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STUDY ON THE SOCIAL RISK OF PETROLEUM EXPLORATION AND DEVELOPMENT ACCIDENTS: A CASE OF MACONDO ACCIDENT IN THE GULF OF MEXICO

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ABSTRACT

The process of petroleum exploration and development is related to many factors. A large number of safety accidents occur every year around the world and have an impact on the society. Due to the particularity of Marine environment, safety accidents in the process of offshore petroleum exploration and development usually have serious impacts. Taking Macondo accident in Gulf of Mexico as an example, this paper studies the social risk of petroleum exploration and development accident. On the basis of introducing the accident background, the accident process and the accident consequence, the technical reason and the management reason of the accident are analyzed, and the social influence of the accident is further analyzed. The root cause of the incident was BP's catch-up schedule, which resulted in a lack of compliance with cementing procedures such as casing running, cement injection, cement waiting, cement bond logging, and negative pressure testing, as well as inadequate supervision. After the accident, the technical treatment effect of petroleum spill was not good, and the government blindly emphasized responsibility and took little initiative to participate in the accident treatment, which turned the social risk into a social crisis and caused terrible effects. The accident seriously affected the lives of coastal residents, caused great harm to Marine life, and damaged the Marine ecological environment of the Gulf of Mexico.

Keywords: Petroleum Exploration and Development, Accident, Social Risk, Well, Gulf of Mexico

1. INTRODUCTION

Petroleum is an important resource for social and economic development, security and stability, which has an important impact on human beings Abudu et al. (2022), Shakya et al. (2022), Yang et al. (2022). Petroleum resources occur in the strata thousands of meters underground, and the underground petroleum usually have high pressure under the action of gravity of the overlying strata Randolph et al. (2011), Lei et al. (2021), Xiong et al. (2021). Exploration, drilling, completion, and production are all stages of petroleum production, each of which intersects with high-pressure reservoirs Eren and Polat (2019), Jiang et al. (2022). In the process of drilling and production, the treatment of these high-pressure petroleum reservoirs directly affects the safety of drilling and production Skogdalen et al. (2011). As a construction process with long operation time and complex environment, petroleum exploitation has certain technical risks and social risks corresponding to technical risks Skogdalen and Vinnem (2012), Zhou et al. (2017). Among various types of petroleum exploration and development, offshore petroleum exploration and development have special characteristics Vora et al. (2021), mainly reflected in the complex marine environment, the high cost of marine equipment used in the development process, and the limited convenience of handling accidents once they occur, so the occurrence of accidents will often cause serious consequences Bijay et al. (2020), Acheampong and Kemp (2022).

On April 20, 2010, the world was shocked by the petroleum spill in the Gulf of Mexico of the United States, which had a significant impact on the lives of local residents and the ecological environment Antonio et al. (2011), Arora and Lodhia (2017). In recent years, as the global economic boom continues, the demand for petroleum resources continues to increase (). Although more than 10 years have passed since the accident, the cause, process, and impact of the accident can be used as a reference for current petroleum drilling and production operations. Since the accident happened, many news reports have reported the detailed process and treatment measures of the accident, and many scholars have analysed its causes Soto et al. (2017), Greening et al. (2018), Challenger (2021). The results of literature survey show that there are few studies based on the accident process on the specific causes of accidents and their impact Harding et al. (2016). Therefore, it is necessary to analyse the social impact to provide a reference for existing petroleum development policies. This paper combs the background, process, and consequences of the accident in the Gulf of Mexico, analyses the technical reasons and management reasons of the accident, and finally studies the social impact of the accident.

2. MACONDO SPILL ACCIDENT

2.1. ACCIDENT BACKGROUND

The Gulf of Mexico, surrounded by the United States, Mexico, and Cuba, is rich in offshore petroleum resources. It is one of the three high petroleum production areas in the United States and makes an important contribution to the energy security of the United States (see Figure 1). The spill occurred in the Macondo exploration area of Block 252 in the Missibi Sea Canyon in the Gulf of Mexico, operated by BP. The Macondo well is an exploration well that is converted to a production well after an economic discovery of petroleum.

In October 2009, the Mariana drilling rig was affected by a hurricane and required repairs. Upon completion of these repairs, the contract expired, and the drilling service was provided by Deepwater Horizon. The Deepwater Horizon is the world's most advanced fifth-generation semi-submersible drilling rig, slightly larger than a standard football field. It was built by Hyundai Heavy Industries of South Korea and owned by Transocean of Switzerland.

Figure 1

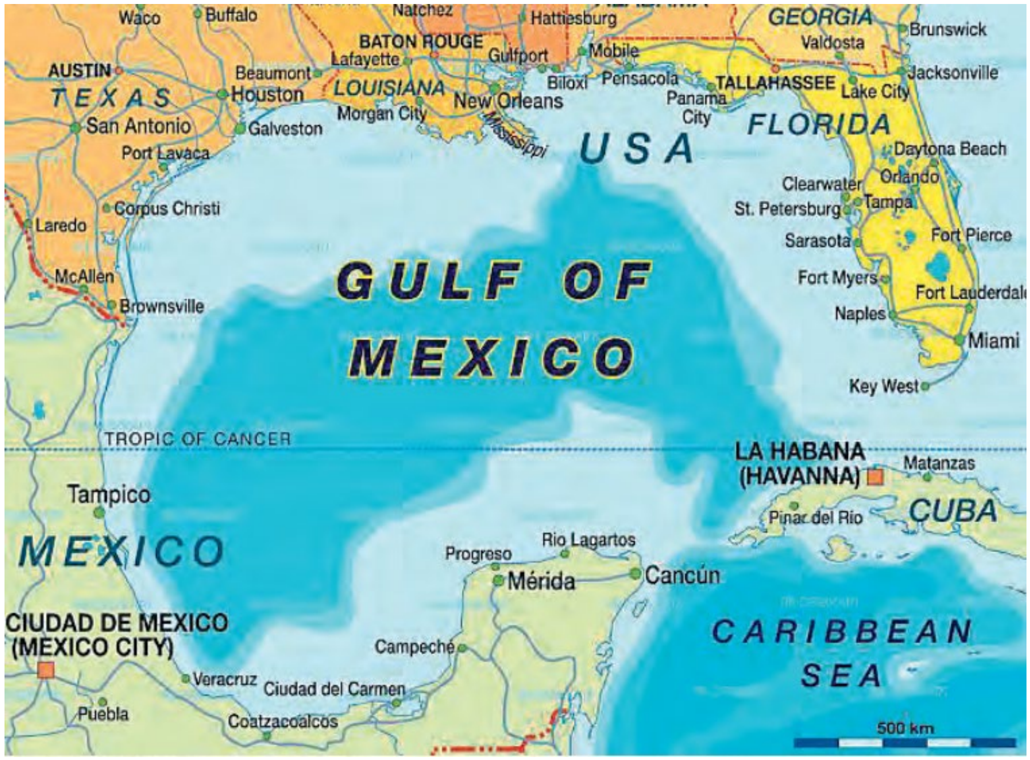

Figure 1 Geographical location in the Gulf of Mexico

2.2. ACCIDNET PROCESS

The Macondo well was drilled to 5,5989.3 m and was abandoned after cementing and pressure testing the production casing to 5,599. 1m. On the night of April 20, 2010, seawater was used to replace the drilling fluid 16. 5 hours after the cement had been waiting to set. However, the riser pressure, which should have fallen, increased by nearly 69MPa. By 240am, the wellbore pressure balance had broken, and the drilling mud and petroleum had spread into the sea. Seven minutes later, the combustible gas alarm went off for the first time and within a minute, the power went out, accompanied by two explosions. After the failure of compensation tests to shut in the well and detach the platform from the well, managers directed personnel to evacuate and abandon the rig at 2200 hours. At 10 a. m.

On April 22, another explosion occurred on the rig and the rescue flotilla failed. The rig sank into the deep sea. Although most of the people on the platform had been evacuated, there were serious casualties.

On April 24, two underwater probes sent by BP showed petroleum leaking from the riser and casing above the mud line. Detection estimates put the petroleum spill at 1,000 barrels a day, and ships and aircraft have been deployed to clean up the water. Figure 2

Figure 2

Figure 2 General View of the “Deepwater Horizon Oil” After Accident

Source https://cdn.britannica.com/58/139558-050-9EEE9E93/Fireboat-response-crews-blaze-oil-rig-Deepwater-April-21-2010.jpg

In the days that followed, the National Oceanic and Atmospheric Administration found multiple leaks and estimated that the petroleum was leaking as much as 5,000 barrels a day. However, BP disagrees with this figure.

On May 2, the first relief well was drilled. A second relief well was drilled on May 16, but it will take about four months to complete.

On May 14, BP installed a suction device at the subsea petroleum vent, but after failing to contain the flow fundamentally, it decided to plug the well.

On May 26, BP began using the "top kill" method, which involves injecting plugging material into the well from the wellhead in an effort to contain the spill.

On May 29, the method failed because of excessive fluid pressure in the well. The leak, which had been partially contained, was restored on June 23 when a device designed to contain the leak failed and began maintenance.

On July 10, BP removed the failed containment device and replaced it with a new one. Five days later, BP announced that the new device had effectively contained the spill and that no more petroleum was leaking from the site. In the meantime, BP will continue drilling relief Wells to permanently plug the well.

On September 19, the relief well was completed and permanently plugged.

2.3. ACCIDENT CONSEQUENCES

A total of 126 people were aboard the Deepwater Horizon rig at the time of the accident. Although most of them were evacuated before the explosion, 11 people were killed and 17 injured.

The Deepwater Horizon was the world's most advanced fifth-generation semisubmersible drilling rig at the time, costing up to $350 million. However, with two explosions in the course of the accident, the rig eventually sank.

The well was eventually capped, but 4 million barrels of petroleum spilled and only 810,000 barrels were recovered. The rest spilled into the sea. The spill contaminated nearly 1,500 kilometers of beaches and covered at least 2,500 square kilometers of seawater with petroleum.

BP was fined $20. 8 billion by the U. S. government on October 5, 2015, for the incident, despite the company's proactive handling of the incident. In response, BP sold more than $50 billion in assets, lost more than $70 billion in market value, and its rating was cut six notches from 3A to 3B.

3. ACCIDENT CAUSE ANALYSIS

3.1. TECHNICAL REASONS

Casing is a steel pipe used to seal formation and fluid in open hole section. The type and specification of casing should be selected according to formation characteristics, well structure and drilling technology. On April 9, 2010, operators were divided over whether to run the liner first or directly into the reservoir casing. Running the liner first would slow down the schedule, while running the casing directly in the reservoir could shave three days off the schedule and save $7 million to $10 million. However, BP ignored the safety option and ran a long string of casing to complete the well on April 15.

A centralizer installed between the casing and the wellbore is used to support the casing and center the casing to ensure cement quality during casing running. Prior to the operation, Halliburton simulated the well with software based on American Petroleum Institute (API) standards and required 21 centralizers to center the casing. However, BP's crew used only six centralizers, increasing the risk of the upper jump tank. BP used nitride foam cement slurry for the completion of the casing. Halliburton's cement cement design was defective, due to factors such as insufficient cement use in the external reinforcement well design and insufficient circulation of drilling mud prior to cement injection. With the initial drilling more than a month behind schedule, BP used seawater to replace the drilling fluid in an effort to catch up. Because the column pressure in the wellbore cannot balance the formation fluid pressure, the formation fluid is immersed in the wellbore.

In fact, after cementing, cement bond logging should be used to check whether the cement is firmly cemented to the casing and the borehole wall. If the cement is not properly cemented, repair measures should be taken. However, in order to save testing time and cost, BP did not perform cement bond logging, so it was not possible to detect poor cementing areas and perform extruded cement remediation accordingly. On the morning of April 20, BP carried out the integrity test of the well, and the positive pressure test was successful. In the afternoon, a negative pressure test was conducted on the liner cement ring, and seawater was used to replace the mud in the hole after the isolator was injected. However, in the case of three failed tests, the technician did not take the necessary action, and the test was deemed a success. In this case, the drilling fluid in the wellbore was continued to be replaced with seawater, resulting in an influx of formation fluid into the wellbore.

Technicians failed to shut down the BOP until an hour after the kick occurred at 20pm. Formation fluid gushed out of the wellhead, followed by an explosion in the mud pump room and a failure of the well control system.

3.2. MANAGEMENT REASONS

In order to save time and cost during the cementing process, BP failed to set the centralizer according to API standards, thereby increasing the risk of casing cementing quality. Halliburton's nitride foam cement test was incomplete and had design flaws, while BP did not identify design quality issues through regulatory oversight. BP used seawater for recycling when there was not enough time to wait for setting after cementing with a defective design. At the same time, the well was not cemented with a cement bond log after cementing, which resulted in a failure to detect cementing quality problems.

The blowout preventer, which is installed at the wellhead and is the last barrier to a blowout, was not activated after the Deepwater Horizon accident, and the associated automatic backup system was not activated. The accident investigation revealed that, to save time and money, the rig's blowout preventer valves were tested instead of using permanent variable diameter RAMS, a design that increased the risk of valve failure.

The investigation found that during the drilling and completion process, the drilling cycle was much longer than expected, and in order to meet the schedule and save the cost of leasing the drilling platform, there were problems such as non-compliance with the design requirements and inadequate supervision during the completion process. According to the design, BP company should be aware of the safety inspection every month, however, BP company's inspection frequency is far less than the design requirements and the implementation is not strict.

The accident happened; the government supervision is not in place is also a big reason. The investigation found that regulators from the Minerals Management Service, which rents out the platform, failed to do their job and accepted gifts from those under their supervision. The investigation even found that the bureau had broken rules by allowing subjects to fill out their own inspection documents with pencils. At the beginning of the accident, the government department failed to realize the severity of the accident in time and blindly blamed BP and demanded that it bear all the responsibility for the accident.

4. SOCIAL IMPACT OF THE ACCIDENT

Social risk is a possibility that causes social conflicts and endangers social stability and social order. To be more precise, social risk is a possibility of social crisis. Once the possibility of social risk turns into reality, the social risk will turn into a social crisis, which will have a disastrous impact on social stability and social order. Any major project involves many influencing factors, there are technical risks and social risks, and the potential social impact is also great.

The accident took five months, and although the well was permanently capped, the impact of the accident was devastating. The worst-hit state, Louisiana, for example, has polluted more than 160 kilometres of coastline. With the "hurricane season" approaching, the impact of petroleum pollution will be further increased. Normally, the marshes of the Gulf coast are a buffer against hurricanes, but the crude petroleum of the ocean coast can greatly increase the impact of hurricanes. To the south are the spawning and breeding grounds of Atlantic bluefin tuna and sperm whales; to the west and east are the reefs and fishing grounds of Texas, Mississippi, Alabama, and Florida; and to the north are the marshlands of Louisiana. Fisheries along the Gulf Coast are unsustainable, many species are endangered, and the environment is devastated.

The petroleum spill in the Gulf of Mexico also covered the sea surface, slowed ocean circulation, and prevented the water from replenishing oxygen. It also consumed a large amount of oxygen in the process of petroleum removal, which seriously affected the survival of Marine life. In addition, BP also used a number of dispersants in the treatment of the petroleum slick, these dispersants contain a variety of harmful components, will also exacerbate the damage to Marine life. In addition, as the petroleum continues to spill, a large number of technicians responding to the accident, workers cleaning up the slick and Gulf Coast residents are experiencing dizziness and nausea. According to the Environmental agency, 46 percent of Louisiana residents surveyed believed they had been harmed by the petroleum spill and treatment agents, and 75 percent believed they were suffering from the resulting side effects.

The United States requires companies to be requalified, and those who fail to meet the requirements will be disqualified. In response to this incident, the U. S. has raised the bar for offshore petroleum production, increasing HSE costs for petroleum companies by more than 10 percent. However, these costs will ultimately be paid by consumers and indirectly contribute to higher petroleum prices. Petroleum, transportation, fishing, and tourism are the major industries in the Gulf of Mexico. The spill has had a major impact on petroleum production, as well as on the fishing, tourism, and shipping industries. With the passage of time, the petroleum spill will continue to spread, bound to have a long-term impact on the industry.

The United States, with its great economic and technological strength, is also ill-equipped to deal with such global public issues that threaten human security and their implications. Up to now, there is still no effective solution for similar petroleum leakage accidents. Beyond that, more of the effects of the spill are already known, but there are many that are currently undetected or undetectable. Of course, this has prompted humans to think about how to prevent similar situations and develop effective emergency response methods and mechanisms. The root cause of the accident was BP's rush to meet the deadline, but many people interviewed were still worried that the government could not prevent a similar accident from happening again. The investigation also showed that the accident caused a large number of residents to suffer from psychological problems, and some were even forced to move.

5. CONCLUSIONS

The Macondo spill was an avoidable human accident. BP, in an effort to catch up, failed to install an adequate number of centralizers in the casing run directly after the well was drilled, used a poorly stable foam nitride cement to cement the well, and did not have enough time to set the cementing slurry. To save time and money, BP did not use a cement bond log to test the bond between the casing and the wellbore. After the kick occurred, the Deepwater Horizon rig failed to effectively control the formation fluid through the blowout preventer. The accident not only caused significant economic losses and waste of crude petroleum, but also resulted in sea water pollution, which further harmed many living things and endangered some species, eventually causing serious ecological damage. The accident also affected the lives of local residents, some of whom suffered from health or psychological problems caused by the petroleum and treatment agents, and even left their homes due to the accident. Of course, the company directly responsible for the accident has been fined heavily, its performance has been damaged, its reputation has been damaged, and the development of the entire petroleum industry has been affected.

CONFLICT OF INTERESTS

None.

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