

## Experiences of some countries for oil spill treatment

**Thanh Hai Truong, Huu Cuong le**

*Ho Chi Minh city University of Transport, Ho Chi Minh city, Vietnam*

---

**Abstract:** Oil spills are the release of liquid petroleum hydrocarbons into the environment due to human activities and causing environmental pollution. This term often refers to oil spills that occur in a marine or river environment. Oil can include various types from crude oil, refining products (such as gasoline or diesel), vessels' oil tanks, waste oil or oily waste. This release may take months or even years to clean up. Oil is also released into the environment due to natural leaks from the seabed geological structures. Most human oil pollution comes from ground-based operations, but the outstanding issues are especially geared towards shipping of oil at sea. The oil seeps through the feathers of seabirds, reduces their isolation, and thus makes them vulnerable to abnormal temperature changes and reduces their buoyancy. It also reduces birds' ability to fly, making them more difficult to escape predators. When trying to preen, birds often swallow oil in the stomach, leading to kidney damage, altering lung function, and stimulating the digestive system. These problems and limited ability to absorb food cause dehydration and metabolic imbalances. Changes in hormone balance including luteinizing protein can also occur in some birds when exposed to oil. Most birds affected by the spill will die, unless human intervention is involved.

**Keywords:** Oil pollution, oil spill, marine ecosystems

---

### I. INTRODUCTION

Crude oil and refined fuel spills from tanker ship accidents have damaged vulnerable ecosystems in Alaska, the Gulf of Mexico, the Galapagos Islands, France, the Sundarbans, Ogoniland, and many other places. The quantity of oil spilled during accidents has ranged from a few hundred tons to several hundred thousand tons (e.g., Deepwater Horizon Oil Spill, Atlantic Empress, Amoco Cadiz) but volume is a limited measure of damage or impact. Smaller spills have already proven to have a great impact on ecosystems, such as the Exxon Valdez oil spill because of the remoteness of the site or the difficulty of an emergency environmental response. In general, spilled oil can affect animals and plants in two ways: direct from the oil and from the response or cleanup process. There is no clear relationship between the amount of oil in the aquatic environment and the likely impact on biodiversity. A smaller spill at the wrong time / wrong season and in a sensitive environment may prove much more harmful than a larger spill at another time of the year in another or even the same environment. Oil penetrates into the structure of the plumage of birds and the fur of mammals, reducing their insulating ability, and making them more vulnerable to temperature fluctuations and much less buoyant in the water.

Animals rely on scent to find their babies or mothers cannot due to the strong scent of the oil. This causes a baby to be rejected and abandoned, leaving the babies to starve and eventually die. Oil can impair a bird's ability to fly, preventing it from foraging or escaping from predators. As they preen, birds may ingest the oil coating their feathers, irritating the digestive tract, altering liver function, and causing kidney damage. Together with their diminished foraging capacity, this can rapidly result in dehydration and metabolic imbalance. Some birds exposed to petroleum also experience changes in their hormonal balance, including changes in their luteinizing protein. The majority of birds affected by oil spills die from complications without human intervention. Some studies have suggested that less than one percent of oil-soaked birds survive, even after cleaning, although the survival rate can also exceed ninety percent, as in the case of the Treasure oil spill. Heavily furred marine mammals exposed to oil spills are affected in similar ways. Oil coats the fur of sea otters and seals, reducing its insulating effect, and leading to fluctuations in body temperature and hypothermia. Oil can also blind an animal, leaving it defenseless. The ingestion of oil causes dehydration and impairs the digestive process. Animals can be poisoned, and may die from oil entering the lungs or liver.

There are three kinds of oil-consuming bacteria. Sulfate-reducing bacteria (SRB) and acid-producing bacteria are anaerobic, while general aerobic bacteria (GAB) are aerobic. These bacteria occur naturally and will act to remove oil from an ecosystem, and their biomass will tend to replace other promising in the food chain. The chemicals from the oil which dissolve in water, and therefore are available to bacteria, are those in the water associated fraction of the oil. In addition, oil spills can also harm air quality. The chemicals in crude oil are mostly hydrocarbons that contain toxic chemicals such as benzenes, toluene, poly-aromatic hydrocarbon and oxygenated polycyclic aromatic hydrocarbons. These chemicals can introduce adverse health effects when being inhaled into human body. In addition, these chemicals can be oxidized by oxidants in the atmosphere to form fine particulate matter after they evaporate into the atmosphere. These particulates can penetrate lungs and carry

toxic chemicals into the human body. Burning surface oil can also be a source for pollution such as soot particles. During the cleanup and recovery process, it will also generate air pollutants such as nitric oxides and ozone from ships. Lastly, bubble bursting can also be a generation pathway for particulate matter during an oil spill. During the Deepwater Horizon oil spill, significant air quality issues were found on the Gulf Coast, which is the downwind of DWH oil spill. Air quality monitoring data showed that criteria pollutants had exceeded the health-based standard in the coastal regions. Since the mankind has been known to exploit and use oil until now, incidents in the exploitation and transportation of oil in the world have become a great threat to the environment in general and the ecosystem sea in particular. Environmentalists estimate that from 1900 to the present, an average of 2 to 4 major oil spills in the world each year. Notable incidents include: in 1978, the Amoco Cadiz vessel poured 231000 tons of crude oil into Brittany, Northwestern France; in 1989, the Exxon Valdez spilled 40,000 tons of oil off Alaska (USA); in 2002, the Prestige ship spilled 77,000 tons of oil off the northwestern coast of Spain; In 2007, the Hebei Spirit ship spilled 2.7 million gallons of oil into the southwestern sea of Korea[1]. Most of the oil spills at sea are serious environmental catastrophes accompanied by huge economic losses[2]. In the history of the world, many horrific oil spills have occurred, which not only affects the ecological environment but also a great damage to the regional national economy. It is impossible not to mention the oil spill that caused the whole US headache in 2010 in the Gulf of Mexico, the Deepwater Horizon oil rig, off the coast of Louisiana - the Gulf of Mexico suddenly exploded and sank, causing at least 11 workers to suffer damage, causing the most serious oil spill in the US in about half a century[3]. Millions of gallons of oil spilling into the sea threaten the ecology of the region that has been hit by floods and storms. This is also the largest oil spill in history. During the 1991 Gulf War, when Iraqi troops withdrew from Kuwait, they opened all valves of oil wells and broke oil pipelines to halt the advance of US troops. As a result, the largest amount of oil in history has covered the Persian Gulf[4]. It is estimated that the amount of oil slicks is equivalent to 240 million gallons of crude oil. Oil spill area is about the size of Hawaii[5]. To protect the water from contamination, they had to mobilize about 40 km of floating oil suction rods and 21 oil separators from the water. Together with the series of oil-suction cars, they collected 58.8 million gallons of oil[6].

Table 1. Some big oil spillage in the world

<b>Spill / Tanker</b>	<b>Location</b>	<b>Date</b>	<b>Tonnes of crude oil (thousands)</b>	<b>Barrels (thousands)</b>	<b>US Gallons (thousands)</b>
Kuwaiti Oil Fires	Kuwait	January 16, 1991 – November 6, 1991	136,000	1,000,000	42,000,000
Kuwaiti Oil Lakes	Kuwait	January 1991 – November 1991	3,409–6,818	25,000–50,000	1,050,000–2,100,000
Lakeview Gusher	Kern County, California, USA	March 14, 1910 – September 1911	1,200	9,000	378,000
Gulf War oil spill	Kuwait, Iraq, and the Persian Gulf	January 19, 1991 – January 28, 1991	818–1,091	6,000–8,000	252,000–336,000
<i>Deepwater Horizon</i>	United States, Gulf of Mexico	April 20, 2010 – July 15, 2010	560–585	4,100–4,900	172,000–180,800
<i>Ixtoc I</i>	Mexico, Gulf of Mexico	June 3, 1979 – March 23, 1980	454–480	3,329–3,520	139,818–147,840
Fergana Valley	Uzbekistan	March 2, 1992	285	2,090	87,780
Nowruz Field Platform	Iran, Persian Gulf	February 4, 1983	260	1,900	80,000
<i>ABT Summer</i>	Angola, 700 nmi (1,300 km; 810 mi) offshore	May 28, 1991	260	1,907	80,080
<i>Castillo de Bellver</i>	South Africa, Saldanha Bay	August 6, 1983	252	1,848	77,616
<i>Amoco Cadiz</i>	France, Brittany	March 16, 1978	223	1,635	68,684
<i>Taylor Energy</i>	United States, Gulf of Mexico	September 23, 2004 – Present	210–490	1,500–3,500	63,000–147,000

Before that, the history of the world has also witnessed many terrible oil spills, which were influenced first by the environment and marine ecosystems. Experts assess that the concentration of oil in water of 0.1mg / l can kill phytoplankton, greatly affecting the juveniles and larvae of benthic organisms, oil adhesion to the body or autoclave consumption through water filtration reduces the use value. Small fish eat microorganisms, and big fish eat small fish. Oil polluting the environment causes mass deaths of fish due to lack of dissolved oxygen in water; oil attached to fish reduces use value due to unpleasant odor; Oil can cause the egg to lose its ability to grow, and the eggs may become cancerous or rotten. As a country with relatively large oil exploitation and import and export activities, Vietnam is inevitably facing the risk of pollution due to oil spills. International conference "Exchange of experiences in the development, response, handling and remediation of oil spill pollution at sea" by the Ministry of Natural Resources and Environment on February 28, 2018 in Hanoi, since 2002 Vietnam has experienced 105 oil spills, causing great ecological and economic losses; Of which, up to 77% of oil spills in our country's waters but have not been compensated or in the process of settlement. A fundamental reason for this situation is that the specialized management agencies in our country lack the legal basis to handle the case. Moreover, many losses can be avoided or reduced if future development planning takes into account the causes of environmental losses.

## II. EFFECTS OF OIL SPILL ON ENVIRONMENT AND MARINE ECOSYSTEMS

In general, spilled oil can affect animals and plants in two ways: direct from the oil and from the response or cleanup process. There is no clear relationship between the amount of oil in the aquatic environment and the likely impact on biodiversity. A smaller spill at the wrong time / wrong season and in a sensitive environment may prove much more harmful than a larger spill at another time of the year in another or even the same environment. Oil penetrates into the structure of the plumage of birds and the fur of mammals, reducing their insulating ability, and making them more vulnerable to temperature fluctuations and much less buoyant in the water. Animals who rely on scent to find their babies or mothers cannot due to the strong scent of the oil. This causes a baby to be rejected and abandoned, leaving the babies to starve and eventually die. Oil can impair a bird's ability to fly, preventing it from foraging or escaping from predators. As they preen, birds may ingest the oil coating their feathers, irritating the digestive tract, altering liver function, and causing kidney damage. Together with their diminished foraging capacity, this can rapidly result in dehydration and metabolic imbalance. Some birds exposed to petroleum also experience changes in their hormonal balance, including changes in their luteinizing protein. The majority of birds affected by oil spills die from complications without human intervention. Some studies have suggested that less than one percent of oil-soaked birds survive, even after cleaning, although the survival rate can also exceed ninety percent, as in the case of the Treasure oil spill.

Heavily furred marine mammals exposed to oil spills are affected in similar ways. Oil coats the fur of sea otters and seals, reducing its insulating effect, and leading to fluctuations in body temperature and hypothermia. Oil can also blind an animal, leaving it defenseless. The ingestion of oil causes dehydration and impairs the digestive process. Animals can be poisoned, and may die from oil entering the lungs or liver. There are three kinds of oil-consuming bacteria. Sulfate-reducing bacteria (SRB) and acid-producing bacteria are anaerobic, while general aerobic bacteria (GAB) are aerobic. These bacteria occur naturally and will act to remove oil from an ecosystem, and their biomass will tend to replace other promising in the food chain. The chemicals from the oil which dissolve in water, and therefore are available to bacteria, are those in the water associated fraction of the oil. In addition, oil spills can also harm air quality. The chemicals in crude oil are mostly hydrocarbons that contain toxic chemicals such as benzenes, toluene, poly-aromatic hydrocarbon and oxygenated polycyclic aromatic hydrocarbons. These chemicals can introduce adverse health effects when being inhaled into human body. In addition, these chemicals can be oxidized by oxidants in the atmosphere to form fine particulate matter after they evaporate into the atmosphere. These particulates can penetrate lungs and carry toxic chemicals into the human body. Burning surface oil can also be a source for pollution such as soot particles. During the cleanup and recovery process, it will also generate air pollutants such as nitric oxides and ozone from ships. Lastly, bubble bursting can also be a generation pathway for particulate matter during an oil spill. During the Deepwater Horizon oil spill, significant air quality issues were found on the Gulf Coast, which is the downwind of DWH oil spill. Air quality monitoring data showed that criteria pollutants had exceeded the health-based standard in the coastal regions.



Fig. 1. Effects of oil spill on marine ecosystems

Crude oil is a mixture of substances that are liquid, viscous, insoluble in water and lighter than water. When slipping on the surface of the water, the oil forms a sticky, hard-to-wash, and difficult to evaporate; May contain toxic compounds before and after decomposition. With the physicochemical properties mentioned above, oil spill acts directly or indirectly on the coastal and coastal ecosystems in the following ways: Firstly, to change the oxygen balance of the ecosystem, prevent oxygen exchange between water and The atmosphere, facilitating the accumulation of toxic gases such as H<sub>2</sub>S, and CH<sub>4</sub>, increases the pH in the environment. Second, the oil penetrates and disturbs the living activities of the organism. Oil interferes with the osmotic pressure between the biofilm membrane and the environment; Losing the ability to regulate the pressure in the body, losing the waterproof ability of feathers and marine animals. Thirdly, oil causes potential toxicity in the ecosystem when decomposed, deposited and accumulates in the sedimentary layers of the ecosystem. When damaging plankton, the oil affects the first link in the ocean's food web, indirectly affecting other species in the chain, causing production decline and imbalance in future species, declining habitats of species living in ecosystems. The effects are due to oil seepage in the soil, sand, groundwater and the impact on adjacent fishing grounds due to the impact from seed sources and related nutrition. By causing damage to corals, sea grass, mangroves, oil spill indirectly causes coastal erosion and reduces the wave break environment. Oil spill also prevents people's activities, reducing people's income by affecting health, reducing landscape and ecological values and reducing income from tourism as well as related services. Oil spills also cause damage to stored values such as affecting natural resources, landscapes, etc. Oil spills gradually lose conservation values like rare plant species as raw materials, precious herbs, rare and precious genetic resources, habitats of some marine creatures, natural resources left for future generations (corals, seagrass ...). The incident also gradually diminishes the value of the ecosystems of the ecosystems, which come from a sense of resource retention based on faith, pride and intangible values related to cultural and spiritual life, etc., losing resources for scientific research, education, aesthetics and culture.

### III. THE POSSIBILITY OF APPLICATION IN VIETNAM

Market price method is a method of determining the value of ecosystems through exchanging and trading of products and services of the ecosystem. Losses due to environmental incidents may be determined by changes in the quantity and quality of goods or services as a consequence of the incident. To apply this method, it is necessary to determine the production surplus and consumer surplus of goods and services before and after the oil spill. Production surpluses are estimated through production costs and the revenue received from goods that meet the market demand. This method is simple, intuitive and easy to understand. Collecting data on market price, buying and selling volume is relatively simple and the cost is not high. To assess the impact of the oil spill in coastal areas of Vietnam, this method has many advantages because the collection of statistics, survey studies is quite diverse and detailed has been conducted by General Department of Statistics and many domestic and foreign organizations and individuals.

However, this method has some limitations such as: it is very difficult to distinguish the impact from incidents with other impact factors to avoid duplication and lack of loss value; it is impossible to measure losses that are not directly reflected in the market, which are unused values. Therefore, the market price method needs to be used in combination with other methods to be able to estimate the total value of losses. The travel cost method uses tourist expenses as a basis for calculating the value of attractions. By collecting the number of travel expense figures and other relevant factors (income, number of visits, etc.), it is possible to estimate the total amount of money that tourists are willing to pay for specific environmental landscapes (2). This method is often applied to tourist areas, monuments with large numbers of visitors from different regions. The travel cost estimation method has three basic approaches: regional travel costs (ZTCM), individual travel costs (ITCM), and the random benefit approach (Random Utility) Approach. It should be noted that the first two approaches are more common and simpler, while the third is more complex and costly and is also the best approach to assess the benefits of specific locations.

This method is acceptable in theory and practice. This method is based on the traditional economic model, which is the practical relationship between the quality of environmental goods and the costs spent to enjoy the value of goods. This method is based on practical behavior so it is easy to understand and implement. Our country now has many tourist destinations with high value, beautiful landscapes ... Therefore, the selection of the method of tourism cost by region is highly feasible. However, the major drawback of this method is that it is only used where there are many tourists. Therefore, places without or few tourists are not applicable. Moreover, even at popular tourist places, instead of visiting often, some buyers are always close to that location to stay. In many cases, the object does not have to spend money (indigenous people) but highly appreciates the quality of the environment there. As such, it is not possible to value the environment with only one tourism cost method, which must be combined with other methods.

The use of these methods requires a database of yields, crop yields, livestock, aquatic and marine product exploitation in the study area just before and after an environmental incident. For localities that have recorded all of these data over time, it is relatively easy to assess the losses to the direct use value. As an agricultural country with existing data and farmers' in-depth knowledge about plants and animals; Productivity change methods can be conveniently applied in Vietnam. However, as many of the evaluation methods stated, there are many factors that affect crop yields, livestock and production yields. Attention should be paid to the separation of the impact of environmental incidents from other impact factors and to account for the fluctuations in productivity over time. Using market prices may produce false results if it is not possible to separate administrative effects such as taxes, subsidies, protections or monopolies.

The health costing method is used to calculate the cost of curing diseases caused by environmental pollution. This cost is considered as the value of damage caused by the oil spill to human resources. In the health cost method, the damage is determined based on the relationship between pollution level and the level of impact on health. Research is based on the incidence of recurrent disease to measure the impact of abnormal events. By measuring the variation in the number of people infected between periods and compared to the period of the incident, the impact of the incident can be determined. The evaluation also examines the extent of the impact of the disease relative to the total cost including medical services; cost of prevention, treatment and recovery. The direct cost is the value of resources instead of creating other goods or services, it is used to pay for medical services, which are costs for medicine, inpatient and outpatient treatment, accommodation, travel expenses from home to the medical center and waiting time. Indirect costs are a person's ability to work, the income of the patient is lost, the loss is interrupted during the period of labor replacement.

In rural areas and coastal areas of Vietnam, where socio-economic development is not strong, short-term and non-dangerous diseases are often of little interest, and people tend to let the disease go away on its own or using some folk remedies, it is difficult to determine the cost of treatment. In addition, the toxins in oil spills when causing dangerous diseases often have large delays, difficult to detect early. Therefore, the application of the health cost method in Vietnam may face many limitations, difficult to bring accurate results. In general, the health cost method is easy to apply to assess environmental impacts when diseases are usually short, isolated, and have no negative effects in the long term. However, this method is difficult to deal with with chronic diseases when the disease stage is prolonged. Health cost studies are often based on estimates, so there may be uncertainty and assumptions exist in determining the cost of disease. In order to apply this method effectively, it is necessary to select suitable projects and programs according to a number of guidelines such as establishing an online relationship. In order to prevent and minimize damage caused by oil spills at sea, many measures need to be implemented in a comprehensive manner such as legal framework, building resources, strengthening equipment and cooperation. to carry out activities from preparing, coping, overcoming and dealing with oil spill consequences. Up to now, a number of legal documents on oil spill incident response and handling have been issued, the system of central to local agencies has been gradually strengthened. According to the current law, the "Oil spill response activities are all activities from the preparation, response, overcoming

and settlement of oil spill consequences", of which "Responding to oil spills" Oil spills are activities that use forces, means, equipment and supplies to promptly handle, eliminate or minimize oil spills, "and" Remedy consequences of spills. " oil is the activities to clean the soil, water, ecosystems of the oil-contaminated area and measures to limit damage, restore the environment and environment after the oil spill. Oil spill recovery is one of the important stages to limit and restore the environment and ecosystem, however, up to now most regulations focusing on coping with oil spills, regulations on dealing with oil spills are still limited. Law on natural resources and environment of sea and islands in 2015 was the first legal document regulating oil spills. at sea and has provided a section on responding to and overcoming oil spills at sea, however, only one article has the content of provisions on dealing with oil spills at sea.

Assessing economic losses due to environmental incidents in particular and environmental assessment in general are indispensable activities in the state management of economy, society and environment. This requirement is even more urgent given the risk that Vietnam is now seriously affected by global climate change. However, activities of evaluating ecosystems and the environment in general still face many difficulties. This is a field that is not entirely new but lacks the apparatus with necessary manpower, material resources and the legal framework for organization and operation. In the United States, the results of estimating the total value of damage from the CVM valuation method have been considered by the legal system of this country as a legal basis for lawsuits of oil spill damage in particular as well as environmental conflicts. general school (Bennett, 2001). A fundamental difficulty of this activity is the lack of background data, namely detailed statistics on environmental economics, fluctuations of environmental quality and the current state of pollution over time. A number of ministries and agencies have conducted their own specialized evaluation activities. However, these activities are relatively independent on a small scale. In order to build an important and consistent system of important data on environment and economy, the Government and concerned ministries and branches should soon implement necessary activities, including research and establishment. organizational system of specialized agencies to measure and build a system of baseline data on the status of natural resources and environmental pollution in the territory of Vietnam.

#### IV. CONCLUSION

Vietnam is a marine country, with about one million square kilometers of sea surface, where there are the second largest oil transportation routes in the world, transporting oil from the Middle East to Northeast Asian countries. Offshore Vietnam currently has many oil fields being exploited. Meanwhile, along the coast from the north to the south there are many shipping ports, oil ports; Every year, Vietnam's coastal areas are also affected by many typhoons and erratic weather changes. This is really a permanent threat to oil spills. According to incomplete statistics, since 1989, there have been more than 100 oil spill incidents due to marine accidents, dumping into the sea from several tens to hundreds of tons of oil. Oil spills often occur from March to June. Typically, the Formosa One oil spill occurred in 2001 in Ganh Rai Bay (Ba Ria - Vung Tau province), because of not following the Port's instructions. In Vung Tau case, Formosa One ship crashed into Petrolimex-01 ship, spilling about 900 m<sup>3</sup> (equivalent to 750 tons) of DO oil. Or the Hong Anh oil spill, which occurred in 2003, due to the large wave that sank the Hong Anh ship in Ganh Rai Bay area, spilling about 100 tons of FO oil, directly affecting the protection forest area of Can Gio and aquaculture areas. Total economic and environmental damage caused by the incident amounted to tens of billion dong. The oil spill in Vietnam not only causes socio-economic damage, but also pollutes the marine environment and severely affects ecosystems. In order to contribute to the prevention, response and overcoming incidents effectively, Vietnam needs to continue to apply science and technology, technology of investigation, assessment and warning of oil spills; building a network of environmental incident response stations in localities.

#### REFERENCES

- [1] S. Simpanen *et al.*, "Biostimulation proved to be the most efficient method in the comparison of in situ soil remediation treatments after a simulated oil spill accident," *Environ. Sci. Pollut. Res.*, 2016.
- [2] J. Sayyad Amin, M. Vared Abkenar, and S. Zendejboudi, "Natural Sorbent for Oil Spill Cleanup from Water Surface: Environmental Implication," *Ind. Eng. Chem. Res.*, vol. 54, no. 43, pp. 10615–10621, 2015.
- [3] G. M. King, J. E. Kostka, T. C. Hazen, and P. A. Sobecky, " Microbial Responses to the Deepwater Horizon Oil Spill: From Coastal Wetlands to the Deep Sea ," *Ann. Rev. Mar. Sci.*, 2014.
- [4] Z. Wang, Y. Xu, Y. Liu, and L. Shao, "A novel mussel-inspired strategy toward superhydrophobic surfaces for self-driven crude oil spill cleanup," *J. Mater. Chem. A*, vol. 3, no. 23, pp. 12171–12178, 2015.
- [6] S. Suni, A. Kosunen, and M. Romantschuk, "Microbially treated peat-cellulose fabric as a biodegradable oil-collection cloth," *J. Environ. Sci. Heal. - Part A Toxic/Hazardous Subst. Environ.*

- Eng.*, vol. 41, no. 6, pp. 999–1007, 2006.
- [7] B. Doshi, M. Sillanpää, and S. Kalliola, “A review of bio-based materials for oil spill treatment,” *Water Research*. 2018.
- [8] Jala and L. Nandagiri, “Evaluation of Economic Value of Pilikula Lake Using Travel Cost and Contingent Valuation Methods,” *Aquat. Procedia*, 2015.
- [9] S.-M. Cheong, “Fishing and Tourism Impacts in the Aftermath of the Hebei-Spirit Oil Spill,” *J. Coast. Res.*, 2012.
- [10] E. B. Barbier, “Marine ecosystem services,” *Current Biology*. 2017.
- [11] S. Shafiee and E. Topal, “An overview of global gold market and gold price forecasting,” *Resour. Policy*, 2010.
- [12] M. N. Islam and N. Q. Hung, “Climate Change Impacts on Marine Ecosystems in Vietnam,” in *Environmental Management of Marine Ecosystems*, 2018.
- [13] C. L. J. Frid and B. A. Caswell, *Marine pollution*. 2017.
- [14] M. Nyström *et al.*, “Confronting Feedbacks of Degraded Marine Ecosystems,” *Ecosystems*, 2012.
- [15] G. S. Fraser and V. Racine, “An evaluation of oil spill responses for offshore oil production projects in Newfoundland and Labrador, Canada: Implications for seabird conservation,” *Mar. Pollut. Bull.*, 2016.
- [16] A. A. Al-Majed, A. R. Adebayo, and M. E. Hossain, “A sustainable approach to controlling oil spills,” *Journal of Environmental Management*, vol. 113, pp. 213–227, 2012.