# OIL POLLUTION CONTROL SYSTEM FOR PROTECTING MARITIME ENVIRONMENT IN INDONESIAN PORTS

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**Abstract:** The aims of this research were to describe the oil pollution control system for protecting maritime environmentin the main port of Tanjung Priok and comparatively analyze the oil spill response methods.Ship oil spill seriously threatenedmarine environment and might cause an enormous loss of energy resources. Ship oil spill emergency response was a challenge due to limited time and resources as well as lack of historical data. The comparative analysis in this research was concerned with the oil spill response method with single case.This research proposed a decision making model for initial ship oil spill emergency response to cope with the problems. The core of this model was developing a hierarchical framework for decision making after identifying and quantifying the influential factors and alternatives from previous researches. Interviews were done with three informants face to face and by phone. The informants and participants consisted of Directorateof Marine and Coast Guard Unit, Disaster Management Section in charge of pollution control activities. The proposed model was implemented to real shipoil spill and the result indicated that it was reasonable to use the proposed model to select the best responseto the oil spill from ship with small volume of oil spill and near the cruise line.Based on the comparative analysis result, the most effective responseto marine oil spill was oil recovery by using a mechanical method and implementing dispersant and subsequently bioremediation.

**Keywords:** Maritime Security; Decision Making; Ship Oil Spill; Emergency Response

## INTRODUCTION

The most recent statistic from 2019 Oil Tanker Spill (ITOPF, 2019)and the annual report of European Maritime Safety Agency (EMSA, 2019)show that nowadays the possibility of oil spill decreases significantly. However, oil spill is still a serious threat for marine environment and bring about enormous lossof energy resources in a big quantity. (Yip et al., 2011)concludes that oil spill incident is the second or third most frequent incident in addition to the accidents of crashand grounding in the sea transportation.Marine pollutioncaused by ship oil spillaround the world is increasingly getting attention from international society(Zhang et al., 2021). Trading activities in the port of Tanjung Priok,as a major means of export and import by sea, becomes a factor causing pollution in the port waters and its surroundings. Marine oil spill due to soil runoff, ship and pipeline accidents, offshore oil exploration and production operation, tank wash, illegal delivery and bilge discharge activities cause various environmental problems due to toxic compound (Yavari et al., 2015). During 2019, ITOPF records one big spill (more than 700 tons) and two medium spills ranging from seven to 700 tons(ITOPF, 2019). Basedon the study (Al-Majed et al., 2012), marine oil spill influences marine life, tourism and aesthetical attractiveness as well as recreation activities. Significant physical and chemical changes of the oil occur after the spill.

Concerning the water condition, according to the study (Afenyo et al., 2016), after the spilled oil experiences various processes. Selecting the most effective technique of coping with oil spill depends on the type and quantity of oil spill, weather condition and surrounding environment (Al-Majed et al., 2012; Fritt-Rasmussen et al., 2015). The Indonesian government and business players in oil industry start to consider the ways to protect environment and their reputation from similar threats (Gao et al., 2010). The developed training programsaccording to (Fingas & Fieldhouse, 2011), can be implemented to reduce human errors, which are considered as the main cause of oil spill. Most of theInternational Maritime Organization jobs related to maritime environment protection are performed by MEPC. However, some environmental problems are also handled indirectly by the Legal Committee (especially the agreement descriptionconcerning obligations and compensation) and by Maritime Safety Committee. The latter has an implication not only because of the safe ship is well built and equipped with good navigation whichtends to experience less accidents causing marine pollution, but also because of the increasing number of problems with safety and environmental aspects (De La Fayette, 2001).arine oil spill includes crude oil, refined oil products such as benzene, solar and other side products, heavier fuel (fuel for bunker) and oily white feces or remaining oil (Etkin, 2009). These processesaccording to (Daling & StrØm, 1999)can lead collectively to formbrown mousse and tar ball as well as various oxygenated products making difficulties to take the oil. Very thick oil tends not to spread (USEPA, 2009). (Payne & Philips, 2018), find that higher viscosity of oil spill forms brown moss uneasy to be degraded or processed.

The recent remediation uses physical, chemical, thermal and biological techniques(Tewari & Sirvaiya, 2015). Physical method is usually used to control oil spill in water environment. It is especially used as barrier to control the spread of oil spill without changing the physical and chemical characteristics. Various barriers are used to control oil spill including: boom, skimmer and absorbent materials(Fingas & Fieldhouse, 2011).Boom is a kind of oil spill response equipment commonly used to prevent the spread of oil spill by providing oil movement barriers that can enhance the oil recovery through skimmer or other response techniques. Fenceboom is having light weight, requiring minimum space for storage, abrasion resistant, easy to handle, clean, and store, and is very reliable in calm waters. However, based on the study (MI News Network., 2020; Potter & Morrison, 2017; Ventikos et al., 2004)it has some weaknesses,namely low stability in strong wind and stream, low flexibility to tow, and low efficiency in high wave.

Chemical method is used in combination with physical method for remediating marine oil spill because they limit the spread of oil spill and help protect the coastal lines and sensitive marine habitat.Various chemical materials are used to handle oil spill because they have ability to change the physical and chemical natures of oil (Vergetis, 2020). The chemical materials used to control oil spill are dispersantand solid substances.Dispersantconsists of surfactant that is a surface active agent dissolved in one or more solvents and stabilizators. Dispersantis able to break down oil slick into smaller drops and to move them into a quickly diluted and degradablewater column(Lessard & DeMarco, 2020). The dispersing agentavailable now is less toxic and more effective than the compound previously used.In situ burningis a quick and simple way to recover oil spill that can be continued with special equipment.

Research by (Gouveia & Guedes Soares, 2010)states that delivery is one of the world's biggest economic activities. Research by (Alves et al., 2014)combines bathymetric, geomorphological, geological data, and the prediction of oil spill to model the oil spill impact in two accident scenariosfrom Kreta offshore, EastMediterranean. The aim is to present the method of using three new steps by the emergency team and local authority in shoreline assessment and the vulnerability of offshore to oil spill. The three-step method consists of: (1) real-time analysis of bathymetric,geomorphological, geological and oceanographic data; (2) simulation of oil dispersion in the condition of known wind and sea wave; and (3) preparation of final hazard mapbased on the information from (1) and (2) as well as the data of shoreline vulnerability.

Research by (Melaku Canu et al., 2015)assesses the hazard faced by Siciliancoast concerning the potential offshore surface oil spill and the risk for Sites of Community Importance and Special Protection Areas. The platform of oil extraction according to the study (Ribotti et al., 2019)is the source of potential oil spill. Therefore, oil spill prediction system is developed to support the oil field emergency situation management in the Italian sea. Whereas(Olita et al., 2019)reveals that the forecasting system and danger assessment for oil dispersion from Italian oil rig are developed in the framework of nationalresearch project. The result of the study(Gouveia & Guedes Soares, 2010)shows that oil spill, in a certain weather and oceanographiccondition, can quickly spread and reach the shoreline 5 to 96 hours after the initial accident. (Alves et al., 2014) explains how the impact can be reduced significantly through the implementation of fast mitigation strategy. Whereas (Melaku Canu et al., 2015)explains, in an emergency condition, the system results in an almost real-time 48-hour estimation concerning the fate of oil slick from each of the seven platforms.

 

Flow of Thinking

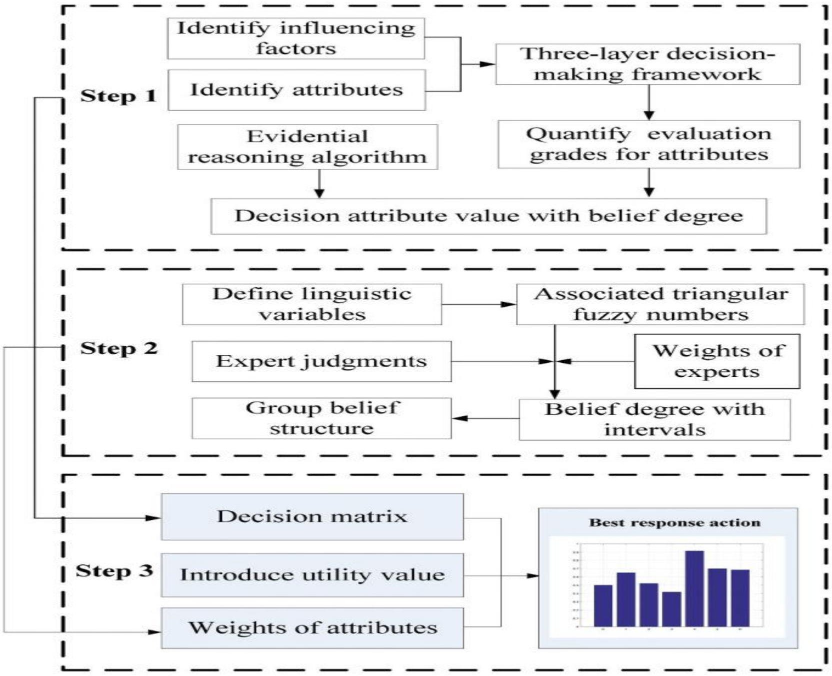


**Figure 1. General DecisionMaking Framework for Ship Oil Spill**

In order to assess all the alternatives, a general framework of decision making is established as in Figure 1.Firstly, the influencing factors and attributes are identified through research and expert experience; decision matrix can be obtained by changing the influencing factors into attribute evaluation valuesand introducing the algorithm of evidentiary reasoning. Secondly, attribute valuecan be defined by using a group belief structure. Finally, final decision making can be made by inputting the utility value after lowering the decision matrix and attribute weights.In Figure 2, the first level is indicated as level for reference, the second level is indicated as level for attributes, and the third level is indicated as level for influencing factors.

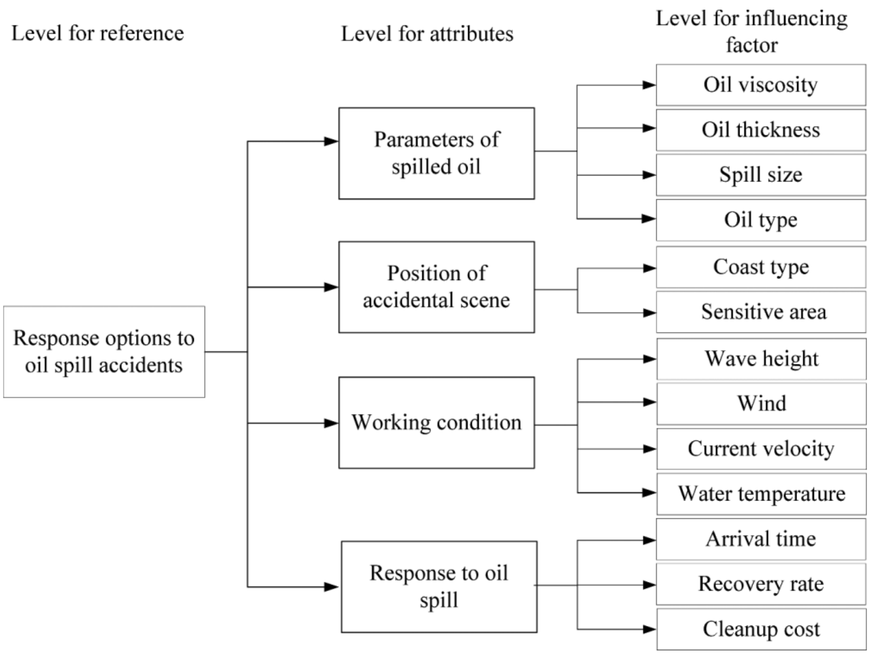


**Figure 2.Three-Layer DecisionMaking Framework for Ship Oil Spill**

## METHODS

Interviewswere done with three informants face to face as well as by phone, and the informants and participants consist of the Directorateof Marine and Coast Guard Unit, Disaster Management Section in charge of pollution control activities. And academicinstitutionsin the main port of Tanjung Priok are invited to participate in the interviews to explore in line with the principle that a comprehensive performance measurement system should involve the interest of all members and relevant stakeholders.Data collection in this research is carried out by interviews designed to explore the oil pollution control system in order to protect maritime environment in the main port of Tanjung Priok and to be able to give understanding about the comparative analysis of oil spill response method. Informants are asked to show the oil pollution control system and how significantthe system is and to hold a Focus Group Discussionwithan academic institution of sea transport management.This research uses an approach of comparative case study (Yin, 2009).Comparative method is defined as a systematicanalysis of a small number of cases (Bryman, 2012).Comparative case study offers an understanding which is rich of certain phenomena. The researchers use this approach because comparative allows the analysis to move outside the description of individual case todevelop a theoretical insight that is more generalizable(Yin, 2009). The comparative analysis in this research is about the oil spill response method with single case.

## RESULTS AND DISCUSSION

Massive oil spill is caused by human error, inappropriate design, or tragic weather incident. The review of three mass massive oil spills is described in the process of this research.The first oil spill research is when the Exxon Valdez oil spillhappened in 1989in Prince William Sound, Alaska(Ballachey et al., 2014; Irons et al., 2000; Marty et al., 2003).The problem is the loss of recreational fish catching, the loss of commercial fish catching amounting USD 300 million and the tourism expense decreases by 35%. As much as totally USD 755.2 is lostbecause of ecosystem destructionand decreased fish stock.Seals in the port of Harlequin Duck, pacific herring and pigeon guillemot have not fully recovered yet. Then it is concluded that physical recovery method must be applied (Boom, and Skimmer).Dispersants (Corexit 7664, Corexit EC 9580, BP1100X) and bioremediation (Fertilizers: Inipol EAP 22 and Customblen).

The second oil spill research is the one in 2002 in Prestige, Galicia Coastin the northwestern Spain (Albaigés Riera et al., 2006; Carracedo et al., 2006; Soriano et al., 2006). The problem is that commercial fishing and fish cultivation experienced a loss of Euro 64.9 million and Tourism loses Euro 133.8 million.It causes pollutions in that area for ten years after the first spill and causes an environmental loss around Euro 574 million.Commercial fishing and cultivation experience a loss as much as Euro 64.9 million and Tourism loses Euro 133.8 million.Then it is concluded that physical recovery method must be taken (Boom,and Skimmer)through bioremediation (Fertilizer S200). The third oil spill research is when an oil spill happened in 2010 in the Gulf of Mexico (Crone & Tolstoy, 2010; Lavrova & Kostianoy, 2011; Summerhays & de Villiers, 2012). The problems found are the losses of recreational fish catching as much as USD 138 millionand commercial fish catching as much as USD 18 million and of Tourism amounting USD 2.8 billion.The conclusion is that the whole assessmenton the impact is still under investigation. To fully understand the environmental and ecological impacts of that disaster, it needs an accurate estimation of the total oil released.

### Research Findings

Based on the interviews with the three informants face to face and by phone, where the informants and participants consist of Directorate of Marine and Coast Guard Unit and Disaster Management Section in charge of pollution control activities, the Directorate General of Sea Transportation through the Head of Tanjung Priok Main Harbor Office issues a Notice to Mariner notifying the ships passing through to be careful in their shipping journey and to avoid the oil spill area of offshore drilling. They also ask the ships passing through around the waters to give a priority to the ships performing pollution control and report to the Harbormaster if extraordinary things happen due to oil spill. Action plan and asset inventory, personnel and other necessary supports from the Directorate General of Sea Transportation or other agencies are focused to cope with the problems of gas leak and oil spill.

The Directorate General of Sea Transportation, Marine and Coast Guard Unit gives full support to cope with the pollution due to oil spill and gas leak, for example by providing additional oil boom, patrol boator additional buoy or beacon. The oil spill and gas leak control inTier 1 which is local in nature will be coordinated by Harbor Office and Port Authority. If the scale of pollution widens and needs personnel and more other supporting facilities and infrastructures, then the emergency status of oil spill and natural gas raises to Tier 2 and the coordinator of pollution control mission is handed over to the Head of Tanjung Priok Main Harbor Office.

Based on the Presidential Regulation concerning the control of marine oil spill emergency situation, there are three levels (tiers) of marine oil spill control, namely Tier 1 which is the categorization of oil spill emergency situation control inside or outsidethe Port Interest Area and Port Working Area, or oil and gas operating unit or other activity units, that can be handled by the available facilities, infrastructures and personnel in the port or oil and gas operating unit or other activity units.Tier 2 is the categorization of oil spill emergency situation control inside or outsidethe Port Interest Area and Port Working Area, or oil and gas operating unit or other activity units, that cannot be handled by the available facilities, infrastructures and personnel in the port or oil and gas operating unit or other activity units based on Tier 1. Whereas Tier 3 is the categorization of oil spill emergency situation control inside or outsidethe Port Interest Area and Port Working Area, or oil and gas operating unit or other activity units, that cannot be handled by the available facilities, infrastructures and personnel in a territory based on Tier 2, or spreading across the territorial boundaries of the Unitary State of the Republic of Indonesia.

Whereas the subfocus in this research analyzes comparatively the oil spill response methods as follows.

**Table 1. Advantages and Disadvantages of Physical Remediation Method for Oil Spill**

| Physical Remediation Facility | Advantage | Disadvantage |
|---|---|---|
| Booms | • All types of oil<br>• Oil recovery is possible | • Expensive<br>• Labor intensive<br>• Complex<br>• Contain oil<br>• Efficient |
| Skimmers | • All types of oil except the flammable one<br>• Oil recovery is possible | • Expensive<br>• Labor intensive<br>• Complex<br>• Collected oil gathers and the need for further maintenance<br>• Efficient in certain weather condition<br>• Possibility of blockage due to floating debris<br>• Need maintenance<br>• There must be oil recovery before it is emulsified |
| Absorbents | • All types of oil<br>• Effective as final cleaning step<br>• Simple<br>• Need no maintenance<br>• Synthetic sorbents made of poly propylene or polyuretan have good hydrophobic and oleophilic nature | • Fairly expensive<br>• Labor intensive<br>• Complex<br>• Used in certain weather conditions<br>• Need to disposeby regulation<br>• Biodegradability is the problem with synthetic sorbents<br>• Sinking in water is the problem with natural absorbents |

**Table 2. Advantagesand Disadvantagesof Chemical Remediation Methodfor Marine Oil Spill**

| Chemical Maintenance | Advantage | Disadvantage |
|---|---|---|
| Booms | • All weather conditions<br>• Fast<br>• Effective for various types of oil<br>• Accelerate oil degradation through natural process<br>• Further formulation has decreased the previous worry about toxicity<br>• Need less manpower<br>• Cheaper than mechanical method | • No oil recovery<br>• Not effective for oil which is very thick, non-diffuse, and waxy<br>• The increase of oil concentration in water which is local and temporary in nature can impact the life of surrounding marine<br>• If dispersionis not achieved, the effectiveness of other response methods can decrease in less oil |
| Solidifiers | • All weather conditions<br>• Fast | • Lack of practical application<br>• Needed in a big quantity<br>• Selected oil<br>• No oil recovery<br>• Ineffective |

**Table 3. Advantagesand Disadvantagesof Thermal Remediation Methodfor MarineOil Spill**

| Advantage | Disadvantage |
|---|---|
| • Effective<br>• Fast<br>• Need at least several special equipment<br>• Need less manpower<br>• Cost saving | • There is no oil recovery<br>• Afraid of flashback and secondary fire<br>• Radiate many compounds related to natural gas to the air environment<br>• Selected oil<br>• Threat marine biota, human resources and surrounding<br>• Burning residueis more viscous than the original product<br>• It is suggested to open the (water)area covered by snow or ice |

**Table 4. Advantagesand Disadvantagesof Bioremediation Methodfor MarineOil Spill**

| Advantage | Disadvantage |
|---|---|
| • All weather conditions<br>• Need less manpower<br>• Cost saving<br>• Oil mineralization becomes $CO_2$and $H_2O$ | • No oil recovery<br>• Selected oil<br>• Lack of capacity for microbial survivalagainst oil contaminant<br>• Depend on the original microorganism existing in the location<br>• Depend on the nutrition available in the impacted location |

**Discussion**

Oil spill contingency plan enables more effective and efficient responseto the spill incident by using an appropriate responsestrategy which is in line with the goal of reducing ecological destruction, economy, and convenience as well as dan the next claim of compensation. Oil spill contingency plan also includes risk assessment andnecessary data gathering, and it becomes the foundation for logical definition of equipment requirements based on local regulations and standar internationalstandards.Oil spill track modelling is a part of oil spill contingency plan with stochastic data from weather agency that provides prediction of oil movement on the water surface. The result of modelling can be integrated with an environment sensitivity map to help the decision making, oil spill drilling practice, and equipment requirements. Every activity involving ship, port, operator of oil drilling unit, and oil storage facilities in the waters must have an oil spill contingency plan approved by the DirectorateGeneral of Sea Transportation and the DirectorateGeneral of Overseas Companies in accordance with the relevant state regulations and international guidances such as IMO, IPIECA, ITOPF, and others.

This research plan is developed to give the whole strategy, procedure, mechanism and response process that must be taken if a chemical material release happens, especially Hazardous and Toxic materials from the activities potential to endanger human beings and pollute environment. Chemical substance spill modelling is part of chemical spill contingency plan used to estimate the threat zone, showing the area where certain danger, such as toxic vaporand thermalradiation is estimated to exceed the level of concern of each chemical materialin a time after the chemical material release begins.The advantages of physical, chemical, thermal and biological methods as well as their disadvantages are used as basics to hold a comparative analysis on the remediation method of marine oil spillresponse. Analysis of the interviewresults related to the oil spill control methodshows that bioremediation is in the highest position. Although in-situ burning occupies the second position, this method is not recommended for all locations of oil spill. Boom and skimmer occupy the third position because they are good for all types of oil but their efficiencies depend much on weather and sea condition. Solidifier is in the low position because it is practically the most inefficient and its remediaton method is more expensive for oil spill.Based on the factors involved in the oil spill, different remediation techniques can be used anytime. In general, the combination of mechanical, chemical, and biological methods can efficiently cope with the oil spill at much lower cost.

During 2020-2021 oil spill has occurred inthe port of Tanjung Priok, but when the incident occurred the ship was in the berthing position, not at the time when the ship was to enter and then the crash happened. If the ship is in berthing position, the spill is automatically and directly localized and guroais done, so that the oil does not spread. This does not disrupt the ships that want to berth at another wharf and does not cause delay due to the spill.The researchers find different implementations in the field.For example, if it is in accordance with effective and efficient rules or regulations to cope with oil spill, first, localize the scene using oil boom and then absorbby using skimmer. If later the spill is thin or a little, absorbent can be used.But the researchers find the practice in the field not in accordance with the guidance of oil spill control; what is done in the field is directly taking action using dispersant in order that the oil is not seen. Whereas, there is a rule that dispersant can be used in the depth of minimum 20 metersbecause it has an impact on the surrounding ecosystem; this makes environment unfriendly.
This research supports the results of several previous researches. Based on the study, (Tangahu et al., 2022)states that the quality of sea water in Batam, Indonesiais still low where much ship's waste oil spill causes marine pollution. This research is also in line with the study (Selasdini & Almuzani, 2022; Tangahu et al., 2022)in the Indonesian main ports that the reception facilitiesused to collect ship's waste has not functioned optimally yet.This research is also in line with the study (Fuad, 2021; Yudhistira et al., 2022)in small ports of eastern Indonesia, finding bigger impacts of marine pollution. The result of simulation indicates that the oil dominantly spreads to east and northern east.This research concerning bio-dispersant and bioremediation techniques is in line with the study(Okeke et al., 2022)mentioning that both techniques are environment friendly. This research also supports the study (Adofo et al., 2022), that there is surfactantin the universe which is not toxic and can be biodegradable, that can be explored to result in potential dispersantto help remove the oil safely from the sea water surface.

## Conclusion

Ten criteria are used to evaluate remediation methods: efficiency, time, cost, impact on marine life, reliability, degree of difficulty, oil gain, weather, influence of the chemical characteristics of oil, and the need for further maintenance.From the comparative analysis, it is the most effective response to marine oil spill is oil recovery using a mechanical method and applying dispersantfollowed by bioremediation.The main goals of the responseare to prevent the spill from moving to coast, to reduce the impact on marine life, and to accelerate the degradation of the found oil. To maximize the goals, the remediationtechniques used will depend on several factors, namely: type of oil, physical, biologicaland economiccharacteristicsof spill location, weather and sea conditon, spill quantity and speed, depth of water column, year time and the effectiveness of cleaning method.

In conducive weather conditions, boom can be used to withstand or divert oil spill, and the oil can be regained by using skimmer or absorbent. Dispersantcan be effective in breaking light or medium oil spill although mixing level, oil weathering rate, and the strength of dispersant being used are the most important factors of its performance. Absorbentcan be used for spill in small volume, or for "polishing" after the other recovery methods or in-situ burning. Bioremediation is a favorable approach compared with the traditional process which is very expensive and intensive labor. However, the uncontrollable variables in oil spill such as oil composition, genuine microorganism existing in the location, water characteristics like temperature and nutrition available in the impacted location can affect the result of oil spill response method.After the oil spill incident, what needs to do first is to know quickly and accurately thespreading area, both visually direct and through remote sensing. Various controlling ways are carried out such as in-situ burning, mechanical setting aside, bioremediation technique, use of sorbent, and use of chemical substance for dispersant, as well as other methods depending the case occurring.

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