CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literatures that support this study as well as problems related to this research title that have been identified by many researchers.

2.2 Oil sources and its characteristics

Rapid economy growth of many countries since World War II has caused a considerable increase of marine transportation of raw materials, especially crude oil and offshore activities (Doerffer, 1992) as oil and gas are one of the main source of fuel energy. However, a significant amount of oil comes into the sea from operational discharges of ships as well as from incidents such as collisions, groundings and contacts (Doerffer, 1992). Examples of the famous oil spills by oil tankers accidents are *Exxon Valdez* (Piatt and Anderson, 1996; Swannell et al., 1996; DuTemple, 1999) and *Amoco Cadiz* (Swannell et al., 1996) as well as the recent Deepwater Horizon oil rig explosion in the Gulf of Mexico (Oil Reaches Louisiana Shores, 2010).

Crude oil and natural gas are both fossil origin and are the result of a variety of successive transformations of organic material originating in marine phytoplankton and land flora (Bocard, 2008). After the fraction of organic deposits had sedimented and slowly been deeply buried, they go through biochemical and thermal processes on a geological time-scale. Chemical reorganization with polymerization, condensation and partial elimination of functional groups resulted in the solid kerogen (diagenesis) which itself transformed as it degraded under the increasingly severe temperature and pressure conditions the deeper the burial in the earth's crust , into a complex mixture of liquid and gaseous hydrocarbons (catagenesis). The oil and gas once formed will migrate to reservoirs consisting of porous rocks covered by an often clayey impermeable layer which are known as oil and gas fields (Bocard, 2008).

Crude oil is mixtures of hydrocarbons compounds that range from smaller, volatile compounds to very large, non-volatile compounds. Hydrocarbon compounds are composed of hydrogen and carbon (Fingas, 2001). Oils can be divided into two hydrocarbon families which are saturated and aromatic (Bocard, 2008). Saturated hydrocarbons consists on the one hand of both normal paraffins (linear) and isoparraffins (ramified) and on the other cycloparaffins which can be either monocyclic or polycyclic with one or more linear or ramified paraffin groups branched on one or more rings (Bocard, 2008). Aromatic hydrocarbons on the other hand consists of monoaromatics (benzene and mono-alkyl derivatives, polylkyls and cycloparaffins) and polyaromatics of about 2 to 7 rings, whose condensed nucleus molecules are the main components of the polycyclic aromatic hydrocarbons which can also contain paraffin cycles an alkyl groups branched into nuclei. Resins contain compounds with one or more heteroatoms, giving them a marked polar character leading to selective retention on chromatographic separation adsorbents (Bocard, 2008). They are mainly oxygenated compounds such as aldehydes, ketones, cyclic ethers and acids in particular naphthenic acids and nitrogenated compounds. Asphaltenes consist of heavy and complex heterocyclic compounds, where some contain nickel and vanadium that are held in micellar suspension in the petroleum by resins and have a property of precipitating when oil is diluted by a large volume of liquid paraffin (Bocard, 2008).

Atlas (1975) stated that the relative amounts of high and low-molecular-weight compounds in the crude oil are of special importance. Heavy oil contain higher percentage of high-molecular-weight components while light oils contain higher percentage of low-molecular-weight components. Lighter crude oils have greater abiotic losses and are more susceptible to biodegradation than heavier crude oils due to the volatility of these low-molecular-weight components (Atlas, 1975).

Oil spilled on water undergoes varies processes. The biologically and chemically induced changes in the composition of a polluting petroleum hydrocarbon are commonly known as weathering (Atlas, 1981). Oil weathers differently but almost immediately after it is spilled depending on the type of oil spilled as well as the environmental conditions. Weathering processes include evaporation, emulsification, natural dispersion, dissolution, photooxidation, sedimentation, adhesion to materials, interaction with mineral fines, biodegradation and formation of tar balls (Atlas, 1981). In Munoz et al (1997) study on the Guadelupian mangroves, the crude oil spilled had weathered over the years and analyses had revealed a major difference in the composition of the aliphatic hydrocarbon fraction after eight years. Munoz et al., 1997 stated that weathering processes reduce the concentration of hydrocarbon in sediments but can impose a large obstacle to identify spilled oil. Chemical and physical weatherings of the oil however, always precede biological weathering (Atlas, 1995).

Evaporation is often the first as well as most important process that takes place during weathering (Doerffer, 1992). Evaporation can lead to a reduction in the volume of pollution in a time ranging from a few hours to a few days depending on the temperature, wind speed and thickness of the film (Bocard, 2008). The rate of evaporation depends on the oil's composition (Fingas, 2001). Oil with more volatile components evaporates fast as compared to heavier oils.

Emulsification of oil is the process of the liquid dispersed into water in a form of small droplets where asphaltenes and resins in the oil interact will water to stabilize (Fingas, 2001). These water-in-oil emulsions are commonly known as 'chocolate mousse' (Bocard, 2008). Fingas and Fieldhouse (2004) considered that the most important factor of oil weathering is the stability of emulsions. The four main states or classes of water-in-oil mixtures are stable, mesostable, unstable and entrained water. These states are distinguished by lifetime, visual appearance, elasticity and differences in viscosity. Stable and mesostable states are the only ones that can be characterized as emulsions. Water-in-emulsions made from crude oil have different classes of stability due to the asphaltene and resin content as well as the viscosity of the starting oil. In weathering, firstly, saturates and smaller aromatic compounds are eliminated that aids the formation of emulsions by reducing the amount of solvating material. Second, viscosity increases as oil weathers. Third, oxidation and photooxidation take place that crate more polar compounds of which some are regarded as resins (Fingas and Fieldhouse, 2004). Emulsification process where water-in-oil are formed, changes the properties and characteristics of oil spills to a very large degree (Fingas and Fieldhouse, 2004). The volume of spilled material increases from two to five times the original volume as a stable emulsions containing between 60 to 80% water (Fingas, 2001; Fingas and Fieldhouse 2004). The dynamic viscosity can change from a few hundred mPa.s to about a hundred thousand mPa.s,; an increase of 1000 times. This causes a liquid product change to a heavy, semi-solid material. Thus often causes clean-up operations to be more difficult (Fingas, 2001).

Natural dispersion occurs when wave action or turbulence transferred the fine droplets of oil into the water and is very dependent on the oil properties and amount of sea energy (Fingas, 2001).

Some of the most soluble components of the oil are lost to the water under the slick through dissolution. Very often the soluble aromatic compounds are toxic to fish and other aquatic life such as gasoline, diesel fuel and light crude oils. Weathered oil is unlikely to dissolve into water (Fingas, 2001).

Photooxidation can change the composition of oil and very often become resins as the sun causes oxygen and carbons to combine and form new products. Resins may become soluble and dissolve into the water forming water-in-emulsions (Fingas 2001).

Sedimentation may take place after oil is spilled where the oil is deposited on the bottom of the sea or near the shoreline. Oil may adhere to other shoreline materials especially when it is moderately weathered. Oil with high percentage of aromatics and alphaltenes from high molecular weight compounds do not degrade significantly and can remain in the environment for decades. Oil may interact with other mineral fines suspended in water column as well (Fingas, 2001).

Microbial degradation plays a major role in the oil weathering process (Atlas, 1981). Biodegradation of petroleum in natural ecosystem is indeed complex (Atlas, 1981). Many species of microorganisms, bacteria, fungi and yeasts are capable of degrading petroleum hydrocarbon (Atlas, 1995) and metabolize them as a food energy source. Hydrocarbons are generally converted to oxidized compounds which may be further degraded, soluble or accumulated. Rate of biodegradation tend to increase with temperature and oxygen (Fingas, 2001). Atlas (1975) found out that biological losses from his seven crude oil experiments showed that heavy oil are more resistant to biodegradation. Biodegraded oil had a lesser weight of paraffins than fresh and weathered oil. There are some greater weights of asphaltic components in some biodegraded oil residues than fresh and weathered oil. Biodegradability of crude oil is highly dependent on crude oil composition and temperature (Atlas, 1975). The low biological losses from heavy oil reflect the resistance to microbial degradation of the complex high-molecular-weight compounds. Palmer (1993) stated that biodegradation produces heavy, low API gravity oils depleted in hydrocarbons and enriched in the nonhydrocarbon nitrogen-, sulfer-, oxygen-bearing (NSO) compounds and asphaltenes. The loss of the n-paraffins relative to the beanched paraffins, naphthenes and aromatic hydrocarbons are most commonly used as indicator of biodegradation because bacteria consume n-paraffins prior to branced parraffins, napthenes and aromatic hydrocarbons. The loss of n-paraffins is readily observed in the whole-oil gas chromatograms and in chromatograms of the C15+ saturated hydrocarbon fraction (Palmer, 1993). Atlas (1995) found that crude oil are never completely degraded and always leave some complex residue and this residue often appears as a black tar containing a high proportion of asphaltic compounds. The toxicity and bioavailability of the residual mixture to flora and fauna is very low and as long as it does not coat and suffocate the animal or plant, and ultimately becomes an inert environmental contaminant with no toxic ecology impact (Atlas, 1995). Persistence of petroleum pollutants depends on the quality and quantity of the hydrocarbon mixture as well as on the properties of the affected ecosystem (Atlas, 1995).

Formation of tar balls are usually the fate of many oils where they are deposited on shorelines. Tar balls are usually less than 10cm in diameter and material bigger than 10cm are often called tar mats (Fingas, 2001).

Oil toxicity depends on the chemical and physical characteristics of the spilled oil. Oil with significant fraction of aromatics is more toxic. The impact of oil toxicity on marine organisms depends on various aspects such as the organism itself and its age, oil concentration, water salinity, temperature and pH, presence of nutrients, pollutants and dispersants (Psaltaki et al., 2004). Oil tends to spread over the surface of water due to the surface and interfacial tension. The spread will remain at least as long as the surface and interfacial tensions are unchanged by weathering (Weaver, 2004).

2.3 Wind and wave currents

Oil spreads faster on water than on land. Oil spilled on water tend to spread into a thin slick over the water surface especially with lighter products such as gasoline, diesel fuel and light crude oil while heavy crude oil tend to form tar balls and tar mats. Oil spreads horizontally on the surface of water even without wind and wave currents. The spreading is caused by the force of gravity and interfacial tension between water and oil. However, wind and wave current may speed up the process of the oil spreading on the water surface (Fingas, 2001).

Fingas (2001) stated that oil slick close to land, and with wind speed less than 10km/hour, it moves at 100% of the surface current and about 3% of the wind speed. If the wind speed is more than 20km/hour, and oil slick on open sea, wind predominates the oil slick's movement.

Oil slicks were transported to the shores and beaches of Pulau Pangkor by the wind and wave current at the time of spill (Ahmad and Hassan, 1983, Jalali et al., 1998). Therefore it is essential to understand the wind and wave currents along the Strait of Malacca as Pulau Pangkor is situated in the central-eastern part of this Strait. The objective of studying the wind and wave currents is to demarcate the areas from which oils spills resulting from shipping accidents would potentially affect Pulau Pangkor (Ahmad and Hassan, 1983). This requires understanding the direction of winds and currents in the Strait of Malacca (Jalali et a., 1998; DuTemple, 1999; Al-Lihaibi, 2000; Schlacher et al., 2010; Samad and Mansor, 2002). Winds and currents will also affect the direction of sediment transport along the coasts of Pulau Pangkor as well as the movement of oil slicks towards the coasts (Lewis, 1983).

The Strait of Malacca lies in a tropical monsoon zone, where the dominant monsoon winds reverse directions twice a year (Chiang et al., 2003). The two main monsoonal periods are the wet Northeast Monsoon from December to February and the warm and drier Southwest Monsoon from June to August. In the two inter-monsoon periods the weather becomes variable (Chiang et al., 2003). The water movement and hydrographic parameters in the Strait are strongly influenced by the monsoons (Amiruddin, 2011).

Amiruddin (2011) stated that during the Northeast Monsoon (December to February), water from the South China Sea penetrates at its least into the south western part of the Strait of Malacca. However, data compiled and interpreted by the NASA Earth Observatory in 2007 showed that during the Northeast Monsoon, the current along the Strait is from the northwest (Fig 2.1). During the Southwest Monsoon (June to August), the flow of surface current along the Strait is from the South China Sea to the Andaman Sea (Amiruddin, 2011). Rizal et al. (2010) advocated that the surface current direction was towards the northwest in February and August 2007 by using three-dimensional numerical model. Wind and current data obtained from the Malaysian Meteorology Department (Appendix 1) from 1988-2008 for the seas off Pangkor Island between latitudes 4.0 - 4.5 N and longitudes 100.0 - 101.0 showed the general dominant wind and current direction to be from the northwest. Wind and current from the southeast do occur but are secondary compared to the wind and current from the northwest (Appendix 1). Samad and Mansor (2002) stated that the sea condition at Strait of Malacca is calm but during the southwest monsoon season, the wind velocity increases to 50 knots. The data from both Amiruddin and Rizal are based on the concept of modeling whereas data from NASA Earth Observatory and Malaysian Meteorology Department are based on observations, and thus are more accurate.

Satellite imagery obtained on 27 April 2011 from Google Earth (2009) showed that the waves and the current flow towards the southeast but are deflected by the Pulau Pangkor landmass. The angle of incidence of the waves along the western coast of Pulau Pangkor (Fig 2.2) indicates that water movement from the northwest is deflected in an eastward direction. In the southwestern part of the island, the apparent wave and current direction is towards the east. In contrast, the apparent wave and current direction on the northeastern coast of the island is towards the southwest as illustrated in Figure 2.2. These different directions are due to the currents and waves wrapping around the island as they are deflected by the island landmass.

The tide along Strait of Malacca is semi-diurnal with a tidal range between the lowest astronomical tide and the mean high water spring tide varying from 2.4 meters to 2.8 meters (Cleary and Goh, 2000). The tidal characteristics in Pulau Pangkor are semi diurnal and an example of the tidal range from 16 June to 22 June 2011 is shown in Table 2.1 below.

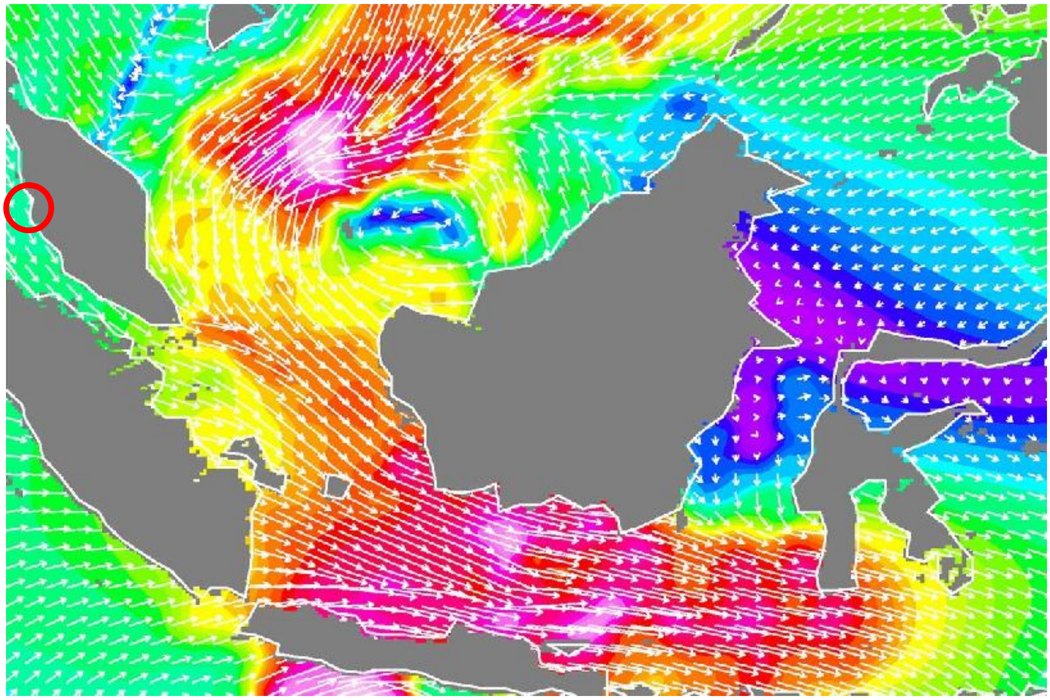

Figure 2.1: Image of surface currents in Southeast Asia in January 2007, indicating that dominant currents flow from the Northwest during the Northeast Monsoon along Strait of Malacca. Image by David Long, Brigham Young University, QuickScat Science Team, Nasa Earth Observatory (Long, 2007).

Table 2.1: Tidal range of Perak obtained from Department of Survey & Mapping Malaysia website (Height in meters)

Thursday (16 June 2011)			**Friday (17 June 2011)**			**Saturday (18 June 2011)**		
Time	**Height**		**Time**	**Height**		**Time**	**Height**	
440	2.3	High	525	2.33	High	606	2.33	High
1032	0.63	Low	1113	0.65	Low	1154	0.7	Low
1625	2.56	High	1705	2.54	High	1742	2.48	High
2302	0.04	Low	2341	0.04	Low			
Sunday (19 June 2011)			**Monday (20 June 2011)**			**Tuesday (21 June 2011)**		
Time	**Height**		**Time**	**Height**		**Time**	**Height**	
18	0.11	Low	50	0.21	Low	122	0.33	Low
648	2.31	High	721	2.26	High	757	2.23	High
1234	0.77	Low	1310	0.84	Low	1351	0.92	Low
1819	2.38	High	1852	2.25	High	1926	2.09	High
Wednesday (22 June 2011)								
Time	**Height**							
153	0.47	Low						
834	2.19	High						
1438	0.99	Low						
2006	1.91	High						

Figure 2.2: Dominant current direction coming from the northwest wrapping around Pulau Pangkor as they are deflected by the island landmass (Retrieved 27 April 2011 from Google Earth 2009)

2.4 Beach Sediment Analysis

Oil spills will affect different types of coastal facies in specific ways (Ahmad and Hassan, 1983; Ng et al., 2008). Environmental Sensitivity Index (ESI) shows the different sensitivity of the coastal beaches (Table 2.2) in the presence of oil (Castro et al., 2004). ESI is based on geomorphologic characteristics of the coast and is very important for the determination of the degree of impact and permanence of the spilled oil as well as for the types of cleaning procedures applied (Castro et al., 2004). Each ESI indicates the sensitivity of the shoreline in a range from 1 to 10, the higher the index, the greater the shoreline sensitivity to oil (Table 2.2) according to the physical characteristics such as sand beach, cliff, mangrove, tidal flats and etc (Castro et al., 2004).

Adler and Inbar (2007) used modified ESI approach to analyse the sensitivity of the Mediterranean coast of Israel to oil spill and was proven effective and permitted further analysis and prioritization of the shoreline for defense and cleanup operations. The Mediterranean shoreline of Israel like the shoreline of Pulau Pangkor, is vulnerable to marine accidents, mainly crude oil loaded tankers entering the Mediterranean from the Gulf through Suez Canal, on their way to Europe, which could cause significant oil spills from heavy traffic of oil tankers. The intensive activity in open sea oil terminals in several locations along the coastline combined with intensive traffic of coal and regular general cargo ships all posed a serious threat to this shoreline.

Ng, et al. (2008) researched on the .assessment of oil spill vulnerability of Southwest Pulau Pinang shoreline, an island to the north of Pulau Pangkor. Pulau Pinang, like Pulau Pangkor, is located in the mid-eastern sector of the Strait of Malacca. This study included field mapping, GIS (Geographic Information System) mapping and analysis of the vulnerability of shoreline resources in various geomorphology and land-use of the island. The study focused only on the southwest part of Pulau Pinang, along a shoreline of about 6 km long, and not the whole island. The objective of this study was to assess the relative vulnerability of different types of shoreline and prioritizing the shorelines types for protection in the event of a large oil spill. Ng, et al. did the assessment based on the oil spill vulnerability index by following the Environmental Sensitivity Index (ESI) approach of National Oceanic and Atmospheric Administration (NOAA) with adaptation to include shoreline types not listed under the ESI.

Table 2.2:Definition of ESI from specific data, modified of table National Oceanic and Atmospheric Administration (NOAA) (depicted from Castro et al., 2004)

Definition of ESI	Coastal geomorphology	Degree of exposition to waves	Slope intertidal	Kind of substratum	Penetration oil in the substratum
1	Exposed cliff, impermeable artificial structures	High	> 30°	Cliff	Impermeable
2	Platforms eroded by action of waves	High	< 30°	Rocky substratum	Impermeable
3	Fine and medium sand beaches	-	< 5°	Fine and medium sand	Semi-impermeable (<10cm)
4	Beaches of sand and gravel	-	5° – 15°	Coarse grain size	Permeable (=25cm)
5	Beaches of sand and gravel	-	8° -15°	Sand and gravel	=50cm
6	Beaches of gravel and rip-rap	-	10° – 20°	Gravel	Highly permeable
7	Exposed flat intertidal areas	Variable high to medium	< 3°	Sand	Limited penetration
8	Protected cliffs	Low	> 15°	Rocky substratum	-
9	Protected flat intertidal areas	Low	< 3°	Mud	Low permeability
10	Salt marshes, mangroves	Medium to low	< 10°	Mud sand	Low permeability

Ng et al. (2008) did not discuss the oil behavioral when it reaches these various shorelines for example, like the penetration of oil into the different shorelines. An oil slick reaching a rocky coast will likely be washed away or degrade quickly but an oil slick deposited on a sandy beach will cause more severe and longer-lasting effects, as the oil might penetrate into the layers of sand. Therefore in this research, a further study had been done by testing the different grades of oil penetrating into various sandy beaches that consist of different mineralogical components and grain sizes. Beach sediment analysis addresses the composition and transport of sediments on the beaches of Pulau Pangkor.

This study had been suggested by Sapari (1987) in his paper entitled "Marine Pollution and Coastal Resources Sensitivity Index". Different maps were produced according to the geomorphology, oil spill vulnerability, environmental value of the shorelines, socio-economic value and lastly a modified oil spill vulnerability map by taking into consideration the environmental and socio-economic values of the shorelines. Ng et al. (2008) modified the oil spill vulnerability index to integrate environmental and socio-economic values of the coastline into the vulnerability analysis so as to provide a better representative of the overall vulnerability. Through these shoreline sensitivity indices, proper contingency plan can be created for the protection of the shoreline according to their vulnerability.

2.5 Oil penetration

The physical properties of spilled crude oil that reaches a beach vary greatly depending on the grade of the crude oil as well as the time and distance the spilled oil has travelled before reaching the shore as oil will biodegrade naturally (Al-Lihaibi, 2000; Schlacher et al., 2010; Ornitz and Champ, 2002; Al-Lihaibi, 2003; Chandru et al., 2008; Payne et al., 2008). To simulate scenarios where different grades of crude oil were to reach the beaches of Pulau Pangkor, oil penetration tests on beach sediments were performed with 3 grades of crude oil, i.e. light crude oil, medium crude oil and heavy crude oil.

It is important to remove oil promptly from contaminated shorelines because as time passes, the oil biodegrades into glue-like masses and will stick firmly to the beach sediments or may become mixed with or buried in beach sediments (DuTemple, 1999; Schlacher et al., 2010). The rate of oil penetration into the sediments is expected to vary for each crude oil type according to the coastal facies as well as the texture and grain size of the sediments in these facies. Large pore spaces in sandy substratum allow deeper and fast penetration of oil while smaller pore space in fine-texture substratum like mangroves would not be readily penetrated by oil.

Doerffer (1992) suggested a sensitivity index (Table 2.3) which is similar to the Environmental Sensitivity Index (ESI) proposed by Castro et al. (2004) as stated above. The sensitivity index by Doerffer (1992) mainly discussed on the oil penetration on the various shoreline type and cleaning up suggestions.

Oil spills that are stranded by high tide allow oil to penetrate and accumulate in the soil. Soil organic matter slows biodegradation as it replaces petroleum hydrocarbons as a substrate for hydrocarbon-consuming bacteria (Pezeshki et al., 2000). Soil organic matter may absorb toxins and thereby reducing their bioavailability. Thus, soil organic matters reduce effects of hydrocarbons on plants. Oil on soil increase the oxygen stress and reduce the gas exchange between soil and atmosphere that disrupt the root membranes function (Pezeshki et al., 2000).

The objectives of the oil penetration tests are to determine the maximum depth of penetration and the rate in which the oil penetrates into the sediments of each beach. This will provide an indication of the buffer time that the authorities can utilize to remove the beach sand mechanically before the oil penetrates too deeply into the sediments rendering it no longer practical to be removed. The layer of oil that lies on the surface is not indicative of the amount of oil trapped in the subsurface (Schlacher et al., 2010).

2.6 Effects of oil spills, mitigating and clean-up measures.

Oil spills can cause severe localized ecological damage to near-shore community (Atlas, 1995). The effects of oil spill towards flora and fauna are influenced by many factors such as concentration of oil, oil type, duration of contact with oil, geographical location of the spill, sensitivity of an organism, its recovery potential, its tendency to

Table 2.3: Sensitivity index of shores (depicted from Doerffer, 1992)

Sensitivity index	Shoreline type	Comments
1	Exposed rocky headlands	Wave reflection keeps most of the oil offshore. No clean-up necessary.
2	Eroding wave-cut platform	Wave-swept. Most oil removed by natural processes within weeks.
3	Fine-grained sand beaches	Oil does not penetrate into the sediment, facilitating mechanical removal if necessary. Otherwise, oil may persist several months
4	Coarse-grained beaches	Oil may sink and/or be buried rapidly making clean-up difficult. Under moderate to high energy conditions, oil will be removed naturally from most of the beachface.
5	Exposed compacted tidal flats	Most oil will not adhere to, nor penetrate into, the compacted tidal flat. Cleaning is usually unnecessary.
6	Mixed sand and gravel	Oil may undergo rapid penetration and burial. Under moderate to low energy condition, oil may persist for years.
7	Gravel beaches	Same as above. Clean-up should concentrate on high-tide/swash areas. A solid asphalt pavement may form under heavy oil spill.
8	Sheltered rocky coasts	Areas of reduced wave action. Oil may persist for many years. Clean-up is not recommended unless the oil concentration is heavy.
9	Sheltered tidal flats	Areas of great biological activity. Oil may persist for years. These areas should receive priority protection by using booms or oil sorbent material. Clean-up avoided.
10	Salt marshes and mangroves	Most productive of aquatic environments. Oil may persist for years. Protection of these environments should receive first priority. Burning or cutting to be avoided.

avoid oil spill, its potential for rehabilitation and the particular life stage of the organism (Fingas, 2001; Yew et al., 2001). For example, tests have shown that juvenile salmon are 100 times more sensitive to aromatic hydrocarbons than adult salmon and salmon eggs are 70 times more sensitive than juvenile salmon (Fingas, 2001).

Plankton living in the upper layers of the sea will particularly at high risk as they are exposed to the highest concentration of water-soluble constituents leaching from floating oil (Yew et al., 2001). In the open sea, adult fish are able to swim away from the oil spill affected areas but plankton, fish eggs and larvae are not able to and thus, they are more sensitive to toxicants.

Primary physical impacts of oil spills towards plants are through the coating of the plant foliage and soil surfaces as well as the age of the plant. Coatings of leaves blocks stromata and reduce the transpiration and photosynthesis of the plants and thus leads to dramatic leaf temperature increase. These immediate effects are dramatic but plants can recover in long term (Pezeshki et al., 2000). Applications of nutrients to oiled shoreline accelerate the bacterial consumption of the oil (Pezeshki et al., 2000). Light crude oil causes immediate toxic to plants and other organisms as compared to heavy oil. However, short-term effects of crude oil on plants may appear to be dramatic initially but the study by Pezeshki et al. (2001) showed that the selected species recovered in long-term. An example from Pezeshki et al.'s (2001) study would be oiled *S. alterniflora* plants that initially showed high mortality but recovered 2 months after oil application. Such recover may be species-specific and may depend on the type of oil, mode of deliver, timing and amount of oil (Pezeshki et al., 2001).

Oil can affect fauna in many ways such as changing their reproductive and feeding behaviour and causing tainting and loss of habitat. One of the examples is that oil can cause birds fail to take care of their nests which result in egg loss and on some birds species, stop laying eggs altogether (Fingas, 2001). Birds die from heat loss through the destruction of thermal insulating properties of the plumage, unable to fly or stay afloat in the water (Doerffer, 1992) as well as damage through oil ingestion when birds are trying to clean the plumage (Cormark, 1999). Seals will react to oiling by not eating and these animals can perish from starvation. Tainting is another negative impact on animals especially fish and shell fish where the marine animals had consumed hydrocarbons that causes their flesh to have the oil taste. These tainted organisms are not safe as food consumption.

Oil can enter organisms by physical exposure, ingestion, absorption and through food chain (Fingas, 2001). Animals can come in contact with the oil directly though oil on the water surface, on shorelines or on land. Ingestion means an organism has directly consume oil, usually by accident such as birds trying to clean oil on their feathers. Absorption is very common among plants and immobile organisms. Fresh crude oil contains volatile compounds such as benzene and toluene that are readily to be absorbed through skin or plant membrane and are very toxic. Bioaccumulation is accumulation of oil toxins in the organisms when organisms exposed to oil are passed through several organisms via food chain (Fingas, 2001).

Intertidal fauna are animals that live in the shoreline zone between the high and low tides, are the most vulnerable to oil spills as their habitat are frequently coated during oil spill (Fingas, 2001). Shoreline clean up efforts such as high-pressure water can add on more negative impact to these intertidal fauna.

Oil spills enter estuarine and marine intertidal systems can cause a number of deleterious effects. When spilled oil enters the mangrove systems, oil soaks into the sediment and coats the exposed trunks, roots and pneumatophores. This causes an extensive mortality of mangroves, decline in productivity and irregular growths (Proffitt et al., 1995). Mangroves located in the intertropical zone especially in the vicinity of oil production areas and tanker routes are at high risk (Munoz et al., 1997).

The environmental sensitivity of coastal line classifies the coastal sections in habitats, in accordance with its geomorphology characteristics, sensitivity to oil spills, natural persistence of oil and conditions of removal (Castro et al., 2004). Castro et al. (2004) stated that the time of permanence of oil on environments of high energy of waves and tides tends to be lesser compared to sheltered environments. As such, natural cleaning of the affected beaches will be faster in bigger exposition to wave energy and tides areas and thus, minor sensitivity to oil spill. The coasts with high slopes are characterized by minimum time of oil permanence.

Oil spills will affect coastal facies in different ways according to their composition and sediment grain size (Ahmad and Hassan, 1983). Mitigating and cleanup measures are proposed based on the potential impact that oil spills causes on specific coastal facies. The objective of ascertaining the impact of oil spills on coastal facies is to be able to propose mitigating and cleanup measures based on the potential effects of an oil spill.

Success of bioremediation treatment depends particularly on the type of contaminated beach, the penetration of the beach material by fertilizer, the presence of the biodegradable petroleum hydrocarbons, the nature of the bioremediation product and the prevailing environmental conditions such as temperature and oxygen content (Swannell et al., 1996). Atlas (1995) stated that using bioremediation to remove oil pollutants is inexpensive compared to physical methods for decontaminating the environment which are extraordinarily expensive. For example, more than $1 million a day was spent on physical washing of shorelines which was only partially successful to clean up the oiled rocks of Prince William Sound, Alaska, after the Exxon tanker ran aground there (Atlas, 1995) on 24 March 1989 spilling 41000m^3 (Swannell et al., 1996). The actual cost for bioremediation for hundreds miles of shoreline was probably less than $1 million, excluding the efficiency and safety testing costs that were about $10 million (Atlas, 1995). However, bioremediation is not the solution for all environmental pollution problems as bioremediation has its limitations such as the material that can be treated, conditions at the treatment site and the time that is available for the treatment (Atlas, 1995). Swannell et al. (1996) stated that success of bioremediation depend on the nature of the contaminated shoreline. A few factors that must be considered before bioremediation should be used include type and concentration of oil, prevalent climatic conditions, type of beach that has been contaminated as well as nutrient and pH of the pore water in the beach (Swannell et al., 1996).

Bioremediation is not recommended on sandy beaches as bioremediation will not result in any additional benefit. Microorganisms on sandy beaches are carbon limited and respond to oil addition by proliferating. Toxicity is reduced and the levels of nitrogen and phosphorus are sufficient to result in rapid biodegradation of oil even at low concentrations of oil (Swannell et al., 1996). The sand microbial community will eventually becomes nutrient limited at higher oil levels and bioremediation by the addition of nutrients will stimulate biodegradation causing enhanced rates of oil removal from sandy beaches (Swannell et al., 1996). In salt marshes, the microbial community is limited by other nutrients such as nitrogen and phosphorus but is not apparently starved of carbon. Therefore, sources of nutrients must be applied to encourage the degradation even at low concentration of oil. Oil degradation was inhibited in the salt marsh sediments at higher concentrations of oil because of the penetration of oil into the anoxic layers of the sediment. Besides, low pH in salt marsh sediments may also reduce oil decomposition. Additional oxygen in some form will be required in such cases as a part of the bioremediation strategy (Swannell et al., 1996). Bioremediation is one of the few processes that will actually remove toxic components from the environment in terms of the biota (Swannell et al., 1996). In the Exxon Valdez case, natural rates of biodegradation on coastal shorelines can be stimulated two to sevenfold by bioremediation strategies but these techniques do not result in a rapid removal of oil comparable to that achieved by intensive physical cleaning methods. Bioremediation is a fairly complete solution to oil contamination as this process leads to the conversion of oil to biomass, water and gases which form part of the carbon cycle whereas physical cleaning results only in transferring the oil from one compartment in the environment to another. Thus, bioremediation encourages natural processes and have a low environmental impact compared to physical and chemical removal of oil. Bioremediation should be focused on the oil remaining on a beach after physical removal processes are largely complete (Swannell et al., 1996).

The most logical method of reducing the problem of oil pollution is clearly by prevention of oil spills. Elements in the prevention of oil spills includes training programs, properly maintained equipment, adequate alarm systems and strict adherence to industry and government codes (Ahmad and Hassan, 1983). For example, all PETRONAS Operators have developed their own Oil Spill Contingency Plan in their operational area. Oil Spill Contingency Plan is a pre-emergency plan that defines the action that must be taken in response to a spill before the actual event occurs (Ahmad and Hassan, 1983). PETRONAS had recently become the 40th member of Oil Spill Response on 1 June 2011 (Oil Spill Response, 2011). This shows the awareness of a need to respond to oil spills efficiently and effectively on a global basis.

In fact, there has been on going contingency plans by regional, multilateral and national efforts in curbing the oil spill according to Contingency Plans, n.d., by Marine Department of Malaysia. There is a need for regional cooperation because of the trans-national nature of this oil spill problem especially along the Strait of Malacca due to the geographical proximity of the countries, for example Malaysia and Indonesia (Ahmad and Hassan, 1983).

Ahmad and Hassan (1983), listed the three existing regional contingency plans which are

1. ASEAN Oil Spill Contingency Plan
2. Ascope Oil Spill Contingency Plan
3. Strait of Malacca Traffic Separation Scheme.

The latest list of contingency plans obtained from the Marine Department of Malaysia website are:

(a) Regional

1. ASIAN-Oil Spill Response Plan (ASEAN-OSRAP);
2. Standard Operating Procedure for Joint Oil Spill in the Straits of Malacca and the Straits of Singapore
3. Standard Operating Procedure for Malaysia and Brunei Darussalam
4. Cooperative Network for Oil Spill Countermeasure in the Lombok/Makassar Straits and Sulawesi Sea
5. Lombok-Macassar Contingency Plan

(b) Bilateral / Multilateral

1. Straits of Malacca Contingency Plan - Malaysia/Indonesia/Singapore
2. Sulu Sea Contingency Plan - Malaysia/Indonesia/Philipines
3. Brunei Bay Contingency Plan - Malaysia/Brunei

(c) National

1. National Contingency Plan for the Control of Oil Spill - Malaysia Water (incl. EEZ)
2. Straits of Malacca Contingency Plan - Straits of Malacca
3. Area of Sabah Contingency Plan - Sabah

4. Area of Sarawak Contingency Plan - Sarawak
5. Area of Johor Contingency Plan - Johor
6. South China Sea Contingency Plan - South China Sea

Another example of the contingency effort in curbing oil spills is The Petroleum Industry of Malaysia Mutual Aid Group that has been established in December 1993 which acts as a non-profit organization to enhance the protection of the environment through the provision of pooled resources in order to respond to oil spill contingencies in Malaysia and Malaysian Waters. The members of this organization include the national oil company and the oil majors operating in Malaysia. This organization operates and maintains seven equipment stockpiles in Malaysia (Petroleum Industry of Malaysia Mutual Aid Group, n.d.; Pyburn, n.d.).