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論 文

# Analysis of Response to Major Oil Spills in the Korean Coastal Waters

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**ABSTRACT** : *With data of historical spill from vessels occurred in korean coastal waters, the author analyze the causes of spill and evaluate response technique adopted during spill. It is found that the majority of spill caused by operational failure, bad weather, violation of navigation rule and hull defect. As a result of evaluation of response measures, it is suggested that responsible agency establishes criteria for various response options and standards of tier response time and capability according to the size of spill.*

**KEY WORDS** : Cause of spill, Response option, Tier system, Response time & capability

## 1. Introduction

The coastal waters are most susceptible to pollution, because of the concentration of urban activities near coasts and rivers that eventually enter the sea. In Korea, metropolitan and medium size cities and ports are located near the coasts and estuary and other coastal areas are widely used for resorts, fishing and cultivation. The coastal waters are special value to Korea as a source of fuel and food as resources on land are being depleted and dependence upon the sea for foreign trade is getting higher. The coastal waters, however, may be in danger of misuse and damage because of intense use as well as the increase of pollutants into the sea.

Pollutants may enter coastal waters by design, as when industrial or domestic wastes are dumped directly into the waters, or by accident, as when oil spill happen during operation of ship and oil facilities. Depending on the nature of the pollutant, whether toxic or nutrient, marine life may be either inhibited or stimulated. People tend to believe that pollutant will be solved by dilution, however, industrial wastes are frequently toxic to marine organism near the source. Domestic sewage, whether treated or not, provides nutrient for marine plants which is causing red tide. Of all pollutant, the spilled oils may physically, biologically and economically affect coastal environment worst, stopping recreational activities, killing marine habitats, reducing fisheries and production of sea farming and so on.

Not only international organization but maritime countrieshave been treating oil spill as a special problem after the spill of 119,000 M/T crude oil by tanker Torrey Canyon off the Scilly Isles, UK in 1967. Major measurements taken by them are preparation and implementation of strict international convention, provision of contingency plans, development and improvement of response techniques, periodical training and drill, establishment of co-operation system between adjacent countries.

Along with international efforts to prevention of oil spill, korean government have been doing well for prevention, preparedness and response against future potentials of spill in past a decade since catastrophic spill accident by tanker Sea Prince occurred off Sorido Island in 1995. Of many steps taken, it is often taken valuable to analyze the statistics of historical spill data. Korea National Maritime Police Agency(hereinafter "KNMPA" ) and some other authors have sometimes presented the results of analysis of historical spills. mainly focusing on number of spill, tonnage of ship involved, quantity of spill, location and causes of spill etc. Most of reports and studies regarding the causes of spill, it can be seen that the cause is typically and simply classified into 5 items such as carelessness, intentional, casualty, breakage and unknown. However, a marine accident is very complex with more than two causes mingled, also each item consists of many sub-items, for example, casualty include collision, grounding, fire, sinking and capsizing etc. As the previous analyzing method seems insufficient, it would be advisable to approach more detailed method to clarify the accidents and make a advantage of the results of analysis for the potentials of spill in the future. Apart from it, response actions taken during spill is very important because adequate measures can mitigate and minimized the damage to mankind, marine organism and property caused by spill, but there is few study and evaluation regarding the response options adopted by responders during spill.

In this regards, the authors attempt to analyze causes of spill more detailed and in different direction from previous study and also to evaluate the response options to major marine oil spill occurred in past 13 years in the korean coastal waters, and we expect this analysis to be of a help to make national guideline for practical contingency plan and adequate response capabilities.

## 2. Methodology

Historical spill data(1982~2001) used for this study is "Case Study of Marine Oil Spill Response" issued by both KNMPA and Korea Marine Pollution Respons Corp(2002), and KNMPA's annual report. In addition, we use international historical spill data(1960~1995) from the Intelligence Report(Etkin, 1997) to compare features between both spill incidents. We, first of all, review some factors such as number of spill accident, type of ship involved, volume of spill and spill location in the similar ways to the other previous study, and then we analyze the cause of spill in different direction from previous other studies.

Regarding response measures to major spill, response techniques employed during spill are dependent upon the product spilled, quantity, location, response time, weather conditions, responders capabilities and availability of response equipment. Of these parameters, we select product spilled, quantity, location, weather conditions and cleanup method within 24 hours of spill because bunker A and C, which is majority of spilled oil near korean coast, tend to make considerable change physically and chemically at the early stage of the spill, and we determine the distance from shore, weather and sea state, water depth, spilled oil characteristics in the following ways to evaluate the adequacy of chemical dispersant use or in-situ burning.

• Distance from shore : Distance is basically measured from the spill site to nearest mainland, but if there is island with inhabitant near spill location, distance is measured form spill site to that island instead.

• Weather and sea condition : Weather and sea condition are an important factor in determining to deploy boom and skimmer as well as the use of chemical dispersant and in-situ burning. These factors are based on the record of "Case Study of Marine Oil Spill Response".

• Water Depth : Determining water depth is relevant because the use of chemical dispersant is limited to a certain water depth, for example, greater than 10 meters in USA and greater than 20 meters in UK. In this paper, water depth is selected the depth at the spill site. In case of irregular depth around the site, water depth is averaged.

• Spilled oil characteristics : For all spills, additional data on the behavior of oil in the environment are needed. The property of majority of spilled oil, bunker A & C, is based on the database of ADIOS(NOAA, 2000) and investigate changes of specific gravity and viscosity of each oil with time to find if adequate for mechanical recovery and/or dispersant use, but figures are omitted in this paper.

## 3. Response Options in the Korean Coastal Waters

In general, there are several options to respond to the spilled oil such as mechanical containment and recovery including the use of sorbent, the use of chemical dispersant and other chemical agents, in-situ burning, shoreline cleanup, natural removal etc. These options have their own features each other as follows.

• Mechanical containment and recovery : This technique is to contain the oil on the surface by booms and recover by skimmer, therefore it can be first choice of response to marine spill. It largely depends on the weather and sea conditions as well as the characteristics of spilled oil.

• Use of chemical dispersant : Dispersant use is the application of some chemical agent that reduces surface tension of oil, allowing an oil slick to break into droplets that are then scattered within the water column through natural mixing. As the dispersant use has been long argued if dispersants are extremely toxix to marine life, many countries limits its use to a certain environment.

• In-situ burning : It is to contain the oil slick on surface by special fire-proof boom and burn it on open waters. This option has a good point to remove oil on the surface, but the some compositions enter into atmosphere and finally fall down to the earth. Though it is not commonly adopted by many countries at present, this techniques are actively under experiment and research and might be taken as one of main response options in the future.

• Shoreline cleanup : Even though all efforts to remove oil at is made, some oil will reach the coast. This can result in contamination of shoreline and cleanup operations may be necessary to allow the coast to recover its natural state and socio-economic value. But we evaluate the response action at the early stage of spill before oil reach get stranded at shore in this paper, thereby the term of shoreline is a measure taken to deploy boom in advance to protect the shore at which oil is expected to reach.

• Natural removal : No action is taken to marine spill and leave the oil untouched and removed naturally. This option can be adopted at high energy area with little sensitive importance.

Besides, the above mentioned measures, responders may consider to employ chemical agents of sinking agent, gelling agent, emulsion breaker, washing agent, biodegradation agent and so on.

Of many response techniques, mechanical recovery, dispersant use and shoreline cleanup have mainly employed in past spill in korean coast waters.

## 4. Results of analysis and Discussions

### 4.1 Examination of historical spill record

Fig.1 is a line graph representing a year-by-year number of spill events in korean coastal waters during 20 years(1982~2001). According to the graph, spill incident occurred about 150~200/year in mid-1980s, afterward the spill gradually increase up to more than 450/year in late 1990s. This is a contrast to the world spill statistics comparing with the Dr. Etkin's report that the annual numbers of spills began to decrease slowly during 1980s and more sharply into the 1990s after peaking in the late 1970s.

Fig. 2 shows year-by-year volume of spill during 20 years(1982~2001). Quantity of spill varies year-by-year irregularly which depends on the occurrence of large spill at the specific year. Looking at the graph, we can see remarkably higher volume in

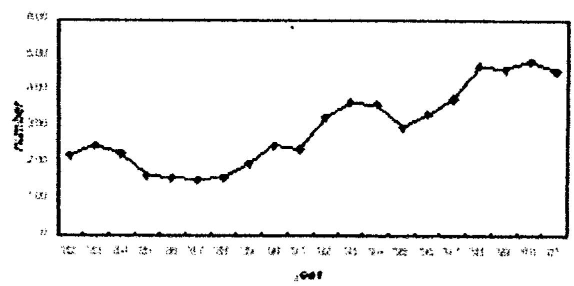


Fig. 1 year-by -year numbers of spill in the korean coastal waters

1993 and 1995. It was caused by large spill incident of tanker Frontier Express, Korea Venus and No.5 Geumdong in 1993 and Sea Prince, Danata, No.1 Yooilho and Honam Sapphire in 1995. In the rest of year except 1993 & 1995, no distinctive feature can be found. In summarizing the spill data in number and quantity, small spills have happened in recent years after 1998 even if slow increase of spill number year-by-year.

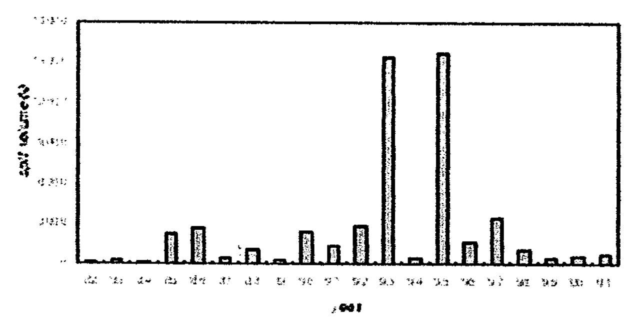
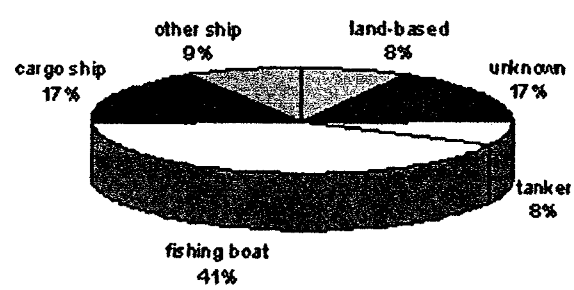


Fig. 2 Spill volumes by year

Fig. 3(upper) shows the source of spill during 20 years(1982~2001) in the korean coastal waters and Fig. 3(lower) shows source of spill during 36 years(1960~1995) in world ocean and estuary saltwater(Etkin, 1997) in which source is classified into only 3 of tanker, oil barge and other ship. In korean waters, the fishing boat ranks first and cargo ship ranks second in number of spill, while tanker is ranking first in the world.



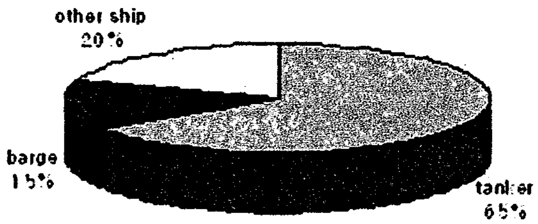



Fig 3 Source of spill in the korean coastal waters(upper) and in world ocean and estuary saltwater(lower)

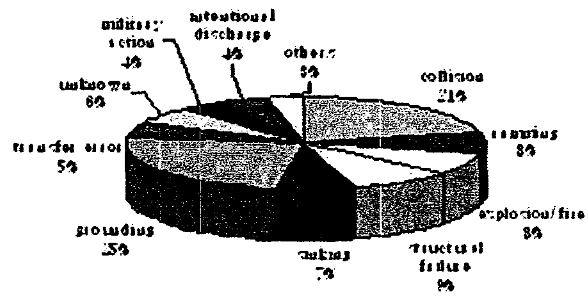


Fig. 6 Percentage of causes of oil spill from vessels(1960-1995) in the world

## 4.2 Cause of spill

For 30 cases of major spill affected marine environment seriously in past 13 years, we classified the cause of spill incidents into fundamental cause(first cause) and primary cause(final cause) to find the appropriate way for prevention of spill. For the analysis of cause of spill, we consider the first cause to be the precipitating factors, while primary cause to be the event that ultimately result in the actual spillage rather than the factors that precipitate it. The factors of first cause are operational failure, violation of navigational rule, bad weather, hull defect, explosion, overloaded and hydrographic problem(Fig. 4). Of these factors, operational failure, weather, violation of navigation rule and hull defect hold the majority of spill. As to the primary cause of spill(Fig. 5), the greatest percentage of spills overall is caused by sinking, collision and grounding, 40%, 23% and 20% respectively, while foundering and cargo work failure account for less than 10%. In comparison with this result, the world data(Fig. 6) show the greatest percentage of spills are grounding and collision, 25% and 21% respectively, while sinking, structural failure, explosion/fire, ramming, transfer error, etc account for less than 10%. From the first causes of spill in korean coastal waters, we can get some preventive measures against the spill incidents, vis, nation must strengthen education and training programs for ship's watch officers to enhance their quality and implement a strict inspection to hull condition at the annual or periodical inspection by classification.

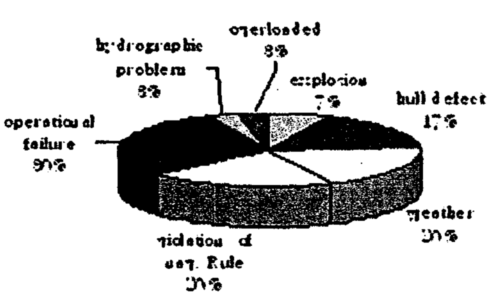



Fig. 4 First cause of 30 case of major spill in past 13 years

## 4.3 Evaluation of response actions to major spill

We selected 30 cases of major spill incident, which were regarded to affect the environment seriously and/or to be costly to respond for long period in korean coastal waters during 13 years(1988~2001), from "Case Study of Marine Oil Spill Response(2002)" in order to evaluate the response actions employed during spill.

Fig. 7 shows location of spill and number of spills per distance from nearest shore. In location figure, spill incidents occur frequently in Incheon, Yeosu, Busan and Ulsan area which seems to be due to high density of marine traffic in and out of the harbors. According to graph regarding the distance from shore, 20 of 30 spills occurred within 3 miles, 6 spills occurred off 3~10 miles and 4 spills occurred off more than 10 miles. By these geographical distribution of spill, we can see that spill events could be addressed at the earlier stage provided that all response resources always get ready. Table 1 describes the details regarding response to 30 spill incidents, ship's name involved, distance from nearest shore(n. mile), water depth(m), type of spilled oil, sea condition, response time and response option employed during spill. It cam be seen the major spilled product is bunker-A & C and most preferable cleanup measures taken at the early stage of spill are boom deployment and/or the use of dispersant. In fact, cleanup options should be considered with type of spilled oil, distance from shore, water depth, weather and sea condition, however the response action taken seems not to be considered all these complex factors together. From response and environmental point of view, we can pick out a few characteristics of the response from historical record. First, boom was deployed at the strong wind or current area in the case of Korea Hope, Hyundai Spirit, Sea Prince and Ocean Jade. Conventional boom can contain surface oil with the force of 1 knot current perpendicular to the

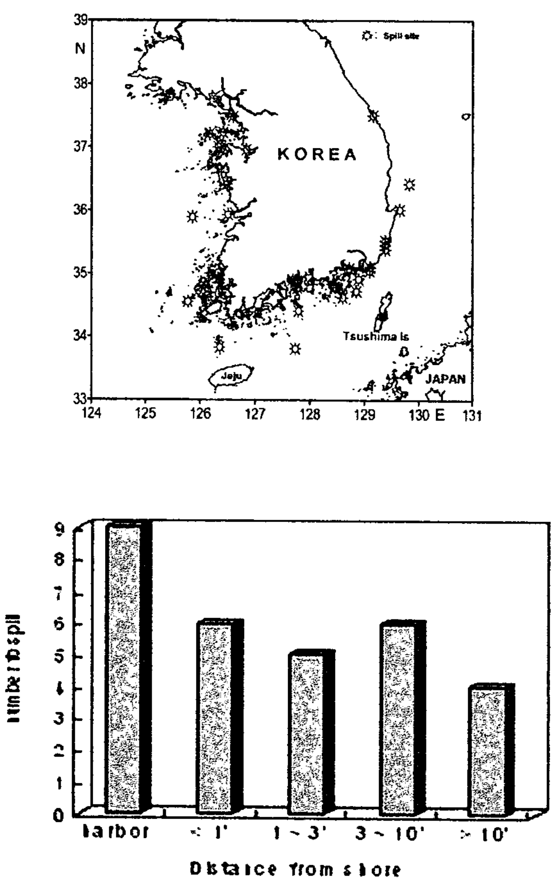



Fig. 8 Location of spill(upper) and number of spill per distance from shore(n.mile)

boom and wind force of 16 knots and less. even though some manufacturers allege recent specific booms to be useful under 2~3 knots of current. Nonetheless, deployment of boom seems to be cost-ineffective jobs in the strong current area of western coast and under strong wind. Second, responders tended to use chemical dispersant preferably in every case of spill. Especially it was used in the harbor or near shore or relatively shallow waters in the case of spill by Honam Sapphire, No.2 Yoohwa, Astro Beta, Daeseung and Anseong 101.

According to Etkin's report(1998a), based on the data available, dispersants are listed as primary response option in 35 countries, while 8 nations prohibit dispersant use under any circumstances, and 9 countries list them as an option of last resort. It can be inferred that last 2 categorized nations are discreet to use dispersant because of possible harmful after-effect to marine organism, In the meantime, since dispersant is most effective at the early time of spill before spilled oil gets well-weathered, some countries such as U.S.A. set the coastal area into 3 categories, pre-authorization, expedited approval and case-by-case for the decision-maker to determine whether to use the dispersant as early as possible. By reference to the advanced countries' policy regarding the dispersant use, Korea need to prepare the clear-cut guidelines or directions considering ecological, physical, chemical and socio-economically aspect of the coastal area. Third, no action has been taken under bad weather for one days or more up to a few days until the weather was abating, It is true that bad weather accelerates to disperse the oil slick naturally, but spilled oil is likely to be changed considerably in physical and chemical properties for 24~36 hours after spill, therefore it requires case-by-case viable possible response to be taken in some ways as early as possible. Fourth, few containing option was taken to protect sensitive areas and/or industry plants in advance forecasting the trajectory of oil slick. To do so, responders must hold sophisticated numerical trajectory model and special designed aircraft with various high-tech sensors. Finally, KNMPA addressed the spill more promptly than other countries did. It was because majority of spills occurred near the depots in which response equipments were in store, and KNMPA's patrol boats were patrolling all the times within the territorial and contiguous waters. But even though KNMPA has a guideline to define the size of spill incident, small spill(30kl≤quantity 〈100kl), medium spill(100kl≤quantity 〈1,000kl) and large spill (quantity≥1,000kl) of persistence oil. there are no definite guides or directives regarding min. required time to initiate theresponse on-scene after notification of spill and response capability according to size of spill unlike Canada and U.S.A.

Table 1 Details of historical response record

| No. | Ship's name | Distance | Depth | Oil type | Sea | Time | Cleanup |
|---|---|---|---|---|---|---|---|
| 1 | Kyeongsin | 3.5 | 90 | B-C | bad | 10 days | no action |
| 2 | Korea Hope | 0.3 | 1.6 | B-C | strong current | 4 hours | boom |
| 3 | Korea Venus | 1.4 | 1.8 | B-A | low vis. | 4 days | no action |
| 4 | No.5 Keumdong | harbor | 15 | B-C | calm | 12 hour | mechanical, dispersant |
| 5 | Frontier Express | 3.4 | 12 | volatile | moderate | 1 days | no action |
| 6 | Sea Prince | 2.5 | 40 | crude /B-C | bad | 20 hours | mechanical, dispersant |
| 7 | No.1 Yooil | 7.3 | 60 | B-C | moderate | 12 hours | sorbent, dispersant |
| 8 | H.Sapphire | harbor | 15 | crude | calm | 2 hours | mechanical, dispersant |
| 9 | No.8 Hanchang | 29 | 42 | B-A | low vis. | 7 hours | sorbent, dispersant |
| 10 | Ocean Jade | 6.5 | 60 | B-C | bad | 15 hours | boom, dispersant |
| 11 | Jutha Jessica | 0.7 | 50 | B-C | bad | 2 days | no action |
| 12 | No.3 Oseong | 4.7 | 40 | B-C | bad | 2 days | no action |
| 13 | Marine Star M | 17.5 | 40 | B-C | low vis. | 1 days | boom, sorbent, dispersant |
| 14 | New Baron | 1.5 | 20 | B-C | bad | 4 days | no action |
| 15 | No.2 Yoohwa | 1.0 | 11 | B-A | calm | 2 hours | mechanical, dispersant |
| 16 | Hakata | 21.0 | 80 | B-C | low vis. | 10 hours | mechanical, dispersant |
| 17 | Astro Beta | Harbor | 31 | B-C | bad | 2 hours | dispersant |
| 18 | Daeseung | harbor | 16 | B-A | calm | 16 hours | mechanical, sorbent, dispersant |
| 19 | No.2 Ooshin | harbor | 15 | Waste | calm | 1 hour | mechanical |
| 20 | Hyundai General | harbor | 14 | B-C | calm | 2 hours | mechanical |
| 21 | Hyundai Spirit | harbor | 3 | B-C | strong current | 6 hours | boom, sorbent |
| 22 | Daelim 501 | harbor | 10 | B-A | low vis. | 1 hour | mechanical |
| 23 | 107 Tongil | 0.5 | 14 | B-A | calm | 1 hour | mechanical |
| 24 | Ooyang Blue | 18 | 100 | B-B | low vis. | 26 hours | no action |
| 25 | 5 Heungyeong | 0.5 | 5 | B-A | bad | 34 hours | no action |
| 26 | Yongjin 2003 | 0.5 | 8 | B-A | bad | 10 hours | boom for shoreline |
| 27 | Ushin | 1.5 | 24 | B-A | bad | 27 hours | no action |
| 28 | P.Harmony | 7.0 | 80 | B-C | bad | 21 hours | mechanical, dispersant |
| 29 | C.D.Singapore | harbor | 10 | B-C | calm | 4 hours | sorbent |
| 30 | Anseong 101 | 1.4 | 15 | B-A | calm | 2 hours | boom, sorbent, dispersant |

* Time denotes time for response to initiate on-scene and cleanup denotes the response measures taken within 24 hours of spill.

For example of tier system in Canada, tier response capability and response organizations are categorized according to their capability to respond to oil spill of a maximum specified quantity in Table 2, and response times, the equipment and resources relating to tier response capability are deployed in respect of an oil spill at a designated port, on the shoreline and in sheltered waters at the port within specified hours after notification of the spill. U.S.A. has similar standards of tier capability and response time as Canada.

Table 2 Classification of tier system in Canada

| Tier | Max. quantity of spilled oil | response time |
|---|---|---|
| Tier 1 | 150 tonnes | 6 hours |
| Tier 2 | 1,000 tonnes | 12 hours |
| Tier 3 | 2,500 tonnes | 48 hours |
| Tier 4 | 10,000 tonnes | 72 hours |

## 5. Concluding Remarks

As it is recognized that analysis of historical spill data is one of important tool to provide a response plan and select adequate response measures against potentials of future spill, we analyzed the cause of past spill and evaluate the response options adopted during spill occurred at korean coastal waters using major historical spill data and got the following results.

It is found that no large spill recently occurred in korean coastal water, however, the number of vessels spill tends to increase slowly year-by-year.

Majority of spill is caused by operational failure, weather, violation of navigation rule and hull defect, therefore it requires responsible authority(MOMAF & KNMPA) to provide appropriate education and training program for ship's watch officers to be quality-upgraded, at the same time, strict inspection to hull condition should be made at the time of every inspection and/or survey.

Preferable response techniques employed in korean coastal waters were booming, recovery by skimmer or sorbent and dispersant use at the early stage of spill. These action such as deploying boom in the rough seas and applying dispersant to oil slick nearshore seems to be without due regard to type of spilled oil, weather condition, distance from shore and water depth.

Considering that knowledge of the product spilled and prediction of probable movement, behavior and fate, geographical features are vital in order to determine the most appropriate response measure, it is suggested that KNMPA provide a basis and criteria of oil type, weather condition, distance from shore and water depth for various response options to be acceptable to a certain condition during spill like advanced maritime countries have, also KNMPA should establish the standards of tier response time and capability according to the size of spill.

Under bad and/or low visibility weather, no action can be a good option, nevertheless, booming to protect sensitive resources in advance will be necessary predicting the movement of oil slick by computer model or aircraft. It is, thus, suggested that KNMPA have to develop the accurate computer models and try to stock with response aircraft which will be also of a great help to deliver the chemical dispersants more rapidly than ships, to apply them precisely to the thickest concentration of slick and to assess the success after application.

In this paper, the authors examined and analyzed 30 cases of historical spills in korean coastal waters. As these results are not enough to make some criteria appropriate for various response techniques, further studies will be extended in the future with collection of more spill data.

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