

# MARINE LITTER IN THE REPUBLIC OF KOREA

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## 1. Overview

Marine litter and debris is now recognized as a major part of marine pollution that destroys the ecological, economic, cultural, recreational and aesthetic values of the marine ecosystem and its components (Carr, 1987; Laist, 1987, 1997; Carr and Harris, 1997; Coe, 1990; Takehama, 1990; 1992; Burgess-Cassler *et al.*, 1991; Nash, 1992; Duguy *et al.*, 1998; UNEP, 2001). Various studies have dealt with the problems caused by debris in various marine environments such as the European coasts (Galgani *et al.*, 2000), the Mediterranean (Bingel *et al.*, 1987; Galgani *et al.*, 1995a,b, 1996, Galil *et al.*, 1995; Golik, 1997; Stefators *et al.*, 1999); Caribbean region (Coe *et al.*, 1997), the United States (reviewed by Ribic *et al.*, 1997), etc. The studies have covered various topics related to marine litter such as the amounts, types and distribution and biological impacts of marine debris in the respective environments, and the sources and solutions to the marine debris dilemma.

In Korea, marine litter has also become one of the serious environmental, economical (especially fisheries) and social problems. Thus, it was urgently required to develop practical management strategies to control the input from shipping (fisheries activities) and land (through rivers), to assess their potential impact on marine environments and fishery resources, and to clean up the accumulated debris on the seabed.

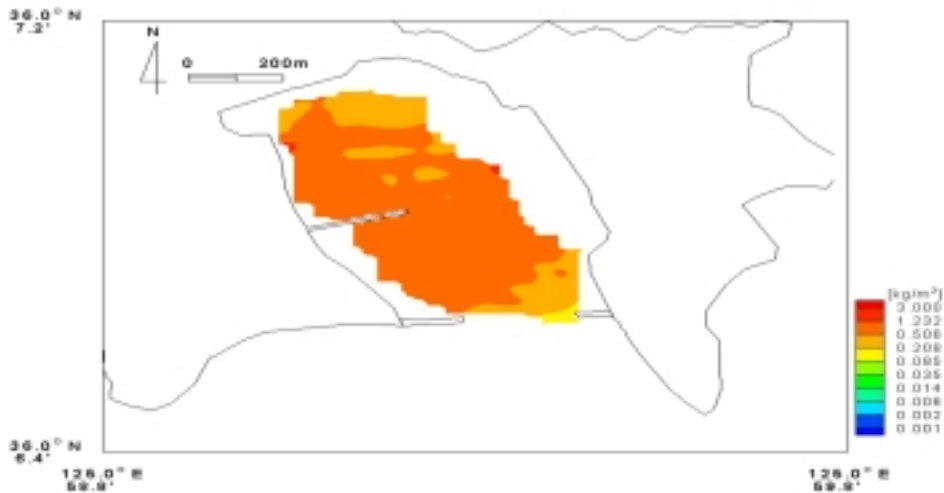
Korea has several national policies for the management of marine litter. Since the late 1990s, the Korean Government has initiated special national R&D projects to develop integrated management strategies and practical guidelines on marine litter problems at the national level, which includes the survey of the status of marine litter in ports and other coastal regions of Korea, including important fishing area, and clean-up of marine litter, prevention of the input of litter to coastal environments especially from the land-based sources, development of equipment and facilities for survey and clean-up of marine litter, prevention of input, treatment for re-use and disposal of collected material, and relevant legal and institutional re-arrangements. These R&D projects have mostly been carried out by the KRISO/KORDI, which is also operating MERRAC (Principal Investigator of the projects: Dr. Chang-Gu Kang, Director of MERRAC)

The projects are largely divided into two parts:

- 1) Survey of amounts, types and distribution patterns of seabed litter in ports and major fisheries areas, which aim to provide the Government with practical guidelines for clean-up operations, and
- 2) Development of a Total Management System for Marine Debris covering the development of technical equipment and/or facilities for practical prevention of



Fig. An example of distribution of marine litter in a port.



## 2.2. Fishery grounds

In addition to the survey in the ports, a project was initiated in 2001 to elucidate the status of marine debris on the seafloor of fishery grounds. Ideally the project is expected to be carried out covering several areas on a year by year basis. The first, sampling survey was carried out in 2001/2 in the West sea of Korea located in eastern part of the Yellow Sea ( $124^{\circ}45'15''$  -  $125^{\circ}38'00''$  E,  $37^{\circ}00'00''$  -  $37^{\circ}25'00''$  N). The sampling was carried out by two methods: 1) trawling and 2) Side Scan Sonar.

### 1) Sampling device : Trawling



### 2) Some major results

- a. trawl method : total area surveyed – 166.70ha, marine litter collected by trawl- 7.293 tons (fishing net-83%)---- the survey indicates that a total 14,300 ton of marine litter is laid on the sea floor in the fisheries ground (average: 18.9 kg/ha)
- b. SSS method: the total area has been covered by the SSS. The results show

spatial distribution of marine litters in the survey area.

*Fig. Relevant photos taken from the sampling work.*



### **3. Development and Application of a Total Management System for Marine Litter in Korea**

#### **3.1. Overview**

This project includes the development of the technical equipment and/or facilities for practical prevention of inputs of land-based litters through rivers, survey and recovery of marine litter on marine shallow and deep sea bottom, treatment and/or reuse of marine litter. This includes the development of relevant national policies and educational programmes to raise public awareness on marine litter problems.

Relevant studies are largely sorted into:

- 1) Prevention of inputs from rivers (such as development of trash booms);
- 2) Survey devices (such as a deep sea camera);
- 3) Clean-up (development of equipment and ships for the clean-up of marine litter)

- 4) Treatment and/or reuse of marine litter (such as development of a pyrolysis system for oil recovery from waste ropes and fishing nets, incinerator, recycling for refuse derived fuel etc.

### 3.2. Major outputs

The main outputs and results are as follows.

- Development of trash booms to prevent the input of marine debris, and the application of such booms in estuarine environments in Korea
- Development of survey equipment for the survey of marine debris on deep sea bottoms (1,000m)
- Development of multi-purpose marine wastes cleaning ships
- Development of a pyrolysis system for oil recovery from waste rope and fishing nets
- Development of downdraft gasifiable incinerator to derive refuse fuel from marine litter
- Development of thermal extrusion system for the reduction ( by 70%) of the volume of waste polystyrene buoys and recycling of such buoys

It is remarkable that most of these results have been used in practice in Korea. The following is a list of titles of papers written under the relevant projects of KRISO/KORDI.

*Fig. Relevant photos are shown below.*





### 3.2 List of academic papers relating to marine debris in Korea

#### a. Prevention of input of marine debris

- Study of Spatial Accumulation of Marine Debris near Han and Nakdong Rivers
- Tracking Experimentation of Floating Debris Drained From Nak-Dong River
- An experimental study on drifting and sinking of marine debris
- A Prediction Method of Tension on Containment Boom for Marine Floating Debris
- A Study of Analysis Method for Marine Debris Boom Design
- Site Experiments of a Floating Debris Containment Boom
- Development of a barrier system for floating debris at river
- Tension calculation on trash curtain in current

#### b. Sampling survey

- Development of a survey equipment for sea bottom fishing nets, which consists of a guides frame of Tow-sled type, deep-sea camera, a recording unit and a position tracking device
- Measurement of the Yellow Sea visibility range by using video cameras
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#### c. Clean-up operation

- Functional Requirement of seabed Cleaning Ships and Organization of the Fleets

- Development of a recovery system for floating debris drained from rivers to coastal water
- Preliminary Conceptual Design of a Seabed Cleaning Ship
- Development of Multipurpose Marine Wastes Cleaning Systems for Shallow Waters
- Functional Requirement of Marine Waste cleaning Ships and Organization of the Fleets
- Development of a Multi-purpose Marine Waste Cleaning Systems for Shallow Waters
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- d. Treatment/reuse of marine litter
  - A Study on a Pyrolysis System Development for Oil Recovery from Waste Rope and Fishing Net
  - An Initial Design of a Downdraft Gasifiable Incinerator for Ocean Waste Recycling of marine debris for Refuse Derived Fuel
  - Application of a thermal extrusion system for the waste polystyrene buoy resource
  - Waste Treatment Technique for the Resources of Marine Debris
  - Development of a thermal extrusion system for the resource of waste polystyrene buoy

### 3.3. Abstracts of academic papers relating to the marine debris in Korea

**A Study on the Spatial Accumulation of Marine Debris near Han and Nakdong Rivers :** Based on the results of the experimental study concerning the physical fate of marine debris on the sea, a numerical experiment was performed to provide marine debris maps near Han Nakdong rivers. For the base flow simulation, current, tide, wind and seasonal fresh water inflow were included, and the floating characteristics of various types of marine debris was considered for the map. It was shown that the spatial accumulation of marine debris can vary widely depending on the floating characteristics.

**Tracking Experimentation of Floating Debris Drained From Nak-Dong River:** MAPCNTR is a tracking software developed by KRISO for floating debris. In this experiment three Buoys that had GPS and other devices installed were used. In consequence of this experimentation, numerical analysis calculated by MAPCNTR is similar to the result of this experimentation and, ocean current and wind driven current have a large influence on the results of the real sea experiments.

**An experimental study of drifting and sinking of marine debris:** An experimental study was performed to provide numerical models to predict the physical fate of marine debris with key information concerning its drifting and sinking on the sea. For hygroscopic materials their floating times in a pseudo ocean environment were measured, and for non-hygroscopic objects their drifting times in a certain wave condition were measured. For sinking materials or objects to become sinkable free falling experiments were performed to evaluate their falling speed. Summarized

information was condensed into a numerical model to predict the most likely region of a significant marine debris accumulation, and the seas connected to the Han river and the Nak-Dong river were considered for the simulation.

**A Prediction Method for Tension on Containment Booms for Marine Floating Debris:** The main functions of containment boom for marine floating debris are to prevent spreading of the marine floating debris and the effective collection by the trash skimmer. The design characteristics of containment boom for marine floating debris in wave, current and wind were investigated. The response of a containment boom to the current is a function of a number of parameters, such as geometric characteristics, buoyance weight ratio and towing velocity. To understand the relationship between these design parameter more clearly, a series of test with three models for current velocity and gap ratio were carried out. The model tests results were developed to a new numerical equation that tension prediction method of containment boom for marine floating debris. In addition, it was compared with open sea experimental results.

**A Study of an Analysis Method for Marine Debris Boom Design:** Marine wastes are solid bodies in ocean and mostly originate from land. Marine debris is a kind of marine wastes such as log, wood pieces, fish nets, wires, ropes, etc. In general, the debris boom consists of a floater, wire net, tension member and fabric connector. This debris boom is deployed in a symmetric or asymmetric configuration like an oil boom. This study introduces an analysis method of a debris boom for collecting or recovering such floating debris. Axial stress and deformation of deployed boom is analysed using the program, ANSYS Release 5.5. The results of the finite element analysis program are compared with those of the theoretical method. The results of this study can be used for the debris boom design with some basic data.

**Site Experiments of a Floating Debris Containment Boom:** It has been widely witnessed that the Korean coastline is congested with debris or litter of various types and from various sources. A great portion of these coastal wastes is believed to have come ashore from land-based human activities through rivers. Furthermore, a recent survey of litter on the seabed around an coastal area of shallow waters revealed that extremely many parts can be attributed to land-based sources. In order to prevent the floating debris from entering a coastal region through rivers or channels, we have during a five year period been developing a floating debris containment boom. In the third phase of development, site experiments were carried out at the appropriate area near Wepo-Hang of Kangwha-Do. The experiments were focused on a trial installation of the hitherto developed form of floating debris containment boom and measurements of boom tension force by fast currents to investigate the applicability of the present method of design parameters. In this paper, the detailed backgrounds and procedures of the site experiments are summarized and discussed with future considerations.

**Development of a barrier system for floating debris in rivers :** Development of a barrier system for floating debris in rivers is introduced. The system is designed to prevent pollution of coastal waters caused by marine debris which originates from land. The system consists of a barrier boom, a mooring system and a boom winder. The barrier boom, which is self-inflatable with circular band spring guides floating debris to

a collecting conveyer system. Design parameters of the barrier system were reviewed and the design criteria were established. Based on the established design criteria, a pilot barrier system was built and tested at the Tanchon branch of the Han river. The suggested system proved to be very efficient for collecting floating debris in the river.

**Tension calculation of a trash curtain in current:** In this study, a theoretical method based on the catenary model is applied to obtain the tension and drag forces acting on the trash curtain which is deployed in a river for preventing the inflow of floating debris into the ocean. Under the assumption that the fluid drag is perpendicular to the trash curtain, the tension and drag forces are uniform along the trash curtain. As a numerical model, the trash curtain is moored both symmetrically and asymmetrically with respect to the flow. The tension and drag forces on the trash curtain are investigated according to the change of gap ratio and inclined angle of the trash curtain. Numerical results show that the tension parameter increases as the gap ratio is increased. It is found that the tension parameter is reduced as the inclined angle is increased in the case of asymmetric deployment. The numerical model is applied to the specific problem for the trash curtain (200m) deployed at the Tanchon on the Han river. The maximum inflow velocity that anchor system can endure is 2m/sec.

**Development of a survey equipment for fishing nets on the sea bottom, which consists of a guide frame of Tow-sled type, deep-sea camera, a recording unit and a position tracking device:** The problem of derelict fishing nets on the seafloor is now to be addressed in Korea because of its continuous influence on the fishing grounds and nearshore/offshore ecosystem particularly on the seabed in deep sea areas (500~1,000m) of the East Sea. In order to resolve this matter, we have developed a practical and efficient survey equipment for sea bottom fishing nets, which consists of a guide frame of Tow-sled type, deep-sea camera, a recording unit and a position tracking device. This paper presents a brief introduction of the developed equipment with description of the mounted attachments and required accessories. In addition, we present meaningful results of site experiments at 230m water depth and indicate requirements for the application to 1,000m. We believe that the developed system has proper specifications for 1,000m depth, and position tracking device, side scan sonar and support vessel must be appropriately chosen for safe and efficient usages.

**Measurement of the Yellow Sea visibility range by using video cameras:** This paper discusses the visibility range in the Yellow Sea by using video cameras. Measurements were carried out in a dark water tank. Visibility ranges were systematically measured with the change of the distance between the video camera and a sample plate, the strength of illumination and the turbidity. The visibility range was determined by the images obtained from video cameras. From test results, it can be concluded that the visibility range of the Yellow Sea is short or in the range of 0.5 meter.

**Functional Requirement of seabed Cleaning Ships and Organization of the Fleets:** This paper describes the initial procedure of the developing the concept of seabed cleaning ships and the fleets. We investigated mission analysis, operating ocean environments, similar cleaning ships, laws and regulations for determining the functional requirements of ships and fleets, and then top-level requirements were drawn

up. According to the volume estimation of marine debris in domestic coastal waters and shoreline, we made alternatives, combination of some design factors, for the evaluation of economical efficiency. As a result of this study, we organized the fleets of seabed cleaning ship adapted to the environments of domestic coastal waters.

**Development of recovery system for floating debris drained from rivers to coastal waters:** Development of a recovery system for floating debris at river is introduced. The system is to prevent pollution of coastal water caused by marine debris which originates from land. The system consists of a barrier boom, collecting conveyer and debris compressor, a mooring system, and a boom winder. The self-inflatable barrier boom with circular band spring, guides floating debris to the conveyer and then the collected trash is compressed to minimize its volume. Design parameters of the recovery system were reviewed and the design criteria were established. A pilot recovery system was built and tested at the Tanchon branch of the Han river. It proved that the suggested system is very efficient for collecting floating debris in rivers.

**Preliminary Conceptual Design of a Seabed Cleaning Ship:** This paper describes an initial procedure for the conceptual design of a seabed cleaning ship to be operated in the Yellow Sea of South Korea. As the first step of a preliminary conceptual design, we made an investigation about operating ocean environments for determining the functional requirements and ship characteristics. Secondly, we carried out the preliminary conceptual design of a sea-bed cleaning ship by integration of cleaning systems and equipments, decisions about ship dimensions and the estimated calculation of ship's weight and trim. Then, the availability and feasibility of the developed ship were evaluated using stability check, computer graphic simulation and performance test of integrated systems at sea in Yeosu ports.

**Development of Multipurpose Marine Wastes Cleaning Systems for Shallow Waters:** This paper describes the development of multipurpose cleaning systems and ships for cleaning up marine wastes in shallow waters like the Yellow Sea of South Korea. It was carried out earlier this year to formulate the prototype multipurpose cleaning systems at a similar size barge for the performance test and evaluation at SoRea port, Incheon city. As results of the test and evaluation at sea, cleaning systems operated fairly well within safety limits and the whole system has shown its validity.

**Functional Requirement of Marine Waste Cleaning Ships and Organization of the Fleets:** This paper describes the initial procedure of concept development for marine waste cleaning ships and the fleets. We investigated and analyzed missions, operating ocean environments; similar cleaning ships, laws and regulations for determining the functional requirements of ships and fleets, and then top-level requirements were drawn up. According to the estimation of volumes of marine wastes in domestic coastal waters and shoreline, we made alternatives, combining some design factors, for the evaluation of economical efficiency. As a result of this study, we organized the fleets of marine waste cleaning ships adapted to the environments of domestic coastal areas.

**Development of Multi-purpose Marine Wastes Cleaning Systems for Shallow Waters (PART I : Preliminary Conceptual Design) :** This paper-following 'Functional requirement of marine waste cleaning ship and organization of the fleets'[1] - describes the preliminary conceptual design procedure for the multi-purpose marine waste cleaning system for shallow waters. The working area of this system is the Yellow Sea and part of the South Sea of South Korea. As the first step, we determined the functional requirements including the daily target for waste collecting. Then, the preliminary conceptual design and general arrangements were carried out. In order to evaluate the safety and efficiency of the designed system, the stability check and the computer graphic simulation were carried out. Finally, the sea trial performance test of integrated systems in Yeosu ports was performed and the designed system showed its validity and effectiveness.

**Development of Multi-purpose Marine Wastes Cleaning Systems for the Shallow Waters (PART II : System Development and Performance Evaluation):** This paper - follows 'Development of multi-purpose marine waste cleaning system for shallow waters (part 1 : preliminary conceptual design)' - describes the system development and the sea trial performance evaluation (Cho[2003]). The multi-functional seabed waste collecting system and the towing hook system was developed. The maximum working depth of these system are 15 and 100 meters, respectively (MOMAF[2001]). For the multi-purpose use to collect the marine waste, this system contains a floating waste collecting device for the waste on seawater and remained waste collecting device for the waste on seabed, while a steel wire cutting system is added for higher efficiency. In order to evaluate the system performance, a prototype of a multi-functional system was constructed and a sea trial test in shallow water was carried out. As a result, this system operated well within safety limits and without any interaction so that the developed systems are practicable and applicable.

**A Study of the Pyrolysis System Development for Oil Recovery from Waste Rope and Fishing Net:** Environmental pollution has become a serious social problem. We must not overlook ocean environment pollution, either. This pollution violates not only breeding of fishes and other production in the sea but also the safety of navigation in harbors. It is necessary to develop an assembly system to take care of this ocean environmental problem. This system can consist of a searching device, a pulling out device and a treating device. Generally there are two methods to treat a waste material, one is to bury it and the other is to incinerate it. It has been found that ocean wastes are combustible high polymers. High polymers take a very long time to decompose naturally, and it is necessary to use some special equipment to incinerate these high polymers. It has been found that the best treatment method is pyrolysis, because it does not produce secondary pollution material and oil can be recovered from the pyrolysis. This study investigated the chemical and physical characteristics of waste rope and fishing net, density heat conductivity specific heat and conversion rate by pyrolysis, to obtain the design data for a pyrolysis system. The pyrolysis experiment has been carried out to recover oil from waste. Then caloric values, viscosity and specific weight of oil are investigated to appraise its value as a fuel.

**An Initial Design of a Downdraft Gasifiable Incinerator for Ocean Waste:** It is necessary to develop the incinerator for treating ocean waste. Most of the combustible ocean wastes consist of polymers that have been wetted by sea water. If ocean wastes are combusted in a general incinerator, serious problems occur as a result of exhaust gas pollution and air supply systems. Thus, it has been found that the downdraft gasifiable incinerator can solve these problems. This paper describes the characteristics of the pyrolysis and the physical and chemical properties of wastes and the investigations carried out on the initial design of the downdraft gasifiable incinerator.

**Recycling of marine debris for Refuse Derived Fuel:** The purpose of this study is the process development of pre-treatment and recycling for the environmental and economical removal of marine debris. Through pre-treatment such as the separation of lead from waste ropes, salt and sludge cleaning and crushing, wastes change into raw materials for fuel resources. Resource recycling is a unique method for the minimization of air pollution and solution of the problems of NIMBY. Thermal and atomic analysis shows that RDF of marine debris is a good substitute energy next to coal.

**Application of thermal extrusion system for the resource of waste polystyrene buoy:** 30 million polystyrene buoys are consumed each year as materials for floating plants and as pointers of fishing net. Because of salt, high water content and oyster shells, these buoys were not disposed of appropriately. The latest dioxin problem associated with the incineration of municipal wastes is one of the causes for leaving the waste on the seashore. Through the introduction of cleaning and drying processes for polystyrenes, volume reduction can be done successfully and the cost reduced to one-tenth compared with that of the outer request treatment is a promising for the practical use of waste buoys' volume reduction system.

**Waste Treatment technique for the Resources of Marine Debris :** The purpose of this study is the RDF process development for the disposal of marine debris. The physical properties of RDF were analyzed with regard reliability as a industrial fuel. Through the separation of lead from the waste rope and pelletizing of material that can be burnt, marine debris changes into fuel resources. The resource recycling process is effective in the clean treatment of waste and securing of an energy substitute.

**Development of resources technique for the marine debris( II) - Development of thermal extrusion system for the resource of waste polystyrene buoys:** By the introduction of cleaning and drying processes, thermal extrusion system for the volume reduction of used polystyrene buoys was developed. It was tested in coastal areas for determination of operational reliability. By the removal of oyster shells and cleaning of salt waste polystyrene buoys were changed into a plastic raw material. The lower cost, one-tenth, compared with that of the outer request treatment is promising for the practical use of the waste buoys' volume reduction system.