International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

Development of Predictive Equation for Dispersion in Crude Oil Spill on Non – Navigable River

Uche, Chikadibia K.A[1], *Akor, Alexander J.[2], Ayotamuno, Miebaka J.[3], Amgbara, Tamunokuro O.[4]

[1]Department of Civil Engineering, Kampala International University, Ishaka, Uganda
[2,3]Department of Agricultural and Environmental Engineering, Rivers State University, Port – Harcourt, Nigeria
[4]Department of Civil Engineering Technology, Kenule Beeson Saro – Wiwa Polytechnic, Bori, Nigeria
Email: chikadibia.uche@gmail.com[1], mjayotamuno@hotmail.com[3], ayotamuno.josiah@ust.edu.ng[3], tamunokuro.amgbara@ust.edu.ng[4]
* Deceased

Abstract: *Oil spill into rivers and reservoirs is of great concern as the contamination of water bodies has a devastating and obnoxious effect on marine ecology and local water supply systems. Dispersion increases the superficial transfer area, favoring dissolution, biodegradation and sedimentation. The objective of this study is to develop predictive equation for the dispersion of crude oil spill on non-navigable rivers. The equation was developed using dimension analysis. The spilled oil parameters used in the analysis were: density and kinematic viscosity of crude oil. The coefficient used in the analysis is: manning's roughness coefficient. Non – navigable river parameters used were: velocity of flow/current and depth of flow. These parameters were obtained from standards published in journal papers in the field of oil spill modeling. Other parameters used were: the volume of oil spilled and time elapsed. The developed equation was validated against a reference mass loss equation for dispersion using the coefficient of determination R^2 and percentage deviation. The equation predicted a dissolution loss of 0.7 percent of initial spill mass 24 hours after a spill. The developed predictive equation had R^2 value of 0.99, which indicates a good fit of the equation. In addition, percentage deviation values of -10.04 between the predictive equation and reference equation indicate a good agreement between the two equations. The predictive equation will be useful in contingency planning, training, spill response and long – term damage assessment of oil spills in non-navigable rivers.*

Keywords: Dispersion, Crude Oil Spill, Non-Navigable River

1. Introduction

An oil spill is the release of a liquid petroleum hydrocarbon into the environment as a result of uncontrolled well blow-out, pipeline rupture or tank failure. The term also refers to marine oil spills where oil is released into the river, sea, and ocean, coastal or inland waters. Oil may be a variety of materials including crude oil, refined petroleum products (such as gasoline or diesel fuel) or by – products, oily refuse or oil mixed in water [1].

According to [2], the persistence of spilled oil in water bodies are determined by physical, chemical and biological processes which are dependent on oil properties, hydrodynamics, meteorological and environmental conditions. These processes are: advection, turbulent diffusion, surface spreading, evaporation, dissolution, dispersion, emulsification, hydrolysis, photo-oxidation, biodegradation and particulation.

When liquid oil is spilled on the water surface it spreads to form a thin oil film – an oil slick. The composition/character of the oil changes extensively from the initial time of the spill, as light (low – molecular weight) fractions evaporate, water – soluble components dissolve in the water column, the immiscible compounds become emulsified and dispersed in the water column as small droplets [3].

Natural dispersion is the removal of oil from the water surface by its incorporation, in the form of small droplets, into the water column by wave action. The rate of dispersion depends on the amount of wave energy and turbulence on the water surface. For low-energy wave conditions, the rate of dispersion is low. For high sea states, dispersion may dominate with the result that most of the oil is removed from water surface in a few hours. Also, the more viscous the oil, the slower the rate of dispersion. In the water column, dispersed oil is present as small droplets, which has a much higher surface area in contact with the water [3]. Turbulence determines the diameter and the distribution of the suspended drops [4]. This increases the rate of dissolution, the rate of natural biodegradation and the rate of sedimentation.

A model for the calculation of amount of oil transferred due to dispersion was proposed by [5]. They stated that the dispersion of oil in the water column is a function of the dynamic viscosity, the oil slick thickness, the interface tension of oil – water and the wind velocity. A simplified model to calculate the dispersion according to dispersion constant, the initial volume of spill, the wind velocity and time elapsed was proposed by [6].

2. MATERIALS AND METHODS

2.1 Description of Non-navigable River

This research was carried out for small non-navigable rivers of the scale typical of a tributary to a navigable river, [7]. According to them, the river is assumed to exhibit a fair degree of meandering and is sheltered from wind by the river banks and vegetation. There may be areas of quiet water or eddies at the inside of river bends and other pools where flow velocities differ from that of the main current.

The cross channel profiles are irregular, with rapids at one extreme and quiet bay at the other. Turbulence results from shear in currents along the banks and river bottom. Increased velocity of flow and bed roughness has direct bearing on turbulence. The river currents and water level are usually increased by seasonal or episodic changes in runoff and rainfall.

2.2 Determination of spilled oil parameters

The spilled oil parameters required for the development of the predictive equation were obtained from standards in papers published by researchers in the field of oil spill modeling. This is because at the initial period of real-life spills, more attention usually is paid to oil combating operations rather than to rigorous measurements. Besides a direct measurement of vast areas, typically affected by such a dynamic event as an oil spill, is an extremely difficult task [8].

Bonny light crude oil was considered as the specimen for this study as it is the most common crude blend exported from Nigeria [9].

The spilled oil parameters obtained are as follows:

- Density (kg/m^3): The value for density was obtained from [9]. This parameter (variable) will be used in the determination of mass loss due to dispersion in an oil spill
- Kinematic Viscosity (m^2/s): The value for kinematic viscosity was obtained from [9]. This parameter (variable) will be used in the determination of mass loss due to dispersion in an oil spill.

2.3 Non – navigable river parameters:

- Mean current velocity (m/s): The value for mean current velocity was obtained for this study according to [7]. This parameter (variable) will be used in the determination of mass loss due to dispersion in an oil spill.
- Average depth of flow (m): Reference [7] provided a value for mean depth of flow and will be adopted for this study. This parameter (variable) will be used in the determination of mass loss due to dispersion in an oil spill.
- Manning's roughness coefficient ($m^{-1/3}/s$): The value of Manning coefficient was calculated using equations provided by [10].

$$V = \frac{k}{n} R_h^{2/3} . S^{1/2} \quad (1)$$

$$R_h = \frac{A}{P} \quad (2)$$

where
V = the cross-sectional average velocity (m/s).
K = a conversion constant equal to 1.486 for U.S. customary units or 1.0 for S.I. units.
n = Manning coefficient of roughness.
R_h = the hydraulic radius.
S = slope of the water surface or the linear hydraulic head loss (ft/ft, m/m).
A = cross-sectional area of flow.
P = wetted perimeter (this is the perimeter of the cross-sectional area that is wet).

- River surface slope / gradient (m/m): The value for the river surface slope/gradient was obtained from (Gulliver *et al.*, 2002). This parameter (variable) will be used in the determination of mass loss due to dispersion in an oil spill.

2.4 Other relevant data:

- Volume of Spill (m^3): A spill volume in the category of a major spill was assumed for this study, according to [11].

2.5 Reference equation:

- A simplified model [6] to calculate the dispersion according to dispersion constant as follows:

$$\frac{dv}{dt} = NV_0U^2t \quad (3)$$

International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

Where,

dV = Dispersion loss

N= dispersion constant (2 x 10^{-8})

V_0 = initial spill volume

U= wind velocity

t = time

2.5 Theory

The governing equations required to evaluate the weathering processes for spilled oil in a river system was established using dimension analysis. With the help of dimensional analysis the equation of physical phenomenon were developed in terms of dimensionless groups or parameters. The methods of dimension analysis are based on the Fourier principle of homogeneity, [12].

- Buckingham's π-theorem: The Buckingham's π-theorem states as follows: If there are n-parameters (governed and governing parameters) in a dimensionally homogenous equation and if these contain m – fundamental dimensions (such as M, L, T, θ and mol), then the parameters are arranged into (n-m) dimensionless terms, called π – terms.

  Mathematically, if any parameter K_1, depends on governing parameter, K_2, K_3, K_4…Kn; the functional equation may be written as:

  $$K_1 = f\ (K_2, K_3, K_3 \ldots K_n)\ = 0 \qquad (4)$$

  Equation (3) may be written as:

  $$f\ (K_1, K_2, K_3, K_4 \ldots K_n)\ = 0 \qquad (5)$$

  It is a dimensionally homogenous equation and contains n parameters. If there are m fundamental dimensions, then according to Buckingham's π- theorem (5) can be written in terms of a number of π-terms (dimensionless groups) in which number of π-terms is equal to $(n-m)$. Hence (4) become:

  $$f_1\ (\pi_1, \pi_2, \pi_3 \ldots \pi_{n-m})\ = 0 \qquad (6)$$

  Each dimensionless π-term is formed by combining m parameters with one of the remaining (n-m) parameter i.e. each π-term contains (m+1) parameter. These m parameters which appear repeatedly in each of π-terms are consequently called repeating parameters and are chosen from among the parameters such that they together involve all the fundamental dimensions and they themselves do not form a dimensionless parameter.

  The final general equation for the phenomenon may be obtained by expressing anyone of the π-terms as a function of the other as:

- Transformation of π–terms: To ensure simplicity in the experimentation process, the present π-terms (π_2, π_3, and π_4,) were adjusted to generate new π-terms by multiplying or dividing with each other [13], while maintaining the independency condition.

- Functional relationship between dimensionless terms (π-terms): The experimental/calculated values of the governed parameter and other governing parameters are substituted into the dimensionless groups. A plot is made of the π-terms containing the governed parameter against the other π-terms. The functional relationship is determined by analyzing the nature of the plot, [14].

3. Development of Predictive Equation

3.1 Determination of Π – Terms

The losses in an oil slick as a result of dispersion into the water column are dependent on the following factors:

- Density of oil, ρ (kg/m^3)
- Kinematic Viscosity of oil, υ (m^2/s)
- Velocity of flow/current, V (ms^-)
- Manning's roughness coefficient, n ($m^{-1/3}$.s)
- Depth of flow, h (m)
- Time (t)

The dispersion loss from an oil slick D_s (kg) is a function of:

ρ, υ, V, n, h, t

Mathematically,

$$D_s\ =\ f\ (\rho, \upsilon, V, n, h, t)\ or\ f\ (D_s, \rho, \upsilon, V, n, h, t)\ =\ 0 \qquad (7)$$

Total no. of variables, n = 7

Table 1 show variables expressed in terms of fundamental dimensions:

Table 1: Variables expressed in terms of fundamental dimensions

International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

D_s	ρ	υ	V	n	h	t
M	ML^{-3}	L^2T^-	LT^-	$L^{-1/3}T$	L	T

The fundamental dimensions are:

- Mass (M)
- Length (L)
- Time (T)

Number of fundamental dimensions, m = 3

Number of π – terms:

$$n - m = 7 - 3 = 4$$

From (4):

$$f\ (\pi_1, \pi_2, \pi_3, \pi_4) = 0 \tag{8}$$

Selecting repeating variables as: ρ, υ, v,

$$\pi_1 = \rho.\upsilon.V.D_s \tag{9}$$

$$\pi_2 = \rho.\upsilon.V.n \tag{10}$$

$$\pi_3 = \rho.\upsilon.V.h \tag{11}$$

$$\pi_4 = \rho.\upsilon.V.t \tag{12}$$

π_1 –term:

$$\pi_1 = \rho^{a_1}.\upsilon^{b_1}.V^{c_1}.D_s \tag{13}$$

$$M^0L^0T^0 = (ML^{-3})^{a_1}.(L^2T^-)^{b_1}.(LT^{-1})^{C_1}.M \tag{14}$$

Equating indices

$M: 0 = a_1 + 1$

$L: 0 = -3a_1 + 2b_1 + c_1$

$T: 0 = -b_1 - c_1$

Solving the above equations,

$a_1 = -1,\ b_1 = -3, c_1 = 3$

$$\pi_1 = \rho^{-1}.\mu^{-3}.V^3.D_s \tag{15}$$

$$\pi_1 = \frac{D_S.V^3}{\rho\mu^3} \tag{16}$$

π_2 – term

$$\pi_2 = \rho^{a_2}.\upsilon^{b_2}.V^{C_2}.n \tag{17}$$

$$M^0L^0T^0 = (ML^{-3})^{a_2}.(L^2T^-)^{b_2}.(LT^-)^{c_2}.(L^{-1/3}T) \tag{18}$$

Equating indices:

$M: 0 = a_2$

$L: 0 = -3a_2 + 2b_2 + c_2 - {}^1/_3$

$T: 0 = -b_2 - c_2 + 1$

Solving the above equations

$a_2 = 0, b_2 = {}^{-2}/_3, c_2 = {}^5/_3$

$$\pi_2 = \rho^0.\upsilon^{-2/3}.V^{5/3}.n \tag{19}$$

$$\pi_2 = \frac{nV^{5/3}}{\upsilon^{2/3}} \tag{20}$$

π_3 – term

$$\pi_3 = \rho^{a_3}.\mu^{b_3}.V^{C_3}.h \tag{21}$$

$$M^0L^0T^0 = (ML^{-3})^{a_3}.(L^2T^-)^{b_3}.(LT^-)^{c_3}.(L) \tag{22}$$

Equating indices

$M: 0 = a_3$

$L: 0 = -a_3 + 2b_3 + c_3 + 1$

$T: 0 = -b_3 - c_3$

Solving the above equations

$$a_3 = 0, b_3 = -1, c_3 = 1$$

$$\pi_3 = \rho^0.\upsilon^{-1}.V^1.n \tag{23}$$

$$\pi_3 = \frac{hV}{\upsilon} \tag{24}$$

π_4 – term

International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

$$\pi_4 = \rho^{a_4}.\mu^{b_4}.V^{C_4}.t \quad (25)$$

$$M^0L^0T^0 = (ML^{-3})^{a_4}.(L^2T^{-})^{b_4}.(LT^{-})^{c_4}.(T) \quad (26)$$

Equating indices

$M: 0 = a_4$

$L: 0 = -3a_4 + 2b_4 + c_4$

$T: 0 = -b_4 - c_4$

Solving the above equations

$$a_4 = 0, b_4 = -1\ c_4 = 2$$

$$\pi_4 = \rho^0.v^{-1}.V^2.n \quad (27)$$

$$\pi_4 = \frac{V^2t}{v} \quad (28)$$

From the above calculations the determined π-terms are:

$$\pi_1 = \frac{D_s.V^3}{\rho v^3}, \pi_2 = \frac{nV^{5/5}}{v^{2/3}}, \pi_3 = \frac{hV}{v}, \pi_4 = \frac{V^2t}{v}$$

3.2 Transformation of π – terms

The π_3 term is divided by the π_4 term as follows:

$$\frac{hV}{v} \div \frac{V^2t}{v}$$

$$\pi_3' = \frac{h}{Vt} \quad (29)$$

The π_3' – term is multiplied by the π_2 – term as follows:

$$\frac{nV^{5/3}}{v^{2/3}} \times \frac{h}{Vt}$$

$$\pi_2' = \frac{nhV^{2/3}}{v^{2/3}t} \quad (30)$$

According to the π-theorem:

$$\pi_1 = \Phi\ (\pi_2') \quad (31)$$

$$\frac{D_S.V^3}{\rho v^3} = \phi\left(\frac{nhV^{2/3}}{v^{2/3}.t}\right) \quad (32)$$

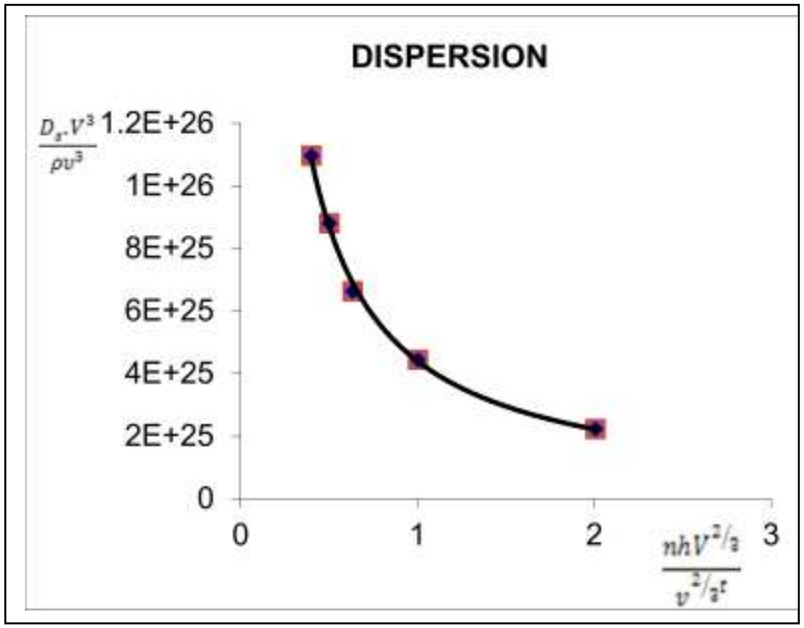
3.3 Determination of functional relationship

Table 2 shows the values of the π – terms after the calculated and pre-determined values of the governing and governed parameters have been substituted:

Table 2: Values of π – terms

$\pi_2' = \frac{nhV^{2/3}}{v^{2/3}t}$	$\pi_1 = \frac{D_s.V^3}{\rho v^3}$
2.008	2.222 x 10^{25}
1.004	4.4289 x 10^{25}
0.634	6.6204 x 10^{25}
0.502	8.7968 x 10^{25}
0.402	10.9582 x 10^{25}

Fig. 1 shows the plot of π_1 (y – axis) against π_2' (x – axis). The functional relationship between the π terms may now be established from the plot.



International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

Figure 1: The plot of π_1 term against π_2' term

As can be seen from the plot, the curve is that of a power function which is represented by the expression:

$$y = ax^b \quad (33)$$

The values of the constants a and b were determined by the method of averages using the procedure suggested [15]. For clarity the procedure is stated as follows:

- The variables in the plot are related by the expression:

  $$y = ax^b \quad (34)$$

  The logarithmic form of which is:

  $$\log y = \log a + b \log x \quad (35)$$

- Substitute the values of *x* and *y* into (35). This will yield a number of equations based on the number of data sets available.
- Divide the number of equations into two to give two different sets of equations. Add each to give two different equations in a and b.
- The solution of the two different equations in a and b gives the following results:

$$a = 4 * 10^{25} \text{ and } b = -0.986$$

Substituting the values of the constants into (23) results as follows:

$$y = 4 * 10^{25} x^{-0.986} \quad (36)$$

The relationship between the π – terms may be written as:

$$\frac{D_S.V^3}{\rho v^3} = 4 * 10^{25} \left(\frac{nhV^{2/3}}{v^{2/3}t}\right)^{-0.986} \quad (37)$$

Re – arranging (26), the Dispersion loss (kg) may be calculated:

$$D_s = \frac{\rho v^3}{V^3}\left(4 * 10^{25}\left(\frac{nhV^{2/3}}{v^{2/3}t}\right)^{-0.986}\right) \quad (38)$$

3.4 Validation

The predictive equations were validated by comparison of computed results from developed and reference equations using coefficient of determination R^2 and percentage deviation. According to [16], the coefficient of determination R^2 is used in the context of equations whose main purpose is the prediction of future outcomes on the basis of other related information. It provides a measure of how well future outcomes are likely to be predicted by the equation. It is a statistic that gives information about the 'goodness of fit' of an equation. A R^2 value of 1.0 indicates a perfect fit of the equation. Percent deviation formula is very useful in determining how accurate the data collected by research really is. The data is usually compared to reference data. If the percent deviation is a negative number that means the student data is lower than the standard value.

Using the equation for coefficient of determination provided by the above mentioned author and percentage deviation formula, the predictive equations were validated against the reference equations for dissolution.

- Coefficient of determination

  $$R^2 = \frac{a\sum Y + b\sum XY - n\bar{Y}^2}{\sum Y^2 - n\bar{Y}^2} \quad (39)$$

  Where,

  R^2 = coefficient of correlation.

  $\bar{Y}$ = mean value of Y

  X = independent variable (calculated values).

  Y = dependent variable (predicted values).

  n = number of measurements / calculations.

- Percentage deviation

  $$\%\ deviation = \frac{Predicted\ value - Standard\ value}{Predicted\ value} \quad (40)$$

4. Results and Discussion

4.1 Spilled oil, navigable river parameters (variables) and other relevant data

The spilled oil and navigable river parameters (variables) in addition to other relevant data which determine the rate of mass loss due to dispersion, in an oil spill on a river system were identified. Table 3 shows the values of the parameters (variables) that determine the rate of mass loss due to dispersion in an oil spill on a non – navigable river.

- Oil Density (kg/m^3): This property determines if the oil will float on water or sink. Reference [3] stated that the density of most crude and refined oil lies between 780 kg/m^3 and 1000 kg/m^3.

- Kinematic Viscosity (m^2/s): Kinematic viscosity is the ratio of dynamic viscosity and density. It is a ratio of the viscous force to the inertial force, the latter characterized by the fluid density. The kinematic viscosity is sometimes referred to as diffusivity of

International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 4, Issue 7, July – 2020, Pages: 9-17

momentum, because it is comparable to and the same unit (m^2/s) as diffusivity of heat and diffusivity of mass [1].

- Manning's roughness coefficient ($m^{-1/3}/s$): The Manning coefficient of roughness, often denoted as 'n', is an empirically derived coefficient, which is dependent on many factors, including river bottom roughness and sinuosity. Values vary greatly in natural stream / river channels and will even vary in a given reach of channel with different stages of flow, [17].
- Mean current velocity (m/s): There are varying current values across the cross-section of a stream channel. Water near the center of a stream channel will flow faster than water near the banks or bottom of the channel where retarding forces of friction with the channel are greater. In stream flow calculations a mean value of these current values is calculated, [3].
- Average depth of flow (m): This parameter is dependent on the variable nature of the river environment, as such an average value is used, [7].
- River surface slope /gradient (m/m): This is the slope of the water surface or the hydraulic head [7].
- Volume of Spill (m^3): A major spill is defined as a discharge of oil in excess of 5000 barrels in inland water ways, land or coastal waters, [11].

Table 3: Values of the parameters (variables) that determine the rate of mass loss due to dispersion, in an oil spill on a non – navigable river

S/no.	Parameters (variables)	Value
1	Oil density	860 kg/m^3
2	Oil kinematic viscosity	4.99 x 10-6 m^2/s
3	Manning's roughness coefficient	0.04 $m^{1/3}$.s
4	Mean current velocity	0.3 m/s
5	Average depth of flow	1m
6	River surface slope	0.04
7	Volume of oil spilled	5,000 barrels = 794.5m^3

4.2 Predictive Dispersion Equation

Predictive dispersion equation was developed from the previously described parameters (variables), using dimension analysis. These equations were used to evaluate the percentage mass loss due to dispersion within a period of 24 hours.

Dispersion poses the most intractable of problems. Dispersion increases the superficial transfer area, favoring the dissolution, the biodegradation and sedimentation. With approximately 0.7% of oil submerged in the water column after 24 hrs, the negative environmental impact is alarming. This is because dispersed oil has been known to resurface hundreds of miles downstream from the initial spill point [12].

Table 4 shows the developed predictive equations and the percentage mass loss due to dispersion, after a period of 24 hours.

Table 4: Developed predictive equation and the percentage mass loss due to dispersion after a period of 24 hours.

Weathering Process	Predictive Equation	Mass loss (%) (after 24 hours)
Disperson	$D_s = \frac{\rho v^3}{V^3}\left(4 \times 10^{25}\left(\frac{nhV^{2/3}}{v^{2/3}.t}\right)^{-0.986}\right)$	0.7

4.3 Validation of Predictive Dissolution Equation

Table 4 shows the comparison between the results of the dispersion equation of [6] and the predictive dispersion equation. The results of the predictive equation show a cumulative mass loss of 20,883 kg after a period of five (5) days.

The developed predictive equation for dispersion shows a good fit with the reference equation of [6]. The predictive equation has a coefficient of determination R^2 value of 0.99 and an average percentage deviation of -10.04, indicating a reasonable agreement between the two equations. A graph showing percentage mass loss due to dispersion with respect to time elapsed was plotted for both equations.

Table 5: Comparison between the results of the dispersion equation of [6] and the predictive dispersion equation

Time Elapsed (days)	1	2	3	4	5
	Cumulative dispersion loss (kg)				
Huang dispersion equation. $\frac{dv}{dt} = NV_0U^2t$	4,726	9,419	14,079	18,708	23,304
Predictive dispersion equation $D_s = \frac{\rho v^3}{V^3}\left(4 \times 10^{25}\left(\frac{nhV^{2/3}}{v^{2/3}.t}\right)^{-0.986}\right)$	4,278	8,473	13,332	16,783	20,883
Coefficient of determination R^2	0.99				
Average percentage (%) deviation	-10.04				

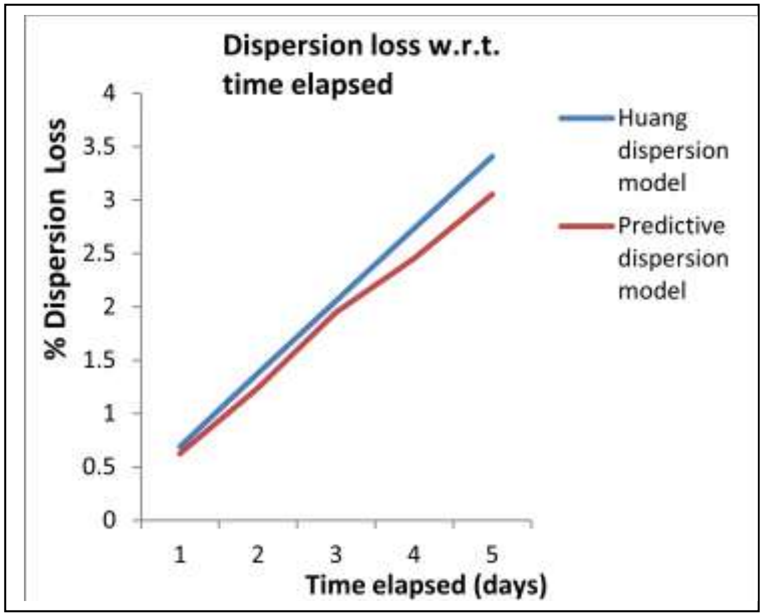


Fig. 2: Percentage mass loss due to dispersion from slick with respect to time

4.4. Conclusion

This study explored the development of predictive equation for dispersion of spilled oil in non-navigable rivers. Dispersion is one among the physico – chemical processes that occurs in an oil spill on a water body. This process results in loss of mass and changes in physical characteristics of the spilled oil. A predictive equation has been developed to evaluate the mass loss due to dispersion process in an oil spill on non-navigable river. Parameters considered in the development of the predictive equation are: Spilled oil and navigable river parameters (variables) in addition to other relevant data. The predictive equation was developed from first principles using dimension analysis. The developed predictive equation is as follows:

Mass loss due to dispersion: $D_s = \frac{\rho v^3}{V^3}\left(4 \times 10^{25}\left(\frac{nhV^{2/3}}{v^{2/3}.t}\right)^{-0.986}\right)$

The result of the predictive equation showed a mass loss of 0.7% for dispersion, after a period of 24 hours. The result of the predictive equation for dispersion was validated using coefficient of determination. The result obtained was compared with the dispersion equation of [6]. The developed predictive equation had R^2 value of 0.99, which indicates a good fit of the equation. In addition percentage deviation values of -10.04 between the predictive equation and reference equation indicate a good agreement between the two equations.

5 Acknowledgment

All Praise, Honour and Glory to Almighty God; the greatest inspiration. We are grateful to our family and friends for their unflinching support, love and encouragement, through the duration of this research.

6 References

[1] Wikipedia Online Encyclopaedia (2009). Oil Spill. Retrieved from: http://en.wikipedia.org/wiki/Oil_spill

[2] Tkalich P., Huda K., & Gin K.Y. (2003). A Multiphase Oil Spill Model. Journal of International Association of Hydraulic Engineering and Research, 41(2), 115 – 125.

[3] ESSO (1999). General Oil Spill Response Plan, Section 04 - Fate and Effects of Spilled Oil. Retrieved August 21, 2009, from: http://www.esso.com

[4] Bentacourt F., Palacio O., & Rodriguez A. (2005). Effects of the Mass Transfer Process in Oil Spill. American Journal of Applied Sciences, 2 (5), 939 -946.

[5] Mackay D., Mascarenhas I.B. & Paterson S. (1980). Oil Spill Processes and Models. *Environment Canada Report EE8.*

[6] Huang, J.C. (1983). A Review of the State-of-the-art of Oil Spill Fate/Behaviour Models. *In Proceedings of the 1983 Oil Spill Conference, Washington D.C.*, 313 – 322.

[7] Gulliver J.S., Vaughan V.R., & Hibbs D.E. (2002). Modeling Oil Spills on River Systems: Evaluation of Aqueous Concentrations. Retrieved February 25, 2009, from: http://www.knovel.com

[8] Rajput R.K. (2003). Heat and Mass Transfer. New Delhi: S.Chand & Company LTD, pp. 208 – 210.

[9] International Tanker Owners' Pollution Federation (2009). Fate of Oil spills & Weathering Processes. Retrieved March 24, 2009, from: http://www.itopf.com/marine-spills

[10] Wikipedia Online Encyclopaedia (2009). Manning Formula. Retrieved from: http://en.wikipedia.org/wiki/Manning_formula

[11] Egberongbe, F., Nwilo, P., & Badejo, O. (2006). Oil Spill Disaster Monitoring Along the Nigerian Coastline TS16.6', Marine and Coastal Zone Management – Environmental Planning Issues TS16. In Proceedings of 5th FIG Regional Conference, Accra Ghana, 2006.

[12] National Oceanic and Atmospheric Administration (2005). *Emergency Response / Planning for Environmental Emergencies (Oil spill in Rivers).* Retrieved from: http://www.response.restoration.noaa.gov [Accessed: 7th April 2009].

[13] Langhaar, H. L. (1980). Dimensional Analysis and Theory of Models. Florida: R. E. Krieger Publishing Co., pp. 173 – 174.

[14] Barenblatt, G.I. (1987). Dimensional Analysis. London: Gordon and Breach Science Publishers, pp. 38 – 48.

[15] Michael, A.M. (2008). *Irrigation: Theory and Practice*. Pradesh, Vikas Publishing House, PVT LTD.

[16] Kazmier L. J. (1976). Theory and Problems of Business Statistics. New York: McGraw Hill Inc., pp. 265 – 267.

[17] Ebrahimi, N.G., Fathi _Moghadam, M. Kashefipour, S.M., Sancie, M., & Ebrahimi, K. (2008). Effects of Flow and Vegetation States on River Roughness Coefficient. *Journal of Applied Sciences, 8(11) 2118 – 2123.*