

Strategy for Neutralizing Sustainable Oil Spills on Coastal and Small Islands in Riau Archipelago Province

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Abstract: Indonesia is one of the largest oil producing countries in the world. Indonesia is recorded to have produced 279.07 million barrels of oil in 2021. Indonesia's geographical location is in a strategic area which is located between the Middle East countries as oil producers and developed countries that consume oil. The Malacca Strait, which is adjacent to the Riau Islands Province as a ship transportation area, even 27% of oil spread throughout the world passes through it. In addition to economic benefits, this sea area is also at risk of oil spills which result in pollution of sea waters. The research method used in this research is literature review. The research focuses on the interior of the coast and small islands in the Riau Archipelago. The research aims to provide a collaborative strategy through sustainable oil spill management policies on coasts and small islands in the Riau Archipelago Province. The results of the research show that strategies that can be applied are socialization regarding the importance of protecting marine waters from pollution and patrolling areas that are prone to being dumps of oil. The vastness of the waters in the Riau Islands requires patrols to coordinate with BAKAMLA, Navy, Aired Police, Customs and Excise and the community. The team for handling oil in the sea of Riau Islands Province that has been formed needs to increase environmental knowledge and deepen understanding related to technology through continuous training. Operational techniques for handling oil spills must be made regular so that it is easier to concentrate and coordinate the handling of oil spills.

Keywords: Coastal and Small Islands; Strategy for Neutralizing; Sustainable Oil Spills

Introduction

Indonesia produces oil in 2020 and 2021 of 279.17 million barrels and 279.07 million barrels (Direktorat Jendral Minyak dan Gas Bumi, 2022). Petroleum resources are used as various raw materials for the manufacture of various products such as gasoline, fuel oil, petroleum gas, wax, asphalt, etc. (Wiyantoko, 2016). One of the largest exports of petroleum from Indonesia comes from the Riau Islands with an exchange rate of US\$ 153.9 million in 2020 and an increase in the following year of US\$ 170 million (Dihni, 2022). Products resulting from petroleum refinery can be used by the community and contribute to national development.

Sectors that use petroleum fuel as the main driving energy source for transportation and mobilization. The use of petroleum also has a negative impact in the form of environmental pollution (Rahmayanti et al., 2021).

Indonesia has a very strategic geographical position because it is located between the Middle East oil producing countries in the west, and oil consuming countries such as Japan, Korea, China and the USA in the east. A strategic position that is economically advantageous, but also provides a risk of environmental damage from an oil spill incident at sea. ALKI (Indonesian Archipelagic Sea Channels) includes the Malacca Strait sea lanes, the Sunda Strait sea lanes, the Lombok Strait sea lanes across the Makassar Strait, and

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the sea lanes through NTT across the Banda Sea heading north towards the Pacific. Crude oil shipments that pass through the Malacca Strait amount to 7 million barrels, an estimated 27% of the total oil transported worldwide (Badan Pusat Statistik, 2022).

Damage caused by the use of petroleum such as air pollution and oil spills (oil spill). Oil spills are caused by the operation of tankers including ship repair and maintenance (docking), loading and unloading terminals in the middle of the sea, bilge water (wastes of water, oil and lubricants produced by machine processes), ship scrapping, and the most common occurrence is accidents or collisions. tankers. The negative impacts of oil spill are the death of organisms, changes in reproduction and behavior of organisms, disruption of fish migration areas, odor disturbances, disruption of aquaculture activities, and damage to ecosystems (Rahmayanti et al., 2021).

The Riau Archipelago is adjacent to the Malacca Strait, one of which is the north coast of Bintan Island and Batam Island which are very vulnerable to environmental pollution. Matter. This is because Bintan Island and Batam Island are directly opposite the South China Sea which is a place for sea transportation for ships to trade and distribute petroleum. Oil waste can easily be found along the north coast of Bintan Island, this is thought to be caused by sea transportation activities. The adverse impacts obtained are reduced fish catches for fishermen, sedimentation, eutrication, anoxia (lack of oxygen), contaminated food chains, presence of foreign species, The Lagoi Bintan Utara beach tourism industry is deserted, the ecosystem is damaged (Country, 2020). Through this research, it can provide an overview to the public about how to minimize the impact of oil spills around the coast in a sustainable manner.

Method

The research method used in this writing is a qualitative method with literature studies in collecting data. Qualitative research. Qualitative research is a series of activities or filtering information from reasonable conditions in the relationship between the life of an object and a problem, theoretically and practically Sugiyono (2012), Literature study does not require researchers to go out into the field and meet with informants and respondents. The data in this study can be obtained from library and document sources. Literature study requires high diligence in preparing and carrying out research so that optimal results are obtained (Melfianora, 2019).

Secondary data was obtained from various literature studies discussing oil spills, especially those

examining oil spills in the Riau Islands. The research begins by discussing the problem of oil spills in the Riau Islands. Furthermore, the efforts that have been made by the community and government to reduce the impact of the oil spill. Finally, it explains the strategies given by researchers to related parties to prevent oil spills from occurring through sustainable management policies.

Result and Discussion

Government Regulation of the Republic of Indonesia Number 21 of 2010 describes the protection of the maritime environment as all efforts to prevent pollution of the aquatic environment originating from activities related to shipping. related to shipping. Based on Government Regulation Number 19 of 1999 concerning Control of Marine Pollution and/or Destruction, marine pollution is the entry or inclusion of living things, substances, energy, and other components into the marine environment by human activities so that their quality decreases to a certain level which causes the marine environment to become unhealthy. accordance with quality standards and functions.

Aspects that cause pollution from sea/shipping transportation are the disposal of liquid waste in waters, oil waste from port activities, as well as offshore exploration and exploitation of petroleum (KKP RI, 2022). According to Widodo and Wahyuni (2020), the main cause of marine pollution is due to ship activities, including.

Sailing

Shipping activities play an important role in supporting the economy between islands and countries. Vessel operational activities can have an impact on pollution of the aquatic environment, the ballast process can occur if there is an error in carrying out the anchoring procedure so that it damages the underwater pipeline.

Drilling

Drilling at sea or offshore dulling projects that have an impact on the marine environment is when a pipe leak occurs.

Refining

The process and residue from refining activities can pollute the environment, especially if it is carried out in sea waters.

Harbor terminals

Loading and unloading and all activities at the port generate sources of pollution, for example refueling if

there is a pipe leak, apart from garbage and human excrement.

Shipyards

Shipyards activities in the blasting process will emit residual rust and if it enters sea waters it will become a pollutant.

Petroleum is petroleum in any form such as crude oil, fuel oil, dirty oil, oil impurities, and refined processed products such as various types of asphalt, diesel fuel, lubricating oil, kerosene, gasoline, refined oil, naphtha, and so on. (KKP RI, 2022). The definition of petroleum according to Law no. 22 of 2001 concerning Oil and Natural Gas is that earth is the result of natural processes of hydrocarbons under conditions of atmospheric pressure and temperature in the form of a liquid or solid phase including those obtained from the mining process, but excluding coal or other solid hydrocarbon deposits obtained from activities that are not relating to Oil and Gas business activities.

Crude oil is a mixture of several hydrocarbons which are present in each location. The physical condition of petroleum is clear to black in color. Petroleum chemistry consists of 84% C, 14% H, and 1-3 S, and less than 1% a combination of N₂, O₂, metals and salts (Wiyantoko, 2016). Oil spill is one of the causes of marine water pollution originating from tanker ship operational activities in the form of repair or maintenance of ships, loading and unloading processes in the middle of the sea (ship to ship (STS)), oil pipeline leaks and ship accidents. Oil spills in marine waters do not only originate from ship operations, but other offshore activities can also be a cause of marine environmental pollution (Sulistiyono, 2013).

Tanker Ship Operations

Indonesia is a country that contributes to the world's oil industry and the Malacca Strait is an area for transporting oil, an estimated 27% of oil worldwide passes through the Malacca Strait. Oil tankers carrying ballast water are placed in slop tanks. Ships that have been anchored, ballast water is channeled into the slop. Waterjet is used to clean the tank. The effluent mixed with water and oil is pumped into a waste storage tank at the terminal, pumped overboard or replaced with new ballast water. The waste products pumped into the sea still contain oil (Hartanto, 2008).

Ship Repair and Maintenance (Docking)

Cleaning of the hull and tanks, including ship maintenance, must be carried out periodically. However, not all ships have this facility so that the remaining waste oil will be wasted into the sea (Clark et al., 1997).

Unloading in the Middle of the Sea

Unloading tankers, especially those carried out in the middle of the sea, has the risk of damaging oil pipelines under the sea either due to human error or accidents.

Bilge and Fuel Tank

Ballast water is needed by ships to sail normally, but when the weather is bad, ballast water containing oil is pumped into the sea. Another waste removed from ships is bilge water (a mixture of water, oil and lubricants).

Ship Scrapping (Cutting ship hulls that have turned into scrap metal)

Scrapping causes a lot of metal and other contents to be wasted into the sea to become pollutants that can pollute the sea. The wasted oil from this process is around 1500 tons/year.

Tanker Ship Accident

Generally, the causes of tanker accidents are hull leaks, explosions, aground, fires and collisions. Oil that enters the sea will experience changes both physically and chemically. The oil fraction will disappear and react with seawater to eventually decompose. But it takes a long time depending on the characteristics of the oil. The processes that oil will experience when it is in seawater are spreading, evaporation, dispersion, emulsification, dissolution, sedimentation, and oxidation. The impact of an oil spill according to (Sulistiyono, 2013) is explained as follows.

Direct Impact on Organisms

Lethal impact (death)

Marine oil pollution first received major public attention in 1967 when the tanker Torrey Canyon spilled 821,000 tonnes of oil into the waters of England's Seven Stones Reef. This event also caused mass death of various species of marine biota. On March 24, 1989, another 200,000 barrel oil spill occurred in Prince William Sound, due to a leak in the oil tanker "Exxon Valdes". Spread of oil covering an area of 260 km² at sea level in 1 week. The incident killed thousands of birds, otters, seals and sea lions. Oil also spreads to salmon spawning areas, threatening the livelihoods of Alaskan fishermen (Hutagalung, 2010).

Sub-lethal impact

Sublethal effects are more accurately detected in the laboratory. Laboratory experiments show results affecting reproduction and behavior in fish and crustaceans. At relatively low concentrations (<0.1 ppm), egg hatchability, survival rate, number of deformed larvae and shell coverage (in mussels) are

severely affected. Many species of shrimp and crabs have developed a distinctive olfactory system to control many of their functions and as a result exposure to B3 causes behavioral problems in shrimp and crabs in their ability to eat, eat and mate (GESAMP, 1993).

Impact on ecosystems and cultivation

The impact of oil spill on aquaculture is very large even with a small leak, apart from the directly affected aquaculture organisms, aquaculture equipment such as nets and ropes cannot be used anymore. Fish stocks are affected if they are available, they can also be affected when there is a large quantity of seawater used to supply stock needs. Coastal and marine ecosystems (mangrove forests, seagrass beds, and coral reefs) have important tasks and functions from an ecological, economic, and socio-cultural perspective. Ecologically, an ecosystem is a reproductive space that provides habitat and food for adult organisms and supports food webs (eg, food supply from leaves) for other ecosystems or environmental habitats. B3 waste input pressure affects the name of the system and the sensitivity of the ecosystem to hazardous toxins is very high, besides that natural degradation (degradation and dilution) in several ecosystems such as mangroves, estuaries and sea grasses is relatively slower. coastal lowlands (IUNC, 1993). The impact of oil pollution in the sea can be classified into long-term and long-term based on (Misran, 2002) which is explained as follows.

Long term impact

Hydrocarbon molecules can damage the cell membranes of marine organisms so that cell fluids will come out of the cells. Marine biota such as fish and shrimp will have an oil smell, so the quality will decrease. The death of marine biota such as fish will occur due to lack of oxygen, carbon dioxide poisoning and poisoning.

Short term impact

Oil that is ingested by marine organisms, some will be excreted through the digestive process while others will accumulate in fat and protein compounds. The accumulated content continues to other organisms in the food chain process. For example, the accumulation of oil in zooplankton, can move to higher organisms and even humans.

Table 1. Ecosystem Damage in the Riau Archipelago

Damage Ecosystem	Location	Source
Coral Reef	Waters Wide Ijau and Mangkait , District South Siantan , Regency Anambas , Province Riau Archipelago (Kepri)	Perpustakaan Emil Salim , 2011
Seagrass _	Village assemble Regency Bintan Island Sand City of B(Mosriula, 2019)atam , Riau Archipelago	(Mosriula, 2019)
Coral Reef	Waters Island Drooped Tanjung Pinang City Province Riau Archipelago	(Rizal et al., 2016)
Mangrove Forest	Sei Jang Estuary Area , Bukit Bestari District, Tanjungpinang City Province Riau Archipelago	(Hazri et al., 2020)
Mangrove Forest	Village Marok Kecil, Debo Singkep , Regency Lingga , Riau Archipelago	(Yogas, 2021)
Seagrass Fields and Mangrove Forests	Beach in the village Confused Sadai Batam City Riau Archipelago	(AKBAR, 2019)
Coral Reef	Waters Village Warehouse Regency Bintan Riau Archipelago	(Kurniawan et al., 2021)

Table 1, the ecosystem damage that occurred on the coast of the Riau Islands was seagrass beds, mangrove forests, and coral reefs. The majority of ecosystem damage affected is coral reefs. The coast is rich in biological natural resources that humans can process, use and exploit. Coastal biodiversity potential consists of: seagrass meadow ecosystems, coral reefs, coral reef ecosystems, seagrass beds and mangroves. More and more efforts are being made to exploit resources in marine coastal areas that are not environmentally friendly, causing a decrease in the primary productivity of the ecosystem. The positive ecological role of coral reefs, sea grasses and mangroves is to balance biological, physical and chemical factors (Vatria, 2013). In general, according to (Widodo & Wahyuni, 2020) handling of oil spills uses the following three methods.

Physics Method

Oil spill handling uses mechanical equipment, which starts with allocating oil using buoys (oil booms). Oil that is on the surface of the water and limited by oil booms will be transferred using pumps (oil skimmers)

to reservoirs in the form of tanks or balloons. The weakness of spill handling physically is that it can only be done in waters with low hydrodynamic water currents and non-extreme weather. The area around the port is also difficult to use this method because it can disrupt port activities. Ports in Indonesia do not yet have a Local Contingency Plan for Oil Pollution (oil spill management). Burning oil on site (in situ burning) is commonly used, but it only transfers water pollution to air pollution.

Chemical Method

The chemical method uses dispersants to treat oil deposits. The application that was made when Torrey Canyon in British waters in 1987 was considered to cause environmental damage. Dispersants are considered to be toxic. The development of dispersants for 30 years has shown satisfactory results, for example a product produced by Exxon Energy Chemical, namely corexit 9500. Corexit 9500 was successfully used in cleaning up the oil spill in the Malacca Strait from the collision of the tankers Evoikos and Orapin Global.

Biological Method

The biological method uses bioremediation, namely the decomposition of organic/inorganic pollutant waste in a controlled biological manner with the aim of controlling and reducing pollutants from the environment. Commercially it is relatively more environmentally friendly, relatively inexpensive and flexible handling costs. Microorganisms used as bioremediator are (liquor, function, and bacteria).

Undang-Undang RI (2009), No. 32 concerning the Protection and Management of the Environment in article 63 paragraph 2 letter (s) regulates the legal aspects of law enforcement to prevent environmental pollution, and also strengthens the authority to implement environmental legislation at the provincial level. Law enforcement officials carry out actions such as monitoring, preventing, cleaning up oil spills in the Riau Archipelago and fulfilling their duties according to the competence of each agency, but not There is action eradication (*repressive*) (Melisa Rahel et al., 2021).

Regulation of the Peraturan Presiden RI (2006), No. 109 concerning Emergency Management of Marine Oil Pollution states that Marine oil spill prevention is a fast, precise and coordinated action to prevent and overcome the spread of oil in the sea and reduce the impact in the form of community losses and environmental damage. Level prevention of oil spill in Indonesia divided become 3 (three) categories between other Levels 1, Level 2 and Level 3. Level 1 is condition For prevent occurrence of oil spills inside or outside DLKP and DLKR or operating units harbor other And can managed by facility, infrastructure And personnel harbor or units

other oil and gas operations . Level 2 is the response to an oil spill when facilities, infrastructure and personnel at ports, oil and gas operations or other Level 1 based operating units are unable to respond. While Level 3 is a classification of handling the oil crisis that cannot be managed by facilities, infrastructure and personnel in Level 2- based areas or in territory that extends beyond national boundaries Republic Indonesia (Direktorat Jendral Perhubungan Laut, 2020).

Marine pollution is divided into two types, namely pollution from shipping and port operations. Ratification of the MARPOL Convention 73/78 in the form of Keputusan Presiden (1986), no. 46 explains that every port is obliged to organize waste storage and every ship is obliged to deliver the waste port waste collection point . As the number of ships arriving at the port increases, the level of port pollution from oil spills also increases (Fakhrurrozi, 2021).

The north coast of Bintan Island, Riau Islands, receives oil spills that occur every season. Figure 1, Shows the existing condition of the oil spill that reached the coast on the island of Bintan. The black oil hit 12,170.2 meters on the north coast of Bintan, which stretches from the Nirwana resort in the west to the Rerot Bintan Lagoon in the east as shown in Figure 2 (Direktorat Jendral Pengelolaan Ruang Laut, 2019). The north wind season on the north coast of Bintan Island usually occurs in winter, the movement of the current is towards the south so that it can be seen that the north wind season brings the current from north to south. Therefore, all floating rubbish and debris will reach the northern coastal area of Bintan Island (Negara, 2020). Figure 1 shows the existing conditions on the north coast of Bintan Island, while Figure 2 shows a map of the distribution of oil spills on the north coast of Bintan Island.



Figure 1 . Existing Coastal Conditions on Bintan Island, Riau Archipelago

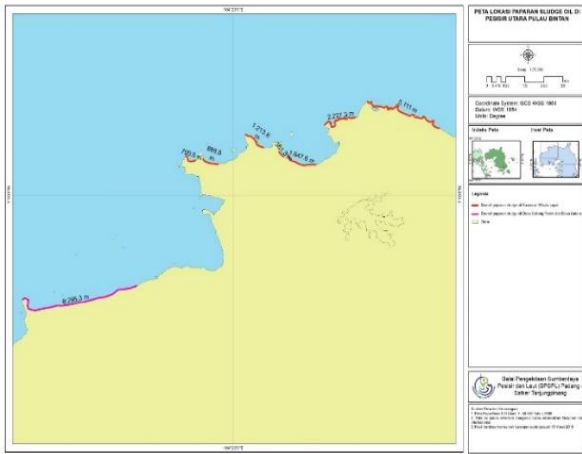


Figure 2. Map of the Distribution of Oil Exposure on the Average of Bintan Island (Source: <https://kkp.go.id>, 2019)

Bintan is an area where oil spills occur every year, allegedly due to tank cleaning activities on ships. Oil that has been spilled in the sea has spread to several resorts in Bintan and has caused losses in both the tourism and fisheries sectors. For example, on December 14 2019 there was an oil spill at sea and spread to 5 (five) Lagoi Tourism resorts, including Nirwana Garden Resort, Bintan Lagoon Resort (BLR), Ria Bintan, Banyan Tree and Club Med. Although examples of oil spills are classified as minor incidents depending on the amount of oil and frequent oil spills have an effect on long-term environmental sustainability. The oil spill that has spread to several resorts in Bintan has certainly caused losses in both the tourism and fisheries sectors. Oil spills that spread in the waters of Bintan Island, more precisely in the Lagoi area, are believed to have originated in international waters at a distance of 30-50 meters. Total oil entering the sea is estimated to reach 1,767 barrels. The oil distribution map is shown in Figure 3 (Puspitasari et al., 2020).

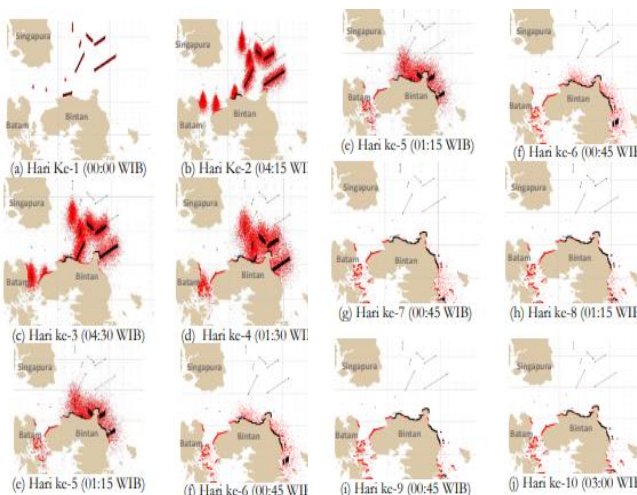


Figure 1. Distribution of Oil Spill on the Coast of Bintan Island (Source: Puspitasari et al., 2020)

The highest volume of oil and gas and non-oil exports from Indonesia in 2022 occurred in March with a total of 61 009.1 thousand tonnes (BPS, 2023). The greater the volume of exports sent by sea through shipping, the greater the risk of oil spills at sea. The black oil spill waste that reached the shores of Bintan Island in March 2022 disrupted the tourism sector and fishermen's livelihoods and damaged coastal ecosystems (Sahputra, 2022). The oil spills that occurred in the Riau Archipelago in 2020 are summarized in a map that uses various data, namely Sentinel-1A and Sentinel-2B. The oil spill distribution map from Sentinel-1A data and Sentinel-2B data in the Batam-Bintan waters is shown in Figures 4 and Figure 5 Wide oil spills that occurred in 2020 based on Sentinel-1A data amounted to 62,128 km², while the map with Sentinel 2-B data spread of oil spills covering an area of 16,241 km² (LAPAN, 2020).

Table 2. Export Volume Oil and Gas - Non- Oil and Gas in Indonesia in 2022

Component Export Import	Export Volumes Oil and Non-Oil and Gas (Thousand Tonnes)		
	Non-Oil and Gas	oil and gas	Amount
January	25 498.8	1 677.7	27 176.5
February	42 938.0	1 692.4	44 630.4
March	58 814.3	2 194.8	61 009.1
April	53 604.8	2 139.8	55 744.6
May	48 756.1	2 322.7	51 078.8
June	53 310.0	2 069.3	55 379.3
July	56 945.0	1 928.6	58 873.6
August	57 233.3	2 309.3	59 542.6
September	58 938.3	2 057.4	60 995.7
October	58 976.1	1 973.1	60 949.2
November	55 363.9	1 795.8	57 159.7
December	52 386.5	2 401.6	54 788.1
Annual	622 764.9	24 562.5	647 327.4

Source : BPS, 2023

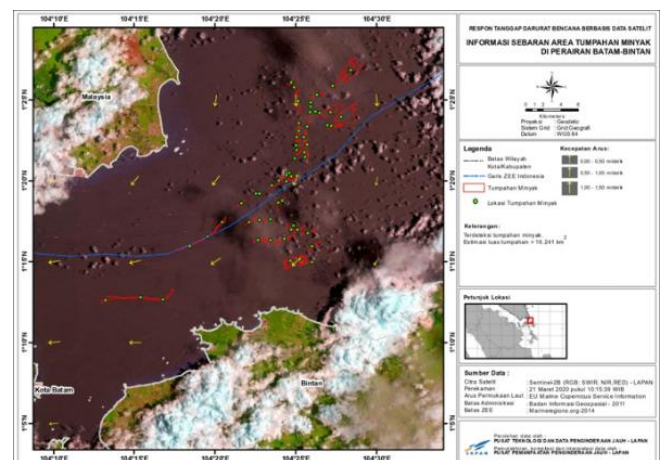


Figure 4. Distribution of Oil Spill Areas in Bintan and Batam Waters from Sentinel-2B Data. (Source: <https://sipandora.lapan.go.id> ; 2020)

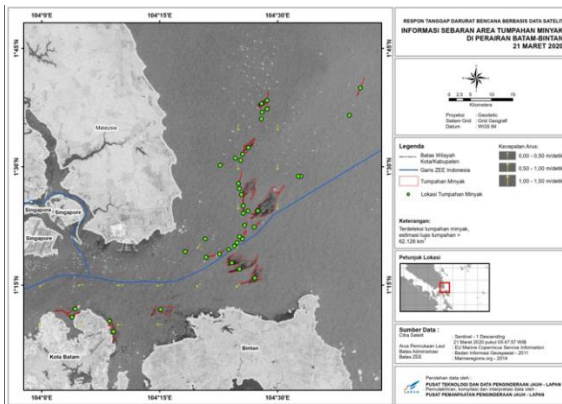


Figure 5. Distribution of Oil Spill Areas in Bintan and Batam Waters from Sentinel-1A Data (Source: <https://sipandora.lapan.go.id> ; 2020)

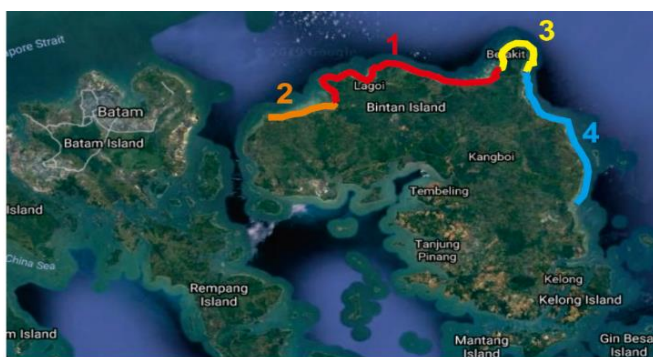


Figure 6. The area affected by the oil spill in Bintan Regency (Source: (Kurniawan, 2023))

The areas affected by the oil spill in Bintan Regency in Figure 6 have three zones including Zone 1 (Lagoi Beach), Zone 2 (Syakera Beach), Zone 3 (Berakit Beach), and Zone 4 (Trikora Beach). The interesting thing that is a constant phenomenon on Bintan Island is that when the north wind blows along the north coast of Bintan Island from Lagoi Beach to Berakit Beach, water pollution in the form of oil spills that look like lumps of oil on the coast often occurs. North wind season, which lasts from December to March. The north wind season is caused by low pressure in the Southern Hemisphere (BBS), so the wind blows from the Northern Hemisphere (BBU) to the Southern Hemisphere (BBS). The north wind season on the north coast of Bintan Island which drives the current will then head south. The north wind season will make the current move from the north. to the south, therefore, any debris, garbage or oil that floats on the surface of the water in the northern part of Bintan Island is brought to the coast. An example of a case where satellite imagery detected a 7 km leak was observed on March 16, 2023 east of Johor waters, Malaysia. The outlet is only about 50-60 km north of Bintan Island in the Riau Archipelago. On March 16, 2023, the ocean currents in the waters where the oil spill occurred moved south towards Bintan Island, making it

possible to carry the oil spill to the north coast of Bintan Island. The collection of coastal oil waste at various coastal points in Bintan Regency is carried out by the tourism area manager with the assistance of volunteers. The total oil spills collected in 2017–2020 were 576 drums of B3 waste. Every year the total oil collected always increases, it is known that in 2017 32 drums of B3 were collected and in 2018 48 drums of B3. In 2019 and 2020, 127 B3 drums and 370 B3 oil spills were collected in B3 drums (Kurniawan, 2023; Negara, 2020; Maritime Security Analysis, 2023). This data is presented in the form of a diagram in Figure 7.

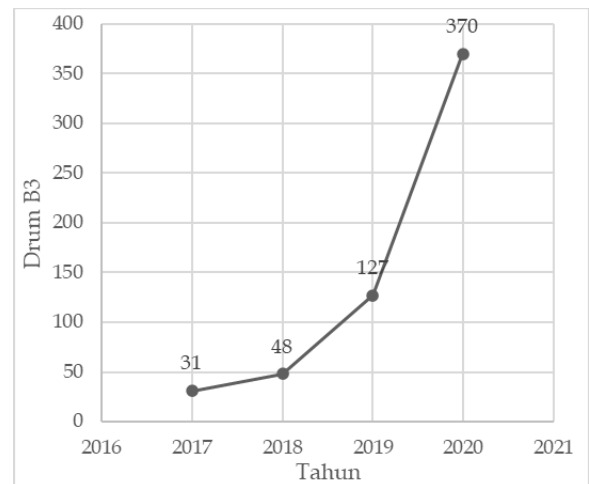


Figure 7. Amount of Oil Spill Waste Collected on the Coast of Bintan Regency (Source: (Kurniawan, 2023))

The oil cleaning carried out in October 2018 and November 2018 along the coast of Syakera Beach was carried out by the Provincial Environment and Forestry Service in collaboration with DLH Bintan Regency and the community. Oil is put into B3 drums to be transported to the B3 waste collection point. The area manager around the tourist beach of Lagoi was also given 100 empty B3 drums. The government issued a Decree of the Surat Keputusan Gubernur Kepulauan Riau (2018), No. 742 on May 14 2018. The government formed an Oil Spill Management Team in the Sea of the Riau Islands Province. This team is tasked with providing government-made leadership and collaboration that brings together various stakeholders to work together to prevent and respond to muddy oil spills. We hope this team can help protect the marine environment through actions that need to be taken by everyone involved. Operational activities in the field did not go well because the operating system was not structured. Coordinated relationships between stakeholders are also an important part of ongoing monitoring in efforts to prevent oil spills in the waters of the Malacca Strait. An active centralized coordination model needs to be created. Each team member needs to

be provided with training related to the environment so that they can realize technical operations in preventing oil spills (Kurniawan, 2016).

Efforts to overcome pollution of marine waters besides cleaning oil directly. by means of chemistry, physics, and biology. The socialization was expanded by notifying the negative impacts of sea pollution to shipping industry operators so they don't dump oil in the middle of the sea. One of the activities of ships that can enter oil in the sea is cleaning tanks in the process of loading and unloading or *docking*. The government punishes those who engage in illegal activities strictly. Therefore, it is necessary to accelerate the revision of Presidential Regulation Number 109 of 2006 concerning Management of Oil Spill Emergencies at Sea (Direktorat Pendayagunaan Pesisir dan Pulau-Pulau Kecil, 2021).

Patrols in vulnerable waters are used as locations for oil disposal and ship maintenance processes in the middle of the sea. Strict supervision will be able to reduce to prevent the disposal of oil in sea waters so that it does not pollute the marine environment. Good communication between stakeholders is needed so that it needs to be maximized through the cooperation of various coordinating agencies such as BAKAMLA (Marine Security Agency), the Navy, Airud Police, Customs, and so on (Negara, 2020).

The use of technology with various approaches in solving the problem of oil spills to completion is also very necessary. Technology is useful for minimizing and determining the location of oil spills. Determining vulnerable locations can be more easily done by using technology so that it is not only focused on patrols. Therefore, understanding technology is very important in preventing illegal disposal of oil (Kurniawan, 2023). Research related to determining the distribution and determining the location of oil spills has been carried out using software approaches and hydrodynamic models, *oil spill models* , *spill analysis* , SNAP, GNOME, etc. (Suwedi, 2017; Firmansyah et al., 2021; Sinurat et al., 2016; Puspitasari et al., 2020).

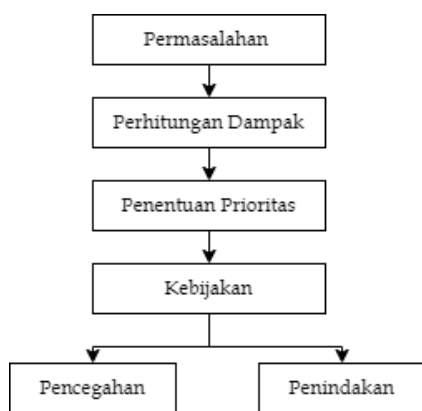


Figure 8. Schematic of Strategy for Handling Oil Spill Problems

Strategies for handling oil spill problems in Figure 8 caused by shipping and port activities through ship repair and maintenance (*docking*), loading and unloading activities, and ship accidents. The Malacca Strait as the busiest waters in the world which is near the Riau Archipelago will have a direct impact on coastal ecosystems. The impact of the oil spill will damage various ecosystems on the coast including mangrove ecosystems, coral reef ecosystems and seagrass meadow ecosystems. The priority locations that received the greatest impact were the coasts of Bintan Island and Batam City. Policies are carried out in 2 (two) ways, namely prevention and prosecution. Prevention is carried out in the form of socialization, increasing the ability and effectiveness of the performance of the Team for Overseas Oil Spill Mitigation, increasing patrols in locations prone to oil spills. Furthermore, prosecution of oil spills is carried out by the Sea Oil Spill Mitigation Team in coordination with relevant *stakeholders* for scattered oil and the perpetrators of the occurrence of the case will be responsible in accordance with applicable law, namely Law Number 39 of 2009 Concerning Protection and Management Environment.

Conclusion

Preserving the environment including the marine environment is a shared responsibility to maintain the beauty of the ecosystem so that future generations will have no difficulty cultivating fisheries and beach tourism in the Riau Archipelago can be well-known to foreign countries. Outreach and Patrols can be one way to prevent *oil spills from occurring*. Outreach to the public is useful for educating sailors to respect and protect the environment more because it will have a domino effect on human life. The patrol aims to catch the perpetrators who dump oil in the sea so that they can be followed up with punishment according to applicable regulations. Patrols are carried out by coordinating between stakeholders through institutions including BAKAMLA (Marine Security Agency), the Navy, Airud Police, Customs, as well as the community and so on. The Riau Archipelago Province Sea Oil Spill Mitigation Team needs to increase environmental knowledge and deepen understanding related to technology through continuous training. Operational techniques for handling oil spills need to be made regularly so that it is easier to focus and coordinate the handling of oil spills.

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Conflicts of Interest

The authors declare no conflict of interest.

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