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論 文

On the Effective Oil Spill Response Model along the Coastal Waters in Korea

- Evaluation of the Regional Response Capabilities at the Port of Ulsan -

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한국연안해역에서의 효과적인 유류오염방제 모델에 관한 연구

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〈목 차〉

Abstract

To find characteristics and areas of greater risk of oil spill at the coastal waters in Korea, some of risk factors were analyzed with historical data of oil spill and marine traffic. As a result, it is characterized that frequency of oil spill is increasing year by year and greatest percentage of spill source is fishing boat. It is proposed that the ports of Ulsan, Yeosu, Incheon and Pusan will be designated as primary area of risk as they have a higher risk of oil spills and its response authority is required to maintain appropriate regional response capability for prompt and effective response to a future spill incident. In addition, the regional response equipments at Ulsan are examined under a assumption of a medium size spill and it is found that the use of chemical dispersant can be an alternative when mechanical containment and recovery is not feasible in this area, and the existing

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response equipments may be appropriate to address that size of spill. However, the response authority is required to maintain more numbers of stronger boom for unsheltered waters and more quantity of concentrate dispersant to disperse all spilled oils on the water, furthermore the response authority should be prepared for a possible future catastrophic spill with sufficient equipments.

1. Introduction

Oil pollution is becoming a special problem in the coastal environment because oil floats on water and does not easily mix with it. Some oil seeps into the sea naturally from submarine oil fields. This kind of oil is usually not a great problem since amount of spill is relatively small and some marine bacteria eventually digest the oil and render it harmless. On the other hand, drilling for oil or transportation of oil in tankers may occasionally result in large scale oil spills. Especially the accident of oil tanker Torrey Canyon's running aground in 1967 drew the international attentions to shipboard oil pollution, releasing 118,000 tons of crude oil into the sea. Some of it was intentionally burned at sea, but most of it drifted along the coast and polluted beaches in UK and France. This accident caused many birds to die, the intertidal organisms to be killed by detergent which was sprayed to disperse oils and affected the ecosystems seriously for several years. After Torrey Canyon's accident, another disastrous oil spill by super tanker Amoco Cardiz occurred off France in 1979, spilling 400,000 tons of oil and caused considerable damage to the beaches of France and affected marine culture for over 15 years. More recently, oil tanker Exxon Valdez ran aground on March 24, 1989, spilling 37,000 tons of oil into Alaska's Prince Williams Sound. This accident made US to set the Oil Pollution Act(OPA), 1990 to strengthen their regulations on oil tanker and oil tanker owners and operators.

Reviewing world large oil spill incidents like the above, huge amounts of oil were stranded along shores and a number of wildlife and marine organisms were seriously damaged at the time of Torrey Canyon's oil spill, since society and British government were not to prepare to contain, clean it up, rehabilitate, or even assess the effects of spill in several days after the spill and the adequate and effective response were delayed. Things were much changed when Sea Empress spilled more than 72,000 tons of crude oil at Milford Haven, UK in 1996. At that time, MPCU(Marine Pollution Control Unit) immediately initiated the contingency plan on receiving the message of the incident and quickly mobilized all its staff and response resources needed to deal with oil pollution, thus the damage to environment were considerably reduced(Harris, 1997).

Noting from the contrast between the case of Torrey Canyon and that of Sea Empress, it was proven that well-designed contingency plan was of great help to successful marine oil spill response.

In the meantime, oil spill incidents, even though not large quantity of spill like worldwide oil spills, have been kept occurring at the coastal areas in Korea in past 10 years such as oil barge No.5 Geumdong-Ho, oil tanker Sea Prince and Honam Sapphire etc. Of many oil spills, the incident by Sea Price, which occurred at off the port of Yeosu on July 23, 1995, has polluted most of the western part of South Sea spilling about 5,000 tons of bunker oil and the damaged environment has still not be rehabilitated by now. And there exists a threat of catastrophic oil spill at the coastal waters as marine traffic is getting heavier and volume of oil transported is increasing rapidly. Accordingly the responsible party is required to be prepared for a possible future disastrous spill in advance.

In this regards, the author investigates and analyzes some factors of spill risk such as historical records of oil spill incidents, traffic density, ship casualties, type and amount of oil transported at the coastal waters in Korea to find characteristics of spill incident and areas of higher risk of oil spill. Besides the author examines and evaluates the regional response capabilities under a assumption of medium size spill at the port of Ulsan, since Ulsan is one of main ports in Korea and always under a threat of large oil spill, then makes a suggestion regarding the improvement of regional response capabilities.

2. General Description of Contingency Plan

According to database of oil spill(ITOPF, 1996), the majority of spill incident falls into the smallest category of less than 7 tons and main cause of spill, cargo operations such as loading, discharging and bunkering, etc., present the small risk of an oil spill in the aspect of quantity. This risk can may be minimized by prompt action with good engineering. However, major spills over tens of thousand tons from tankers took place from time to time and this kinds of catastrophic spills can occur anywhere and anytime. Therefore any countries exposed to potentials of catastrophic spill should provide a representative picture of oil spill planning and preparedness across the country against the possible spill accidents at all times. It can be recognized that the best way to protect the environment is to prevent spills from occurring, and such prevention measures include provision of new legislation, enforcement of the law, regular inspection to ship and oil handling facilities. For these preventive efforts are not enough as oil spill will inevitably occur, many countries have developed contingency plan together with prevention measures.

The contingency plan can be defined as a plan for an event which may happen and the timing of which is obscure or unknown. The benefits of the contingency plan is to instill confidence, expedite efficient and effective emergency response, mitigate environmental damage and assist with good media relations. In fact, it was reported that 3 major spills in US in 1989 while massive Exxon Valdez effort was still underway were handled quickly and effectively(Skinner and Reilly, 1990) and response to Sea Empress' spill was a success(Harris, 1997) with well-designed contingency plan.

In Korea, national contingency plan is at the final stage of construction as Korea is preparing to ratify International Convention on Oil Pollution Preparedness, Response and Co-operation(OPRC), 1990, at the same time, Korea National Maritime Police Agency (KNMPA) as lead agency is planning to develop the regional contingency plan in next a couple of years.

While developing a contingency plan, it is necessary for responsible team to include following 3 main elements of strategic section, operation section and data directory in the plan which was advised by IMO(1996) and IPIECA (1991).

The strategic section include :

- Scope and responsibility
- Risk assessment
- Movement of and fate of oil
- Resources at risk
- Protection priorities
- Clean-up strategies,

and the operation section include :

- Initial reporting procedures
- Mobilization procedures
- Assessment of situation
- Selection of response strategies
- Implementation and termination of operations,

and data directory includes :

- Maps and charts
- Equipment stockpile lists
- Support and auxiliary equipment
- Contact directory
- Oil characteristics
- Pre-prepared press information

Of many items included in contingency plan, risk assessment is taken to be a very important item to make a decision of adequate response capabilities.

There are many ways to make a risk assessment in a specific port, but we can say it generally includes historical spill records, frequency of call of vessels, type and amount of oil transported, weather and sea conditions, navigational hazards, type of shoreline and sensitive resources, geographic location, terminal design and so on.

Some of these factors will be analyzed in next chapter to find areas of higher risk of oil spill at the coastal waters in Korea.

3. Historical oil spill incidents and areas at higher risk of oil spill

3.1. Analysis of oil spill incidents

The frequency of spill incidents by year was drawn at the coastal waters in Korea during 14 years(1984~1997) and worldwide during 12 years(1984~1995). in Fig. 1 with the data of KNMPA and Oil Spill Intelligence Report(Etkin, 1997) The figure shows that the frequency of spill incidents in Korea is gradually increasing year by year, while that of worldwide has downward trend. Fig. 2 shows its sources of spilled oil at the coastal waters in Korea for 14 years(1984~1997), and it indicates that fishing boats holds the majority of spill, about 45 %. This result also stands in contrast to most frequent source by tankers in worldwide incidents(Etkin, 1997).

Oil spills from vessels occur due to collision,

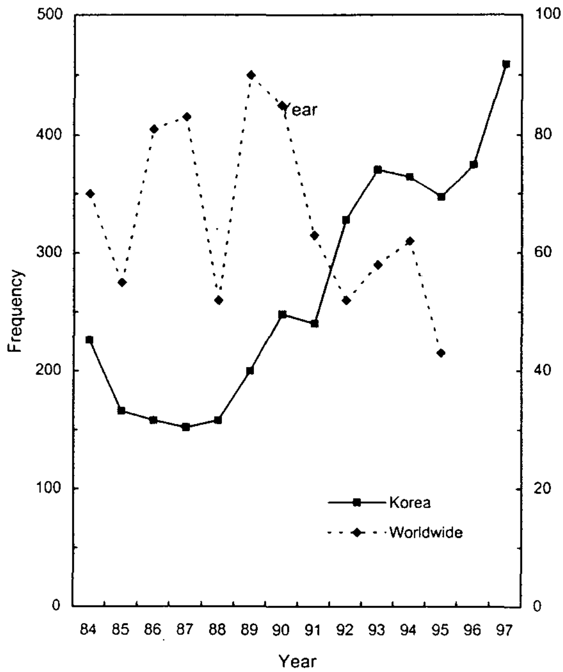

Fig. 1 The frequency of spill incidents in Korea (left Y-axis) from 1984 to 1997 and worldwide (right Y-axis) from 1984 to 1995. Number of worldwide incident is number of spills over 10,000 US Gallon (about 38 tons).

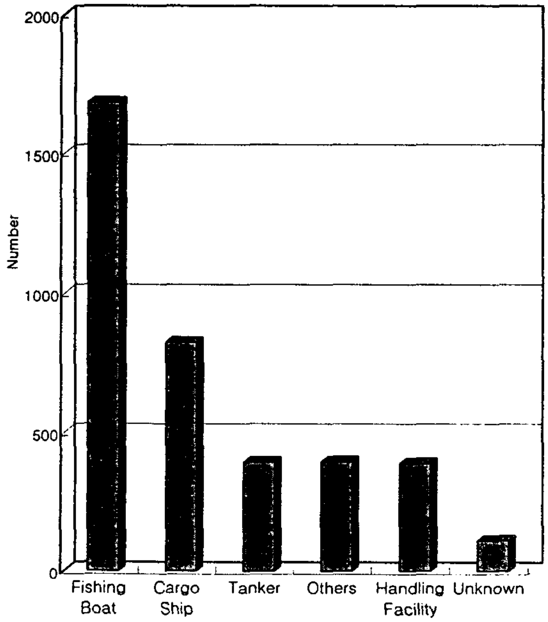

Fig. 2 Total number of oil spill incident per source at the coastal waters in Korea for 14 years (1984~1997). Data source : KNMPA(1999)

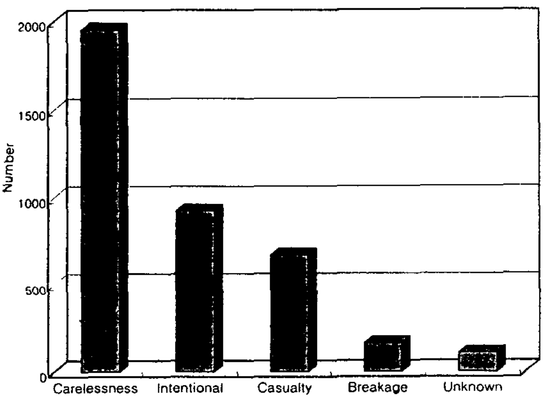

Fig. 3 Total number of oil spill per cause at the coastal waters in Korea for 14 years (1984~1997). Data source : KNMPA (1999)

grounding, damage to a vessel, structural failure, sinking, malfunctioning equipment, explosion or fire, intentional discharge, etc. According to analysis of cause of spill at the coastal waters in Fig. 3, seamen's carelessness is the primary cause, and intentional discharge and ship casualty are also important cause.

Table 1 shows annual quantity of spilled oil and number of spill incident per type of oil during 10 years(1988~1997). Oils spilled in the coastal waters is bunker-C, diesel oil, bilge and oily waste. It can be seen no significant trend in quantity and type of oil spilled per year, but two categories of bunker-C and diesel oil, as major pollutants, account for about 60% of total quantity. The quantity of oil spilled in 1993 and 1995 is remarkably larger than that in other years, which is attributed to spill incidents from oil tanker Korea Vinus and No.5 Geundong-Ho in 1993 and from oil tanker Sea Prince, No.1 Yooil-Ho and Honam Shappire in 1995.

3.2. Geographic areas at higher risk of oil spill

Table 2 shows annual number of call of all type of vessels at the main port in Korea during 3 years(1994~1996). It can be seen that there is no constant tendency of increase, but numbers of call at all ports except Mokpo and Donghae tend to increase a little year by year.

Fig. 4 shows total number of ship casualties per location for 5 years(1991~1995) at the coastal waters, one can see that casualties with largest number occur in Namhae (South Sea) and at the port of Pusan and Incheon.

Table 3 shows annual volume of crude and refined oil transported per port during 4 years(1994~1997). One can see that crude oil was transported much more than refined oil in Ulsan and Yeosu, while refined oil is more than crude oil at other ports, and it can be also

Table 1. Annual number and quantity of oil spill per type

year \ type	Bunker-C	Diesel	Bilge	Others	Waste	Total
1988	36/1018.4	32/32.0	69/7.8	9/1.6	12/0.4	158/1058.2
1989	48/263.2	48/59.6	82/27.0	11/17.4	11/0.8	200/368.0
1990	49/1789.2	59/428.4	105/186.6	8/0.4	27/16.0	248/2420.6
1991	52/792.0	54/436.2	112/26.4	12/2.0	10/0.4	240/1257.0
1992	66/363.1	72/611.4	120/236.7	43/21.7	24/209.5	325/1442.4
1993	70/1505.4	91/4969.2	133/388.4	41/8525.4	29/71.5	364/15459.9
1994	68/211.5	117/162.7	91/26.6	63/17.3	18/10.9	357/429.0
1995	80/1960.3	87/5746.6	99/82.6	45/5601.6	22/12.2	333/13403.3
1996	66/524.0	114/624.2	102/76.0	50/481.5	39/116.0	371/1821.7
1997	66/695.0	135/688.0	167/20.0	51/325.0	38/25.0	457/1753.0

Source : KNMPA (1999)
Remark : Figures in the cell denote number/quantity(*kl*)

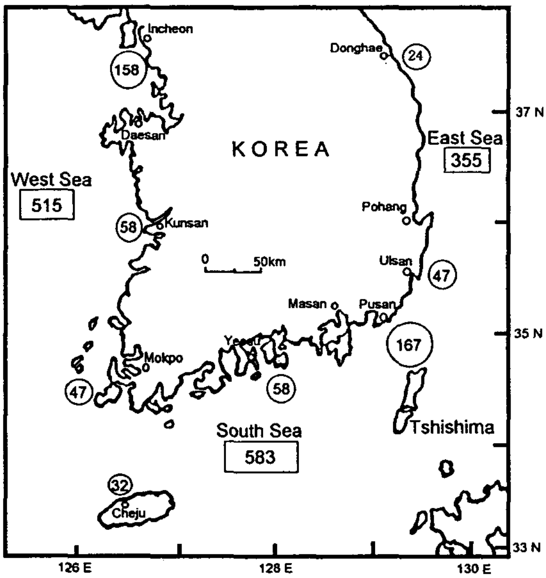

Fig. 4 Total number of ship casualties per location for 5 years (1991～1995) (from Jeong *et al.*, 1998)

found that Ulsan is a primary port in Korea on the aspect of volume of both crude and refined oil moved, and especially about 60% of total crude oil is handled at Ulsan.

With an analysis of some factors of oil spill risk, it can be proposed that 4 region of Incheon, Yeosu, Pusan and Ulsan will be designated as primary areas of risks because these areas have greater probability of a spill occurrence and require adequate response capability at all times.

4. Response capabilities at the port of Ulsan

4.1. Types of shoreline and oil transported

As stated in previous chapter, one can expect that even though Ulsan has not experienced serious problems in ship casualty and oil spill incidents (Hugh *et al.*, 1996) up to present, it may and/or must be confronted in near future

Table 2. Annual number of call of vessel per port

Year	Incheon	Daesan	Kunsan	Mokpo	Yeosu	Masan	Pusan	Ulsan	Pohang	Donghae	Cheju
1994	20559	6867	3349	4384	17253	7670	27621	19079	5586	5644	3120
1995	20098	6740	4437	5938	18528	8737	30648	20604	6223	5936	3170
1996	22677	9100	5276	5714	19340	8887	33409	21031	6985	5634	3400

Source : Jeong *et al.*(1998). Numbers of Daesan, Yeosu, Masan and Donghae include number of neighboring ports.

Table 3. Annual volume of oil transported per port

Unit : 1,000 *kl*

Year	Type oil	Ports					Total
		Incheon	Daesan	Yeosu	Pusan	Ulsan	
94	Crude	6,038	4,487	8,867	1,531	42,936	64,218
	Refined	12,025	7,803	36	6,936	34,389	66,977
95	Crude	11,137	7,895	16,454	1,228	49,733	83,200
	Refined	16,726	2,658	359	7,799	41,156	80,562
96	Crude	11,642	5,431	17,039	1,262	48,974	91,664
	Refined	20,622	2,928	254	9,172	41,188	92,910
97	Crude	11,730	6,607	15,532	714	65,466	108,179
	Refined	18,347	2,914	386	12,522	44,526	99,628

Source : Annual Report of MOMAF Statistics (1994~1997)
Remark : Total means annual total volume of oil transported at all ports in Korea.

by a threat of catastrophic oil spill as numbers of call of vessel are increasing year after year, about 60% of total petroleum transported in Korea is handled in Ulsan, and also offshore oil-gas production will be done in a few years. Therefore all parties concerned with marine pollution should get ready for possible disastrous spill incidents.

As one of response strategy, understanding of shoreline type and sensitive areas are very important. Shorelines around Ulsan approximately consist of 7 categories such as seawall and pier in the industrial port and fishery harbor, exposed rocky shore, boulder shore, sandy beach, exposed tidal flat, aquaculture and fishing ground shown in Fig. 5. Of them, the category of seawall and pier is ranking first and exposed rocky shore and boulder beach are in second rank group, while tidal flat and sandy beach have very small portion of shoreline. Considering types of shoreline and sensitive resources around this area, responders can determine shoreline countermeasures according to oil type. For instances, employable measures against light crude oil spilled are natural recovery, flooding and low pressure cold water washing, and employable measures against heavy oil spilled are low pressure warm water

Table 4. Monthly quantity of major crude oil imported in SK Terminal in 1993

Unit : 1,000 tons

Oil type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Arabian Light	1,473	1,509	1,650	438	567	1,760	1,688	1,187	1,409	1,424	1,777	1,739
Arabian Medium	331	415	492	448	447	527	726	244	359	605	509	262
Arabian Heavy	1,137	467	734	695	672	703	710	645	789	658	675	672
Kuwait	532	519	550	495	645	385	572	165	459	640	162	107
Iranian Heavy	1,158	1,048	1,370	875	1,176	1,219	1,006	1,752	1,154	1,039	1363	1,404
Oman	909	952	1,383	1,097	1,172	893	1,178	1,305	980	570	728	955

Source : SK Terminal (1994)

Remark : There may happen a small error in the process of converting unit from barrel to ton.

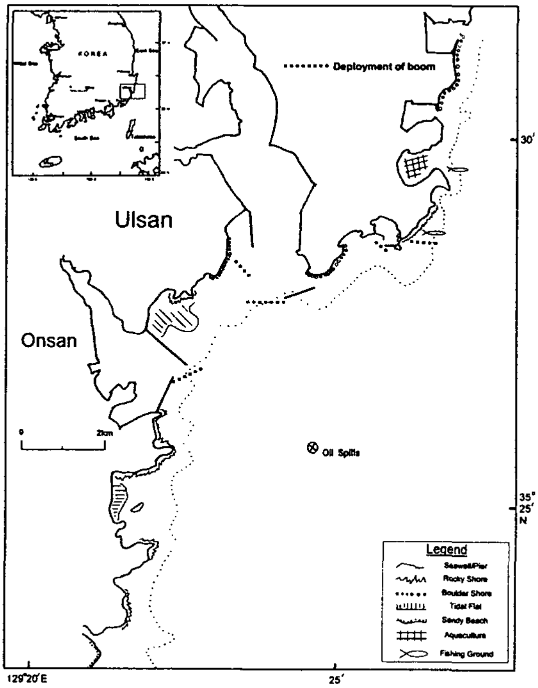

Fig. 5 Type of shorelines (from korean nautical chart No.119 and 142) and areas to be protected by boom. Dotted line and ⊗ mark denote isobath of 20m and place of oil spill in a scenario respectively.

washing, manual removal and mechanical removal.

Table 4 shows monthly quantity of major crude oil imported in SK terminal in Ulsan in 1993. One can see that Arabian Light is ranked first in term of importing quantity and Iranian Heavy and Oman crude oil are in the second group.

4.2. Stockpiles of response equipments at Ulsan

In the region of Ulsan, response equipments are maintained by 2 groups. One is government sector which consists of KNMPA, municipal government and navy, the other is private sector which consists of industry and Korea Marine Pollution Response Corporation. Table 5 shows total stockpiles of response equipments per sector as of May, 1999. Each boat has its own equipments such as boom, skimmer, spraying equipment, sorbent, dispersant and storage facility. These quantities or numbers are included in each item of the Table 5. It is characterized that stockpiles at private sector are more than those at government sector. This sound reasonable because of a principle that polluter must pay and be responsible for the

Table 5. Stockpiles of response equipments at Ulsan

Equipment		Government sector	Private sector	Total
Boat		1	9	10
Boom (m)		5,950	25,620	31,570
Skimmer (*kl*/h)		410.6	1,200.8	1,611.4
Sorbent (kg)		12,743	16,830	29,573
Spraying equipment		4	20	24
Pressure Washer		1	4	5
Storage Tank (m^3)		235.35	379.55	614.9
Dispersant (*l*)	Conventional	39,162	115,253	154,415
	Concentrate	900	-	900

Source : KNMPA (1999)

spill incident.

4.3. Evaluation of regional response capability

Response capability is defined as the equipment, appurtenances and personnel typically employed in an oil spill response. IMO proposed and suggested 3-tier approach for appropriate capacity. This model says that tire 1 is concerned with a small size spill within capacity of facility operator or harbor authority, tier 2 is concerned with a medium size spill that requires the regional resources, and tier 3 is concerned with a major spill that requires national resources. We can say that tier 2 corresponds to regional capability. However, it is very complex and objective, thus its standard varies country by country. For instances, Korea has 3 categories in size of spill and define medium size as a discharge of 30 to 100 *kl* in case of crude and heavy oil. US has 3 categories and define medium size as a discharge of 10,000 to 100,000 US gallon (about 38~380 *kl*) to the coastal waters, while Canada has 4 categories and define the tier 2 class for designated port as a maximum quantity of oil spilled 1,000 metric tons.

With not only those criteria but also the size of most frequent visiting tanker and a depth of waterway, we assume a spill of 250 metric tons as a medium size spill and evaluate a regional capability accordingly, focusing on the level of response equipments.

For this purpose, suppose an oil tanker is collided with a cargo ship on her port side at the junction point to Ulsan and Onsan harbor marked on Fig. 5 and about 250 metric tons of cargo in a wing tank get spilled instantaneouly. As seen in Table 4 that Arabian Light is ranked first in importing volume in Ulsan, we will separately examine 2 cases of spill incident with Arabian Light in winter and summer.

Once oil is released on the water, it undergoes weathering which is the changes in chemical composition and physical properties caused by the prevailing temperature and wind. Important weathering mechanism include spreading, evaporation, dispersion, dissolution, formation of emulsion, sedimentation and biodegradation. As weathering significantly affects how a spill will be treated to, it should be considered for a spill response. At the same time, responder should try to predict the movement of oil slick by observation and/or computer modelling and determine protection priorities.

- In case of a spill in winter

We first have to check how spilled oil is changing with time on the condition that wind speed, sea surface temperature and salinity near the entrance of Ulsan are 2.4m/s, 13.1℃ and 34.34‰ respectively and computed weathering process by use of ADIOS program(NOAA, 1994). The data came from Annual Report of Meteorology by Korea Meteorological Agency (1987~1996) and that of oceanographic observation by National Fisheries Research and Development Agency(1990~1994).

Looking at Fig. 6 which shows changes of density, evaporation, viscosity and emulsification of Arabian Light with times after a spill in winter. one can see that density is changed to 0.97g/cm^3 and 26% of oil get evaporated during first 24 hours after a spill, then they tend to increase more slowly. Likewise emulsification get formed rapidly during 24 hours after a spill, vis, water content is 30% within 12 hours, 55% within 24 hours, and then it is getting retarded. In contrast, viscosity changes a little untill it reaches to 2,000 cSt at 36 hours after spill, but increases rapidly afterward.

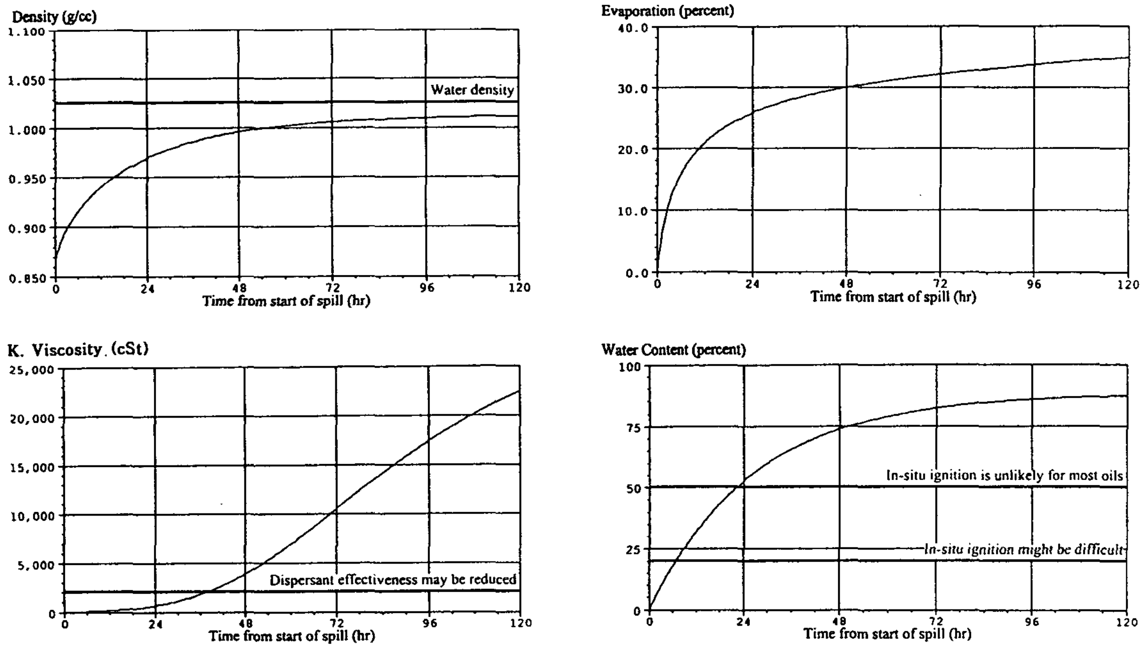

Fig. 6 Changes of density, evaporation, viscosity and emulsification of Arabian Light crude oil with times in winter

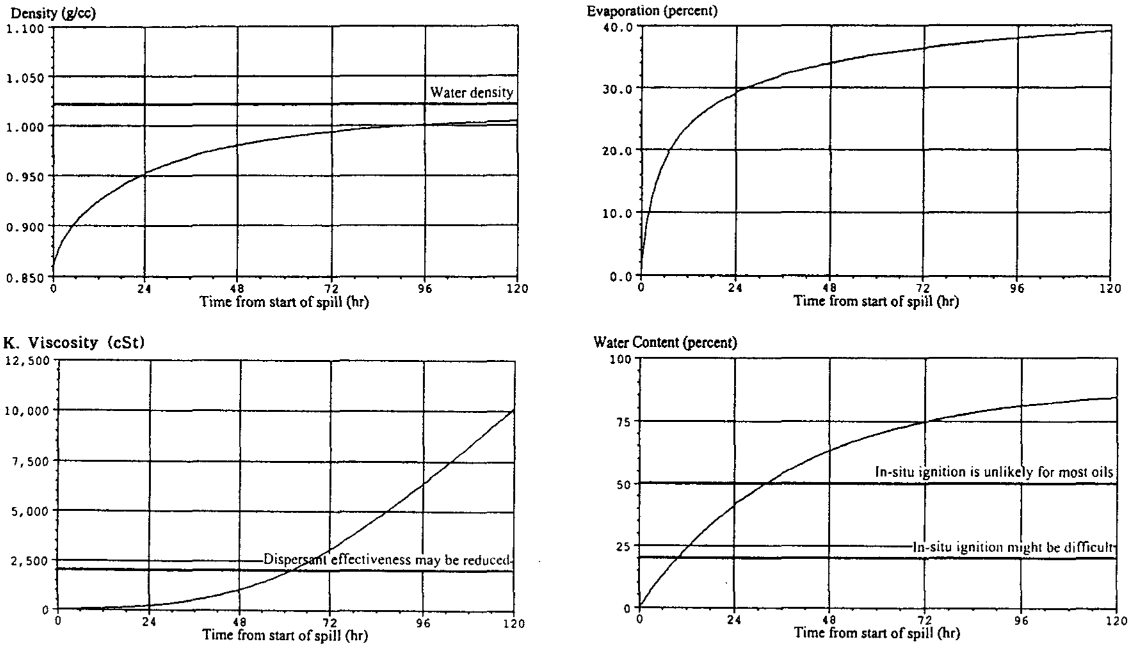

Fig. 7 Changes of density, evaporation, viscosity and emulsification of Arabian Light crude oil with times in summer.

• In case of a spill in summer

Weathering is computed by ADIOS program (NOAA, 1994), inputting wind speed of 2.0m/s, sea surface temperature of 24.7℃ and salinity of 31.66‰ near the entrance of Ulsan in August.

In Fig. 7 which shows density, evaporation, viscosity and emulsification of Arabian Light with times after a spill in summer, it can be found that density is changed to 0.95g/cm^3 and 29% of oil get evaporated during 24 hours after a spill, then they tend to increase more slowly. Emulsification is almost linearly progressing to 36 hours, and water content within 12, 24 hours is 25%, 42% respectively. Viscosity is increasing slowly to 48 hours and reaches to 2,000 cSt at 60 hours after a spill. Comparing all these results with those in winter, one can see that a spilled oil in summer has a tendency of slower change of density and viscosity, faster evaporation and less water content within 24 hours after a spill.

Making reference to all the process of a spilled oil, we can figure out that since spilled oil will turn into a heavy, viscous and high emulsified oil during 12~24 hours after spill, every efforts to contain and recover mechanically with possible use of dispersant should be initiated instantly after spill both in winter and summer.

4.4. Response equipments required

In this case of incident, there are a few kinds of response techniques such as mechanical containment and recovery, chemical dispersant and shoreline countermeasures. We can employ only 1 technique or more than 2 techniques at the same time, but most preferable one is the mechanical containment and recovery. Whichever techniques are employed, sensitive areas must be protected by boom.

Let us examine response equipments required against a spill in winter for worse case. It is proposed by Cho *et al.*(1998) that 80% of a spilled oil is contained and recovered and the rest 20 % is dispersed by chemical dispersant or absorbed by sorbents.

We suppose that all spilled oils will be treated only at sea and response activities continue for 2 days, then it can roughly be estimated that the remaining mass of oil at 2 days after a spill will be about 300 tons including water-in-oil emulsion.

- Boom

If boom is deployed in a circle, 500m of boom is required to contain 100 tons of oil with an average thickness of 5mm slick(CCG, 1992), therefore response authority is required to maintain about 1,500m of offshore boom to contain all remaining oils. If sweeping systems are used, 500m of boom is required to contain about 35 tons of oil with an average thickness of 1mm slick(CCG, 1992), thus response authority is required to provide about 4,300m of sweep system boom. Response authority can employ only one of the above two methods, also mixture of two methods. In either case, about 1,000m and 3,000m of additional offshore boom are needed to encircle a damaged tanker for further oil leakage and to protect sensitive areas shown in Fig. 5 respectively.

- Skimmer

All skimmers are normally de-rated to 20% of the manufacturer's stated recovery rate, and the daily recovery rate is based on 10 hours a day, therefore response authority is required to maintain total skimming capacity of 75 tons/hour by manufacturer's rated capacity. The number of skimmers required and one skimmer's capacity will vary according to the skimming system and the type of skimmer must be adequate for unsheltered waters such as oleophilic skimmer.

- Dispersant

To disperse 20% of oils on the waters, response authority is required to maintain 60,000 liters of conventional dispersant with a dose rate of 1:1 or 3,000 liters of concentrate dispersant with a dose rate of 1:20.

- Sorbent

If sorbent is used instead of chemical dispersant, response authority is required to provide 15,000kg of straw or 4,000kg of polyethylene sheet sorbent to absorb 20% of oils on the waters.

- Support equipments

The amount and type of support equipments required for this area is a function of the number of skimming system required to recover a certain percentage of oil. the response authority is to provide 8 towing boats, 6 self-propelled barges or vessels to support skimming operation with 50 tons or more internal storage capacity and on-deck scanting tank will be needed if sweeping operations with 500m length of boom are conducted at 4 sites and containing operations are simultaneously conducted at 2 sites deploying 400m length of boom in a circle. The response authority will not be required to purchase them permanently, however the response authority must maintain an up-to-date list of vessels available in the area.

There is one more response method other than the above operations. It can be taken that only chemical dispersants may be used to disperse all spilled oil at the early stage, since the coastal waters are deep enough to use chemical dispersant and no many higher sensitive areas exist around the region. In this case, the response authority will be required to maintain 300,000 liters of conventional or 15,000 liters of concentrate dispersants.

5. Concluding remarks

To improve response capabilities and develop effective oil spill response at the coastal waters in Korea, historical records of oil spill and some factors of spill risk were analyzed and the regional response capacity was evaluated at the port of Ulsan in this paper.

Prevention of oil spill is the utmost, but spills will continue to occur and affect the local environment in spite of preventive efforts. Thus it is paramountly important for the response authority to develop a contingency plan in order to respond to a future incident promptly and effectively and minimize the damage to the environment. In this regards, development of not only national contingency plan but regional and area contingency plan are imminent for a possible future catastrophic spill in Korea.

As results of analysis of historical data of oil spill and marine traffic, it is found that frequency of spill incidents is increasing year by year and the greatest percentage of cause of spills overall is carelessness and that of spill source is fishing boat. Besides, as it is found that the region of Ulsan, Yeosu, Incheon and Pusan have a higher risk of oil spills, they should be designated as primary area of risk and sufficient response resources are to be maintained at all times.

We evaluate the regional response equipments at Ulsan, a area of higher risk in future, making a scenario of spill incident from a tanker near the entrance of Ulsan with 250 tons of crude oil being spilled from a wing tank. The scenario is assumed that response activities will continue for 2 days after a spill, 80% of spilled oil will be contained and recovered and the rest 20% will be treated by chemical dispersant or sorbent. As a result, it is taken that the response authority shall put the first priority on the response technique of mechanical containment and recovery and can alternatively employ the use of chemical dispersant in this area. And it is proposed that the response authority shall maintain stockpiles of response equipments for that size of spill incident as follows.

• boom	- sweep system boom and - offshore boom	2,000m 4,800m
• skimmer	- oleophilic rope/belt	75 ton/hr
• dispersant	- conventional or - concentrate	60,000 ltr 3,000 ltr
• sorbent	- natural(straw) or - synthetic (polyethylene sheet)	15,000 kg 4,000 kg
• towing boat	- sweeping boat	8
• barge or vessel	- 50 tons storage tank	6
• oil transfer equipment		as needed

It is found that the existing stockpiles turn out to be able to address a medium size spill, however, it is recommended that the response authority maintains more numbers of stronger boom for open waters, more quantity of concentrate dispersant for the case of response technique by chemical dispersants being taken most effective, and a small and single aircraft like Piper Pawnee for rapid response with high application rate.

In this paper, a simple model is introduced to evaluate the adequacy of regional response equipments at Ulsan, making a scenario that a typical size VLCC is collided and spilied about 250 tons of crude oil from a wing tank, and response activities are done at sea and continue for 2 days after a spill. Therefore, it is taken that a further study regarding the improvement of response capabilities should follow including response to a larger quantity of spilled oil, shoreline countermeasures and response personnels, since a threat of catastrophic spill always exists in this area.

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