DEVELOPMENT OF A NEW AVERAGE SPREADING RATE REGRESSION MODEL FOR CRUDE OIL DURING OIL SPILL

by

EDOGA, M.O. AND OLUGBENGA, A.G

Department of Chemical Engineering,
Federal University of Technology,
Minna-Nigerial.

ABSTRACT

The target of this study was to develop a new average spreading rate regression model capable of predicting rate of flow of crude oil spills on Nigerian waters. The major factors responsible for spreading rate of crude oil on waters were considered, namely surface tension, viscosity, Reid vapour pressure, and specific gravity/ American Petroleum Institute degree (^{0}API), all at specified temperatures. Fourteen different Nigerian crude oils were collected and used to develop the new model. The spreading rate of each crude oil was determined by artificially spilling them on laboratory calm/stagnant water in a rectangular tank and their averages were also computed. These averages were used to develop a regression model equation for a new average spreading rate. Results obtained from the model showed that an average spreading rate was 4.53 cm/sec and the predictive regression model is $y = 3.694 + 0.003x_1 - 0.181x_2 - 0.096x_3 -+1.279x_4 + 0.009x_5 - 0.001x_6$. However, wind drift current and waves are also secondary factors for determining spreading rate of oil on waters but in this work, they were considered to be constant.

KEYWORDS: *crude oil, oil spill, oil slick, spreading medium (water), spreading rate, regression model, surface tension, specific gravity/API.*

INTRODUCTION

Both natural and accidental pollutions including oil spillage affect aquatic and terretrial habitat as well as the physical and chemical nature of the sea surface/environment The world production of crude oil is about 3 billion tons per year and half of it is transported by sea (Clark, 1992). During the transportation, a significant amount of the oil is spilled into the sea due to operational discharges of ships as well as from accidental tankers collisions and grounding (Clark,1992). The incidence of oil spills resulting from tanker traffic, offshore drilling, and associated activities will increase in years to come as the world's demand for petroleum and petroleum products continues to rise.

In Nigeria, these oil activities take place in Niger Delta, being strategically positioned in the Niger Delta, oil shipping and refinement are crucial industries for the Nigerian economy but are also potential threats to the coastal marine environment. An example of this was the recent oil spill in October, 1997, in Singapore strait between the Indian and Pacific Oceans, caused by the collision of two tankers: "Evoikos" and "Oraphin Global", when approximately 28,000 tons of marine fuel oil was accidentally discharged into the Straits. Similarly in Nigeria, the local says they cannot fish on river; they can neither farm as their land has being devastated this is the story of communities in the Niger delta region of Nigeria". (Adesina, 2002) At present, it is not possible to determine the location, extent, thickness and type of oil – pollutant using just one single model. The regression model presented here is expected to provide a practical solution to oil spill responses as well as remediation action to be taken. It is hoped to be applicable to continuous use for in –situ monitoring of the inherent spreading rates of oil spills on sea. Moreover, such surface spreading properties constitute the requisite input data for modeling the spreading rate of oil spill. In general, the spreading of large oil mass is chiefly driven by specific gravity, vapour pressure, temperature, viscosity surface tension properties of the oil. In the event of unintentional releases of oil into coastal waters, oils form slicks and can have deleterious impacts on biota in exposed ecosystems. Their effects will depend to a large extent on the ultimate location of the oil as well as on its chemical composition at the time of interaction with aquatic biota. Oil slicks usually spread rapidly to a large area because of the lower specific gravity and low viscosity, therefore a quick response to ameliorate the damage has to be initiated.

Five clean-up strategies that frequently receive consideration include; mechanical clean-up or recovery, burning, bioremediation, treatment with chemical dispersants, and adsorption.

The morphology of the slick near its leading edge and over the entire covered area in the terminal stages of spreading is strongly affected by surface tension forces (Camp and Berg, 1987).

Another critical factor that affects the spreading rate of spilled oil is temperature which invariably affects viscosity of the spilled oil (Lily,2008), the viscosity of oil is influenced by the ambient temperature, that is, if it is warm the spilled oil will be less viscous so it will spread more rapidly.

The surface properties in particular, surface and interfacial tensions of the water body themselves are equally of key importance. Such information is crucial for determining the actual or potential pollution pathways of crude oil spills. The microlayer surfactants present in sea water (unlike artificial sea water) originate from several sources – petroleum deposits, biological activity of plankton, terrestrial material or atmospheric precipitation (Hunter and Liss, 1981), and can affect the way oil spreads on water. In addition, the presence of surfactants in both the aqueous and oil phases can lead to interfacial tension gradients giving rise to Marangoni stresses (Bauget et al. 2001) that could also initiate and drive the spreading process (Craster and Matar, 2006). An understanding of the structure of liquids adjacent to other surfaces, and of how surface wettability is governed by interfacial forces or phenomena, is important in many technological, industrial, chemical and biological situations (Adamson and Gast, 1997) especially in oil spill and remediation.

In this paper, we reviewed recent experimental progress, provided a conceptual framework within which the majority of the spreading experiments could be understood and evaluated, and pointed out discrepancies between experiment and theory, and finally developed predictive models that could describe the spreading rate of oil spill on Nigerian coastal waters.

EXPERIMENTAL PROCEDURE

Determination of the Spreading Rate of Crude oils on Water

A rectangular container (56cmx41cm x13) was filled with 14 liters of sea water but the container was allowed to remain still until it equilibrated to ambient temperature (21° C). The syringe was filled with 50ml of crude oil. Subsequently, a plexiglass grid was placed on top of the container. A hole was drilled at the center of the plexiglass that is large enough for the passage of the nose of the syringe through which the oil was spilled on the water. With the aid of a tripod stand a video camera was mounted directly above the spill and focused on the spilled zone. The radius moved by the oil was visualized with the aid of the video camera and it was recorded for the first test group, test series and trial and the time taken for oil to reach the following distances 150 cm, 300 cm, 450 cm 600 cm and 750 cm was recorded. The oil was monitored and observed to spread until it had stopped spreading using the handset video camera. At the end of each round of the experiment, the spilled oil was cleaned using polypropylene pads and subsequently the pads were disposed in trash bag.

The same process was repeated at different temperatures, at an interval of 5 °C starting from 20 °C to 65 °C. For each 5° C increment in the temperature of water, the crude oil sample used was maintained at the same experimental temperature and the Reid vapour pressure, viscosity, surface tension, and the specific gravity/°API of the crude oil were determined for each run.

The results for each test was ranged and the standard was compared with the variables tested.

When the oil first touched the water surface the time was recorded and when the oil reached the determined point, the time was also recorded. The difference in time was determined and entered into the data table, the distances oil spreads north-south and east-west were rounded and were averaged. Graphs were created to represent the flow data and the rates per second were obtained from the graphs and were entered into the data table. All the contaminated materials were disposed (polypropylene pads) while all materials that have been contaminated were cleaned such as syringe, plexiglass and tub.

The model development was carried out with a software package (polymath) the data obtained from the above experiment.

RESULTS

Spreading rates of the oils: the results of the spreading rates of the oils are presented in figures 1 to 14.

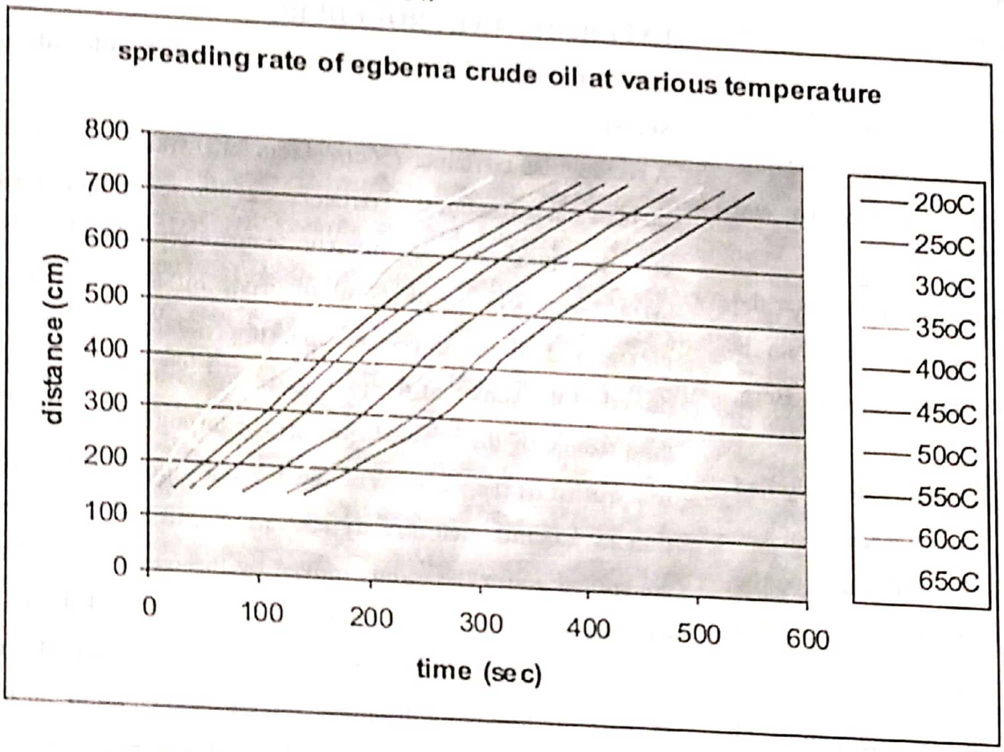

Fig 1: Spreading Rate of Egbema Crude Oil at Various Temperatures.

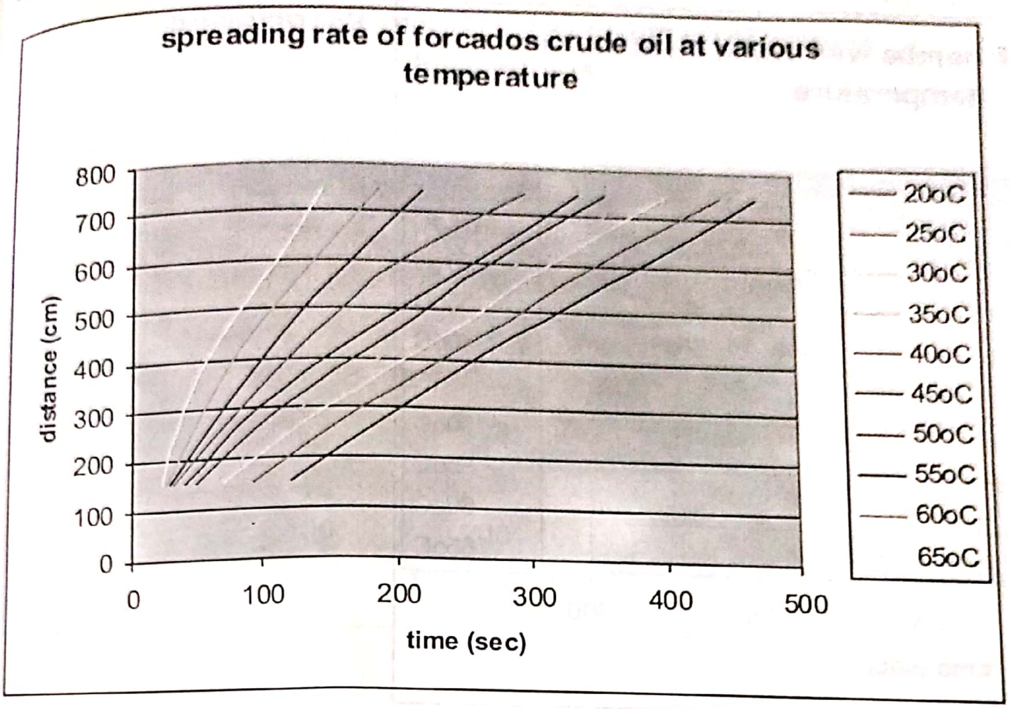

Fig 2: Spreading Rate of Forcado Crude Oil at Various Temperatures

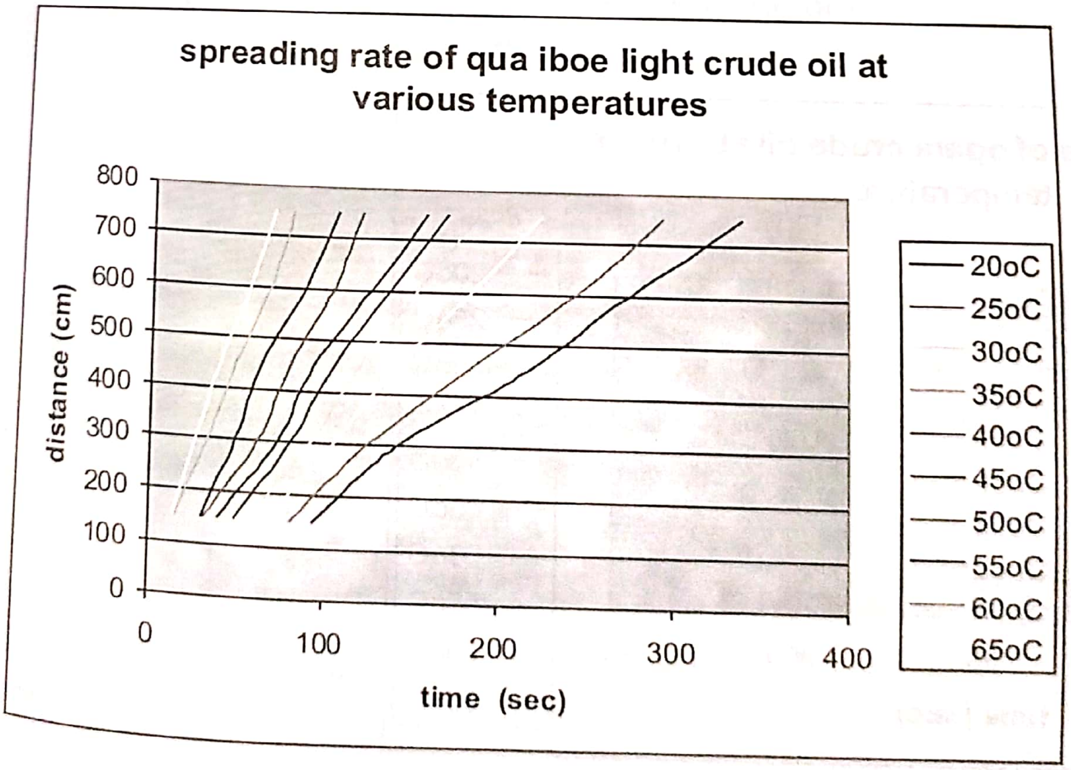

Fig 3: Spreading Rate of Qua Iboe Light Crude Oil at Various Temperatures

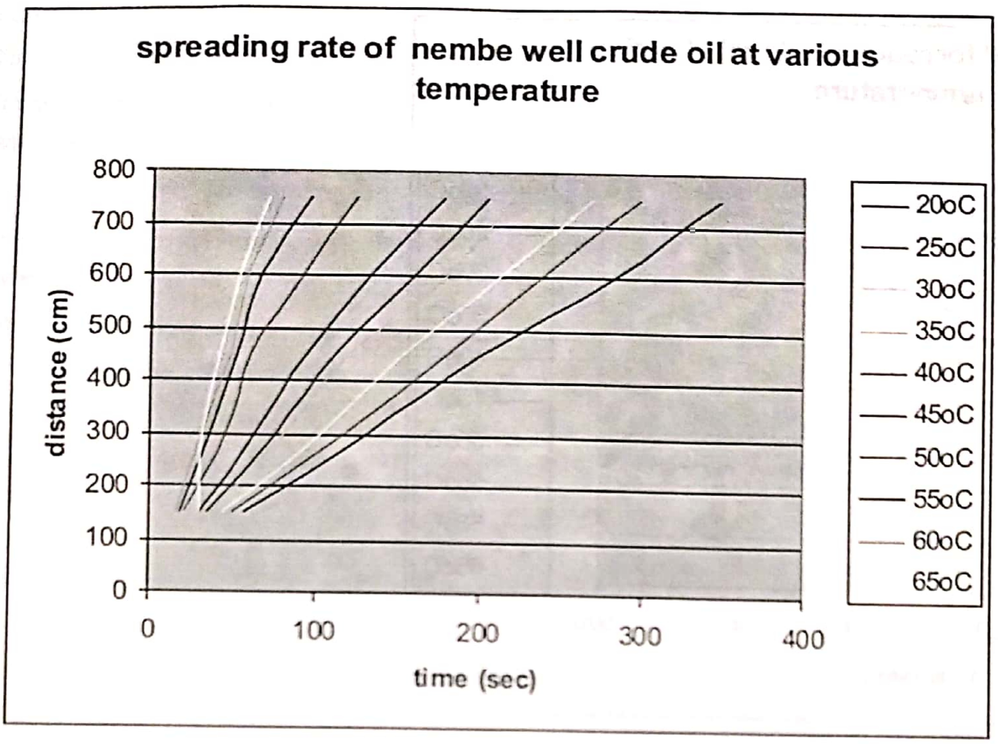

Fig 4: Spreading Rate of Nembe Well Crude Oil at Various Temperatures

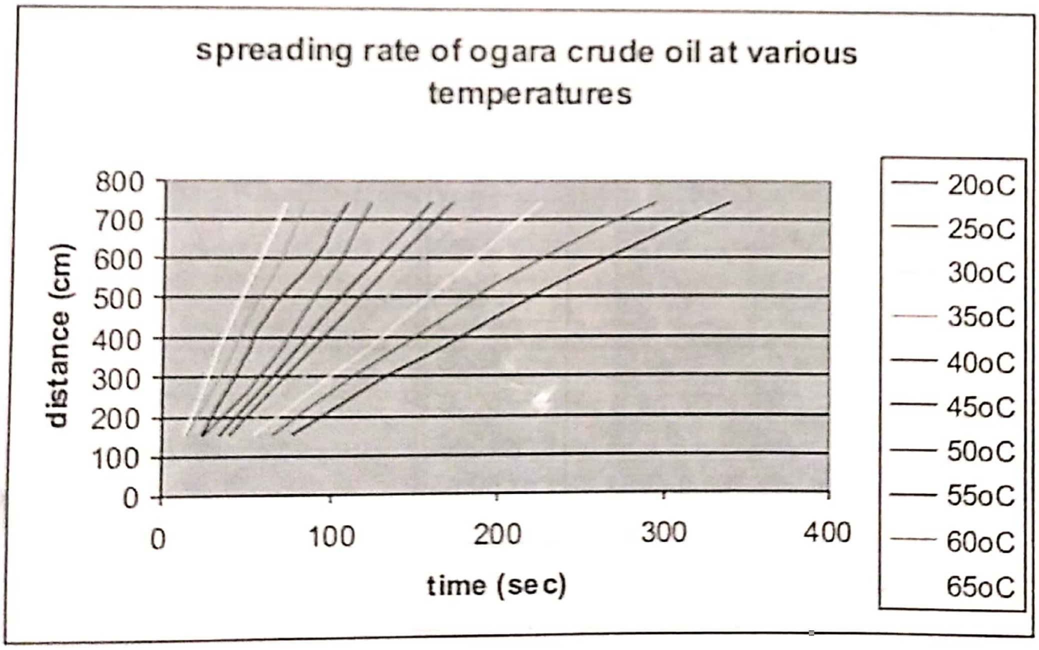

Fig 5: Spreading Rate of Ogara Crude Oil at Various Temperatures

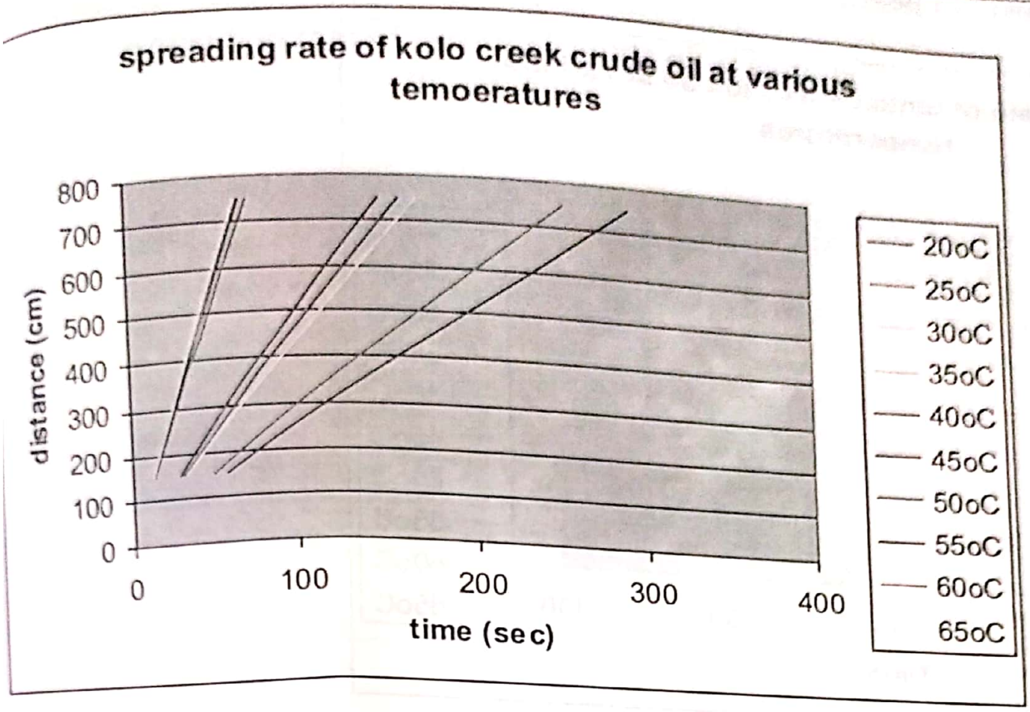

Fig 6: Spreading Rate of Kolo Creek Crude Oil at Various Temperatures

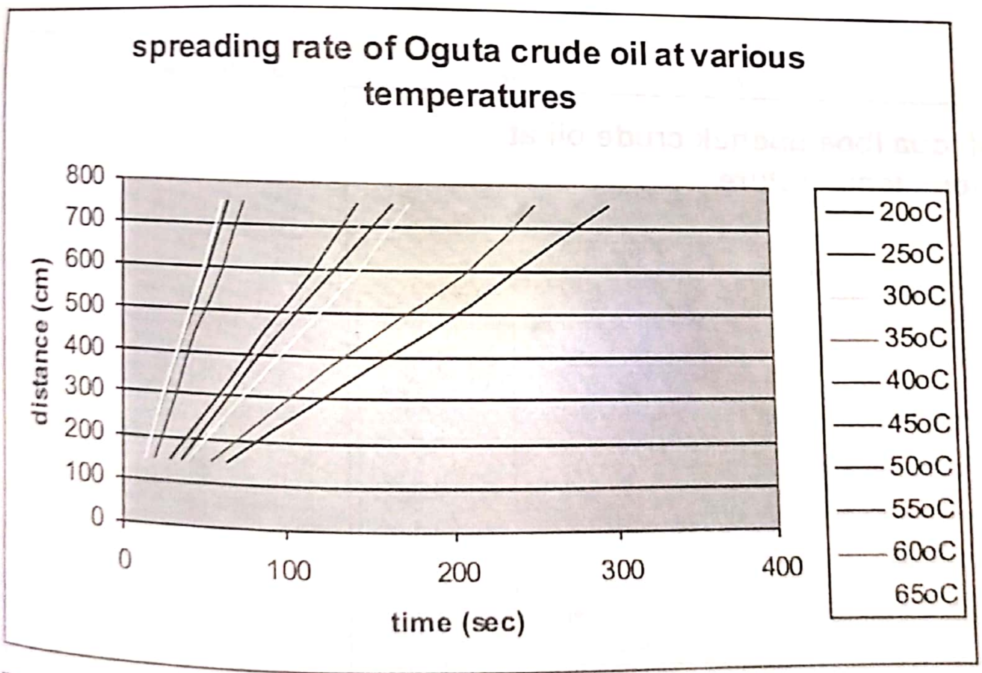

Fig 7: Spreading Rate of Oguta Oil at Various Temperatures

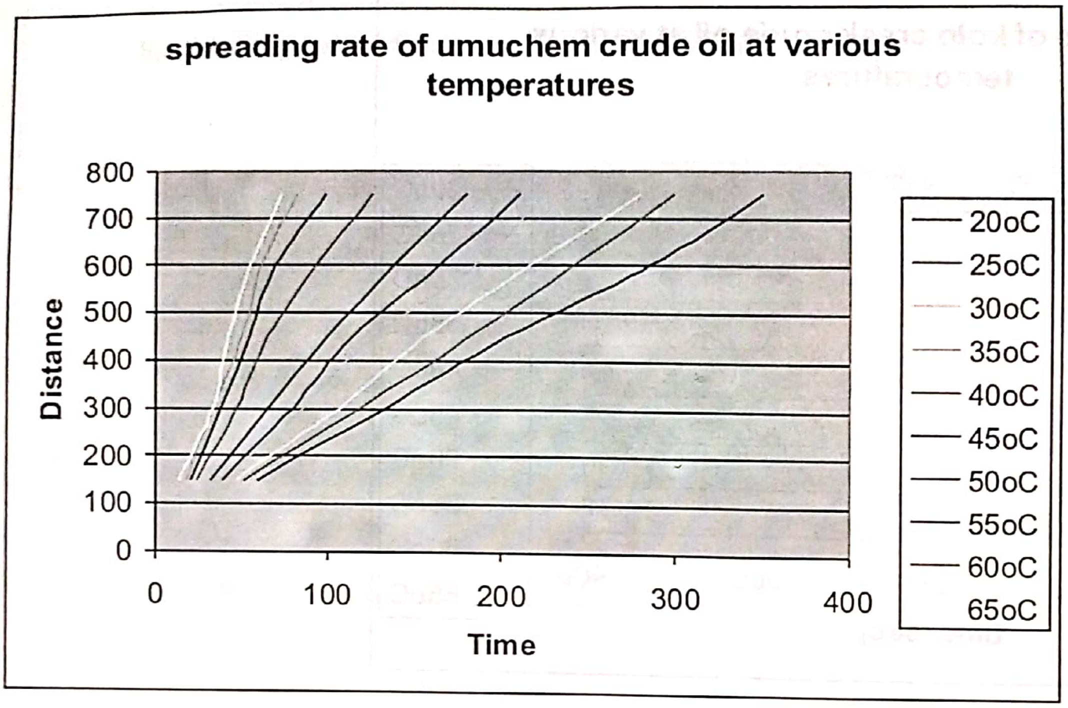

Fig 8: Spreading Rate of Umuchem Crude Oil at Various Temperatures

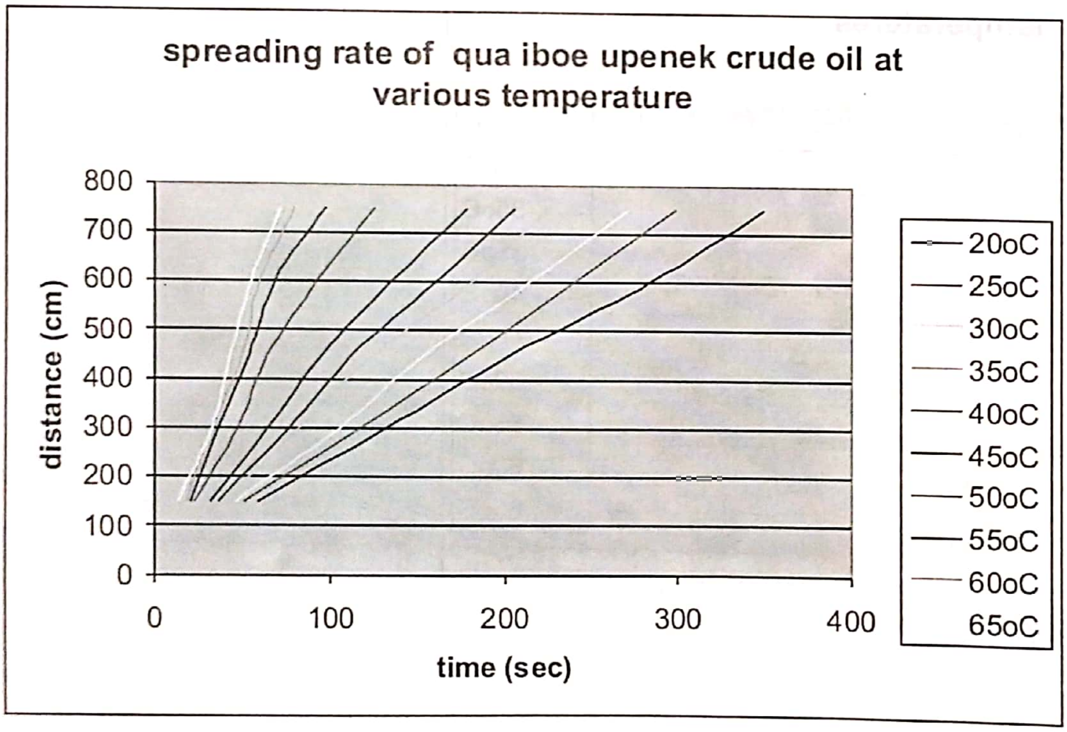

Fig 9: Spreading Rate of Qua Iboe Upenek Crude Oil at Various Temperatures

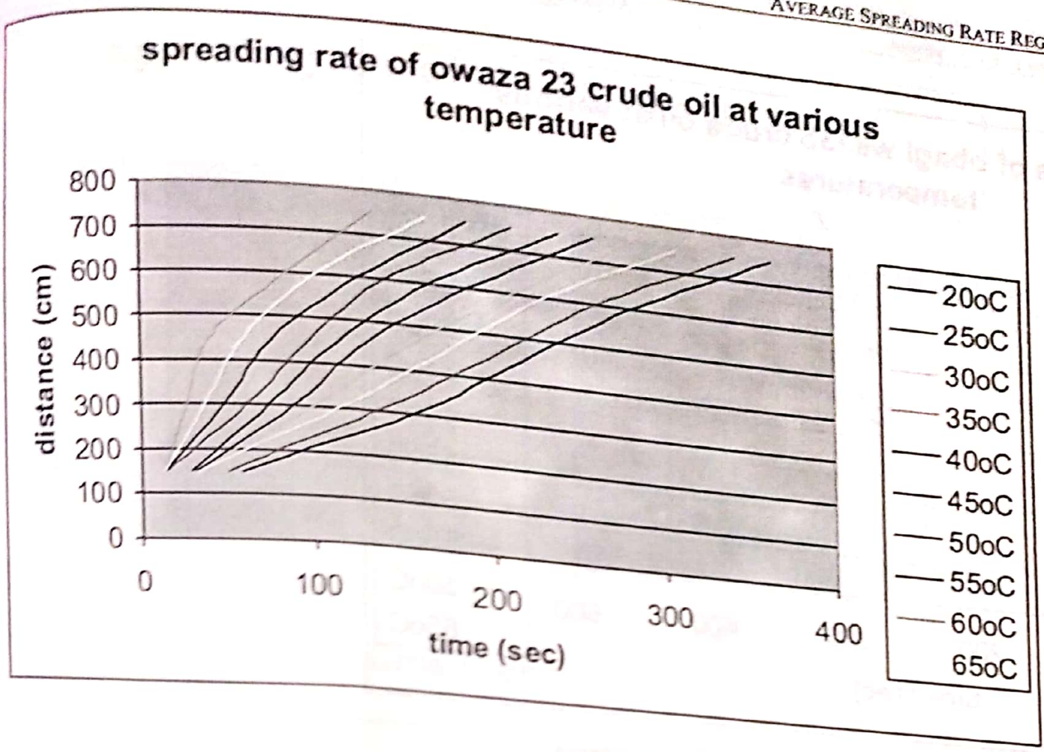

Fig 10: Spreading Rate of Owaza 23 Crude Oil at Various Temperatures

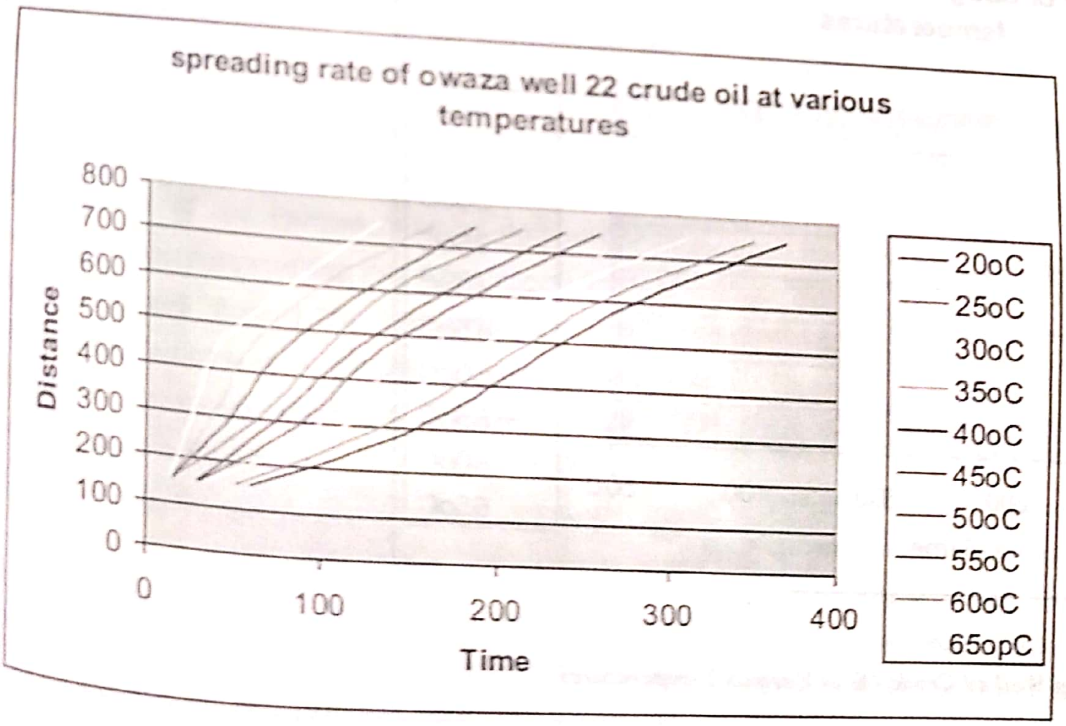

Fig 11: Spreading Rate of Owaza 22 Crude Oil at Various Temperatures

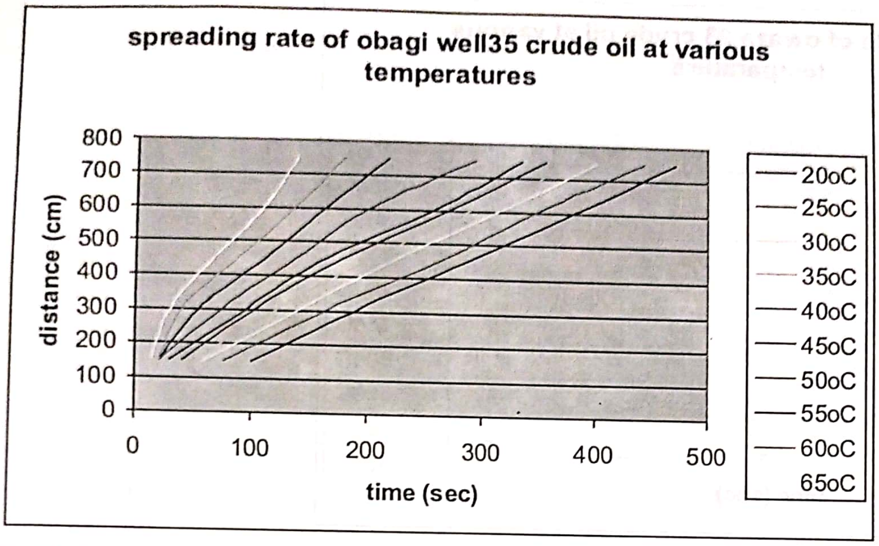

Fig 12: Spreading Rate of Obagi Well 35 Crude Oil at Various Temperatures

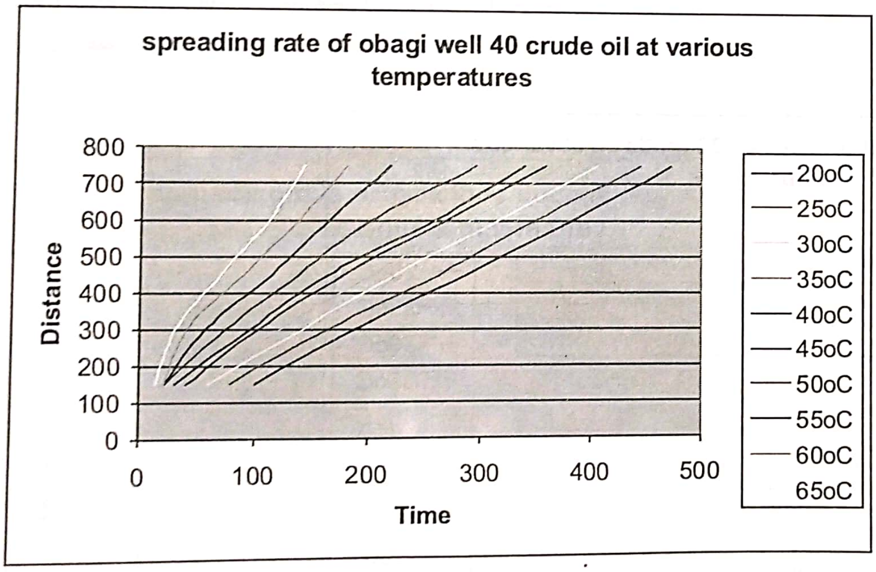

Fig 13: Spreading Rate of Obagi Well 40 Crude Oil at Various Temperatures

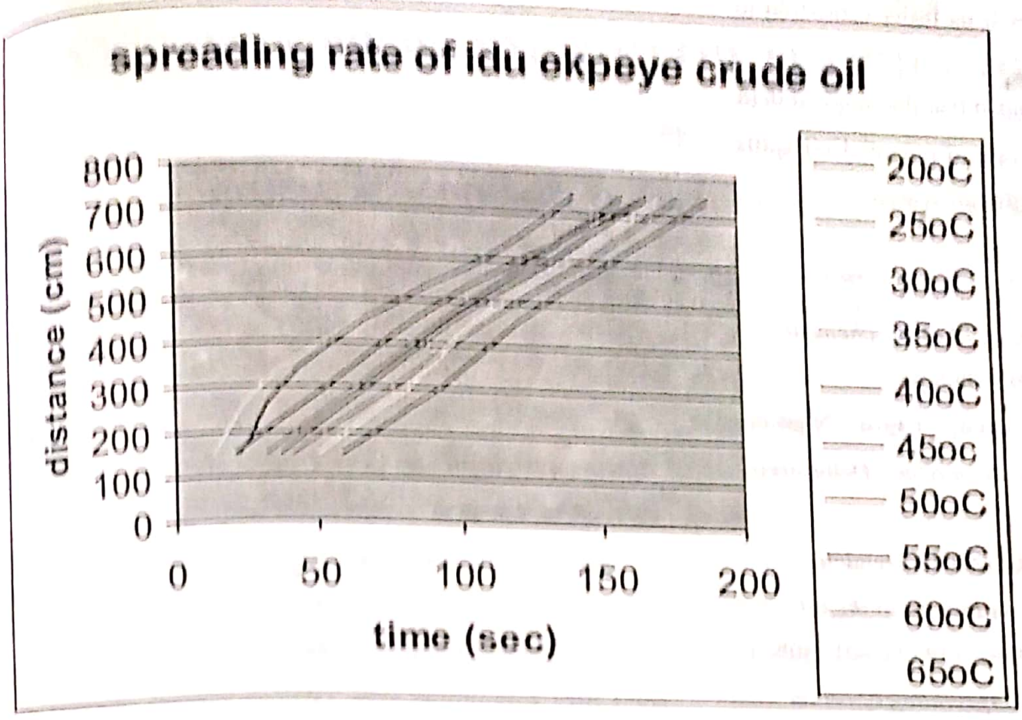

Fig 14: Spreading Rate of Idu Ekpeye Crude Oil at Various Temperatures

DISCUSSION OF RESULTS

The regression model obtained for all the crude oil samples indicates clearly that the spreading rate of Nigerian crude oils have very close range which is a good indication that they have similar physicochemical properties.

The viscosities of the fourteen samples decreased with increase in temperature resulting into a faster spreading rate. This rate ranged from 1.234 cm/sec to 11.01cm/sec. Similarly, the surface tension of the crude oil decreased with increase in temperature, which also enhanced the rate of spreading of the crude oils.

In the same vein, the specific gravity decreased with increase in the temperature of the crude oil but with an increase in °API gravity for this reason, the crude oil was observed to float on water. Moreso, at various increasing temperatures, the crude oil was found to be lighter than water. This allowed the crude oil to be exposed to both the wind, tidal and dispersion, which invariably are the major factors that affect the rate of spreading.

The vapour pressure, a measure of the volatility of the crude oil, is a major factor affecting the rate of spreading. The vapour pressure increased slightly at a temperature range of 20°C, 25°C and 30°C but at temperatures of 45°C and above the values increased greatly and the more volatile components of the crude oil were believed to have evaporated into the atmosphere implying a loss of volume and molecular weight of the crude oil thereby increasing the spreading rate of the crude oils.

CONCLUSIONS AND RECOMMENDATIONS

The regression model $y = 1.6315 - 0.0035x_1 + 0.6627x_2 - 0.0062x_3 - 0.0020x_4 - 0.0003x_5 + 0.0289x_6$ where, y is spreading rate, x_1 is temperature, x_2 is surface tension, x_3 is viscosity, x_4 is specific gravity, x_5 is °API and x_6 is the reid vapou pressure was obtained as the spreading rate of the 14 Nigerian crude oil samples this clearly indicates that the spreading rate of Nigerian crude oils are similar, an indication that they have similar physicochemical properties. The model can be used for a predictive action for oil spill response in the Niger Delta, Nigeria.

It is noticed that the spreading rate is faster at higher temperatures than at lower temperatures because these properties namely surface tension, viscosities and the specific gravity of the crude oil are reduced at higher temperatures. On the other hand higher temperatures increased the volatilities of the crude oils. One will expect that on a sunny day, the rate of spreading of oil when it is spilled will be faster compared to cold weather.

In view of the above, it is recommended that the range of drift be used in modeling the spreading rate of potential oil spills any where in the world during the different seasons.

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