International Journal of
Science and Engineering Investigations
vol. 5, issue 55, August 2016
ISSN: 2251-8843

Oil Spill Control: an Automatic Pollutant Sensing and Dispelling Approach

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Abstract-The Nigerian Oil and Gas industry is one of the leading and sensitive sectors of the Nigerian economy which contributes about 35% of gross domestic product and petroleum export revenue represents over 90% of total exports revenue. This makes the industry important to the economic stability of Nigeria. Oil and Gas exploration takes place in the south-western region in Nigeria, which is mostly enclosed with sea and swamp where hydrocarbon is conventionally found. The Nigerian oil industry is mainly operated and controlled by expatriates with locals restricted to support field strength. In the course of operation, oil spillage is often encountered leading to loss of resources, human, animal and material. In order to remedy this bad occurrence which has damaging effect on equipment, contamination of the sea with accompany threat to sea creatures, human beings as well as high cost of clean ups, an "Automatic Oil Spill Dispelling Device Model" is presented as part of efforts put in place to mitigate oil spillage in the Nigerian Oil and Gas industry.

Keywords- *oil and gas, oil dispeller, exploration, hydrocarbon, oil spillage*

I. INTRODUCTION

Oil was first found in Nigeria in 1956, then a British protectorate, by a joint operation between Royal Dutch Shell and British Petroleum. The two began production in 1958, and were soon joined by a host of other foreign oil companies in the 1960s after the country gained independence [1, 2]. Oil and Gas exploration in the offshore area of Niger Delta has been characterized by incessant oil spillage which has been bringing agitations from the indigenous groups as well as human right activists. Several corrective measures have been tried with little or no improvement in this damaging situation by the Nigerian government as well as the concerned companies despite blame games going on [3]. Sections of the populace have started saying that the discovery of oil in Nigeria has brought curses and wanton destructions on the once thriving agriculture-centered economy of the country. Visits to oil production terminals have shown that crude method of tackling oil spillage is still being widely used. This human intervention in tackling oil spillage is more reactive in that oil spill would have occurred before cleanup measure are embarked upon through direct pouring of a cleanup chemical called "Rig Wash" which neutralizes the damaging effect of oil on sea water and environment. A better way of tackling oil spill problems should be proactive in nature. That is, a device that should have the ability to automatically detect oil spill around susceptible zones be introduced whose action would be prompt, intelligent, cost effective and suitable for all oil production platforms be designed, modeled and deployed to combat the issue of oil spill in Nigeria.

The rest of this paper is concerned with; review of oil spills and attempted solutions, methodology, device performance test and discussion as well as conclusion.

II. REVIEW OF OIL SPILLS AND ATTEMPTED SOLUTIONS

An estimated 9 million- 13 million (1.5 million tons) of oil has been spilled into the Niger Delta ecosystem over the past 50 years. 50 times the estimated volume spilled in Exxon Valdez oil spill in Alaska 1989 [4]. The first oil spill in Nigeria was at Araromi in the present Ondo state in 1908. In July 1979, the Forcados tank 6 Terminal in Delta state incidence spilled 570,000 barrels of oil into the Forcados estuary polluting the aquatic environment and surrounding swamp [5].

The Funiwa No.5 well in Funiwa Field blew out an estimate 421,000 barrels of oil into the ocean from January 17th to January 30th 1980 when the oil flow ceased, 836 acres of mangrove forest within six miles off the shore was contaminated. The Oyakama oil spillage of 10th May, 1980 with a spill of approximately 30,000bbl was also enormous [6]. In August 1983 Oshika village in River state witnessed a spill of 5,000 barrels of oil from Ebocha Brass (Ogada-Brass 24) pipeline which flooded the lake and swamp forest, the area had previously experienced an oil spill of smaller quantity; 500 barrels in September 1979 with mortality in crabs, fish and shrimp. Eight months after the occurrence of the spill there was high mortality in embryonic shrimp and reduced reproduction due to oil in the lake sediments [7]. The Ogada-Brass pipeline oil spillage near Etiama Nembe in February 1995 spilled approximately 24,000 barrels of oil which spread over freshwater swamp forest and into the brackish water mangrove swamp.

The Shell Petroleum Development Company (SPDC) since 1989 recorded an average of 221 spills per year in its operational area involving 7,350 barrels annually [8]. Between

1976 and 1996 a total of 4647 oil spill incidences spilling approximately 2,369,470 barrels of oil into the environment of which 1,820,410.5 (77%) were not recovered. Most of these oil spill incidences in the Niger Delta occur on land, swamp and the offshore environment. NNPC estimates 2,300 cubic meters of oil has spilled in 300 separate incidences annually between 1976 and 1996.

The Punch Newspaper on February 20, 1991:2 reported a total of 2,796 oil spill incidences recorded between the periods of 1976-1990 leading to 2,105,393 barrels of oil spilled. The UNDP 2006:181 also reported that between the period of 1976-2001, 3 million barrels of oil were lost in 6,817 oil spill incidences of which over 70% of the spilt oil was not recovered. In 2001 the western operations of the Shell Petroleum Development Company (SPDC) recorded a total of 115 incidences of oil spills in which 5,187.14 barrels of oil were spilled and 734,053 barrels of the spilt oil representing 14.2% were recovered. In January 1998, 40,000 barrels of crude oil was spilled by Mobil in Eket but the largest spill in Nigeria was the offshore well blowout in January 1980 with a spill of approximately 200,000 barrels of oil into the Atlantic Ocean from an oil facility which damaged 340 hectares of mangrove forest [9].

The Niger Delta has a complex and extensive system of pipelines running across the region and large amounts of oil spill incidences have occurred through the pipelines and storage facility failures, these failures could be caused by material defect, pipeline corrosion, ground erosion but the oil companies blame most of the spills on sabotage (pipeline bunkering). The Department of Petroleum Resources (DPR) contends that 88% of the oil spill incidences are traceable to equipment failure, main causes of oil spills in the Niger Delta are vandalism, oil blowouts from the flow stations, accidental and deliberate releases and oil tankers at sea [10].

A number of advanced response mechanisms are available for controlling oil spills and minimizing their impacts on human health and the environment. The key to effectively combating spills is careful selection and proper use of the equipment and materials best suited to the type of oil and the conditions at the spill site. Most spill response equipment and materials are greatly affected by such factors as conditions at sea, water currents, and wind. Damage to spill-contaminated shorelines and dangers to other threatened areas can be reduced by timely and proper use of containment and recovery equipment [11].

Mechanical control and Recovery is the primary line of defence against oil spills. Control and recovery equipment includes a variety of booms, barriers, and skimmers, as well as natural and synthetic sorbent materials. Mechanical control is used to capture and store the spilled oil until it can be disposed of properly.

Chemical and Biological Methods could also be used in conjunction with mechanical means for containing and cleaning up oil spills [12]. Dispersing agents and gelling agents are most useful in helping to keep oil from reaching shorelines and other sensitive habitats. Biological agents have the potential to assist recovery in sensitive areas such as shorelines, marshes, and wetlands. Research into these technologies continues to improve oil spill cleanup. Subpart J of the National Contingency Plan (NCP) establishes the process for authorizing the use of dispersants and other chemical response agents which includes the NCP Product Schedule, which is the federal government's listing of chemical countermeasures that are available for use during or after an oil spill response [13].

III. METHODOLOGY

The process flowchart is shown in figure 1. This helps in the accomplishment of the auto-cleaning model design and operation as contained in figure 2.

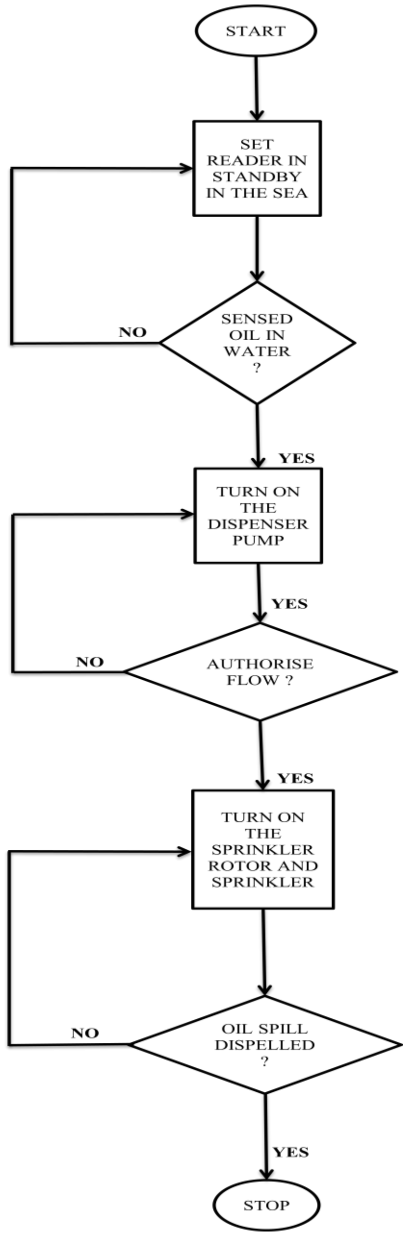


Figure 1. Process Flowchart

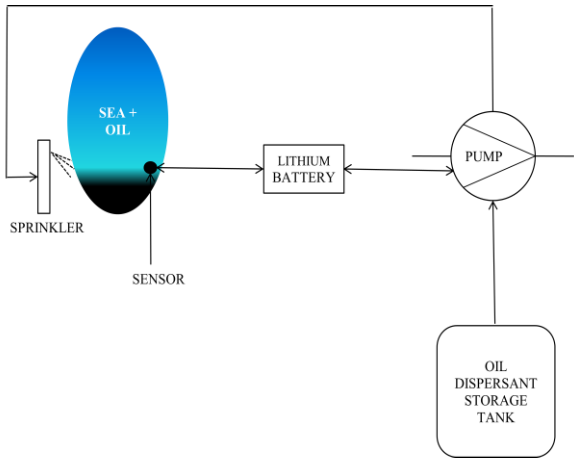


Figure 2. Block diagram of the Automatic Oil Spill Dispeller

Incorporated in figure 2 are the improvised sprinkler and pump whose operation are based on the hydrocarbon sensor that triggers them on upon the detection of oil spill on the water surface.

The consideration of fluid mechanics is the idea behind the use of a sprinkler system which has numerous amounts of pores, the reduction in area of the pores leads to increase in pressure. That is, converting laminar flow to turbulence flow which allows a widespread of the dispersant to react on the oil spill easily.

Since pressure is force per unit area and is a scalar quantity.

$$P = \frac{F}{A}(\mathrm{Pa})\,;(1\mathrm{bar} = 10^5\ \mathrm{Pa}) \quad (1)$$

For a fluid at rest, the tangential viscous forces are absent and the only force between adjacent surfaces is normal to the surface. In a resting fluid there is only a normal stress (pressure). In other words, force caused by the pressure on a surface is normal to that surface.

Laminar flows are, therefore smooth, the disturbances are damped via viscous effects, and generally deterministic.

In turbulent flows, flow and fluid variables show random fluctuations in time and space, that is, the flow is stochastic, and there are eddies of velocity and length scales over a very wide range.

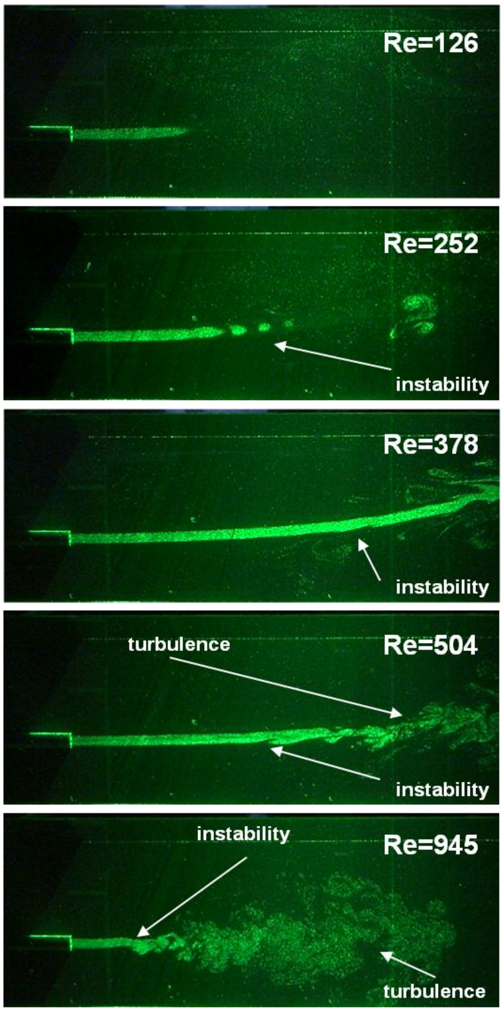


Figure 3. Laminar to Turbulent Transition of a Submerge Jet Flow (Available: http://en.m.wikiversity.org/wiki/Fluid_Mechanics_for_MAP/Introduction)

Laminar to turbulent transition occurs when the disturbances in the flow cannot be damped anymore by viscous forces. This happens when the inertia of the flow is increased and/or the flow configuration (boundaries, states of the fluid(s)) causes the generation and/or amplification of very small disturbances. As Reynolds number (Re) is the ratio of the inertial forces to viscous forces, for different types of flows, over a critical Reynolds number, transition to turbulence takes place. Below are the lists of simple but still technically interesting flow cases and critical Reynolds numbers are listed for useful parameters.

Pipe flow:

$$Re = \frac{U_b\,D_{pipe}}{v} > 2200 \quad (2)$$

Jet flow:

$$Re = \frac{U_b\,D_{jet}}{v} > 1000 \quad (3)$$

Flow over a flat plate:

$$Re = \frac{U_\infty\,\delta_l}{v} > 950 \quad (4)$$

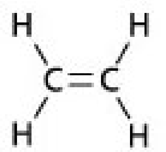
Where, U_b , U_∞ are the bulk velocity of the fluid or the velocity of fluid approaching to the plate. D_{pipe} , D_{jet} and l are the pipe diameter, jet diameter or the length of the plate.

The displacement thickness is given by:

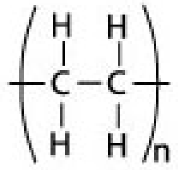
$$\delta_l = 1.75\sqrt{vl/U_\infty} \quad (5)$$

Plastic for the casing is polyethylene, the most common plastic with chemical composition:

$$C_2H_4 \equiv (CH_2 = CH_2) \quad (6)$$



Ethylene



Polyethylene Polymer

For the electrical control section, we have:

$$F = \frac{1.44}{(R_1 \times C_1)} \quad (7)$$

Equation (7) determines the timing for the dispenser operation.

The power unit section is determined by using a 240V transformer on a 50Hz power supply that is converted by the step down transformer which produces r.m.s. voltage output of 12V.

$$\text{Peak Voltage, Vp} = \text{Vrms} \times \sqrt{2} \quad (8)$$

$$\text{Supply frequency, f} = \frac{1}{period(T)} \quad (9)$$

$$\text{Period, T} = \frac{1}{f} \quad (10)$$

The total voltage drop, V_d, for the two diodes involved in the rectification process in either positive or negative cycles,

$$V_d = 2V_{BE}\ [V_{BE} = 0.7V \text{ for a silicon diode}] \quad (11)$$

Actual peak voltage value,

$$V_{LM} = (V_{IN} - 2\,V_{BE})\ V \quad (12)$$

Change in peak voltage value over the discharge period is,

$$\delta V = V_{LM} - V_{dc} \quad (13)$$

The filter capacitor should not discharge down to 6V in accordance with the input voltage specification of the voltage regulator.

Charge in time over the discharge period, $\delta t = 10ms$

Total current consumption for this design is not expected to exceed 600mA.

IV. DEVICE PERFORMANCE TEST AND DISCUSSION

The device is arranged as shown in figure 4 below. Two test containers, ‘A’ and ‘E’ were used to represent two liquid regions. Container labelled ‘A’ represents polluted water while container that is labelled ‘B’ has the spill dispelling solution. ‘D’ is the electronic unit that does the work of control with the aid of an oil spill sensor which senses the spill at the instant of occurrence. ‘B’ is the sprinkler and ‘C’ is the hose along which the spill dispelling solution travels. ‘E’ contains a pump for lifting the solution during cleaning operation.

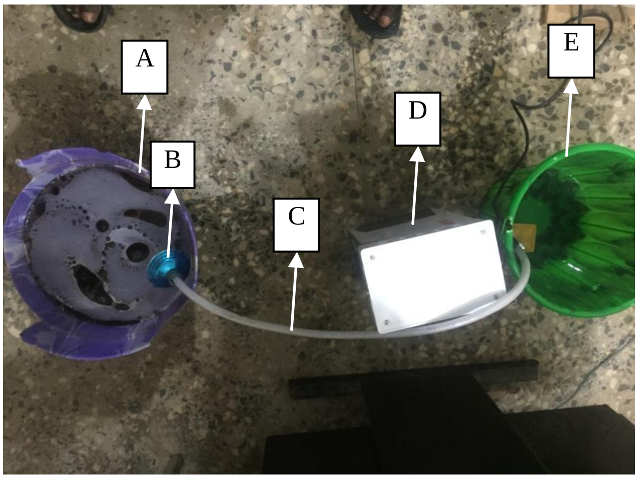


Figure 4. Oil spill dispelling setup

A. Discussion

The device picks up a few seconds of sensing spill via the operation of the attached sensor with an observed delay of 0.3s at starting and 0.1s at intermittent spills. After which the dc suction pump starts pumping the required spill dispelling solution whose intensity is directly proportional to the amount of spill on the water surface. The maximum flow rate is 0.0210301 liters per second and the flow restriction pressure is 1 psi which is approximately 6.9kPa for a dc source of 12V.

Also, the oil dispelling solution breaks the spill into droplets, as could be seen in container ‘A’ of figure 4, until the spill becomes relatively unnoticed.

V. CONCLUSION

This relatively cheap device could be used in operations that are highly vulnerable to oil spills. Failure to contain oil spill instantaneously would lead to losses in human, animal, plant, and material resources. It is therefore a means of containing the oil spill before a major damage is done. This device is a remote intervention approach before a major repair work is carried out on the source(s) of oil leakage. Further work on this device could look into the incorporation of data logger, satellite monitoring device, and temporary oil flow shut down functions.

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