of the frame with ANSYS software.

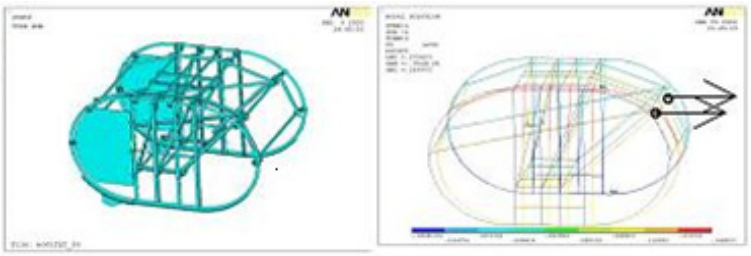


Fig 1. *The structure of the Tow-sled was analyzed to confirm the strength of the frame with ANSYS software.*

Real Time Surveying System

The in-situ survey system which was developed before this experiment used an off-line method whose time interval between the survey and the data checking was not close enough to mapping the exact distribution of derelict marine litter and others. It is hard to know the status of the deep sea environment while towing the equipment. In order to improve the data acquisition, on-line method system without communication cable was developed using the underwater acoustic modem. This method made it possible to check the deep sea events immediately while towing the Tow-sled, surveying and transmitting the images of the sea bottom. These images allow one to know the type, quality, and distribution of the debris at the sea bottom. With its user friendly GUI interface and menu, the width of survey area, resolution, number of files and et al. can be controlled easily at the sea surface.

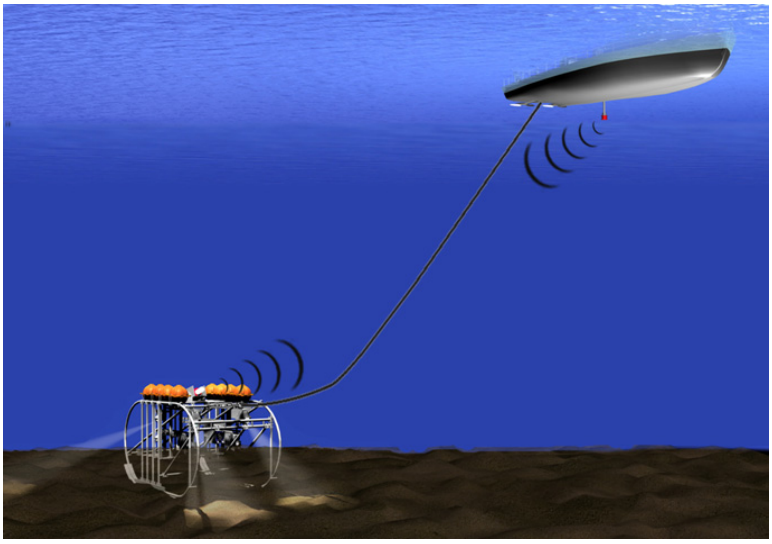


Fig 2. *Picture of the Tow-sled and the mother ship. Images are transmitted via acoustic modem while the Tow-sled is being towed.*

Acoustic communication system

Acoustic communication system is the main part for the real time survey system and is made up of an on deck acoustic modem, while the other acoustic modem is attached on the survey equipment on the sea bottom, process module, and battery. The underwater image acquisition and processing system, which is in the pressure resisting can, receives, processes compresses, and transmits the signal to the deck via the acoustic modems. The images transmitted with this method are sent to the computer which has a program for displaying and controlling the underwater system. For this system, 1,000 meter pressure resisting can which contains command processing and image processing module, a couple of acoustic modems of about 1,500 m transmit range, and the battery of appropriate capacity are needed. The UWM2000 model of LinkQuest was adapted and the maximum transmission rate of this model is 9600bps. However, the substantial data transmission rate is 6600bps due to the command processing part with serial communication. But the actual speed is expected to vary according to the underwater transmit environment. Two acoustic modems are located on the Tow-sled and the mother ship, respectively.

Real time image processing system - underwater part

The camera and the image processing part are protected in the pressure resistant can. Image processing part has an image process module and a command process module. Command process module interprets the command from the deck computer and controls the image process module, power, and camera. It uses LANC port to control the camera and extract the image from the image extraction device. The images taken from the camera are compressed and transmitted to the deck through the acoustic modem. The camera is a typical 6 mm type camera recorder and is accessed by the control protocol LANC. The exclusive converter was adapted to convert serial port command to LANC protocol. The camera is powered by both the exclusive battery for the camera and the system battery. Transmission rate is controlled to vary depending on the sea status so that the transmission error and the noise could be minimized. Working range is about 1,500 meters so that the 1,000 meter depth can be safely covered, but the practical range is shorter than the ideal condition. Two acoustic modems of the same model are mounted to the Tow-sled and the deck, respectively. The two lights and the two battery cans with same specification are mounted on the Tow-sled. The model of the adapted camera recorder is SONY DCR-HC21 and connected by the A/V terminal to the image process parts. Lights are LED types and controlled from the deck. Pentium CPU of PC104 type was chosen for the image processing. After recording, images can be downloaded to the computer through the USB terminal of the pressure resist can to the computer. Several sensors are added inside the can to monitor the internal status of the system. Battery power monitoring sensor sends the periodical values of the voltage so that the possible survey time can be estimated. Temperature and humidity in the can, are also measured to help monitor the damages to the system. Fig 3 shows the diagram of the signal and power system of the image process part and the camera. All the wires are designed to go through the main board in order to make the structure of the internal systems simple and easy to assemble and disassemble. The camera recorder and the image processing unit are assembled to be inside of the pressure resistant can.

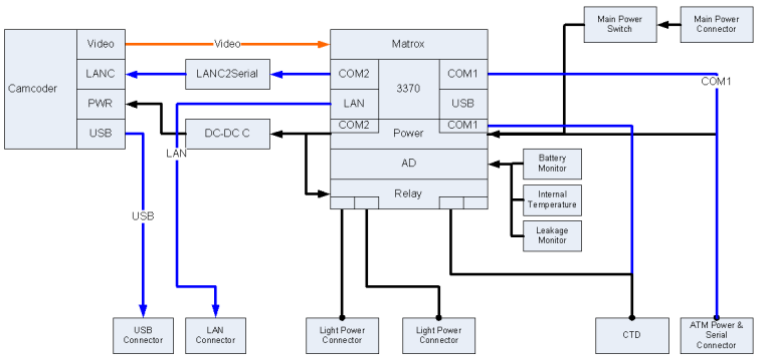


Fig 3. *The diagram of the signal and power system of the image process part, the camera, CTD, and battery.*

Real time image processing system-deck part

The deck part consists of an acoustic modem, connecting cable, and notebook computer. Data transmission method between the acoustic modem and the computer is done in a RS422 way to protect the serial signal from noise. RS422-RS232 converter was used for the computer. The images that were received in computer are displayed instantly on the monitor and the transmission call for the images is designed to request, selectively, from 1 to 20 or continually. The deck part is organized as in Fig.3. The acoustic modem for the deck part is same as that of the one on the Tow-sled, and the 24V power is supplied from the ship directly. The power supply converts the AC 220V of the ship to the DC 24V, and the maximum ampere is 5A.

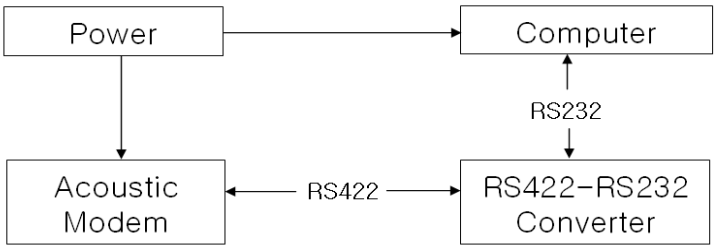


Fig 4. *The diagram of the signal and power system of the deck part.*

Field Experiment: Development of in-situ survey equipment

The fishery of the crab and the Alaska Pollack was developed especially for the 300 meters in the eastern coast of Korea. The field experiment was made to check the capability of the real-time underwater acoustic survey equipment around Wang-dol-cho, a shallow sea area with the depth of around 5meters and goes deep and steeply outward. This area is famous for its high productivity of fishery but the excessive fishing has caused it to decline. Ghost fishing is also considered to be occurring in this area. Five areas were selected for experimentation from September 4th to the 16th, in 2006. The mother ship for the experiment had the following function. The A-type frame should be more than 5 meters high, and the winch should be able to handle the 1,500 meters of wire length with the diameter of 24 mm. The frame for the acoustic modem should be attached firmly to the ship beneath the sea surface. Tow-sled is supplemented with the weights and the floats so that it can be safely lowered to the bottom without being upturned. Upon reaching the sea bottom, the underwater system was controlled by the command signal from the deck system and began recording and transmitting of the images at the sea bottom immediately via acoustic modem to the deck. The signals can be interrupted in case of rough sea condition thus causing it take longer time to complete the image transmission. The computer on the deck system records the command signal from the deck and all the signals from the underwater system automatically displays the information (as shown in the Fig 6) and also logged them up in a file.

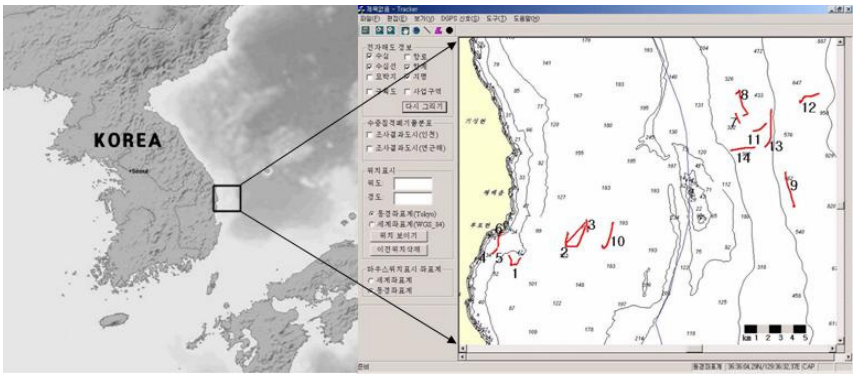


Fig 5. *Map of the experiment area off the Korea Peninsula.*

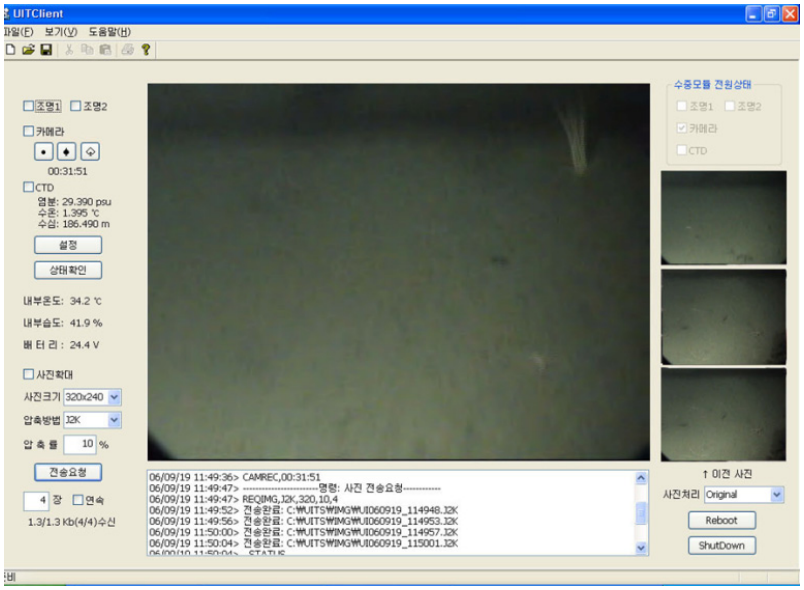


Fig 6. *Monitor display of the real-time underwater acoustic survey system with GUI interface. Commands are given from this menu to the underwater system and the received data and the contents of the log file are shown above.*

Results

In the experiment at the Wang-dong-cho area, it succeeded in getting images like the sea weeds, starfish, shrimp, sea snake bottles, and etc. on the sea bed. The transmission rate of the deep sea images depend on the condition of the sea and its depth. Fig 7 shows the images taken from the above experiment at the depth of 500 meters with 2.5 meters wave height, and the range of the transmission being 600 meters. The size of each image is 640*480 pixels and the real width was tested to reach 100 centimeters. The average transmission time was about 10 to 13 seconds. Fig 8 (a), (b) show the transmission time of the images according to its depth. The average time was about 10 seconds in 300 m when the number of pixel is 320*240. The width of the image is 0.5 m, and was about 15 seconds at 500 meters. When the number of pixel was 640*480, the distribution of the elapsed time was scattered, but the average time were about 15 and 20 seconds respectively with same depth. This may be regarded enhanced result from the previous development. The method of image process optimization in a wave of 2.5 meters in average height is considered to have an effect on the image transmission stability.

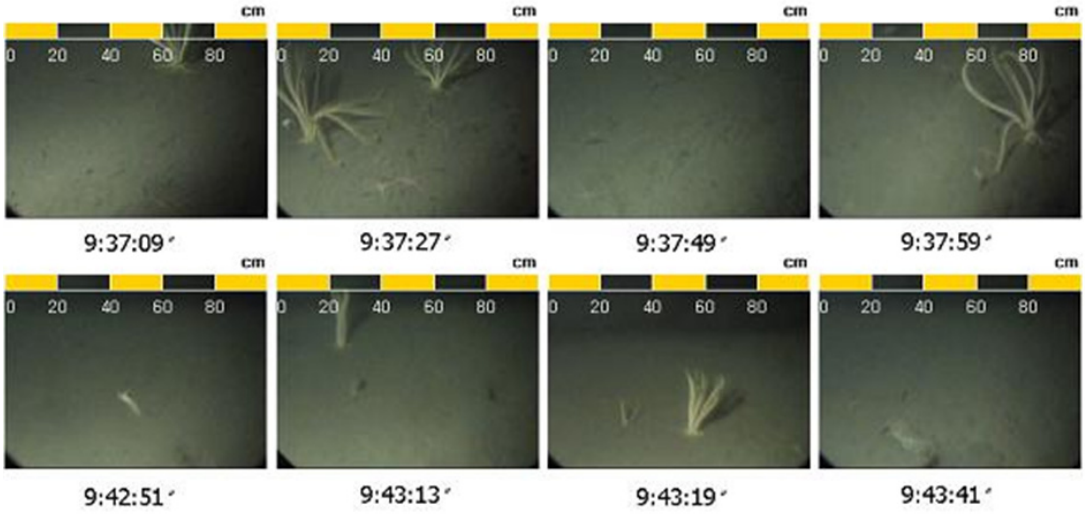


Fig 7. *Two sets of sea bed images taken from the experiment at the Wang-dol-cho area in 2006. Average depth is 500 meters and the actual transmission range is 600 meters with wave heights of 2.5 meters. Pixel size is 640*480.*

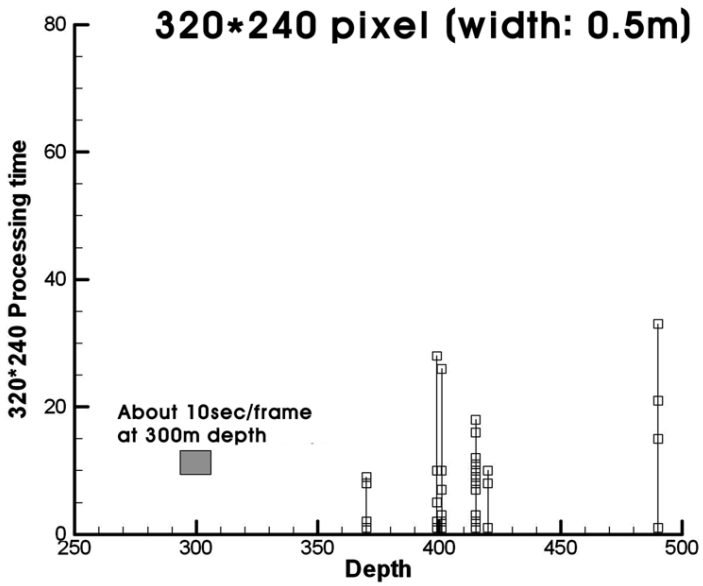


Fig 8 (a). *Processing time of the image transmission according to the depth and the image size (320*240).*

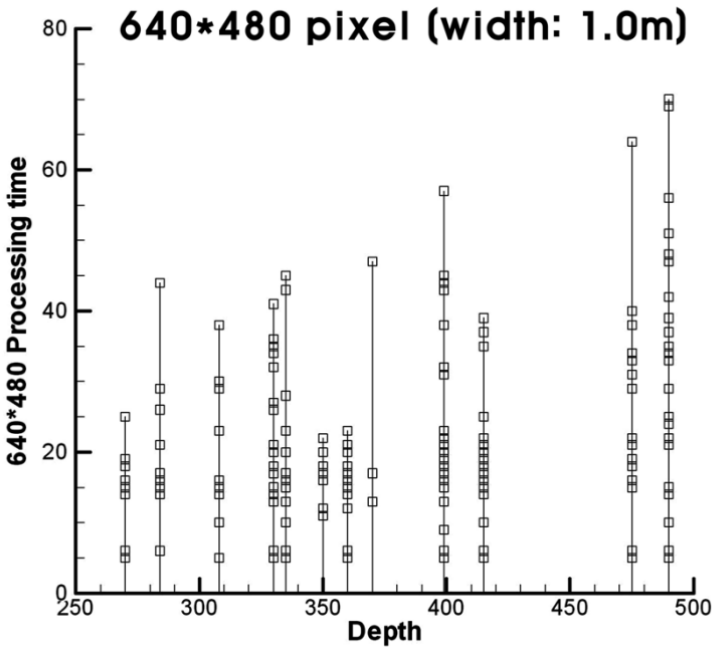


Fig 8 (b). *Processing time of the image transmission according to the depth and the image size (640*480).*

Conclusion

The real time underwater acoustic survey system was developed and tested in Wang-dol-cho area of the east coast of the Korean Peninsula. It is designed to investigate the sea bottom environment up to the depth of 1,000 meters by recording and transmitting the images extracted from the camera recorder and the CTD data. Data are transmitted to the deck via underwater acoustic modem without cable so that the real-time survey is possible without retrieving the tape. In this way, the sea bottom environment can be surveyed with real time response. It can also use the 3 off-line method cameras so that the range of 7 meter width can be monitored on one track. With this equipment the sea bottom investigation can be safely made even at a rough sea bed. When the survey area is rough and deep, the time lag of the transmission gets longer because of the noise. This equipment is expected to be used for investigation of sea bed sediment, management of fishing ground, and surveying of the marine litter as well as the deep sea marine ecosystem and minerals.

2.3. Preventive measures against marine litter in Japan

Enactment of legislation

In Japan, a significant amount of marine litters from both domestic and foreign areas is accumulated on the beach, causing serious problems such as damage to the environment and landscape, and creating a threat to marine navigation and fishery safety.

Because of this situation, the Law for the Promotion of Marine Litter Disposal was enacted in July 2009. The purpose of the law is to promote proper disposal and reduction of the generation of marine litter in order to conserve the coastal landscape and environment. The law puts emphasis on importance of the collaboration with private and public sectors. It stipulates that the central and local governments endeavor to 1) conduct a regular survey of the condition and consequence of marine litter generation, and 2) take necessary measures to prevent illegal dumping within; forest areas, farm land, urban area, rivers, and coast, aiding in the prevention of marine litter generation. It is expected that various activities, encouraged by the law, are going to lower the amount of marine liter in Japan.

Countermeasure for Driftwood

Driftwood causes adverse impacts such as; operational depression of shore protection facilities and vessel moorings, problem to vessel screw propeller, and entanglement of fishing nets. In recent years, as a result of an increased number of regional heavy rainstorms such as the 2005 typhoons season, the driftwood problem has occurred more often in various locations. The Forestry Agency and Ministry of Land, Infrastructure, Transport and Tourism conducted a survey and analysis of the status of forests, located in the upstream water source area, in relation to the mechanism of driftwood generation and fate. This study was conducted with the consideration of the recent change in natural conditions such as the precipitation pattern. The aim was to develop an effective and efficient preventative measure in driftwood problem by determining the tasks for the problem caused by driftwood that fly into dam reservoir (The Forestry Agency and Ministry of Land, Infrastructure, Transport and Tourism, 2007). The result suggests that “deep-seated landslides” tend to occur underground, far deeper than forest root system, as a direct result of

the recent increased occurrence of regional heavy rainstorms. This causes large amounts of sediment and trees to collapse and drift. Additionally, forests along the river channel generate significant volume of driftwood during times of flood due to the decrease in trimming of forest along the river that was caused in response to the decreasing amount of storm flow from the dam.

The framework for future prevention of driftwood will involve various business bodies and administrations, since the generation point of driftwood differs from accumulation, collection and disposal points. In effect, the local administration or business bodies in charge of collection of driftwood have to bear heavy responsibility. For implementation of efficient countermeasures against driftwood within the river basin area, common awareness and closer cooperation of the related bodies and administration will be the essential challenge.

Estimation of marine litter drifting route

The location and season of marine litter generation were calculated and determined using computer simulation capable of simulating the drifting status of marine litter and was based on the survey results of marine litter from East China Sea coast area (Isobe et. al., 2009). This has been used in conjunction with the marine litter drift forecast that has been conducted since January 2009 in the area of Goto Islands in Nagasaki. This was based on the existing study result of drifting route estimate marine litter using surface current or ocean particle model (http://mepl1.cmes.ehime-u.ac.jp/~kako/forecast/Forecast.html). If estimation of a high accuracy is assured, marine litter collection using the litter-collecting vessel may be proposed as an efficient alternative to the more expensive litter collection on the beach.

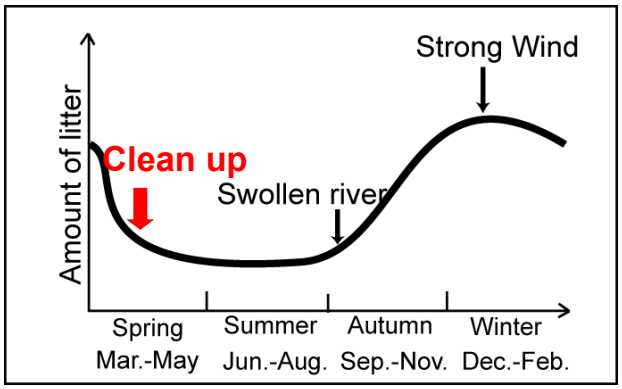
2.4. Collection and transport method of marine litter in Japan

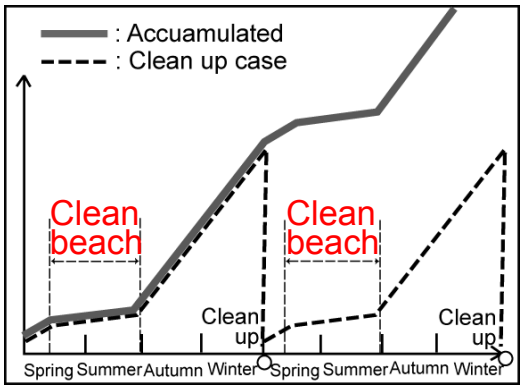
Model Survey for Reduction of Marine Litter

A Model Survey for Reduction of Marine Litter was conducted by the Ministry of the Environment 11 for Japanese seacoasts to consider efficient methods for collection and disposal of marine litter, with consideration to the local condition. The survey includes detailed analyses of the types and quantities of marine litter, understanding actual situation of marine litter such as the seasonal quantity fluctuation, a trial of efficient collecting and disposal methods according to coast characteristics.

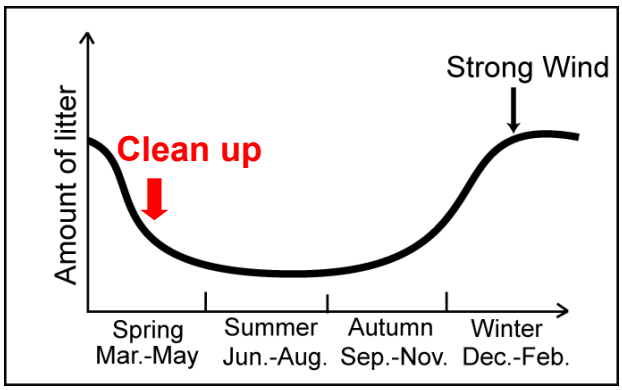
Firstly the efficient marine litter collection period was decided based on the seasonal quantity fluctuations of marine litter within each model area. The seasonal data of marine litter quantity in each model was categorized into 4 types, and efficient collection period was determined (Fig.1). The efficient collection period being the season in which one collection activity may keep the seacoasts clean for a long period of time. In case where marine litter peak is obvious (A - C), collection after marine litter peak is effective to keep the seacoast clean for a long period. However, in a case where seasonal fluctuation is not obvious and litter constantly reaches the beach throughout the year (D), collection should be performed frequently. This would be effective to prevent marine litter from drifting to other locations.

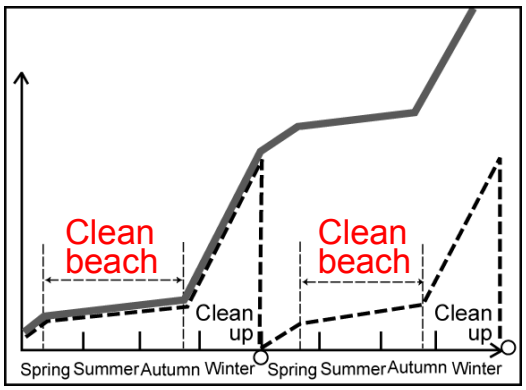
(A) In the case of the seacoast of Japan (Coast facing north): Yamagata, Ishikawa, and Fukui Prefectures



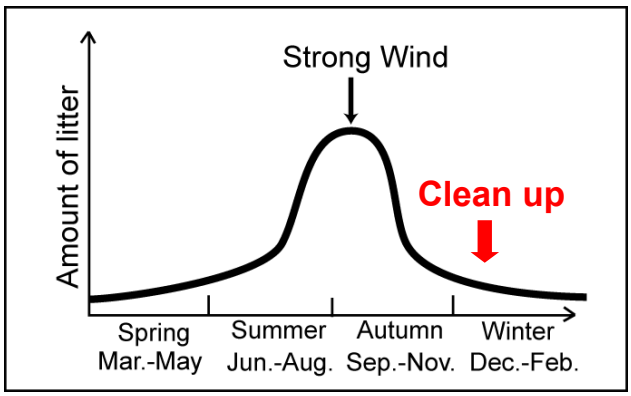


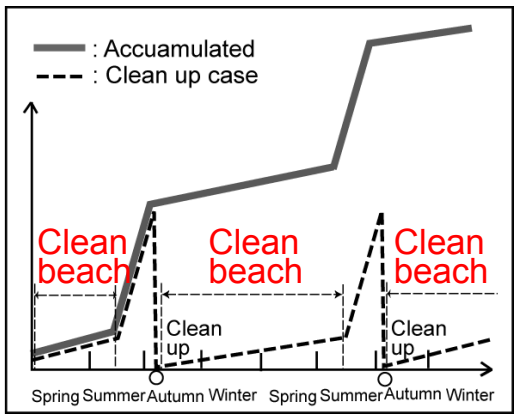
(B) In the case of the East China Sea (Coast facing north): Okinawa Prefecture





(C) In the case of the seacoast of Japan and the East China Sea (Coast facing south): Nagasaki and Kumamoto Prefectures (Tomioka Beach)





(D) In the case of inner bays: Mie and Kumamoto Prefectures (Hinoshima Beach)

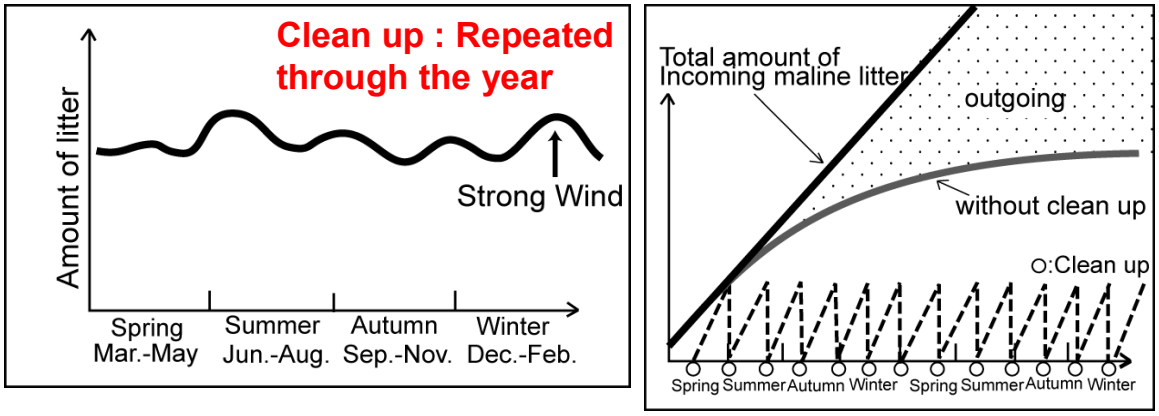


Fig. 1. *Effective collection period considering seasonal fluctuations in the amount of marine litter.*

Secondly, the collection and transport methods of marine litter are decided based on the characteristics of seacoast (Table 1). The survey areas are classified into either sand beach or pebble beach, and existence of access roads. A vehicle approach road is essential for utilization of back hoe, an all-terrain vehicle and other heavy equipment will ensure a very efficient collection activity. Lack of an appropriate approach road limits the types of target litter that can be collected. The survey shows that a backhoe is very efficient for collecting large amounts of driftwood and large fishnets. Electric cutting equipment is required for cutting fishnets, ropes and hard plastic buoys.

Rake dozers have been used for collecting reeds that have drifted onto the beach. A rake dozer is wheel-driven and is able to perform collection at a higher speed with faster and more flexible movement compared to a caterpillar-driven beach cleaner. For an effective operation of rake dozer, 1) large litter (e.g., larger driftwood, rope), artificial materials (e.g., bottles, cans, plastics and PET bottles) and other litters that may prevent swift collection activity should be collected by human labor, 2) reeds should be collected separately by rake dozer, and 3) reeds collected by rake dozer should be separated from sand by using a screen.

A beach cleaner is required for a thorough collection of litter, including artificial materials scattered on the beach. However collected litter contains sand, and human labor is necessary for separating the litter. Additionally, larger litter such as large driftwood and ropes should be collected separately.

Driving heavy equipment and vehicles onto a sand beach may cause hardening of the sand. Prior negotiation with the seacoast administrator and other related bodies will be necessary. Collection of seaweed that drifts on the beach should be considered on a case by case basis, taking into account the coast's ecosystem, as well as the protection of the landscape in the respective area.

In the model survey, the collection activity was tested in combination with the methods described above in various ways. Then the collection efficiency (kg/h/person) was calculated by using the weight of collected/transported marine litter and the total working hours. Collection efficiency largely depends on litter density. The collection efficiency value in representative cases is shown in Table 2 by collection/carry-out method.

Table 1. *Collection and carry-out methods of marine litter*

Method	Item	Type	Sand beach	Pebble beach		Rocky beach	Remarks
				With a road	Without a road		
Collection method	Human labor	Human labor	○	○	○	○	The basic method. Small pieces of litter can be collected. Certain amount of people are required for effective collection.
		Vacuum cleaner	×	○	○	○	Effective to collect small pieces of foamed polystyrene from the gaps between rocks, but cannot be used for a long time.
		Chain saw	○	○	○	○	Fit to cut driftwood. Inconvenient for carrying around.
		Engine cutter	○	○	○	○	Suitable to cut ropes and buoys. Inconvenient for carrying around.
	Heavy machinery	Backhoe	○	○	×	×	Can collect heavy objects. Human labor is also required.
		Rake dozer	○	×	×	×	Fit to collect litter on a sand beach. Human labor is required to sort litter out.
		Beach cleaner	○	×	×	×	
Carry-out method	Human labor	Human labor	○	○	○	○	Suitable to carry out litter other than heavy objects and bulky refuse.
		Two-wheeled cart	○	×	×	×	Can be used on a flat, compacted sand beach.
		Wheelbarrow	○	×	×	×	
		Platform truck	○	×	×	×	
	Heavy machinery	Rough terrain dumper	○	○	×	×	Can be used on a flat seacoast.
		Car	○	○	×	×	Can be used on a flat, compacted sand or pebble beach.
		Small boat	○	○	○	○	Sailing or landing depends on the weather, the sea, or the lay of the land.
		Crane	○	○	○	○	A temporary storage site is required within the operation range of the crane.
		Monorail	○	○	○	○	Installation, maintenance, and removal costs are needed. Partial alteration of the surrounding environment is required.
		Winch	○	○	○	○	

Note: ○ and × denote practicable and not practicable.

Table 2. *Collection/transport method and collection efficiency*

Collection/transport method	Collection efficiency (kg/h/person)	Remarks
Collection: Human labor Transport: Human labor	6 - 7	Transport of marine litter on a slope of vertical interval 60 meters with 300 people by bucket brigade.
Collection: Human labor Transport: Vehicle/ship	5 - 31	
Collection: Machine Transport: Vehicle	3 - 6 (t/h/unit)	Data of driftwood collection calculated from the number of backhoe used for collection. All-terrain vehicle of the same number of backhoe were used for transportation.

Seabed litter survey

According to the seabed litter survey in Seto Inland Sea, conducted by the Ministry of Environment in 2007, marine litter was observed in 52 out of 53 survey points, indicating that marine litter is widely spread along the Seto seabed. The survey shows that plastics account for the largest percentage of litter both in quantity and in weight.

The collection and disposal of seabed litter in the Seto Inland Sea is currently conducted by fishermen as a social contribution as a way of helping the related body solve the assumed problems of litter collection, and promoting and expanding such challenges. The “Guidebook for Promotion of Seabed Litter Collection/Disposal” was published in 2009. It provides recommendations concerning most appropriate method to collect seabed litter. The term “seabed litter” in this guidebook usually refers to any artificial materials in the litter caught in a fishing net during fishing activities, with the exception of natural materials including living organisms, sediment, and seashells.

Seabed litter collected by fishermen is stored, pre-treated, transported, and finally disposed of either through municipal facility for general waste disposal, or through commissioned waste disposal company. In this guidebook, the collection and disposal of seabed litter to municipal facility is classified in four stages: 1) collection, 2) storage and pre-treatment, 3) transportation, and 4) disposal. Recommendations for each stage are described in detail.

In reality, the collection of seabed litter depends largely on the social contribution of fisherman carrying back the litter caught while fishing. Consequently, fishermen are expected to continuously carry back the litter caught during the course of fishing operations to the fullest extent. Also, Fisheries Cooperative Association is expected to coordinate the fishermen with the local government, as well as support the fishermen in storing, managing, and transporting the collected seabed litter.

Handling Dangerous Marine Litter

Hazardous materials such as used syringes, gas canisters, and pyrotechnic signals were often found in marine litter. These may cause people on the beach to be damaged. Such hazardous materials require specific handling methods. However, seacoast administrators usually do not have sufficient

expertise to handle all of these items. It is, therefore, required to prepare a procedure for the safe handling of hazardous materials. “The Guideline for Handling Dangerous Marine Litter” (2009) was developed by the Ministry of Agriculture, Forestry and Fisheries, Ministry of Land, Infrastructure, Transport, and Tourism. This provides the guidelines for initial action that a coast administrator should take once they reach the hazardous marine litter because generally confusion arises. “Handbook for Dangerous Marine Litter” describes it in an easy way, even small children to understand, the danger of hazardous marine litter that drifts in a simple manner.

Chapter 3. Technologies and research outcomes related to treatment of marine litter

3.1. Waste Fiber Reinforced Plastic Vessel melting treatment system in Korea

Introduction

Fiberglass Reinforced Plastic (FRP) is synthetic materials made of a polymer matrix reinforced with fibers to mechanically enhance the strength and elasticity of plastics. The fibers are usually fiberglass, carbon, or aramid, while polymer is usually an epoxy, vinylester or polyester thermosetting plastic. FRPs are commonly used in aerospace, automotive, marine, and construction industry. The global polymer production industry matured in 1970's and the fiber reinforced plastics have been a significant aspect of this industry from the beginning. In Korea, ships began to be made out of FRP in late 1970's and, the total number amounted to 64,000 in 2009. FRP vessels are easy to build and repair, lighter than wooden and steel and strong. However, FRP requires more complicated treatment methods and higher cost when it needs to be disposed. These things make the FRP vessels more likely to be abandoned around coast and harbor.

Although FRP has many merits, moving vessels and harbors' safety may get hampered and impropriate method of treatment of them may threaten the marine environment and human habitat. Furthermore, rules of FRP disposal are rather vague and the proper treatment system is absent so the possibilities of near coast accident by them are increasing.

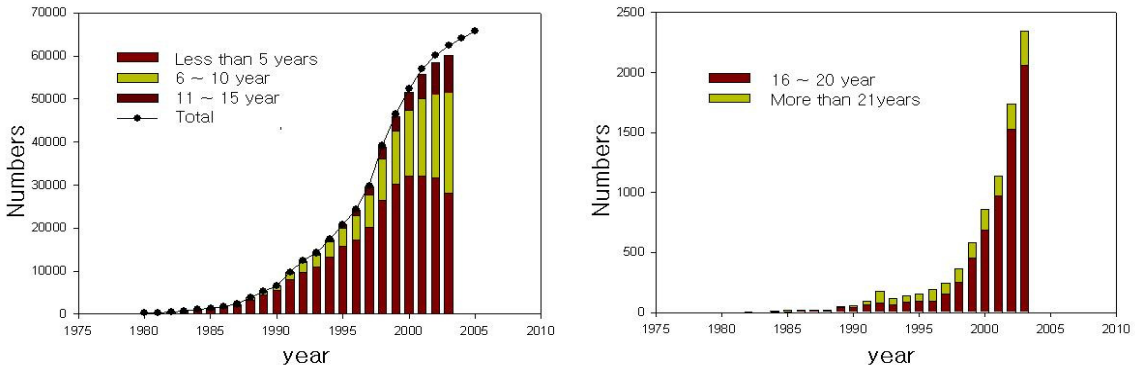


Fig 1. *The number of the FRP vessels built by age.*

Assuming the life span of the FRP vessel as 25 years, the amount of the FRP vessels to be disposed of is expected to sharply increase within few years. From the number of fishing boats will increase more than 500 ships every year (Fig 1) for the next 5 years and 1,500 ships the next 10 years. Nowadays, most of the leisure boats are made out of FRP except rubber boats. The numbers of those who enjoy water leisure and the new production and import of the water leisure equipment are increasing in Korea, so the proper disposal of waste FRP may become a big issue in near future.

Physical and chemical treatment, and recycling methods are already in use or being developed. There are many methods to treat the FRPs such as incineration after crushing, landfill, melting; chemically decompose and synthesize, or dissolve with supercritical solvent. Recycling method needs physical preprocessing. They are cut into small pieces and used as resources for cement and fuel, the resources for the strengthening materials, oil or gas by pyrolysis, glass recycling, and reef through carbonization of FRP vessels. But, most treatment methods have low economic productibility and the possibility of 2nd environmental pollution such as remnants of glass slag after incineration.

Current State of treatment of FRP vessels in Korea

Melting is regarded as safe technique against 2nd pollution for the environmental treatment of FRP vessel, even till today. Korea Ocean Research and Development Institute (KORDI) is in charge of “Development of the melting treatment system of waste FRP vessels” project from the Ministry of Land, Transport and Maritime affairs (MLTM) from 2005. This consists of two parts such as development of pilot facility for the melting treatment system for the waste FRP vessels and construction of treatment system. It aims to have this working in 2010.

The pilot facility of melting treatment system for the waste FRP vessels in small size was developed and tested from 2005 to 2007. This system uses FRP’s own energy in melting and extracting the glass slag so that the economical productibility is maximized by recycling the energy and remaining slag. Development needs are derived and supported by practical use of facility (150 kg/hour) and is under process for building each unit by 2010.

Fig 2. *Pilot plant for the FRP vessel melting treatment and the anti-air pollution facility.*

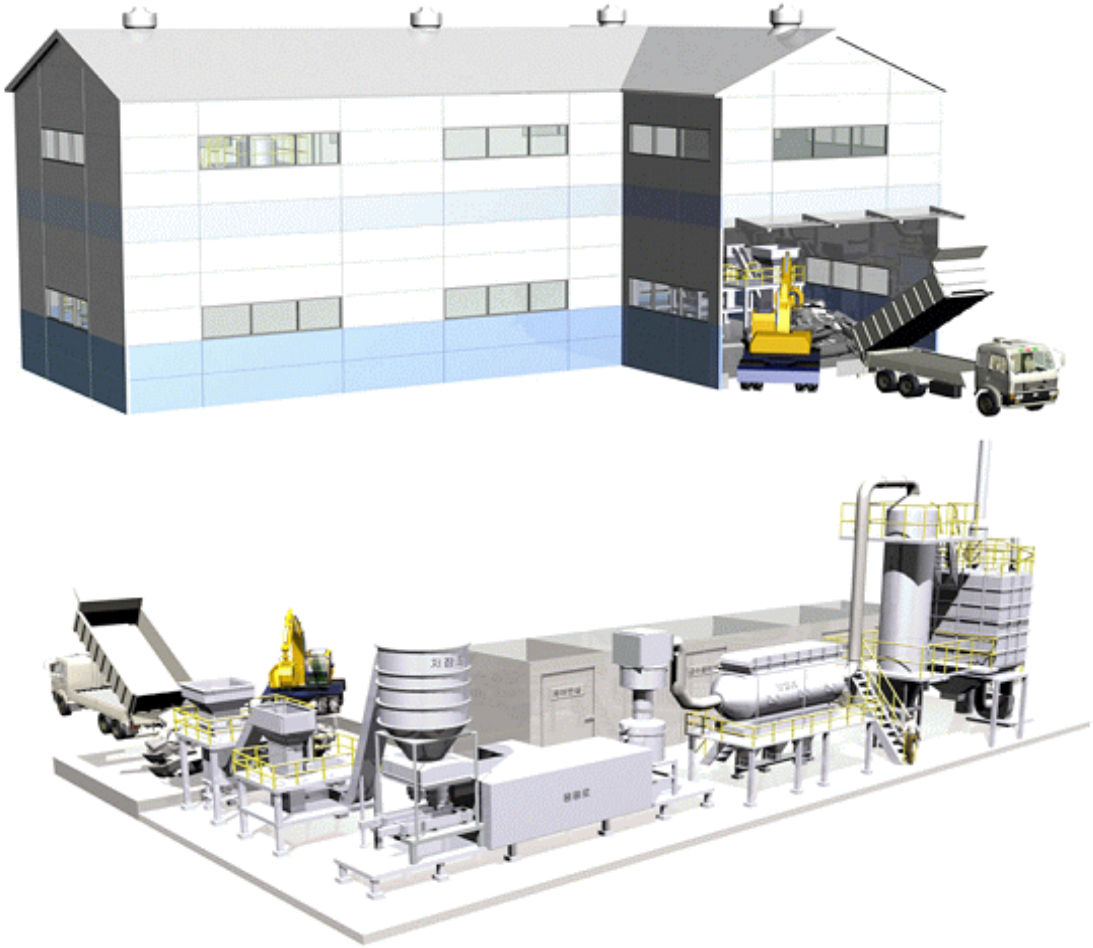


Fig 3. *Practical plant for the FRP vessel melting treatment system (150 kg/hr, operational goal of the year 2010).*

Unit process and its Characteristics of melting system for the waste FRP vessels

There are many steps to properly treat a waste FRP ship such as recovery on land, transportation, cutting, transportation of the fractions, incineration, landfill and pyrolysis of them. The pretreatment processes are as follows, shown in figure 5.

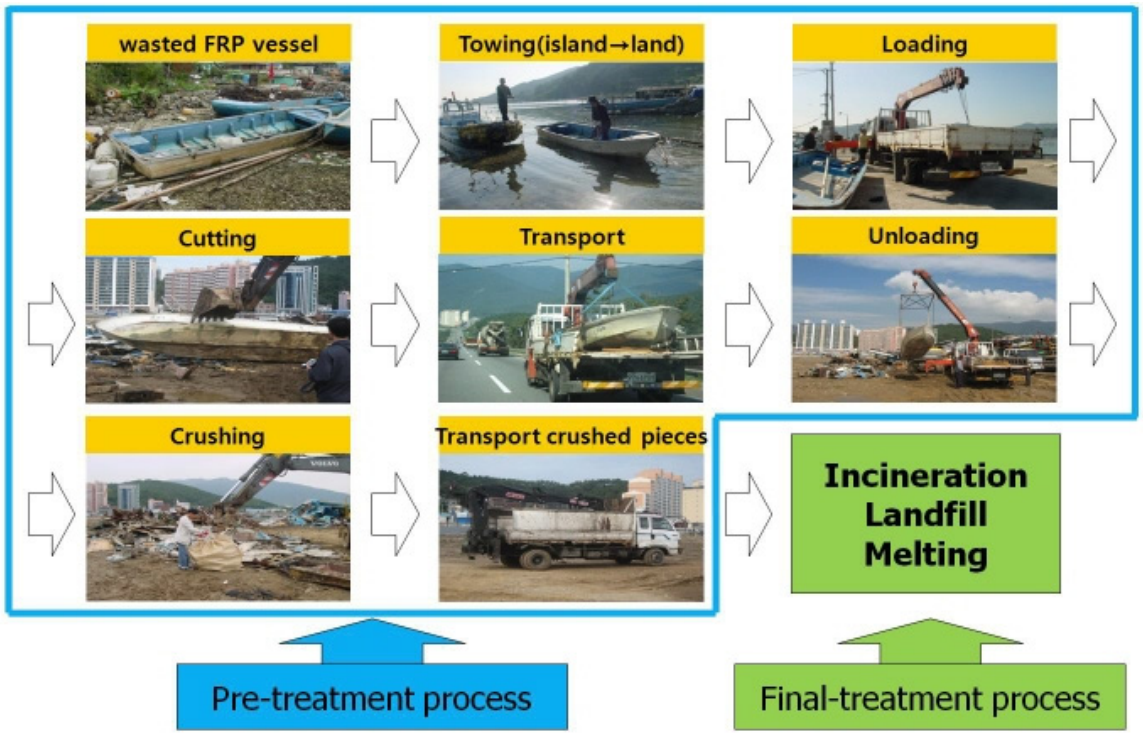


Fig 4. *Pretreatment processes for the waste FRP vessel.*

There are 2 processes in final melting treatment step: Primary pretreatment process consists of cutting, pulverizing of fragments, (1st, 2nd, and 3rd), sorting, storing of fine fragments. Secondary treatment process consists of supplying, melting of fine fragments, recovery of waste heat, cleansing, dust collection, and ventilation.

The characteristics of melting treatment system are that it uses its own incinerating heat from waste FRP ships fragments for its melting and that it depresses the generation of air polluting gas in environmentally friendly ways. It uses fuel gas before the waste FRP ship fragments are inputted, and when

the inner temperature reaches 1,200 degC, the subsidiary fuel gas is get reduced because of waste FRP ship fragments are used as a fuel for heating in melting furnace. The waste FRP ships fragments consists of 66 % of epoxy (adheresive) and 34% of glass fiber. The FRP has a calorific value of about 3,800 Kcal/kg so that once the inside temperature of the melting furnace reaches around 1,600 degC it does not need extra fuel from outside except for the waste FRP fragments. Through the test of the pilot melting furnace the hazardous ventilated gases like NOx, SOx and dioxin are effectively depressed and removed.

FRP fragments are melted into glass slags using its epoxy as fuel gas. The remaining slags are recycled into sand and used for cements, permeable tiles, cup-saucer, and permeable block. The some parts like engine of the used FRP vessels, marine electrical equipment, and scrap irons can also can be reused, but the main body has little method to be recycled or reused. Thus they are usually incinerated and buried at the end.

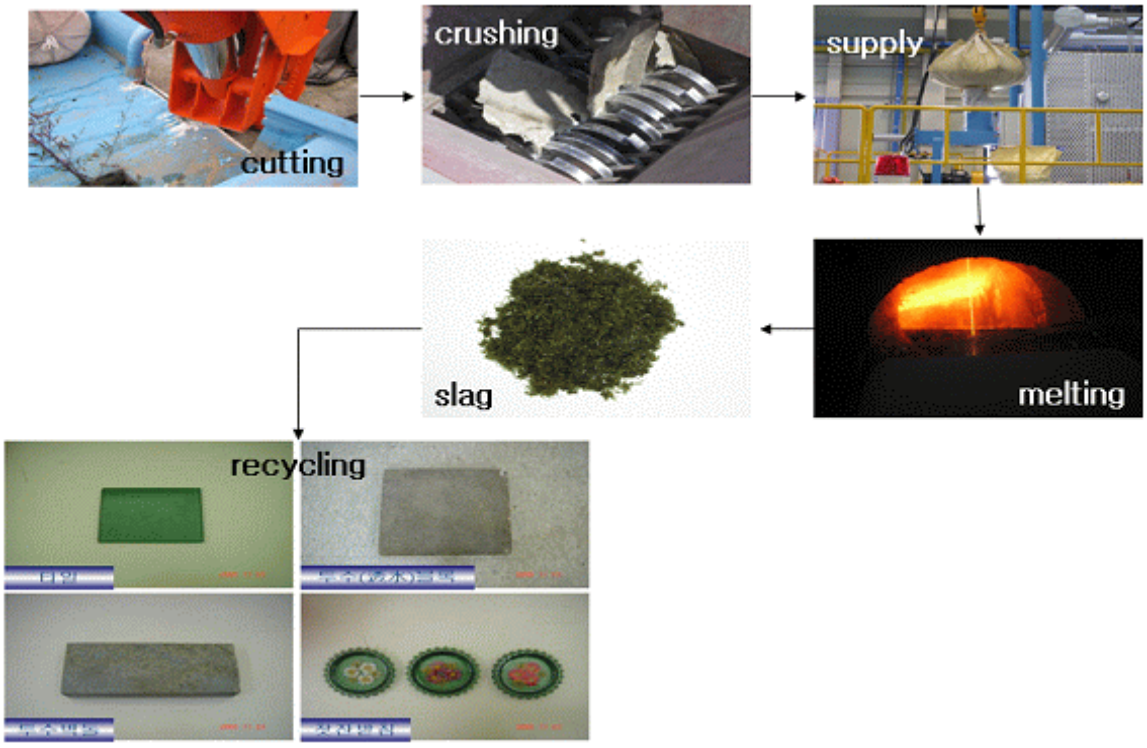


Fig. 5. *Processes of waste FRP vessel Melting treatment.*

Treatment cost for the waste FRP vessel

The treatment cost for the FRP vessel varies according to their anchored location and its condition. For example, if the ship is located on an island or is severely damaged, it needs additional tugging fee to the port, where the treatment facility can be easily accessed. Ships stranded on rocks or mud flat absorbs most of its treatment cost from salvage. The cost in general, except in extreme case, considers this report to analyze the detail cost for each treatment steps. Table 1 shows the suggested cost for the each treatment steps in Korean won. Total treatment steps are classified as tugging, cutting, loading, transport, unloading, crushing, labor cost, fraction transport, and final melting. A ship, smaller than 2 tons is usually about the size of 7 meters x 2.5 meters so that it can be transported without the first step, cutting. But if a ship is larger than 2 tons, it should be cut before being transported by a truck with a special precaution to not pollute around with small fractions and waste oil.

The ships cut into small fractions are usually incinerated with other debris and buried. But, due to the possibility of a subsidiary pollution from pulverized glass fiber so that the melting method is strongly recommended. The melting method solves the problem of scattering of glass fibers, and can also be recycled into other practical products. Though this method of treating the waste from FRP vessels is an environmentally friendly, the treatment cost is 1.5 times higher than the ordinary incinerating method. However, considering the cleansing cost of the probable environmental pollution, the melting treatment is still recommended for final proper disposal of the waste FRP vessel waste. Also, additional and more efficient government support for the owner of the waste FRP ship may be considered. The transport cost occupies a large portion of the total treatment cost as shown in Table 1. To reduce the transport cost, on-barge-pretreatment system was suggested and it is estimated that the whole transport cost can be reduced by 15%. If the whole treatment system become well established in nationwide, total cost for the treatment of waste FRP vessel is expected to get lower in future.

Table 1. *Disposal cost for the FRP vessels that are 2 to 3 tons*

(unit:10,000 Korean Won)

Treatment step	Equipment	Current cost	Suggested cost
Tugging	Tugboat	20	22 (With Barge and labor cost included)
Cutting	Excavator	20	
Load	Crane	25	
Transport	Truck	20	
Unload	Crane	25	
Crushing	Excavator	20	
Labor cost	Worker	20	
Fraction transport	Waste transport truck	15	15
Final disposal	Incinerator melting furnace	41 (incineration)	60 (Melting)
sum		206	97

Results and Discussion

FRP vessels are configured with difficult materials for an environmentally friendly treatment. Incineration and landfill are being used, but they are likely to cause secondary environmental pollution. For this reason we introduced 'Waste FRP vessel melting treatment system' in the FRP industry and the environment. However, the FRP vessel treatment system can be fully processed, with glass fibers that are recycled as the byproduct of slag glass, various glass, tiles, and permeable blocks with a variety of value-added products will.

In order to lower the costs for the treatment of waste FRP vessels, improvement of legal system, recycling system, networking of the hulk processing company, ship statistics management program, and communication among vessel owners and the system are also needed. In addition to the people who value marine environment, if the education and outreach activities are performed FRP vessel treatment system is expected to perform successfully and contribute to keeping the coast and harbor clean.

3.2. Incinerator for the marine debris in Korea

Introduction

Marine litter can be classified as plastics, woods, metals, and others according to its elements. Reuse and recycling should be considered 1st in handling marine litter. Incineration of marine litter is the safest way if reuse and recycling are not possible. This stabilizes the nature of waste and landfills the ashes. In the past, there was landfill without incineration, but because the decreasing landfills and the concern about the secondary pollution by landfill, landfill without incineration is in no longer the desirable option in recent years. In case of marine litter with high humidity and salt, most land incinerator agencies do not want to treat them due to concern about the possible damage to the facilities. Therefore, the development of the technique of the incinerator for marine litter was needed to properly handle them and keep the coastal area clean. Thus, the incinerator for the marine litter was designed to environmentally and effectively treat the various types of waste that is found on either the seabed, the sea surface, or on the coast with high humidity and salt. This incinerator specifically targets combustible marine waste, which is difficult to reuse or recycle as well as other means.

According to the data from the Korea Marine Pollution Response Corporation (KMPRC), which recently changed its name to Korea Environment Management Corporation (KOEM) recently, the total amount of the collected marine litter is about 12,000 ton per year. 16.2% of reuse and recycling and 48.5% of incineration and landfill were accounted for in 2001 (Table 1). It should be noted that waste from seabed usually comes with lots of mud as shown in Fig 1. Inorganic mud, without additional rinsing process may degrade the efficiency of the incinerator. Before the development of the incinerator for marine litter, most of the wastes from sea were usually burned or buried directly in unrelated locations. Collected wastes from coastal areas with lots of inorganic mud, which are hard to properly treat, are usually dumped back to the ocean.

Table 1. *The treatment status of the treatment of the marine debris by KMPRC in 2001*

Method	Volume(ton)	Percent(%)
Reuse and recycling	1,956	16.2
Incineration	4,515	37.3
Landfill	1,354	11.2
Ocean dumping	3,869	31.9
Etc.	417	3.5
sum	12,111	100.0

Fig 1. *Collected marine litter with mud.*

Development of the incinerator for the marine debris in Korea

The research project for the development of the incinerator for the marine debris was conducted by Korea Ocean Research and Development Institute(KORDI) with the support from the Ministry of Maritime Affairs and

Fisheries (MOMAF), which was recently renamed to Ministry of Land, Transport and Maritime affairs (MLTM) from 2001-2002. Its facility was built in 2002-2003. Environmental standards were certified with the testing of exhaustion gas, temperature, and dioxin to ensure complete environmental protection. Public demonstration of the actual operation and survey for the suitable local society was conducted in 2003. Thus the Socheon-do (island) in Inchon city was chosen last, and the transfer of the entire facility was done in 2006 in a part of project 'Integrated Treatment System for Marine Debris'.

Fig 2. *Incinerator for marine debris in Socheong-do.*

Socheong-do is located in Yellow Sea about 160km away from Inchon city and has about 100 households and a military presence. The incinerator on this island has 100 kg/hr processing capacity processing 85.8% of marine debris that occur on the island and 14.2% of the municipal waste.

Configuration and technical characteristics of the incinerator for marine litter

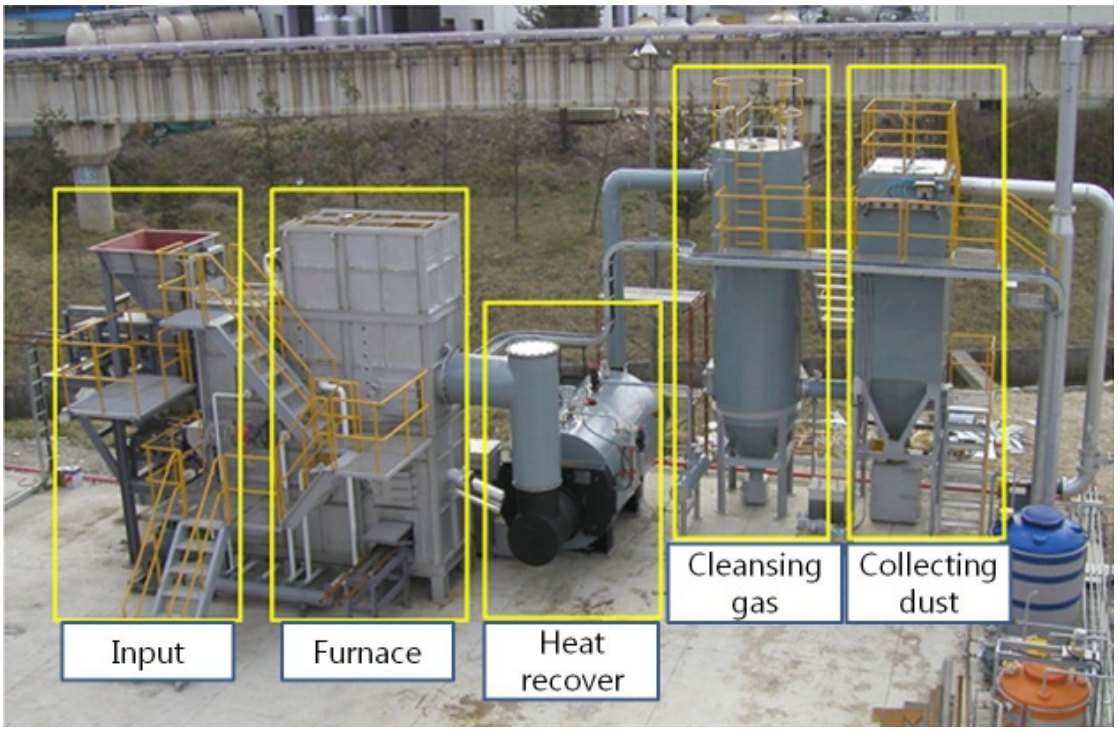


Fig 3. *Configuration of the incinerator for marine litter.*

The incinerator consists of waste input, furnace, waste heat recovery parts, gas scrubber, and dust collection tower. Outer parts have little difference with the land incinerator, but the inner part is designed with the consideration for the characteristics of marine litter

The developed incinerator is composed of waste input parts, furnace, waste heat recovery unit, gas scrubber, and dust collecting tower. Though the outer part is not much different from that of the land incinerator, but the inner part is designed with the consideration of characteristics of the marine litter. And, the function of the gas scrubber is specified according to the marine litter. There are fluidized-bed type, stoker-type, and rotary-Kiln type processes in incinerator design. The developed incinerator was designed in stoker-type to handle the marine litter because they are not all uniform. The incinerator, with fluidized-bed type, puts sands in the furnace and burns the waste with them. Sands are used to expand the contact area of burning surface to increase efficiency. This method is usually used for the waste with the uniform size like sludge. But, there are also derelict fishing gears, woods, mud, and shells in marine litters so they are not suitable for fluidized-bed type pyrolysis.

With an incinerator with Rotary-kiln type, waste should be inputted into the horizontal rotating cylinder with waste being in uniform size and quality, unless incineration is completed. Incinerator with Stoker-type is designed for two combustion chambers. 1st chamber burns the combustible waste while the remaining non-combustible waste and ashes are emitted. Exhaustion gases are treated in the 2nd chamber and exits through the upper exit.

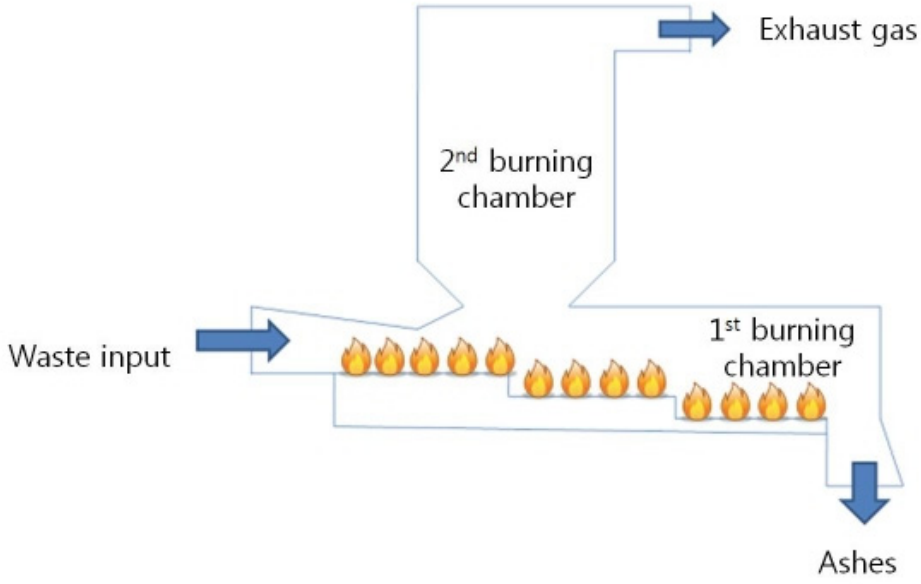


Fig 4. *Stoker type incinerator.*

While the Stoker-type marine waste incinerator was designed for because the nature of the waste is not uniform, high heat capacity of marine litter is the main factor to design the 1st combustion chamber. The inner wall of the 1st chamber was designed with the heat load rate of 3,000-4,000 kcal/kg.

In general there are woods, plastics, rubbers, food, and incombustible materials in land waste while ropes, nets, buoys, plastic buoys, and woods are in marine litter. The majority of marine wastes are composed of synthetic polymers with very high heating value. The maximum heating value of land waste is about 1,800-3,000 kcal/kg, while 3,000-4,000 kcal/kg for marine waste. Generally, stokers or fire grates with specific standards are installed inside the wall of the 1st burning chamber to withstand the high heat. When marine litters are incinerated in the usual land incinerator, there is a high possibility of corruption within the thermal shock and the corrosion of with salt in the furnace.

The key factor in designing the 2nd burning chamber is how to make a lighter incinerator. Marine litters are usually generated from islands and coastal areas where accessibility is low, so it is necessary that the incinerator be light so that it can be easily transported to the needed area. Incinerator should also be able to be installed on vessels. Usually, called “castable refractory”, is installed inside the wall of the 2nd chamber in stoker-type incinerator to withstand the high heat. But this refractory is so heavy that the lighter refractory fiber called “Cerakwool” is used in the incinerator for the marine debris.

Gas scrubber was also designed with a consideration for the combustion gases of marine litter. The accompanying hazardous gases include chlorine, dioxins, acid gases, SOx and more. They are generated when the marine litters with salt are incinerated. Therefore the usual gas scrubber should be strengthened. The gas scrubber is semi-dry type and lots of its scrubbing rods are coated with slaked lime and activated carbon so that it can sequestrate the hazardous gases while passing the combustion gases.

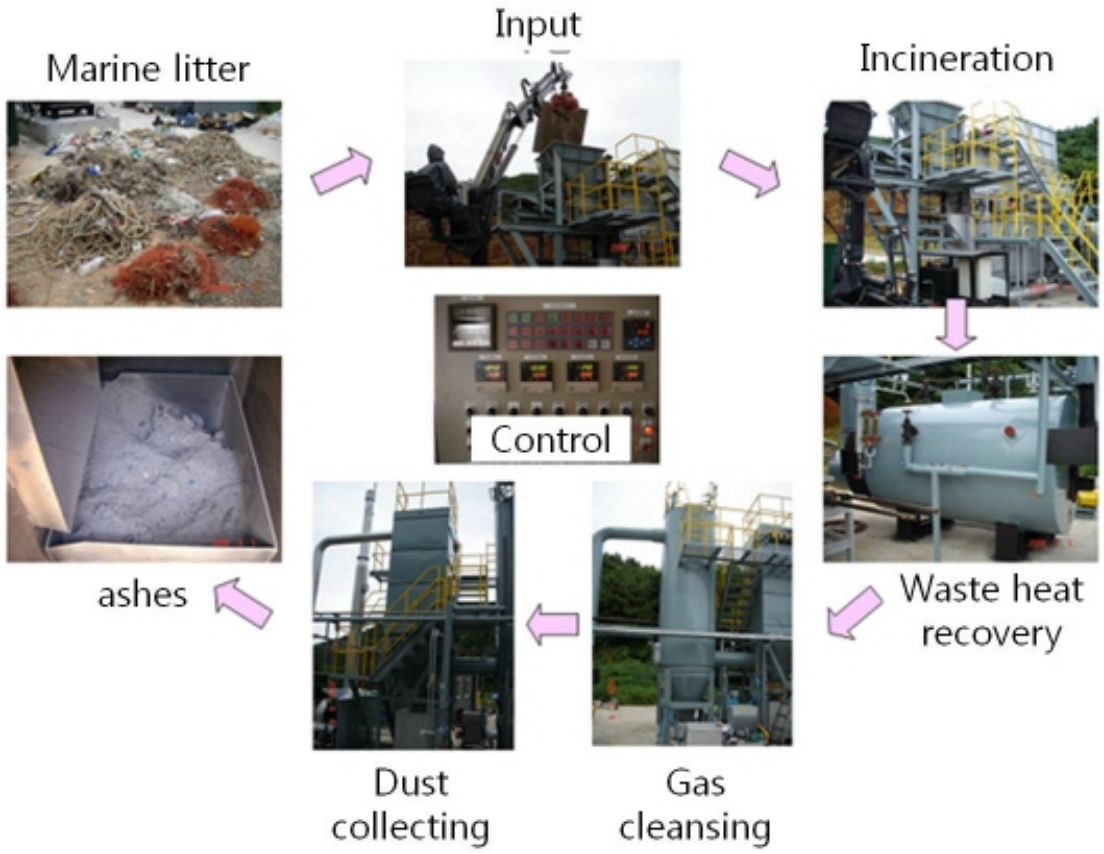


Fig 5. *The processes of marine litter incinerator.*

Fig 5 shows the processes for the incinerator of marine litter. Marine litters which are put into the incinerator with the crane, are burnt in the 1st and 2nd burning chamber, while the combustion gases are processed through the gas scrubber sequestrating the hazardous gases and the ashes. The dusts are then collected finally. The heat from the chamber to the scrubber process can be reused for heating water with the heat recovery facility

Conclusion

Most desirable, economical, and environmentally friendly ways to handle waste are to reuse and recycle, but it still requires lot more time and work. Marine litters were usually buried in land or dumped in the ocean in the past resulting in secondary marine pollution and shortage of landfills. Incineration for marine litter was developed by KORDI with the considering for the nature of wastes from ocean. It was installed in Sochung-do, in the Yellow Sea, and has successfully worked in dealing with the wastes from land and sea since 2006, it has generated good reputation for conserving and the improving the marine environment.

3.3. Garbage Incineration Power Plant in China

The Hazard of Marine Litter

The hazardous of marine litter can be classified into two categories: impacts on wildlife and impacts on human beings. As far as the impact on wildlife is concerned, marine litter that sinks in water usually ends up resting on the sea bed. This can smother any living thing there by restricting the amount of light or nutrients; Marine litter also damages the plants and animals simply by the impact of landing on them. Marine litter can also sometimes resemble natural items of food. Therefore marine litter impacts the sea animals. Entanglement is another main threat to wildlife. In regard to the impacts on human, some marine litter can be toxic, which threatens the heath of human beings. The cleanup cost is also a financial burden. Marine litter threatens safe navigation, for example, litter getting into the propeller of the engine. Litter contaminates fishing catches, which wastes both time and money for fisherman. Marine litter can also damage fishing gears. Therefore, marine litter must be collected and disposed properly.

The Source of Marine Litter in China

In China, marine litter mainly comes from sea-culture, sea-drill platforms, ships etc. Most of the marine litters discharged from ships are produced by merchant ships, fishing boats, yachts and other types of ships. With the rapid development of marine transportation, marine exploiting and marine economy strategy, the increase in sustainable marine activities leads to the dramatical marine litter output climbing . More threats to the environment accompany the discharging of marine litter. Chinese government, on one hand, takes controlling measures to prevent the discharging of marine litter. For example, China Maritime Safety Administration controls the garbage discharging from merchant ships, while it is strengthening the construction and management of the garbage reception facilities by initiating the study on garbage treatment technology for a sustainable development.

The Traditional Treatment of Marine Litter in China

There are mainly two ways of garbage treatment in China. Traditionally, garbage was disposed of through landfill. Recently, garbage incineration technology has been widely adopted. According to statistics, from 2008, the gross production of municipal waste in China was 155 [1] million tons. And, 82.7% [1] of garbage was landfilled; only 15% [1] of them were incinerated. Despite the fact that the cost of landfill treatment is relatively low, a large scale of soil has to be occupied by landfill plant, and the environmental threats from landfill are also very high from such things as heavy metal pollution and toxic liquid penetration. Compared with landfill technology, incineration technology has many advantages. Therefore, many garbage incineration power plant projects were initiated by Chinese government, and some garbage incineration power plants have been built in many big cities.

The Advantages and Disadvantages of Garbage Incineration Power Plant

1. Incineration power plant occupies little land. Garbage landfill plant occupies large scale of land, which consumes the soil resource dramatically. Situation would be much more serious in larger cities and coastal cities with high density of population. However, a medium size garbage incineration power plant will only account for 5-10% area of garbage landfill plant.

2. The period of incineration treatment is short. Natural degradation of garbage is 10-15 years, sometimes longer. During the process, some toxic liquid may penetrate into the soil, which will cause great harm to the environment. However, the incineration process is very short and the side effects of incineration are small.

3. Ash and combustion residues can be utilized as raw materials in construction. After combustion, garbage transforms into ashes and residues, which can be used as raw materials in construction.

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1 Quoted from the speech of Zhang Lijun, the vice minister of Ministry of Environment Protection, 2008, Choose the Appropriate Approach to Deal with Garbage

4. The heat energy can be transferred into electric energy. During the process of incineration, large quantity of heat energy is released, these heat energy can be utilized to generate electricity. The electricity output for a garbage incineration power plant with capacity of 1000 tons per day, is approximately 12 million watts [2].

Despite garbage incineration, compared with landfill methodology, has many advantages; it still has side-effects during the process of combustion. For example, some toxic gas, known as dioxin will emit. The combustion also needs combustible materials, such as coal or fuel oil.

The Improvement of Garbage Combustion Technology

In order to reduce the emission of toxic gas and reduce the side-effects of garbage incineration, the following measures have been taken.

1. The pre-selection procedure has been implemented to sort out the organic substances. The production of dioxin is a combination of phenyl in the organic substances with chlorine at certain temperature, generally between 400 and 780 °C [2]. Therefore, sorting out those organic substances is an effective way to prevent phenyl from combining with chlorine. Selected organic substances can be made into organic fertilizer.

2. Addictive has been added into the boiler with garbage to increase the combustion efficiency. Adding some combustion-supporting materials, such as coal or fuel oil, can make the combustion process much more sufficient, thus, reducing the emission of dioxin. Circulating Fluidized Bed Boilers (CFB Boiler) is an application of the addictive technology. CFB boilers are widely used by garbage incineration power plants.

3. Strict control of the combustion temperature. When the combustion temperature is between 400 and 600 °C [2], dioxins are released. When combustion temperature exceeds 1000 °C [2], dioxin is not produced. Therefore, make the combustion process more sufficient and control the temperature at 1000°C, where emission of dioxin can be controlled.

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2 Chen Li, Garbage Treatment Technology and CFB Garbage Incinerator, http://www.chinaep.net/feiwu/laji/laji-14.htm

Conclusion

Combusting garbage to generate electricity technology has been widely adopted around the world, China also applies the technology in the garbage treatment. Recent years, many big-size garbage incineration power plants have been built, and many other plants are either in planning or under construction. Despite the public criticism that garbage incineration technology will produce toxic gas and dioxin that are harmful to the health of human beings, through appropriate choice of combustion method, pretreatment techniques, and improved equipment, pollution from garbage combustion can be controlled. Garbage treatment can be an environmentally friendly business.

3.4. Survey concerning the disposal and treatment of marine litter in Japan

Current situation of disposal and treatment

According to the document compiled in 2007 by The Government Conference of the Marine litter-related Ministries and Agencies in Japan, the cleaning activities of marine litter are performed mostly by private organizations such as residents and volunteer groups. The collected marine litter is finally disposed of by seacoast administrator, the municipal government, harbor administrator or fishing port administrator In many cases, they are disposed of at a municipal facility for general waste disposal. Thirty to forty percent of those administrators contract a waste disposal companies. On remote islands where waste processing is difficult due to lack of sufficient facilities, the marine litter is disposed mostly by the contracted waste disposal companies.

Plastics constitutes a great part of the marine litter. The survey concerning the technology of domestic treatment, reuse, and recycling of waste plastics, was conducted by Northwest Pacific Region Environmental Cooperation Center (NPEC) (NPEC, 2007). The result of the survey was compiled into the report, “Recycling Plastic Marine Litter” (NOWPAP CEARAC, 2007).

Effective use of driftwood

The efficient use of driftwood is considered in the Model Survey for Reduction of Marine Litter (Ministry of the Environment, 2009). Disposal method of driftwood includes incineration, landfill, and chipping. Chipping is an efficient use of driftwood, and Fig.1 shows the example of chipped driftwood usage. Chipping has the lowest disposal cost, followed by incineration and landfill

(A) Biomass fuel: chipped driftwood is sold as biomass fuel

Sorted chip

Chip used as biomass fuel.

(B) Chip mulching: chipped driftwood is carbonized and sold as mulching material*.

Sorted chip

Carbonized chip

(C) Fermented chip deodorant for livestock: chipped driftwood mixed with compost is fermented and sold as deodorant.

Sorted chip

Compost facility

Fig 1. *Effective use cases of driftwood.*

* Material used to cover the tree base of the tree for prevention of water evaporation from soil surface, weed development, and soil erosion.

Volume reduction test of foamed polystyrene

In the survey conducted by Ministry of the Environment, the volume reduction of foamed polystyrene was considered for the purpose of decreasing collection/transportation cost. Following three are the representative volume reduction methods; 1) volume reduction by heating, 2) volume reduction by compressing, and 3) volume reduction through solvent was selected since special facility is needed, and the treated material may be recycled into plastic. Foamed polystyrene materials such as buoys are collected on the beach as a sample, and then the amount of the material that was dissolved by 100L of solvent was measured. The result showed that 100L of solvent can dissolve approximately 3 m^3 of foamed polystyrene, in 2 hours, by 2 people. According to the solvent manufacturer, solvent is usually capable of dissolving foamed polystyrene 3 times the amount of the solvent itself, though it requires a longer time. When practicing volume reduction using solvent method, purchase cost of solvent, storage site for collected foamed polystyrene, as well as dissolving time and labor cost should also be taken into consideration.

Fig 2. *Drum can containing solvent and manual volume reduction equipment for drum can.*

Fig 3. *Volume reduction test.*

3.5. Development of Recycling System for Waste Expanded Polystyrene (EPS) Floats in Japan

Background

Beach litter was collected from sand samples on beaches, and polystyrene (EPS) floats for v various things such as for the production of net-cage rafts for marine culture (e.g., the floats of oyster farming rafts), and fenders for boats in coastal areas (Fig 1). 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. *EPS float for the production of net-cage rafts.*

From 2004 to 2006, studies were conducted to account for the number of small plastic fragments that had either washed-up or become buried along 30 beaches in Japan (Fig 2). In addition, Japan Foam Styrene Industry Association surveyed EPS float production in 2005. Surveys showed that discoveries of EPS pieces were greater in western Japan than in eastern Japan.

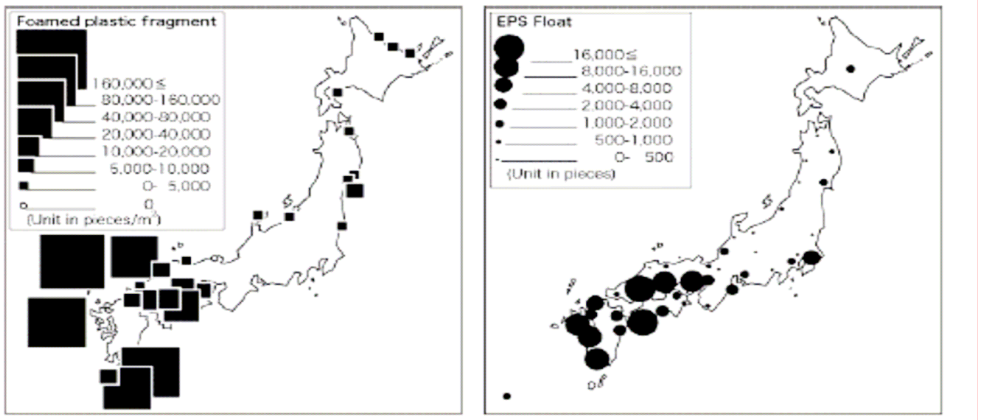

Fig 2. *Distribution of foamed-plastic fragment (left) and EPS float production in 2005 (right).*

Recently, concerns have risen regarding the impact of small plastic marine debris on fisheries. These small fragments must be removed by hand in fish processing plants, as failure to do so would result in contamination of marine food products. While this not only decreases the commercial value of marine food products, it also increases production costs. Left unchecked, food contamination by marine debris is likely to have an indirect, sustained and progressively negative impact on coastal fisheries. Such situation is also erosion of trust of consumers in marine products and coastal fishing.

New recycling system of EPS floats

EPS floats have been incinerated at shores and reused as fenders or buoys at sea. However, recently, incineration was prohibited by regulation. As a result, the some have demanded economical disposal or recycling of the floats.

Improved recycling of EPS floats started in 2003. Using this new system, once wasted EPS floats are now compressed with a portable compressor (Fig 3) at the fishing port near the marine culture area. They are then transported to Refuse Paper and Plastic Fuel (RPF) manufactures. At the RPF manufacturer, compressed floats are mixed with waste paper and other plastics, and are made into Refuse Paper and Plastic Fuel (RPF). The RPF is then transported to paper companies, and used it as fuel instead of coal (Fig 4).

The compression treatment process consists of the following stages: input, crashing by screw, and compressed by cone. The system has the advantage of being able to considerably reduce transport costs considerably by reducing the volume of the waste floats to less than one-tenth of their original volume.

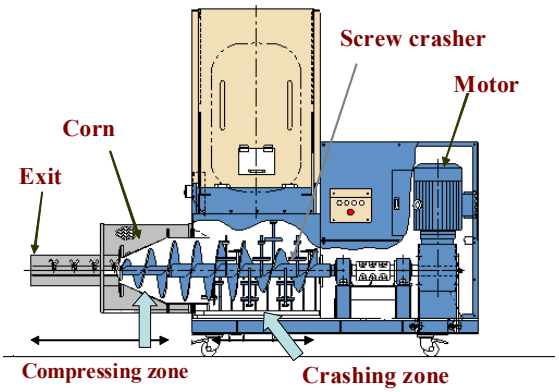

Fig 3. *EPS float Compressor for recycling.*

The RPF manufacture

Fig 4. *New recycling system of EPS floats.*

Results

In four years of testing, 25,836 floats have been recycled in southern Kyusyu and western Shikoku (Fig 5). A new system will be deployed as part of a government program from 2007.

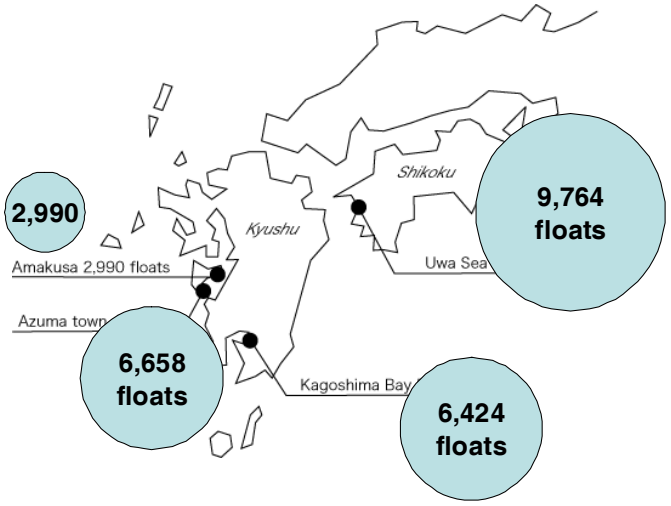

Fig 5. *Total amount of recycled EPS float in four years.*

3.6. Development of the Polystyrene-Buoy Thermal Volume-Reduction System in Korea

Background

A high amount of waste polystyrene fishing buoys in Korean coastal waters is found to be scattered in every year. These buoys degrade the coastal scenery, damage the environment, and constitute as main source of loss for the fishing industry. The purpose of this system is to develop an environmentally friendly method of treating and recycling polystyrene fishing buoys, by thermal volume reduction. Originally, this system was developed to treat large amounts of used buoys; therefore, was built at a dedicated facility with a storage area. Afterward, the necessity for an on-site treatment grew so a mobile type of volume-reduction system was developed in 2007. This system was a success in improving the coastal environment through onsite demonstrations. On the other hand, by the end of 2008, 22 fixed systems, each with the capacity of 100 kg/hr, has been constructed by local governments. The system thermally reduces the waste polystyrene buoys to ingots, 100% of which can be recycled to produce other plastic products, and therefore produces subsidiary income.

This system was developed in a project, ‘Integrated Treatment System for Marine Debris’, which constitutes a cooperative enterprise between the central government, the local government, and Korea Ocean Research and Development Institute (KORDI), as each group contributed its expertise in the area recycling of marine debris. These fixed and mobile systems are expected to play an important role in improving our coastal environment.

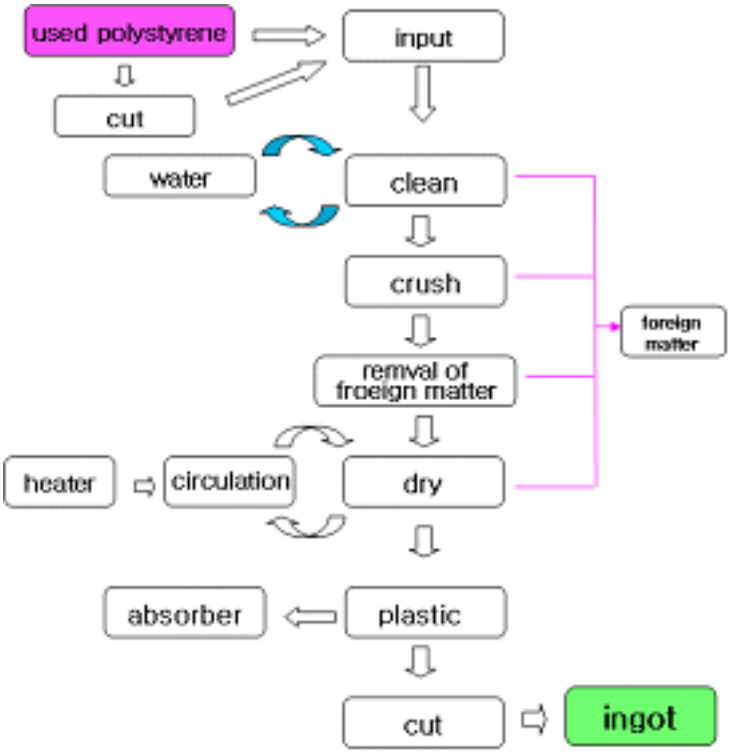

Fig 1. *Reduction system process.*

Fig 2. *Used polystyrene buoy thermal volume reduction system.*

Methodology

There are several methods to treat polystyrene buoy that are in use such as thermal volume reduction, high pressure compression, melting, and so forth. Each method has its own merits but after considering cost and workers' environment thermal volume reduction method was regarded as the most suitable one in Korea.

The treatment process consists of following stages: input, crushing, removal of foreign matters, drying and deformation. The system includes a hydraulic cutter for large buoys before the input process and uses an air transfer method to convey large amount of crushed polystyrene buoy to the next step of each process. Foreign matters such as shells, mud, and sand are removed so that high-value ingots can be produced. The system includes an exhaustion gas absorber to prevent air pollution and to remove bad odor. Blowers that create noise are cased in a highly sound-proof room to provide a safe and worker-friendly environment.

A truck-mounted mobile system was developed for locations where lack of quantity of used polystyrene buoys did not much to justify a fixed facility, or in locations where the local population has concerns having a fixed facility in their community. After repeated tests and improvements, this mobile system showed a good performance during the demonstration in December 2007. The production capacity of the mobile prototype is 30 kg/h. After distributing the mobile systems to the local governments, it is expected that onsite treatment for waste buoys would create a better environment for coastal zone.

Fig 3. *Hydraulic cutter for large buoy.*
(a)Buoy cutter loaded on the truck(left) (b)Large buoy cutting test(right)

Buoys, larger than 60 liters in volume, need to be cut into smaller pieces in order to be put into the pulverizer. Therefore hydraulic cutter is included in this system. Pulverizer is a dual axis shearing type, and the feeding part is inclined so that buoys can be easily shredded into sizes less than 2cm in diameter. It is designed mostly for the shells that are attached to the buoys, so that heavier polystyrene buoy can be easily divided.

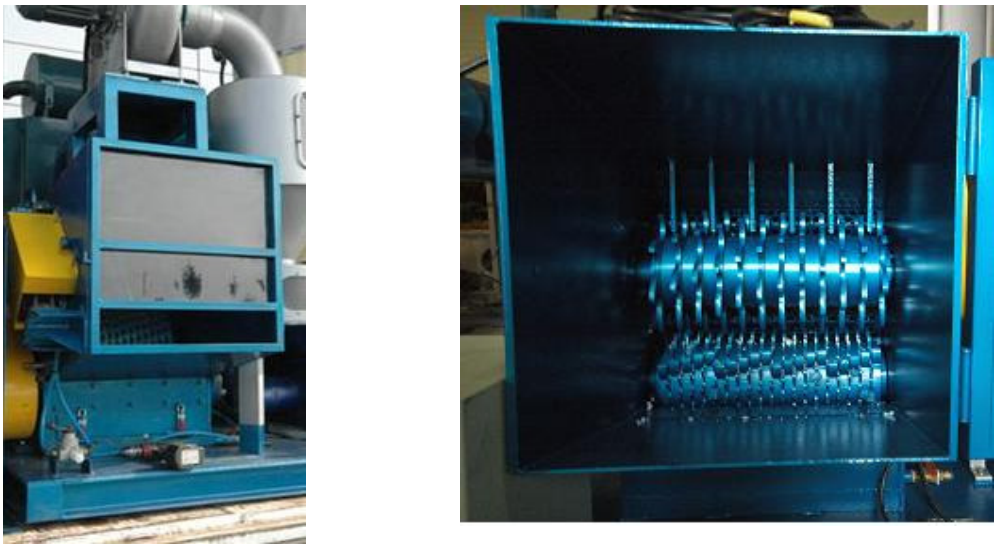

Fig 4. *Pulverizer (Dual axis shearing type, Maximum 60 liter buoy can be pulverized into 2cm diameter).*

Shells, sands and other debris that still remain with the shredded pieces of buoys are eliminated in the centrifugal separator. They are transferred in along with blower and only the polystyrene pieces remain in the centrifugal separator. Sometimes buoys were covered with mud and sand so the washing device was considered to clean the polystyrene pieces before and after the shredding steps. But this idea was dropped out because most of the mud is removed while in the pulverizer and the centrifugal separator. The merit of cleaner ingot is not a big considering the needed space, energy, and cost for the rinsing process after the test. The polystyrene pieces need to be dry in order to be molded into ingots. The omission of the washing step also decreases the time and energy for the drying process. The drier is centrifugal hot air blowing type and its top is made from a strong textile so that water vapor may easily flow away.

Fig 5. *Centrifugal separator.*

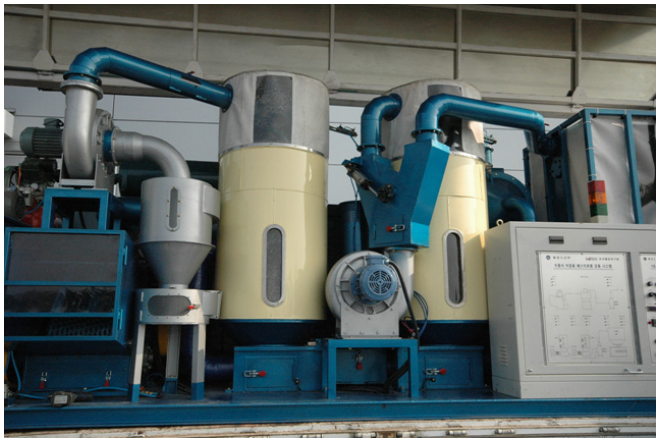

Fig 6. *Drier.*

The injection molder changes dry pieces of polystyrene buoy into ingots. It heats up and melts the pieces at the rate of 30 Kg/hour so that the volume of the buoy may be reduced to about 1/80-1/100. The generated odor and heat are absorbed into the absorption tower.

Fig 7. *Injection molder (30 kg/hour).*

Fig 8. *Absorption Tower.*

All the energy needed for each processes is supplied with a power generator and its exhaust gas is also absorbed into the absorption tower. All the processes are control with the control panel so that the whole process can be done continuously or separately.

Fig 9. *Control panel.*

Fig 10. *Loading system on the truck.*

Results and Discussion

Though the fixed type of volume reduction system can deal with large amount of polystyrene buoys, the mobile type has its own merits; it does not need large storage space, and it can deal with the used buoy, on-site. Furthermore, it does not concern itself about people's NIMBY attitude. The fixed type is distributed around the coastal areas where large amount of used polystyrene buoys are made. The mobile type is also plays significant role in areas where lesser amount of used buoys do not justify building a fixed one. 22 fixed type of volume reduction system were distributed, but the mobile type is now ready to be distributed.

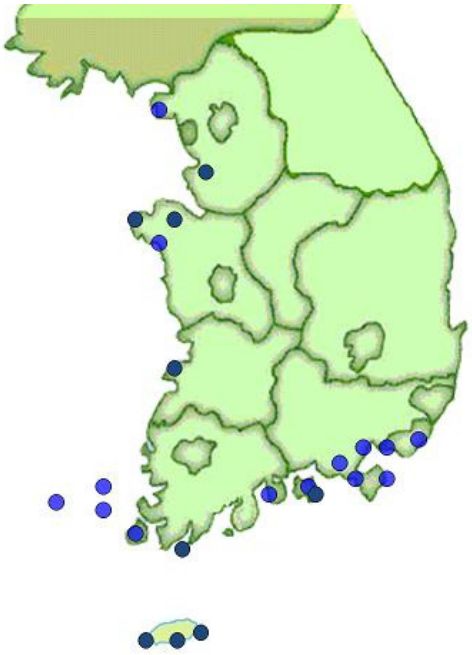

Fig 11. *Distribution of the thermal volume reduction system.*

(a) used polystyrene buoys

(b) ingots

(c) reused products

Fig 12. *Reusing of the waste polystyrene buoys.*

Fig. 13. *Before and after utilizing the polystyrene buoy thermal volume reduction system.*

Chapter 4. Conclusions and Recommendations

In this report related measures and techniques for the prevention of occurrence, survey, recovery and the treatment of marine litter in China, Japan, and South Korea were briefly introduced. In the area of the preventative measures and survey of current status of marine debris, it was introduced that the Solid Garbage Recovery Equipment (SGRE) in China, the real-time underwater acoustic equipment for deep sea survey in Korea, and collection and transport method of marine litter with modeling in Japan.

Regarding the treatment techniques, the NOWPAP member states considered many ways of treatments as types of marine litter and environment are various. In Korea, the number of waste Fiber Reinforced Plastic (FRP) vessels in Korea is rapidly increasing, and the technique of melting treatment system has been developed to contribute to deal with FRP vessels. Incinerating for various mixed marine litters has also been developed in China and Korea in order to handle them with environmentally friendly ways, because incineration is regarded as effective techniques for treatment of mixed marine litter. The volume reduction of foamed polystyrene has been developed in Japan, and mobile volume reduction system for the waste buoys has also been developed in Korea. For driftwood that has been washed onto shorelines the efficient use of driftwood was investigated for incineration, landfill and chipping in Japan. Though driftwood is not defined as marine litter, Japan investigated the treatment of driftwood because of its possibility of navigational hazards and negative impacts to fishery and esthetic value of the ocean.

Regarding the marine litter issue, the NOWPAP member states should strengthen regional cooperation in technical research, management practices and joint efforts on marine litter prevention. This report can contribute to cooperation between NOWPAP member states that will help to reduce marine litter and conserve marine and coastal environment in the NOWPAP region as a whole. Collaboration among various stakeholders is also necessary to develop partnerships and voluntary agreements for marine litter problem. Marine litter problem is one of the urgent environmental issues in the NOWPAP region, and large interest, various measures and dynamic efforts should be taken.

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Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

P.O. Box 23, Yuseong, Daejeon 305-600, Republic of Korea
(c/o MOERI/KORDI)
Tel: (+82-42) 866-3638, Fax: (+82-42) 866-3698
E-mail: nowpap@moeri.re.kr
Website: http://merrac.nowpap.org

92400
9 788993 604030
ISBN 978-89-93604-03-0