A Review on Oil Spill Management in Remote and Narrow Creeks

Kinigoma, B.S. & Ani, G.O.

Department of Petroleum and Gas Engineering,

University of Port Harcourt,

Port Harcourt, Nigeria.

Email: gpasting@gmail.com

ABSTRACT

Oil and gas spill from production facilities, due to corrosion, vandalism, or equipment failure, have negative effect on environmental components (air, water, and soil). This paper aims to review the prospect for oil spill management in remote and narrow creeks where conventional clean up machinery cannot be deployed. The effectiveness of using locally available improvised oil slick containment materials and the application of dispersants to accelerate the process of natural dispersion followed by the process of biodegradation by micro-organisms are also reviewed. The early history and works of other researchers regarding hydrocarbon degradation by microbes have been cited to support the feasibility of the proposed technique. If bioremediation lives up to the result produced thus far in testing the petroleum produced and transportation industries may finally look forward to a degree of relief in a lighting battle with the environmental community. Bioremediation is going to be an important stopper for spills that cannot be removed efficiently or that have already spread into critical shoreline or estuarine areas.

Keywords: Spill; Oil Slick; Micro-Organism; Creeks; Biodegradation,

INTRODUCTION

Oil slick, when they occur have to be removed, and this process can be systematic containment and recovery are important control processes, which must be carried out if the above mentioned facts are to be avoided. The processes employed here are varied and its use depends on the type of slicks and on the chemical and physical nature of the oil spilled (Fay, 2001).

The most common approach is to use some form of barrier to check the drift of the slick and so concentrate it to a mass so that it can be pumped or skimmed off. Actions of waves on oil slick promote the natural dispersion process. Oil droplets resulting from this can easily mix with the water column. Under this condition, the oil becomes more readily available for degradation by micro-organisms. This process can sometimes be accelerated by the use of chemical dispersants, especially when containment and recovery are impractical.

This paper reviews oil spill management techniques in remote and narrow creeks where conventional skimmers and booms cannot be deployed for slick containment and recovery. Improvised booms and barriers are used as an alternative to purpose built equipment when these are not available. They can be built with indigenous material such as bamboo. Oil drums, hoses and rubber tires and sorbent booms constructed from fishing nets. They are mostly applied in shallow waters where they may be anchored on the ground from the stakes (Kinigoma, 2006).

Dispersants are principally used as a means for oil slick control to accelerate the process of natural dispersion. The action of waves on oil slick promotes the natural dispersion of oil into small droplets which can now be available for biodegradation by micro-organisms. Two main types of dispersants are:

1. Hydrocarbon Dispersants: these are conventional dispersants which are based on hydrocarbon solvents and contain between 15 and 25% surfactant. Sea water renders these dispersants ineffective.
2. Concentrate or self-mix dispersants: these have alcohol and glycol solvents and usually contain a higher concentration of surfactant composite.

According to Atlas and Bartha (2003), bioremediation is the process of using organisms to convert hazardous pollutants into less toxic compounds. It involves the manipulation of the process of molecular degradation of compounds through biological activity. Research has been conducted on the possible uses of bioremediation since the 1940s. Bioremediation was used in the 1970s for the in situ clean-up of fuel contaminated soil and groundwater. It has since developed into a popular method of pollution remediation and has expanded to such areas as sludges, surface waters and process waters contaminated with pesticides, metals, crude oil and industrial solvents. Following such success stories as the treatment of crude oil contamination on the Alaskan Shoreline after the Exxon Valdez spill in 1989 its popularity as expected has grown.

MATERIALS AND METHODS

This study which aims at managing oil spill in remote and narrow creeks involves the use of improvised booms and barriers as an alternative to purpose built equipment of oil slick containment materials. This then followed by chemical dispersion and bioremediation processes.

MATERIALS

Containment: bamboo sticks, oil drums, hoses, rubber tires, fishing nets and dry grass.

Dispersion: CorExiT

Bioremediation: BioSea, Oleophilic fertilizer such as customBlem Inipol EAP22 and Petrobac.

METHODS OF APPLICATION

Physical containment and recovery: containment of oil slick in remote and narrow creeks requires the deployment of locally available improvised materials. Ahead of the oil slick front, bamboo sticks should be cut and pinned on the opposite sides of the creeks, with the net attached firmly to it. The net should be lowered to about two feet below the surface of the water. This allows easy flow of water underneath while traversing the thickness of the oil slick. It also ensures minimum pressure on the net. Stability of the net is enhanced by tying some bamboo sticks to the lower end of the net below the water surface.

Farther away from the point of deployment of the netting system, grasses can be used to prevent any oil particle that escapes the net from being carried away by the water current. After the oil stick has been effectively contained, the next step is recovery of the oil by scooping or squeezing it out of the net and grasses into containers.

Chemical dispersion and bioremediation: depending on the gravity and the nature of the spilled oil, it might be preferable to use chemical dispersants to increase the bio-availability of the hydrocarbons to micro-organisms. The principal objective of this method is to break up the slick into minutes droplets that can be rapidly assimilated by naturally occurring bacteria. Crude oil is a naturally occurring material, and a relatively large number of bacterial species have evolved genetically to use it as food (offshore, 1996).

Enhancing the consumption and conversion of hydrocarbons and related chemical compounds is the foundation of bioremediation. The process involves injection of cultured bacteria nutrients, or both to convert undesired substances to neutral products.

A dispersing agent such as CorExit should be added to the dispersant in ratios ranging from 1:1 to 1:50, with 1:10 being a nominal ratio. It is worth noting that only selected dispersants can be used with proper permission. Manual or aerial spraying could be used in the application of the dispersants. However, it is advisable to use manual spraying because of the terrain being considered in this report. It also ensures better precision.

The next step is the fertilization of the spill site. This is the addition of nutrients such as nitrogen and phosphorus to a contaminated environment to stimulate the growth of indigenous micro organism.

Oleophilic fertilizers such as Inipol EAP 22, Petrobac etc could be used to achieve this manual spraying to ensure precision. A monitoring team can then take samples from affected site after about 3 weeks of the fertilizer application for laboratory analysis to ascertain the extent of biodegradation of the oil slick. Depending on the laboratory test results, a second fertilizer application may commence to replenish the nutrients and stimulate more microbial activity. Regular laboratory tests to ascertain the gravity of hydrocarbons left after each bioremediation effort can be conducted using spectrophotometric techniques, gas liquid chromatography (GLC) and Gel permeation chromatography (GPC).

RESULTS AND DISCUSSION

Bioremediation has emerged as a less intrusive relatively cost effective and environmentally friendly technology for the cleanup of petroleum hydrocarbon polluted environments since its successful application for the cleanup of EXXon Valdez oil spillage.

Following the methods highlighted in this paper, a review of cases where similar methods have been applied with success are presented to buttress the need to apply same in the management of spills in remote and narrow creeks where conventional clean up machinery cannot be deployed.

The USSR and Germany are considered to have made the earliest known discoveries regarding hydrocarbon degradation by microbes. In the 1930s, scientists were seeking artificial methods of breaking down crude oil into its components. Serious study of the microbial biochemical process of breaking down hydrocarbons began in the mid-1950s.

By 1960, scientists were beginning to catalog the types of active bacteria and the primary hydrocarbon or chemical food source.

The first offshore use of enhanced bioremediation of spilled oil was at Prince William Sound, Alaska (Offshore, 1990).

A committee appointed to select the bioremediation products for shoreline testing voted for a nutrient type product that enhanced natural microbiological process. The U.S Environmental Protection Agency (EPA), EXXon and the Alaska department of Environmental conservation supervised the limited application of fertilizers, Inipol and Custom Blen, to Alaska beaches.

Wagbara (1995) reported the management of a spill caused by the rupture of a 12" diameter delivery line onto a stream where sticks and other local materials were used as containment tools. He opined that the use of grass was very effective as it easily assumed the contour of the ground surface thereby preventing the oil from passing beneath the angling of the barrier reduced the force exerted on it by the current thereby preventing the formation of Vortex which could have siphoned the oil away.

Laboratory studies carried out by Odu in 2007 using marine water, tested the ability of Petrobac (a commercial strain of nutrients micro-organisms which are designed to degrade hydrocarbons) to get rid of oil under aquatic conditions. Petrobac I is formulated to disperse, emulsify and solublise crude or refined oils.

The characteristics of the water used in this investigation are presented in Table 1.

Table 1: Characteristics of water used in Bacterial Seeding Experiments with Petrobac.

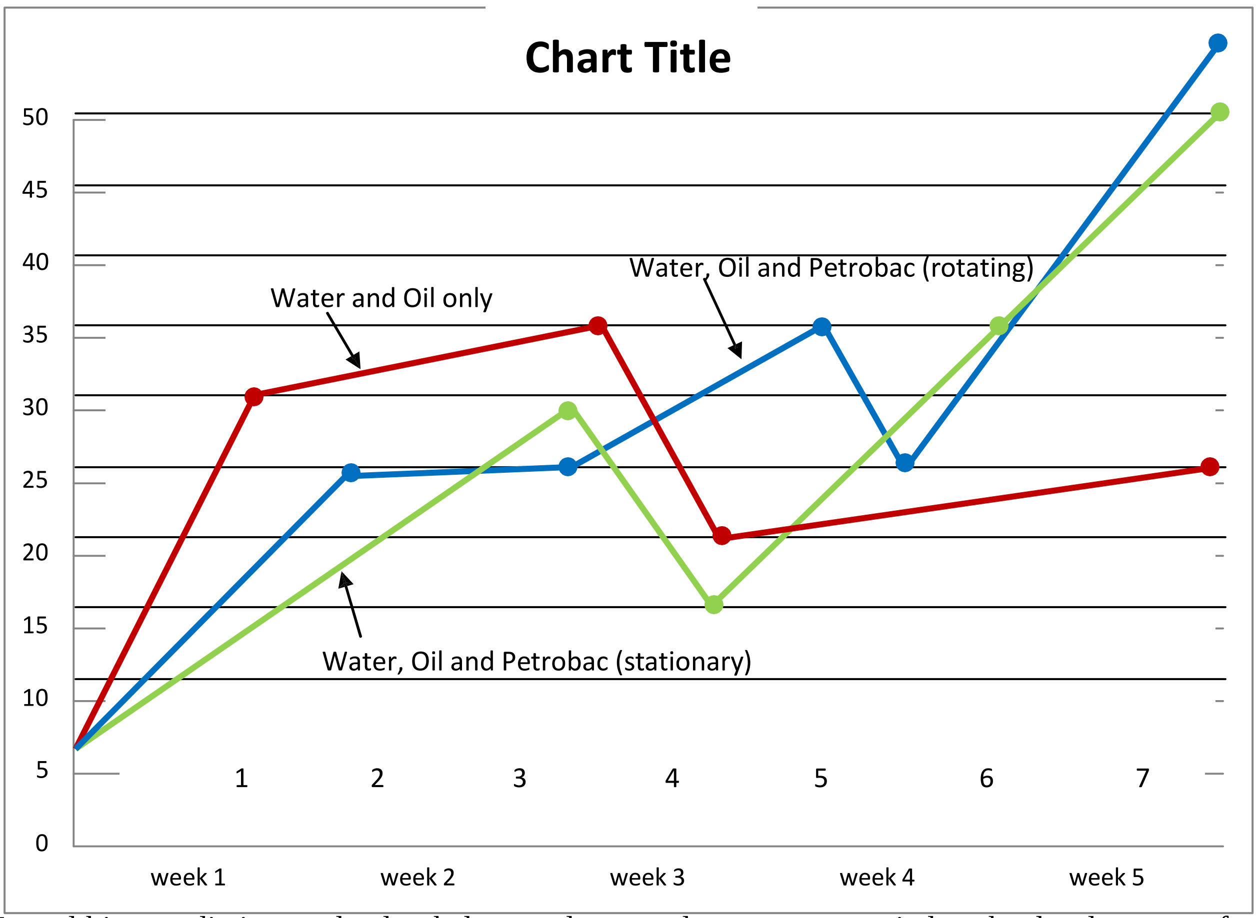
pH	**Electrical conductivity**	**Exchangeable Bases (ppm)**				**NO (ppm)**	**Available ppm**	**microbes**
		Na	R	Ca	Mg			
7.2	1490 x10^6	91,560	70	120	4.5	149	4.5	2000

Source: Odu, 2007.

Petrobac I was applied with Petrobac N (a blend of nitrogen bearing compounds to ensure optimum growth and oil degradation when used in conjunction with Petrobac I) and Petrobac E (which is a blend of insoluble oil and water).

These three systems were inoculcated with oil treated saline water (related and stationery).

A summary of the results as presented in Figure 1 shows that Petrobac systems can actually enhance oil degradation



Natural bioremediation evolved to help recycle protoplasm a process vital to the development of new cell life.

Hydrocarbon compounds provide a ready food supply of carbon in nature for the assembly of protoplasm. Bacteria evolved generally to take advantage of this research.

Enzymatic protein: like substances in the cells of bacteria act as organic catalyst in initiating the chemical reactions that breakdown the hydrocarbon chains. In the breakdown, bonds between some of the carbon and hydrocarbon atoms are broken. Free elemental oxygen participates in the breakdown and becomes a part of the new bonds formed. The process is known as carboxylation and beta-oxydation.

In the conversion process the various simple-bond hydrocarbon ring structures are altered. Among the intermediate products that result from the reaction are fatty acids. These harmless products serve as a food material for other bacteria and other organisms. The fatty acids are eventually broken down into their basic elements-carbon, hydrogen and oxygen. The bacteria use these elements plus nitrogen and phosphorous as well as extract minerals to build protoplasm and divide into even more bacteria. Microbiologists estimate that for every 106 carbon atoms in a bacterium, there are about 15 nitrogen atoms and I phosphorous atom (Cooney 1998). These stiochiometric proportions approximate the ratio of elemental materials needed by the bacteria to sustain life. If one of these building block elements becomes unavailable, the process comes to a halt. The depletion of oxygen used to form the hydroxyl bond in the fatty acids and later in protoplasm formation, will also stop the process.

Summary of biochemical reaction:

$$\text{Bacteria} + C_xH_y + O_2 \longrightarrow CO_2 + H_2O + \text{more bacteria}$$

Detailed cell reaction

$$\text{Enzyme} + CH_2 + CH_3 + O_2 + \text{Energy} \longrightarrow \text{Enzyme} + CH_2 + CH_2OCH_2$$

$$\text{Enzyme} + CH_2 + CH_2OH_2 + \text{Energy} \longrightarrow \text{Enzyme} + CH_2 + CHO$$

$$\text{Enzyme} + CH_2 + CHO + \text{Energy} \longrightarrow \text{Enzyme} + CH_2 + COOH$$

$$\text{Enzyme} + CH_2 + COOH + \text{Energy} \longrightarrow CH_3 + H_2O + \text{Enzyme}$$

Thus, the major goal in enhancing bioremediation is to continue to deliver these products as they are needed in the necessary proportions. If the hydrocarbon material or one of these elements becomes unavailable, the bacteria will cease large-scale multiplication and retreat to back ground population levels.

CONCLUSION

Bioremediation and the use of locally available containment materials has proved to be successful in remote and narrow creeks where conventional oil clean up equipment cannot be deployed. The technique is cost effective and environmentally friendly. If bioremediation lives up to the results produced thus far in testing, the petroleum producing and transportation industries may finally look forward to a degree of relief in a tightening battle with the environmental community. Bioremediation is going to be an important stop gap for spills that cannot be collected efficiently or that have already spread into critical shoreline or in remote and narrow estuarine areas.

REFERENCES

Atlas, E.S. and Bartha, J.N. (2003): "Biodegradation of Oil Spills". Environmental International. Vol. 3 pp 155.

Cooney, J.J. (1998): "Microbial Ecology and Hydrocarbon Degradation". Paper presented at the Alaska Story Synposium. Pp 17.

Fay, J.A. (2001): Physical Processes in the Spread of Oil on a water surface". Joint Conference on Prevention and Control of Oil Spills, Washington D.C. pp15.

Kinigoma, B.S. (2006): Lecture Notes on Industrial Safety and Oil Pollution Control. Department of Petroleum and Gas Engineering, Uniport. Pp 35-60.

Odu, C.T.I. (2007): Degradation and Weathering of Crude Oil Under Tropical Conditions". Tec. Publishers. Pp 77-105.

Offshore (1990): Bioremediation: Striking Successes in Soil Cleanup.

Wagbara, N. (1995): Oil Spill Management in the Niger Delta. On Published

Work, Department of Petroleum Engineering University of Portharcourt.

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