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MODELLING THE IMPACT OF SPILLED OIL AT NIGERIA LIQUEFIED NATURAL GAS (NLNG) JETTY ON SURFACE WATER QUALITY

Elems D. N and Ugbebor J. N

Department of Civil and Environmental Engineering, University of Port Harcourt, P.M.B. 5323, Nigeria.

ABSTRACT: *This study was to model the impact of oily wastes discharge and other contaminants to the river at Nigeria Liquefied Natural Gas (NLNG) Base Jetty. The methodology of the study include review of relevant literatures, field measurement of hydraulic properties and laboratory analysis of physico-chemical parameters of the stream from eight (8) sampling stations covering the dry and rainy seasons. The results obtained from the analysis showed that the DO varied from 2.51mg/l to 4.22mg/l and* BOD_5 *varied from 4.31mg/l to 12.42mg/l along the stream. The re-aeration coefficient* K_r *of the stream varied from* $0.018d^{-1}$ *to* $0.340d^{-1}$*. The model developed from the values of* K_r *observed and* K_r *predicted showed strong correlation with a coefficient of correlation of 0.93. The observed* K_r *was compared with predicted* K_r*, Gualtieri, Churchill, Agunwamba, O'Connor and Dobbins, and Ugbebor which gave standard errors of 0.0404, 0.1290, 0.1860, 0.0451, 0.1868 and 3.1118 respectively.. This showed that the study* K_r *model performed better than the other* K_r *models. The self-purification factor of the study river gave 0.36, indicating that the stream is sluggish and polluted. The study recommended close monitoring of discharges and activities at Nigeria Liquefied Natural Gas (NLNG) Base Jetty.*

KEYWORDS: Spilled Oil, Nigeria Liquefied Natural Gas, Water Quality

INTRODUCTION

Surface water is water that collects on the surface of the earth in rivers, creeks, streams, seas and lakes. It is a vital component of the environment that provides water resources for domestic, fishery, irrigation, recreation, transportation and industrial purposes. However, the declining quality of surface water bodies caused by the uncontrolled discharge of oil and its derivatives into the environment from anthropogenic activities is a source of major concern for developing countries like Nigeria. The effect is damaging not only to individual species and populations, but also to the natural biological communities, and it accounts for the deaths of more than 14,000 people daily (WHO, 2007). Oil in surface water body consists of a floating oil film and emulsion that changes the integrity of water physically, chemically and biologically such that water is no longer suitable for any intended purpose. Oil Pollution is one of the most critical environmental problems confronting the Niger Delta Area. Industrial effluents, oil production, transportation activities and run-offs are some of the major sources of surface water pollution. The use of waterways for transportation activities has been associated with the disposal of oily wastes that deteriorates the quality of water. Pollution of water from oil and fuel spills are among the most extensive and environmentally damaging pollution problems constituting potential threats to human health and ecosystems (Onojake *et al*., 2014).

The Niger Delta Area of Nigeria is rated as the most oil impacted environment and polluted area in the world (Kia, 2009), where most oil facilities and infrastructures are located close to

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settlements and sources of water. The Nigeria Liquefied Natural Gas (NLNG) Base and Jetty in Port Harcourt is a typical example and the discharge of their effluents represents a major environmental challenge. The oily wastes generated from the operations of the Jetty are toxic, carcinogenic and persistent in nature when discharged on land or washed into waterways. They form floating oil film, emulsions, adsorbate and bio-accumulate in surface water and this is detrimental to the environment and health of the public who depend on the aquatic ecosystem for survival. According to Ukoli (2005), oil film floating on the water surface prevents natural aeration and leads to death of fresh water or marine life and on land lead to retardation of vegetation growth, cause soil infertility for a long period of time. The presence of floating oil film on water-atmosphere interface prevents the natural re-aeration process and this is a major problem of oil pollution in surface water bodies. Re-aeartion which is the physical trapping of oxygen from the atmosphere as water flows downstream is an important process that maintains the quality of surface water bodies. If dissolved oxygen (DO) drops below recommended limits, aquatic ecosystem health could be seriously impaired and desirable uses of resources could be precluded (Nwidi, 2008).

Water resources in the Niger Delta Area of Nigeria are vulnerable to pollution and it needs to be scientifically managed to protect public health and water resource. Water quality modeling which involves the representation of water quality investigation with mathematical relationships useful for predictions is an important tool for assessing the impact of wastes on surface water quality and environment. Therefore, the aim of this study is to examine the impact of oil spilled into the stream from Nigeria Liquefied Natural Gas (NLNG) Jetty in Port Harcourt.

MATERIALS AND METHODS

Study Area

The Nigeria Liquefied Natural Gas (NLNG) Base Jetty is geographically located along Ntawogba stream between latitude N4°47′34.667″ and longitude E7°01′17.964″ in Port Harcourt, Rivers State of Nigeria. The Ntawogba stream originated from Oroazi forest and empties into Amadi creek in Port Harcourt as shown in Fig 1. The climate of the area is tropical marked by two distinct seasons, which are rainy and dry seasons. The rainy season starts from March to October while the dry season begins from November to February. There are indigenous occupants at the portion where the research was conducted and they use the stream for fishing, swimming, transportation, domestic water supply, irrigation and sand mining. The stream is also used by NLNG for navigation because it links Port Harcourt city with Bonny Island where most of the oil and gas installations such as the NLNG Plant in Rivers State are situated.

The stream receives oily wastes generated from servicing of motorized boats, washings and leakages from vessels from NLNG Base Jetty. Other sources of pollution in the stream include run-offs and municipal wastes.

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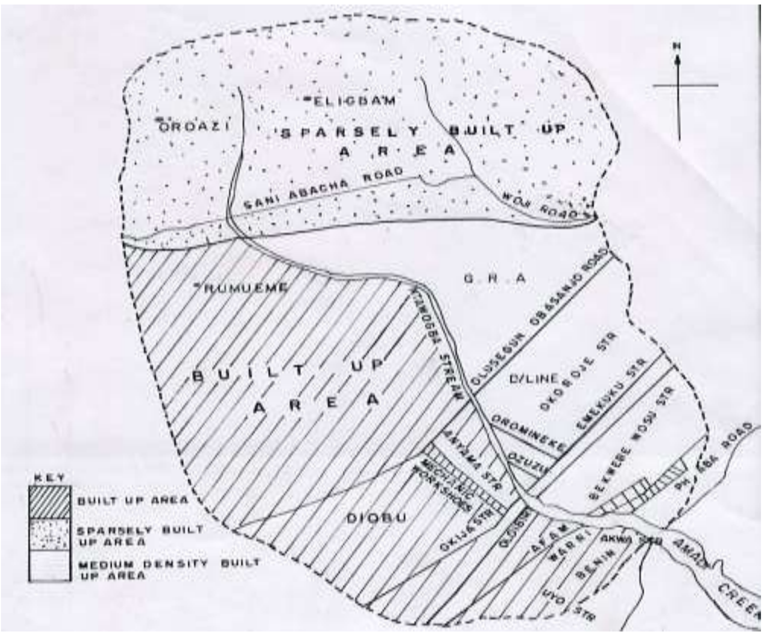

Figure 1: Map of Study Area

Methods of Data Collection

Physico-Chemical Parameters of the Stream

Water samples were collected from eight (8) stations uniformly located at a distance of 100 meters interval along the stream stretch starting from Nigeria Liquefied Natural Gas (NLNG) Jetty in Port Harcourt. Adequate precautions were taken to avoid accidental contamination of the collected samples. Water samples were collected against the flow of current using well labeled pre-cleaned 1liter plastic bottles and 250ml amber reagent glass bottles with tight stoppers. All collected water samples were sealed with aluminium foil and transported to the laboratory for physico-chemical analysis. The physico-chemical parameters were analyzed and the methods used were shown in Table 1.

Table 1: Parameters and methods of analysis

Parameters	Analysis Method
pH	APHA 4500H
Temperature, ^oC	APHA 2550B
Dissolved Oxygen (DO), mg/l	APHA 5210B
Biological Oxygen Demand (BOD_5), mg/l	APHA 5210B

Hydraulic Properties of the Stream

The velocity of flow of the stream at each sampling station was determined by the use of floater technique and a stopwatch. The depth of each sampling station was measured by dropping a calibrated bar to the bottom of the stream and readings taken**.** The width of the stream at each sampling station was obtained using a measuring tape across the stream. The coordinates and

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distance of each sampling station in the stream was determined using Geographical Positioning System (GPS) and the time of sampling at each station was collected using stopwatch.

Mathematical Models

Developing Re-aeration Rate Kr Model of the Stream

All the re-aeration rate models developed for streams are based on O'Connor and Dobbins (1956) equation. The equation is of the form:

$$K_r = \frac{a_0 V^{a_1}}{H^{a_2}} \quad \ldots\ldots (1)$$

Where:

K_r = Re-aeration rate constant (d^{-1})

H = Depth of stream (m)

V = Velocity of flow (m/s)

a_0, a_1, and a_2 are constants obtained using regression equations.

Taking natural logarithm of both sides of the expression, we have;

$$\ln K_r = \ln a_0 + a_1 \ln V - a_2 H \quad \ldots\ldots (2)$$

Equation (2) can be restated as:

$$Y = a_0' + a_1 x_1 - a_2 x_2 \quad \ldots\ldots (3)$$

Where:

$$Y = \ln K_r \quad \ldots\ldots (4)$$

$$x_1 = \ln V \quad \ldots\ldots (5)$$

$$x_2 = \ln H \quad \ldots\ldots (6)$$

$$a_0{}' = \ln a_0 \quad \ldots\ldots (7)$$

$$a_0 = e^{a_0'} \quad \ldots\ldots (8)$$

The normal equations for estimating unknown model parameters are:

$$\sum y = n a_0' + a_1 \sum x_1 - a_2 \sum x_2 \ldots\ldots (9)$$

$$\sum y x_1 = a_0' \sum x_1 + a_1 \sum x_1^2 - a_2 \sum x_1 x_2 \quad \ldots\ldots (10)$$

$$\sum y x_2 = a_0' \sum x_2 + a_1 \sum x_1 x_2 - a_2 \sum x_2^2 \ldots\ldots (11)$$

The newly developed re-aeration rate K_r model was calibrated with field data and used to predict the K_r of the stream. The results obtained was statistically validated and compared with other K_r models proposed by O'Connor and Dobbins, Churchill and Buckingham, Gualtieri, Agunwamba and Ugbebor.

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RESULTS AND DISCUSSIONS

The results are presented graphically in Figures 2 to Figures 10.

Variation of K_r with Velocity

The variations of K_r with Velocity for dry and rainy seasons were shown in Figures 2 and 3 respectively. The coefficient of correlation between K_r and Velocity gave 0.93 and 0.94 for dry and rainy seasons respectively. The variations of LN K_r with LN V for dry and rainy seasons are shown in Figures 4 and 5. The coefficient of correlation between LN K_r and LN V gave 0.93 and 0.93 respectively. It was observed that as the velocity of flow of the stream increases, the K_r of the stream also increases indicating that direct relationship exists between them.

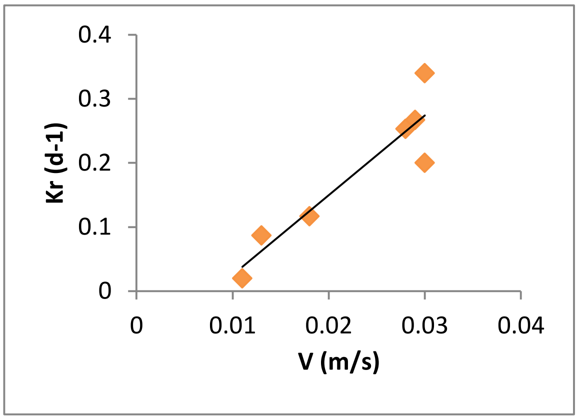

Figure 2: K_r against V for Dry Season

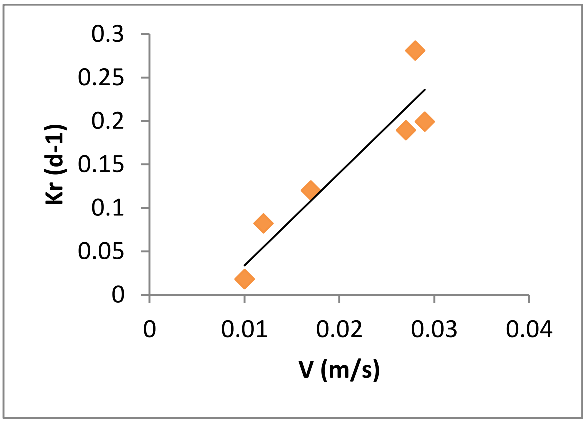

Figure 3: K_r against V for Rainy Season

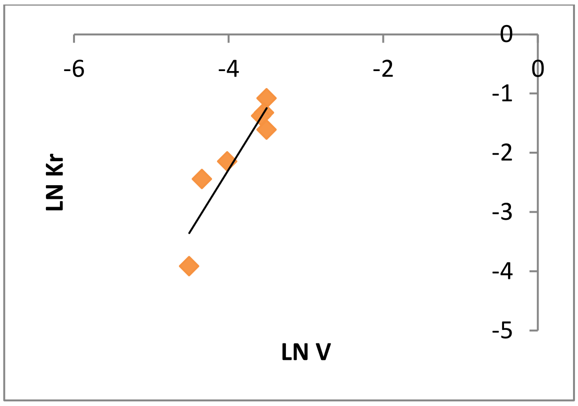

Figure 4: LNK_r against LNV for Dry Season

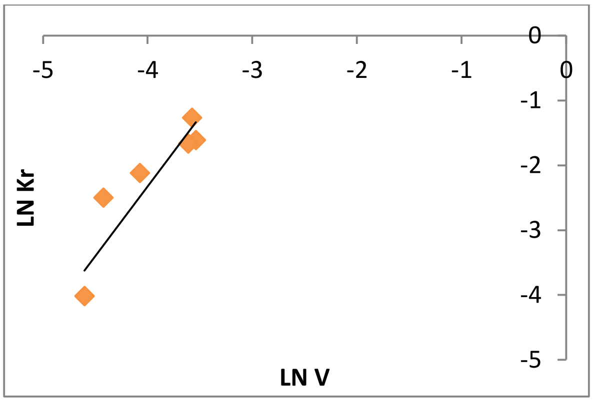

Figure 5: LNK_r against LNV for Rainy Season

Variation of K_r with Hydraulic Radius R

Figures 6 and 7 represent the variation of K_r with Hydraulic Radius R for dry and rainy seasons. The coefficient of correlation between K_r and Hydraulic Radius R for dry and rainy seasons gave 0.76 and 0.92 respectively. This high correlation coefficient shows that as K_r of the stream decreases, the hydraulic radius increases. . It was observed that as the K_r of the stream decreases while the hydraulic radius increases indicating that inverse relationship exists between them.

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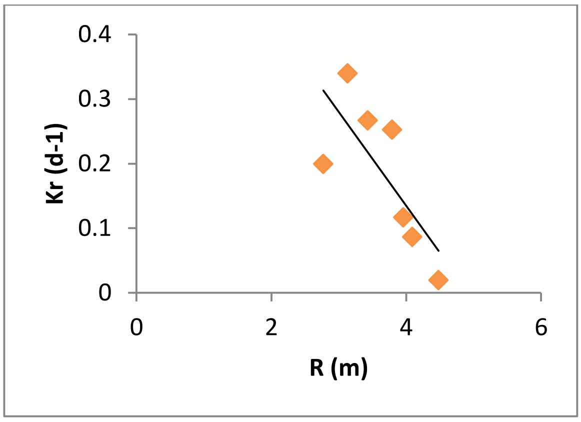

Figure 6: K_r against R for Dry Season

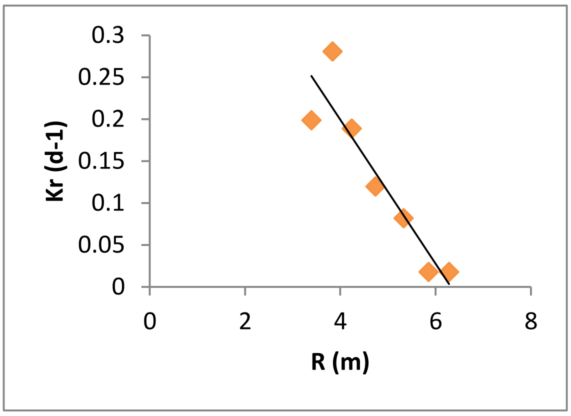

Figure 7: K_r against R for Rainy Season

Variation of Velocity V with Hydraulic Radius R

The variation of Velocity V with Hydraulic Radius R for dry and rainy seasons was shown in Figures 8 and 9 respectively. The coefficient of correlation between Velocity V and Hydraulic Radius R for dry and rainy seasons gave 0.88 and 0.96 respectively. It was observed that the lower the speed of stream flow the higher the hydraulic radius.

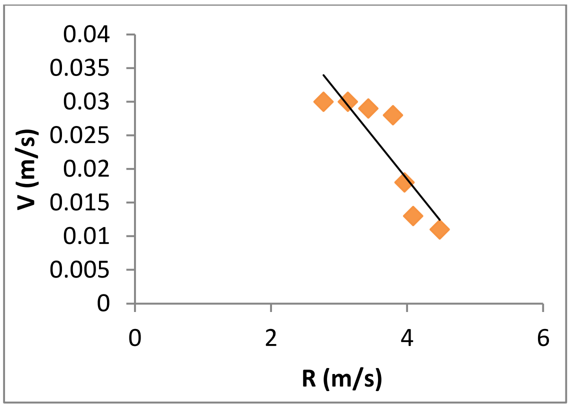

Figure 8: V against R for Dry Season

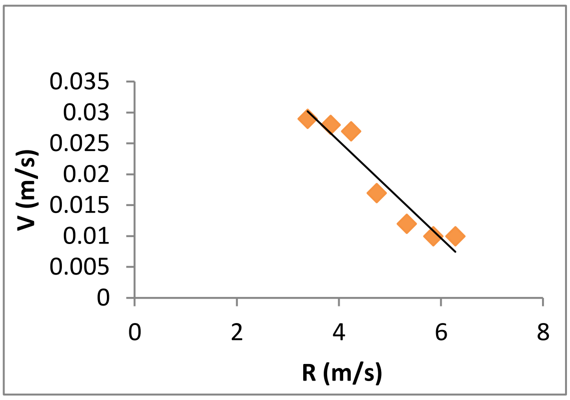

Figure 9: V against R for Rainy Season

Re-aeration Rate K_r Model of the Stream

The K_r model developed for the stream by regression analysis is given as:

$$K_r = \frac{517.495V^{2.139}}{H^{0.001}} \quad \ldots\ldots\ldots\ldots (12)$$

The values of predicted K_r and observed K_r showed strong correlation with a coefficient of correlation of 0.93 as shown in Figure 10. The comparison of observed K_r and predicted K_r with K_r models proposed by Gualtieri, Churchill, Agunwamba, O'Connor and Ugbebor indicated standard errors of 0.0404, 0.1290, 0.1860, 0.0451, 0.1868 and 3.1118 respectively. This showed that the study K_r model performed better than Agunwamba K_r model and the other models. The difference between the K_r models may be due to the prevailing natural conditions

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of the stream and the composition of effluents discharged. The re-aeration rate constant K_r of the stream varied from $0.018d^{-1}$ to $0.340d^{-1}$. The self-purification factor of the stream gave 0.36, indicating that the stream is sluggish and polluted.

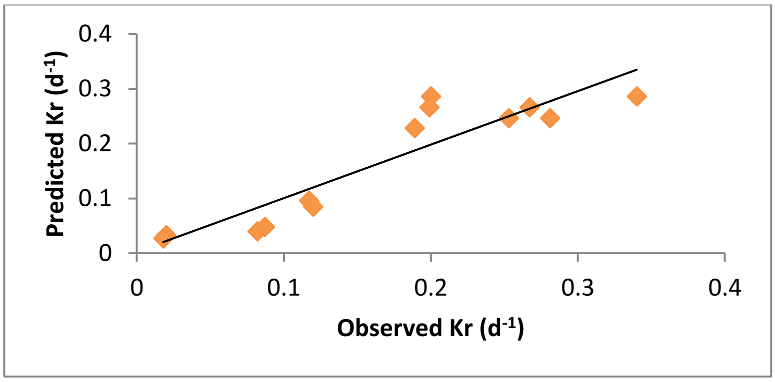

Figure 10: Variation of Predicted K_r with Observed K_r

CONCLUSION AND RECOMMENDATION

This study developed a K_r model for Ntawogba stream with small standard error that can be used for water quality modelling in Nigeria. The re-aeration rate constant K_r of the stream varied from $0.018d^{-1}$ to $0.340d^{-1}$. The self-purification factor of the stream gave 0.36, indicating that the stream is sluggish and polluted. It is recommended that the usage of the stream water without adequate treatment should be discouraged and the effluents from Nigeria Liquefied Natural Gas (NLNG) Base Jetty should be monitored to reduce pollution.

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