An Analysis of Oil Spill Clean-up Techniques by Reviewing Historical Oil Spills and Analysis of Advanced Cleanup Techniques

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Abstract-*Oil spillage is one of major disaster. Once oil spill occurs, it poses adverse effects on marine as well as coastal ecosystem. This paper will contrast techniques used for oil spill clean-up by reviewing historical oil spills. I will provide a comparative analysis for response to oil spills that occurred in Santa Barbara, California in 1969; the 1989 Exxon Valdez Oil Spill; a 1997 spill that occurred in the Sea of Japan; and the 2010 Deep Water Horizon spill that occurred in the Gulf of Mexico. I will use these four spills as case studies to illustrate the methods used in the past for oil spill responses with the aim of contrasting oil spill remediation techniques used in each instance and to examine the outcomes of the response effort. Another goal of this research paper is to provide a review that summarizes cleanup techniques and strategies, and to determine under what conditions they are most effective. An additional goal is to assess what progress has been made in spill response and remediation technology. I will conclude with recommendations for future oil spill cleanups based on my findings.*

Keywords-Disaster, Incidents, Environment, Spill response, Cleaning up, Coastlines.

I. INTRODUCTION

The world has become more and more dependent upon oil based products, derived from petroleum. These products are used to fuel automobiles, heat homes, produce energy, and are used for machinery in various industries. Some of the products that come from petroleum are gasoline, diesel, motor oil, kerosene, jet oil, heating oil, asphalt, and plastics. Oil is primarily stored and transported in large volumes via tankers because populous countries use large quantities of oils, and it is more cost effective to transport oil this way. However, while in storage or in transport, oils are sometimes spilled onto land or into waterways. Oil spills are a continuing problem throughout the world. Disasters such as the Deep Water Horizon oil spill and the Exxon Valdez oil spill, provide evidence that coastal oil spills pose danger to the economy and natural resources, and could directly affect the public's health.

II.OIL SPILL RESPONSE METHODS

Oil spill response methods continue to evolve and research is constantly ongoing due to the constant impact of environmental factors and how they interact with oil spills. Many improvements for response methods currently being used continue to be tested and redeveloped. Furthermore, each spill response can bring understanding of new ways of cleaning up oil. The Deep Water Horizon oil spill that occurred in the Gulf of Mexico in 2010 reinforced the need for responders to understand in situ burning and dispersants in a new way.

There are many different types of response methods including: passive removal, manual removal, and mechanical techniques. Some of the techniques used are: natural attenuation, sorbents, booms, bioremediation, chemical techniques such as dispersants, in situ burning, flushing and flooding, and high pressure hot water flushing.

Oil spill cleanup methods pose environmental impacts because not only is there oil in a place where there shouldn't be, but now there is a cleanup crew there as well. Some cleanup methods are effective at removing oil but can result in environmental stressors to the coastlines and natural habitat. Some of these environmental stressors include: trampling the shoreline by response crews, vehicle degradation, and equipment overloading the shoreline.

There are two classifications for oil spill response methods. These classifications are either non aggressive removal or aggressive removal. The first classification is nonaggressive removal, which includes methods such as, vacuum removal which used vacuum trucks to collect standing oil; physical removal such as using machinery to remove oiled debris form fouled coastlines; manually removing the spilled oil by using sorbent materials like straw to absorb the oil; low

pressure washing of the coastlines, with the use of non-hot water; and finally the use of bioremediation to eliminate the oil by adding oil eating organisms in the affected area. The second classification is aggressive removal, which includes methods such as: relocating oil fouled sediments by using trucks, bulldozers, and heavy machinery that tramples and causes disruption to the natural coastline; the use of water with high temperature that is sprayed at high pressure to remove the oil; chemical cleaning to remove the oil, which in return will harm the natural environment by introducing toxic chemicals, and finally sand blasting the coastline to remove the oil. Oil spill response methods differ along coastlines because of the vast amount of variables that influence the spilled oil's direction and destination. Methods such as flooding and flushing, high pressure hot water flushing, in situ burning, booming and sorbent, dispersants, bioremediation, and other chemical treatments have been used and prove to be effective along shorelines. When responders decide what technique to use when responding to an oil spill they have to consider many factors such as; keeping the responder safe on the job site, shoreline accessibility, availability of response equipment for cleaning oil, the weather currently at the coastline while still factoring in wave and tidal predictions, how deep the water is, and finally what is the physical state of the weathered oil at the time of the response. Equipment such as: booms, skimmers, sorbents, chemical and biological agents, vacuums, and shovels are used to collect oil. The goal of these response methods is to remove the spilled oil from the fouled coastline, and to create a catalyst for the natural environment to recover from an oil spill. Incident command systems have to factor in a number of tradeoffs for social and economic interests when considering what response method to use for an oil spill cleanup, so it is not always a straightforward decision.

Table -1: Methods For Cleaning Up Spilled Oil

Methods for cleaning up oil	**Advantage and Dis-advantage**	**When to Use**
Bioremediation; which is the use of biological agents to break down or remove spilled oil.	Inexpensive, effective, but hard to control and still poses risks on human health	bacteria needs to be readily available, when other methods will cause harm to natural environments
Controlled burning/ In-situ Burning	Reduces oil but can cause wind pollution	Large oil slick, when human health is not at risk
Dispersants; which cause the oil slick to break up and disband.	Separates the oil slick, but still pollutes the water	Large oil slick, bacteria needs to be readily available
Vacuum and centrifuge; which collects and separated the oil and water	Effective method, but can disturb the natural environmental with heavy clean up machinery	When oil is floating, when oil can easily be collected, when location allows access
Natural Attenuation; is a method of allowing the natural environment to degrade the oil	Used in ecological sensitive areas like wetlands	When other methods will disrupt the natural environment
Dredging; used for oil that is dispersed with detergents.	Eliminates oil by physical removal, but can only be used for oils denser than water and can disrupt the surrounding environment.	When the environment allows access, when oil has been removed from the top layer of sediment but still exists below.
Skimming; which traps spilled oil for later separation	Effective method, but requires calm waters at all times during the process of skimming	When oil is floating, easy to surround the oil, clam winds and ocean current

Table -2: Equipment Used For Cleanup Operations

Oil Spill Clean Up Equipment	**Description**
Booms	Floating connected barriers that gather the oil for easy collection, can relocate oil floating on ocean's surface, can be used as a sorbent as well
Oil Skimmers	Skims the oil floating on the ocean's surface for collection and separation.
Oil Sorbents	Large solid absorbents that absorbs oil, can be chemical and natural forms
Chemical and biological agents	Helps to break down the slick oil, and disperse the oil for later collection
Vacuums	Removes spilled oil from fouled coastlines and the ocean surface.
Rakes, shovels, tractors, bulldozers, conveyor belts, and other road equipment	Manual labor tools used to clean up/collect oil on beaches

Table -3: The Best Suitable Cleanup Method For A Particular Oil

Oil	Cleanup method
Diesel	Surface Dispersant
Heavy Crude Oil	Skimmer
Light Crude Oil	Skimmer
Bunker C Oil	Sorbents

III.HISTORICAL SPILL INCIDENTS

There have been many oil spill events that have occurred in the past and damaged coastlines throughout the world. Some spills are larger than others, and some spills although not as large as, have a greater environmental impact. I researched four different oil spill events that have occurred over the past 50 years: The Santa Barbara oil spill of 1969 in Santa Barbara, California; the Exxon Valdez oil spill of 1989 in Prince Williams Sound, Alaska; the Sea of Japan oil spill of 1997; and the Deep Water Horizon oil spill of 2010 in the Gulf of Mexico. What follows is a summary of each incident, the different types of response methods used during each cleanup, any long term impacts that arose during the oil spill cleanup, and lessons learned after the response.

A. Santa Barbara Oil Spill 1969

The Santa Barbara Channel was where the first offshore oil drilling took place in the world. On January 28 1969, a 3,500-foot deep well had a disastrous pressure increase 5 miles off the coast of Santa Barbara California. Union oil which is now called Unocal, was granted a waiver by the United States Geological Survey (USGS), which allowed Unocal to use a shorter casing than required on the pipe that went into the sea floor than Federal Standards had originally prescribed 34 to use. A casing on a well is the part on the well that prevents blowouts. In this incident, the seafloor underneath the well cracked, causing oil and natural gas to disperse from the sea floor. On the eleventh day of the oil spill the well cracks were sealed by chemical mud, however shortly thereafter, more oil escaped, approximately 3 million gallons more. All wildlife in the incident area was affected by the toxicity of the oil. Following the spill, close to 3,500 dead coastal birds were removed from the coastline along with many seals and dolphins. Many bird populations were disrupted due to the incident, and many of them were endangered already. The oil spill incident also killed intertidal invertebrates and fish. Coastal kelp became disrupted as well and indirectly choked out food chains. Oil spill clean ups began immediately following the oil spill. Much of the response help came from the local communities of Santa Barbara. Many responders used boom made of straw piles to absorb the oil. The contaminated boom was bulldozed and trucked off location for proper hazardous material disposal. The use of skimmers also helped to gather the oil that was on the top layer of the ocean's surface.

B. Exxon Valdez Oil Spill 1989

The Exxon Valdez oil spill disaster occurred on March 23, 1989 in Prince William Sound, Alaska. This oil spill at the time was the largest in United States history. The Exxon Valdez tanker ran off course and grounded on Bligh Reef. An estimated 11 million gallons of oil was spilled during the disaster's duration. The responsible party for the oil spill was the Exxon Corporation. The oil spill resulted in an estimated 2.1-billion-dollar cost. The largest spread of oil from the spill was 460 miles.

C. Sea of Japan Oil Spill 1997

The shipwreck of the Russian tanker Nakhodka, occurred along its journey from Shanghai to Russia. The oil spill disaster occurred on January 2, 1997 in the Sea of Japan, off the Island of Honshu. The oil tanker broke into two while carrying 6 million gallons of fuel oil. Initially, 1.9 million gallons of oil spilled out of the tanker with the remaining oil left in the bow of the ship. When the bow of the tanker reached the Japanese coastline, it released the 46 remaining amount of oil and fouled the beaches. An estimated 300 km of coastline was fouled with oil.

D. Deep Water Horizon Oil Spill 2010

The Deep Water Horizon oil spill occurred on April 20, 2010 in the Gulf of Mexico and lasted for 87 days. This oil spill was rated the largest oil spill in United States history. The oil spill happened due to an explosion on an oil rig which resulted in 11 initial deaths, 2 response deaths, and 17 injured. The oil rig was near the states of Louisiana, Alabama, Mississippi, and northern parts of Florida. The largest reported slick was 24,435 square kilometers. The coastline was fouled with a reported 1665 kilometers of shoreline oiled. The oil spill resulted in an estimated 4.9 million barrels of oil spilled. The responsible party involved with the disaster was British Petroleum BP. Clean up costs for the incident ran close to 11.6 billion dollars.

Table -4: Summary of Historical Oil Spills; Santa Barbara 1969, Exxon Valdez 1989, Sea oJapan 1997, Deep Water Horizon 2010.

Santa Barbara	**Exxon Valdez**	**Sea Of Japan**	**Deep Water Horizon**
Gallons of oil 3 million gallons	11 million gallons	1.9 million gallons	210 million gallons
Occurrence Oil Platform blowout	Tanker crashed into Reef	Tanker broke into two	Oil Well Explosion
Clean up Cost $ $25 Million	$2.1 Billion	Undetermined	$11.6 Billion
Resources at Risk Amenity, Beaches, Fish, Recreation	Economy, Fish, Tourism	Historical Sites, Fish, Beaches, Recreation	Fish, Beaches, Recreation, Economy
Response method(s) Sorbent, Boom, Manual removal, Press	Hot washing, High Pressure Washing, Boom Sorbent,	Labor, Boom, Sorbent, Dispersants	In-situ Burning, Dispersants, Sorbent, Boom, Skimmers, Vacuums
Effectiveness Effective due to spill occurring almost 50 years ago.	Oil still present And ecosystem has not fully recovered	Effective, recovered ecosystem and coastline	Undetermined, More research needed in the future

IV. ADVANCED AND FUTURE CLEANUP TECHNIQUES

A. Grooved Disc Skimmer Technology

Grooved disc skimmer is an improvement over existing disc skimmers. The skimming discs are provided with grooves which increase the surfaces area resulting in skimming efficiency. This technology is patented by a company named "ELASTEC". The company was awarded first prize in "Wendy Schmidt Oil Cleanup X Challenge" for the innovative technology by recovering at a rate of 17677.87liters per minute with an oil to water efficiency rate of 89.5%.

B. Magnetic Separation Using Nanotechnology

This method uses magnetic nanoparticles and a magnetic field system to collect oil from water. The nanoparticles are water repellent and when poured into oil-water mixture sticks with oil. The surfactants present on the nanoparticles are hydrophobic and lyophilic and thus enables to stick with oil. The process is envisioned to be conducted on a recovery vessel so that a possible mixing up nanoparticles directly with sea is avoided and also helps to calculate the concentration of nanoparticles to be used in the mixture.

C. Basalt Fiber Technology

Basalt fiber is manufactured from basalt rock which is a lava derived rock. Basalt rocks are melted and extruded though small opening to produce basalt fiber. The basalt fibers are lyophilic and hydrophobic which help them to absorb oil up to 75 times their own weight. So when the fibers come into contact with oil, the oil alone is absorbed, which makes basalt fibers usable in oil spills. The oil can be reused and basalt fibers can be recycled and be used for other purposes.

D. Microbes

The use of genetically modified microbes to eat up oil is being tested by scientists. The scientists are looking forward to create microbes which would eat up oil and die after it has been completed thus ensuring safety to the biodiversity.

E. Swarm Robotic System

Swarm robotic system is a collection of individual robots working collectively to achieve a desired task. This system could be implemented on sea with each individual robot having a cleaning system on board and being coordinated by GPS during cleanup. The cleaning system may include anything from simple burring to collection and dumping (on to a floating barge) system. The research is going on to create a robot with proper cleaning method that can cleanup oil effectively and efficiently.

F. Sponges

As a sponge would naturally absorb water, a sponge that would absorb oil is in the making. The sponge being

tested under Switzerland's Material Science lab can hold oil up to 50 times its weight and continue to float in water. The latter combined with absorption capacity hold promising prospects of using such sponge with boom arrangement to attain maximum efficiency.

V. CONCLUSIONS AND RECOMMENDATION

Oil spills into coastal waters have impacts on the environment, animal and their habitats, economic interests, and social resources. The cycle process for petroleum poses a spill risk at every point; from exploration to find the petroleum, drilling, production/refining the petroleum, transporting the product, and consumption of the product. Those who produce, refine, and transport petroleum products are responsible for responding to spills quickly in order to accelerate the natural recovery process. The goals for an effective oil spill response is first, for the environmental impacts from the spilled oil to be reduced or eliminated, and second, for response activities to not disrupt the environment further.

Decisions that are made at the time of an oil spill incident need to be explained and documented for the reasoning used in making the choice. The documentation is completed so responders can determine if the appropriate response method was used, and can then be used to help determine future oil spill responses. Responders also rely on lessons learned from oil spills to understand how oil behaves in different environments. Responders also use lessons learned to understand how effective oil spill techniques were, and to better understand how the environment responds to spilled oil and cleanup activities. Every organization and individual involved in the petroleum lifestyle, including consumers, needs to be responsible for ensuring safe and effective petroleum management.

REFERENCES

[1] MervFingas. (2000,May 10)Basics of oil spill cleanup. (2nded.)[Online].Available: https://www.crcpress.com/The-Basics-of-Oil-Spill-Cleanup-Second-Edition/Fingas Fingas/9781566705370
[2] http://www.cnbc.com/2010/06/09/17-Ways-To-Clean-Up-The-Gulf-Oil-Spill.html
[3] 5 Innovative Solutions That Clean Up Oil Spills. http://inhabitat.com/top-5-green-ways-to-clean-up-oil-spills/
[4] How to cleanup oil spills. http://news.mit.edu/2012/how-to-clean-up-oil-spills-0912.
[5] 3 Future Oil spill fighters. http://news.nationalgeographic.com/news/2010/05/100511-science-environment-gulf-oil-spill-cleanup-future/
[6] How do you clean up oilspill?http://science.howstuffworks.com/environmental/green-science/cleaning-oil-spill1.html?
[7] Symposium, O. S. (1997). THE NAKHODKA OIL SPILL RESPONSE - THE TECHNICAL ADVISER' S PERSPECTIVE Dr. T. H. Moller Technical Team Manager, International Tanker Owners Pollution Federation Ltd, (July), 10–11.
[8] Samudro, G., & Mangkoedihardjo, S. (2012). ASSESSMENT FRAMEWORK FOR
[9] REMEDIATION TECHNOLOGIES OF OIL POLLUTED ENVIRONMENT, 4(2), 37–41.
[10] Santa Barbara Oil Spill | CounterSpill. (n.d.). Retrieved October 23, 2014, from http://www.counterspill.org/disaster/santa-barbara-oil-spill#photos-645
[11] Morse, K. (2012). There Will Be Birds: Images of Oil Disasters in the Nineteenth and Twentieth Centuries. Journal of American History, 99(1), 124–134. doi:10.1093/jahist/jar651
[12] Sylves, R. T., & Comfort, L. K. (2012). The Exxon Valdez and BP Deepwater Horizon Oil Spills: Reducing Risk in Socio-Technical Systems. American Behavioral Scientist, 56(1), 76–103. doi:10.1177/0002764211413116
[13] Xhelilaj, E., Sinanaj, S., Qemali, I., Sheshi, V., & Vlore, S. (2010). THE BEHAVIOUR AND EFFECTS OF OIL POLLUTION INTO MARINE ENVIRONMENT AND OCEANS, 1, 19–26.