Risk Analysis and Emergency Response to Marine Oil Spill Environmental Pollution

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Abstract: The offshore petroleum industry operates in a harsh environment, which poses a great safety risk and accident rescue difficulty. With the increasing volume of world offshore oil transportation and the vigorous development of the offshore oil exploration and development business, the number of marine oil spill accidents has increased significantly, which will cause huge pollution to the marine ecological environment and also attract widespread attention from the media and the public. This paper mainly analyzes the risk of marine oil spill pollution accidents in terms of causes, characteristics and hazards, and proposes specific measures and accident prevention and emergency disposal plans in accordance with relevant standards.

1. Risk analysis of oil spill pollution incidents

1.1. Causes of Oil Spill Accidents
(1) Ship or platform operator factors. On the one hand, the operator lacks responsibility and fails to do his job properly, and is only opportunistically lazy; on the other hand, the operator is physically and mentally overworked due to long hours of continuous operation, resulting in abnormal operation.

(2) Weather. Atmospheric flow at sea changes rapidly, resulting in unpredictable and often severe extreme weather on the sea surface. In the face of blizzards and other unfavorable weather for operations, both the equipment of the tanker and the operators operating the equipment are prone to failures and mistakes, ultimately leading to oil spill accidents.

(3) Equipment Defects. The oil spill accident caused by equipment failure and damage is the most common and the most uncontrollable, such as pipelines, oil storage facilities, etc. In the case of long-term use, if there is no timely overhaul and maintenance, it is very easy to damage and cause oil spill environmental pollution.

1.2. Characteristics of common oil spill incidents
First, suddenness. The oil spill accident is a small probability accident, but it has its inevitability, and there is a great suddenness in terms of the occurrence time. Whether it can respond quickly and promptly in the face of this kind of sudden event is an important indicator of the ability of the oil spill emergency response unit.
Secondly, the extensiveness of the occurring sea area. Oil spill accidents may occur in equipment and installations such as transport ships, ocean-going cargo ships, oil pipelines, oil production platforms and sewage treatment plants. The occurrence of the accident is not limited to a certain geographical range, but may occur in the offshore, open sea and on land. Therefore, it is necessary to make the oil spill incident response resources cover as large a geographical area as possible to deal with the oil spill incident promptly and quickly.

2. Impact Hazards of Oil Spill Accidents

Marine oil spills are composed mainly of crude oil and its derivatives, which are flammable, explosive and toxic complex chemical mixtures. Once it is spilled on the sea, in addition to the most basic water pollution, it also causes great harm to the surrounding environment and organisms.

2.1. Health Hazards of Oil Spills

Due to its low boiling point, oil quickly evaporates into a gas when exposed to air. Once this gas is received by the body, it can damage the body's organs and cause a variety of pathological symptoms. The organs affected are: lungs, stomach, intestines, kidneys, central nervous system, and hematopoietic system. The central nervous system experiences symptoms such as weakness, lethargy, dizziness, seizures, and coma [1]. The oil can be harmful to the human body in other ways than in vapor form.

(1) Direct inhalation. Most often, when the pressure pump transporting the oil fails, the oil is sprayed directly to the person concerned in the form of a liquid or mist, resulting in direct inhalation into the lungs of the human body causing toxicity.

(2) Skin contact. This is the most common and most likely form of harm in oil spill accidents. All petroleum substances have some damage to human skin, not only that, these toxic substances also penetrate into the human body through the skin surface to cause harm. Take gasoline as an example, some people wash their hands with gasoline when they have oily substances on them, but their hands turn white immediately after washing. In the process, the sweat glands on the hands have already infiltrated a large amount of gasoline, which can lead to various skin diseases and even cancer in the long run [2].

(3) Indirect ingestion. This type of poisoning is caused by the indirect ingestion of toxic substances from direct contact with food and other items without washing the hands or other parts of the body after they have been contaminated with petroleum.

2.2. The Impact of Oil Spills on Safety Accidents

In addition to the most intuitive human hazards, these spilled oil substances, with their flammable and explosive nature, also pose a greater threat to safety. In the event of an oil spill, fires or even explosions can result from the inadvertent introduction of fires, such as the use of electronic communication tools, static electricity from synthetic clothing, sparks from the use of tools, and smoking, among other violations. Of course, such accidents also pose a huge safety risk when it comes to inclement weather such as thunderstorms.

2.3. Environmental Hazards of Oil Spills

The oil itself is toxic, and the damage to the marine environment when it enters the ocean is manifold. From the natural environment to a variety of organisms can be harmed in varying degrees, and the cycle of such harm is often long. [3]

(1) The impact of oil spill on shallow water coast. The fragile ecological environment along shallow waters makes it difficult for him to withstand the damage caused by the oil spill accident. Once eroded by oil, it will not only cause huge economic losses, but also pollute the surrounding ecological environment for a long period of time and is extremely difficult to control. This is especially true for oil-contaminated salt and alkali beaches, medium-coarse beaches, and gravel
beaches. Oil spills can penetrate deep and are difficult to clean up, which can have long-term harmful effects and even hinder the recolonization of organisms.

(2) Effects of the oil spill on marine organisms. First, plankton. As the lower organisms of the ocean, their resistance to oil spill toxicity is particularly weak. Plankton exist in the ocean in large quantities and are in direct contact with the oil slick produced by the oil spill accident, they will not know how to actively stay away from oil pollutants like other higher organisms, which leads to the large absorption of these oil slicks by plankton. In addition, the oil film on the surface of the sea has a strong shading ability, and without sufficient sunlight for light and action, some of the plankton will decay and become diseased, thus affecting other organisms that feed on these plankton; second, marine fish. Although fish have a more sensitive sense of smell and flexible swimming ability, and will actively stay away from nearby polluted waters, there are still a large proportion of juvenile fish without the ability to escape are vulnerable to oil spill pollution. When an oil spill occurs in such waters, whether it is left to natural decontamination or artificial use of chemical dispersants, they will be harmed; third, marine mammals. Similar to marine fish creatures, different marine mammals react differently to oil spill pollution. Some sensitive animals will be quicker to move away from the source of pollution, while those that are slower to react will be affected by harmful substances, and even some marine mammals will not want to leave the habitat they depend on to survive even if they feel the pollution, thus being poisoned.

(3) Damage to birds and other animals caused by the oil spill. In terms of the damage caused by the oil spill accident, it is the birds and creatures in the sea area around the accident, especially those birds that enter the sea to get food. These birds feed on marine plankton, fish and even marine mammals, and will not only come into direct contact with the oil film, causing their feathers to soak up large amounts of oil substances and lose their waterproof and thermal insulation abilities. They can also be starved to death or poisoned by actually eating or ingesting food that has been poisoned by oil spill contamination.

3. Problems and Challenges in Current Oil Spill Research

(1) The lack of detailed historical records of oil spill accidents is one of the major difficulties in our current in-depth study of oil spill risks. Although the numerous oil spill accidents brought about by the rapid development of the offshore oil industry in recent years have made this problem receive more extensive attention, it is difficult to carry out systematic and comprehensive summary and study of the entire accident type by relying only on the accident analysis of these concentrated time periods.

(2) Although the gradual perfection of fluid dynamics has further developed the risk assessment of oil spill accidents, there is still no specific research direction to consider the diffusion and pollution of oil spill accidents by using kinetic models, in addition, the emergency disposal for this accident also lacks scientific and reasonable reference and relevant arguments.

(3) At present, the most commonly used means to predict the oil spill accident is the statistical projection method of big data, but this method needs to be based on huge historical data and scientific and rapid algorithm. Due to the lack of a large amount of historical data and the mismatch of algorithms, this method often appears too crude and subjective. In addition, oil spills at sea are affected by various risk factors that do not always follow a predictable pattern, so we need to improve the quantification of uncertainties. In addition, the study of human reliability and failure analysis is also a major challenge that we need to address.

(4) In the process of risk analysis of environmental hazards caused by oil spill accidents, the chain of relationship between pollutants and ecosystems often remains at a superficial level, but in fact, the relationship between them is very complex.

(5) Each oil spill accident will cause large and difficult to treat environmental damage, the natural self-purification cycle of such chemical pollution is very long, so we need to carry out artificial oil removal and restoration of the environmental ecology. The funds required for this manual disposal method are huge, not to mention the cost of restoration as usual, but the cost of remediation at the early stage of the accident is unpredictable, and with the passage of time, the source of pollution will
expand and lead to an increasing shortage of funds, so whether there is a timely and adequate compensation and operation of funds for the oil spill is particularly important, which also determines the degree of environmental damage and restoration efficiency to a large extent. The accident claims in China involve many items and the claim process is complicated. Due to legislative shortcomings and outdated assessment theory methods, oil spill accidents often do not receive adequate compensation [4]. The lack of timely and adequate compensation will lead to the interruption of the pollution control process, increasing losses, and eventually forming a vicious circle.

4. Oil spill pollution accident prevention and disposal measures

4.1. Oil Spill Monitoring Technology
The most effective way to deal with the oil spill accident is to deal with the accident at the source at the early stage, so a scientific and effective oil spill monitoring system is particularly important. There are many kinds of measures for oil spill monitoring, such as sea surface patrol boat monitoring, coastal lighthouse monitoring, sea plane monitoring and satellite technology monitoring. Among them, coastal monitoring often sets monitoring device in the sea area where oil spill accidents occur, sea surface monitoring is random navigation monitoring for monitoring ships in the outer sea area where accidents may occur, and sea monitoring and satellite monitoring are mostly used for all-round monitoring of large area sea areas. In addition to the different monitoring methods, the equipment used for monitoring will also be divided into many types with the different situations of the accident.

1) Photoelectric reflective type. Photoelectric conversion of different reflected light spectral signals of seawater and oil slick into different electrical signals for display, thus determining the oil spill position.

2) Infrared light monitoring. Mainly used to determine the thickness of the oil layer on the sea surface, according to the different infrared spectra of seawater and oil layer using infrared spectral monitor, to get the maximum up to 0.1m information on the thickness of the oil layer.

3) Ultraviolet light monitoring. Its working principle is similar to infrared light monitoring, mainly through the ultraviolet spectrum monitor, to obtain the thickness of the oil spill oil film. Different from infrared light monitoring, UV light monitoring can be monitored in rainy and foggy days, and cannot work at night. And infrared light monitoring can work at night, but can not monitor in rain and fog.

4) Radar monitoring. Mainly through the radar monitor, to locate the location of the oil spill accident and the size of the oil film.

5) Laser monitoring. Laser monitor is also used to obtain oil layer thickness information, and its measurement value is better than infrared monitor, and can work in rain and fog, but cannot detect the emulsified oil film thickness value [5].

Since different monitors have different functions and application ranges, multiple detectors are often used simultaneously to obtain accurate and reasonable data in actual oil spill monitoring work.

4.2. Oil Spill Cleanup Countermeasures
(1) Set up oil boom. The oil slick on the sea surface will spread rapidly under the influence of seawater flow, so after the oil spill accident, we should first set up oil booms to prevent the spread and also facilitate further measures afterwards. There are two main modes of operation: towing booms by ships (such as U-shape, J-shape, V-shape, single-vessel unilateral side sweeping and single-vessel bilateral side sweeping, etc.); and mooring booms at fixed points in shallow water or coastal waters. (According to the environment of the accidental waters, the oil boom will be arranged at a certain angle with the seawater flow direction, and the angle will be changed in time according to the flow direction, so as to intercept the oil spill effectively.)
Table 1. Deployment length of oil boom under normal conditions.

| Applications                        | Water Environment     | Oil boom length                   |
|-------------------------------------|-----------------------|----------------------------------|
| Enclosure Control Wrecks            | Depends on sea state  | Captain’s 3 times                |
| For use with oil skimmers           | Marine                | Each oil skimmer 460~610 m       |
| Protecting River Estuaries          | Calm Waters           | 3 to 4 times the width of the water |
| Protection of harbors/ports/marshlands | Calm waters or depending on sea conditions | 5 times the width of the water domain + a multiple of the flow rate (knots) |

(2) Using oil spill recovery equipment. Oil spill recovery equipment, commonly known as skimmer, is divided into 4 major categories according to its working principle, mainly weir skimmer, oleophilic skimmer, vacuum skimmer, mechanical skimmer. The skimmers should be reasonably selected according to the actual situation in order to achieve the best oil spill recovery effect.

(3) Use chemical oil dispersant. In the process of handling oil spill accident, chemical dispersant is like a double-edged sword, on the one hand, its efficient dispersant ability plays a vital role in the whole accident handling process; on the other hand, its own chemical resistance will cause a certain degree of harm to the environment and secondary pollution. Therefore, we need to use this method under appropriate circumstances. The principle of its action is mainly to mix with the oil film, and through the up and down floating of seawater, the oil film is dispersed into many small oil droplets, and then spread with the flow of seawater, thus increasing the contact area of the oil spill and seawater, and the degradation degree of microorganisms in seawater also increases, ultimately accelerating the natural purification of the oil spill.

(4) Using biological treatment technology to remove oil spills. Biological treatment technology is a new type of oil removal method, mainly through the metabolism of microorganisms to consume the oil substances on the sea surface, so as to achieve the purpose of purifying pollution. Although the method is safe, efficient and non-polluting, and can well compensate for the shortcomings of mechanical or chemical methods, once the large-scale thick oil layer is encountered, blocking the oxygen and sunlight needed by microorganisms, the effect of this method will be greatly reduced. Experimental research shows that after adding nutrients to the oil spill oil film, the reduction rate of oil spill in 7 days increases from 10%-20% to 60%-80%.

(5) Use adsorption technology to remove oil spill. In the final stage of oil spill accident treatment, for those cases where mechanical methods of removal are incomplete and chemical methods are likely to cause secondary pollution, adsorption technology can be used to remove the oil spill. Previously, the commonly used adsorption materials include activated carbon, wood chips, chicken feathers, straw, foam and so on, but now almost all of them are eliminated and replaced by some new types of adsorption materials, which have the characteristics of oleophilic but not hydrophilic, and can also be used twice and are not toxic to the environment at the same time. After the completion of the adsorption operation, the adsorbent materials that have been adsorbed with oil have to be treated by incineration.

(6) Oil spill removal by combustion technology. Although this burning method can remove a large amount of sea surface oil spill efficiently and rapidly, it also has more stringent requirements: not only a certain thickness and area of the oil layer, but also suitable leakage speed, weather conditions, etc., as well as corresponding equipment (oil fire boom). The former is an internal factor for oil spill burning, and the corresponding.

5. Emergency Response Process for Oil Spill Pollution Accidents

5.1. Oil Spill Assessment

After the oil spill accident occurs, we should first carry out an assessment report of the accident, and the work at this stage is divided into the preliminary assessment of the oil spill accident and the further assessment at a later stage. The preliminary assessment should confirm the type and source of the oil
spill, the scale level of the accident, the severity of the damage of the accident, the negative impact of the accident as well as the emergency cost needed to control the accident pollution and remove the oil spill, etc. These contents will provide a strong basis for subsequent action decisions. In view of the characteristics of the oil spill accident, further evaluation should be carried out at a later stage in the emergency handling process, so as to ensure that no major mistakes and dangers occur in the accident handling process and no secondary pollution is caused after the accident.

5.2. Emergency Alarm
The emergency authorities should call the police urgently after evaluating the oil spill accident, and the police here mainly refers to emergency warning, emergency evacuation, emergency treatment and emergency reporting. The personnel of the organization to receive the alarm include at least: emergency command structure, command members, support agencies, emergency response team; units and individuals that may be threatened by the accident and the corresponding news media organizations.

5.3. Command Structure Emergency Decision Making
This step is to notify or establish the emergency command organization to make the guiding decision that can quickly control the scene and ensure safety based on the previous oil spill assessment and the actual situation at the scene. The specific contents include at least: emergency control and clean-up measures; traffic control measures in the accident area; measures to avoid fire and explosion at the accident site; dispatch measures for emergency resources and logistics; measures to determine the list of assisting units and their respective tasks; measures for rescue communication and accident information transmission during the accident. For those major oil spill accidents that are beyond the capacity of local emergency response departments, requests for assistance should be made to other neighboring regions or higher level agencies. If necessary, request international.

5.4. Emergency Operations Plan and its Management
After the above emergency decision is made, the action plan should be launched immediately according to the actual situation. In the process of implementation of the plan, it should be ensured that the pollution treatment equipment is properly used; the containment form to control the spread of pollution is properly arranged; the site and the surrounding sea areas are free of unrelated personnel and additional hazards; emergency resources and logistics supplies are smoothly supplied; and the work of all parties involved is properly distributed. In addition, real-time monitoring and recording of emergency actions should be carried out to ensure that emergency situations can be responded to in a timely manner.

5.5. Emergency Response Termination
Since the emergency response requires a large amount of human and material resources, it is necessary to monitor the progress of the field operation to determine whether the emergency action plan should be continued. If the overall accident control treatment reaches the expected standard and the hazard is reduced to an acceptable level, the emergency response should be terminated and ecological restoration of the treatment area should be proposed.

5.6. Evidence Summary of Incident Costs
Immediately after the emergency response is complete, an evidentiary summary of the costs incurred during the response should be conducted. This summary should include the personnel and resources spent during the response, the duration and specific items of equipment operation, the location and amount of contaminants cleaned up, and various record forms, including a forensic description of the personnel and equipment spent, in order to standardize the process for subsequent.
5.7. Summary evaluation and documentation
After all steps are completed, a summary assessment of the oil spill should be conducted to determine in retrospect the implementation of the plan throughout the emergency response, such as whether the division of tasks among emergency departments and personnel was reasonable? Did the corresponding positions do their jobs? Was the entire process smooth? Are emergency resources available to meet the emergency needs of the oil spill area? Are the safety and health measures of the operators ensured? [6] and so on. The staff should also make records to provide experience and lay a good foundation for future revision of the implementation plan and improvement of the oil spill accident model and big data calculation.

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