

Simulation Of the Spread of Spilled Crude Oil Pollutants Along a Creek

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Abstract- This study was carried out to have an insight into the spread of crude oil pollutants along a creek from the point of spill. A computer simulation was developed for 10 barrels of crude spilled into a 1,000 m² of water area in a creek to spread a 1-kilometer distance of it. First, a mathematical model describing the spread of the crude oil pollutants along the creek was developed. Secondly, the resulting model equation was then written in a BASIC programming language. Finally, the program was run to determine the spread of crude oil pollutants along the creek in kg/m³ of pollutants concentration at varying distances along the creek and the time interval of spread. It conclusively recommended that oil companies operating in Nigeria should learn to respond quickly to spill reports as they are known for always delaying in response to spill reports, thereby leading to improper clean-up.

Keywords: Simulation, Spread, Crude oil, pollutants, Creek.

I. INTRODUCTION

In order for a successful clean-up design for a creek area spill site, knowledge of the spread of pollutants along the creek with time due to the water current is really necessary. Computer simulation can be used to accomplish this. If we can successfully develop a model describing the spread of crude oil pollutants with time along the creek, and code with a computer programming language.

Simulation is an imitative representation of a real-world process, system or phenomenon over time by using mathematical models and computer algorithms (Alexander, 2009). Simulations allow engineers, scientists and analysts to test scenarios, predict outcomes and study behavior conclusively without the risks or costs of physical experiments (Juan, 2018).

Crude oil spills in creeks lead to devastation by hydrocarbon pollutions, severe and prolonged ecological damage, and environmental degradation, notably in the Niger Delta area of Nigeria (Ike, 2018). Local residents often suffer contaminated water, poisoned aquatic life and ruined livelihoods, thereby leading to serious humanitarian crisis (Ajono, 2007).

Immediate containment, emergency environmental remediation and rigorous regulatory enforcement are consistently required to mitigate the damages (Yinka, 2014). Simulation of the spread of hydrocarbon pollutants along the creek with time due to the water current will probably help to establish an insight into a successful clean-up and remediation design.

II. METHODOLOGY

The model equation is first developed and then written in a BASIC programming language.

2.1 Mathematical Modelling

Using the Reynold's analogy for mass transfer through turbulent flow, we have:

$$KL / V = Re \cdot 0.25 \text{ (Reynold's analogy)} \quad 1.1$$

Where:

KL = The liquid phase mass transfer coefficient

V = Velocity of flow

Re = Reynold's number, which is further defined as:

$$Re = (\rho \times V \times L) / \mu$$

Where:

ρ = density of fluid

V = velocity of flow

L = length or diameter

μ = viscosity of fluid

Assuming the coefficient of mass transfer for the hydrocarbon pollutants to be equal to the velocity of flow of the water, and substituting for the Reynold's number:

$$1 = [(p \times V \times L) / \mu]^{-0.25} \quad 1.2$$

Evaluating further:

$$p = (\mu / V) \times (1 / L) \quad 1.3$$

Where:

- p = The mass concentration of pollutants in kg/m^3
- μ / V = viscosity / velocity $\times (\text{kg} \cdot \text{s}) / (\text{m} \cdot \text{s}) \times \text{m/m} = \text{Md}$
- $^{\circ} \text{Md}$ = The spilled crude oil distribution over the spill site in kg/m^2
- L = The distance of pollutants spread along the creek

Hence substituting:

$$p = \text{Md} * (1 / L) = \text{Md} / L \quad 1.4$$

Equation 1.4 gives the model equation, describing the spread of hydrocarbons pollutants in mass concentration of pollutants (p) in kg/m^3 along the creek at varying distances (L) in meter (m).

The time interval of spread at any distance is given by:

$$T = L / V \quad 1.5$$

Where:

- T = The time interval of spread of pollutants any distance
- L = The distance of spread of pollutants along the creek in meter (m)
- V = The velocity of flow of the water current on which the spread of pollutants depends

This can be determined by timing a floating object between two points along the creek, the distance between the two points measured and then divided by the time taken.

2.2 Computer Simulation

The simulation of the spread of 10bbl of spilled crude oil pollutants over a site of 1000m^2 estimated area

along a creek, with an estimated water current of 2.5m/s to a distance of 1km is then carried out, using BASIC programming language.

2.3 Data Input Summary: Data Profile:

- $M = 10\text{bbl} / 1000\text{m}^2 = 1400\text{kg} / 1000\text{m}^2 = 1.4 \text{ kg/m}^2$
- L = The distance along the creek / the varying distance along the creek = 0 to 1km (1000m).
- p = Spreading hydrocarbon pollutants concentration in kg/m^3
- V = Water current in $\text{m/s} = 2.5 \text{ m/s}$
- T = Time of pollutant spread in s

2.4 Basic Program Screenplay

```
10 INPUT M = 1.4
20 INPUT V = 2.5
30 INPUT L = 0 TO 1000 STEP 10
40 INPUT p = M / L
50 INPUT T = L / V
60 PRINT L, p, T
70 RUNS
80 STOPS
```

```
L   p   T
0   *   0
```

0	0.0000	0
10	0.1400	4
20	0.0700	8
30	0.0467	12
40	0.0350	16
50	0.0280	20
60	0.0233	24
70	0.0200	28
80	0.0175	32
90	0.0156	36
100	0.0140	40
110	0.0127	44
120	0.0117	48
130	0.0108	52

140	0.0100	56	470	0.0030	188
150	0.0093	60	480	0.0029	192
160	0.0087	64	490	0.0029	196
170	0.0082	68	500	0.0028	200
180	0.0078	72	510	0.0027	204
190	0.0074	76	520	0.0027	208
200	0.0070	80	530	0.0026	212
210	0.0067	84	540	0.0026	216
220	0.0064	88	550	0.0025	220
230	0.0061	92	560	0.0025	224
240	0.0058	96	570	0.0025	228
250	0.0056	100	580	0.0024	232
260	0.0054	104	590	0.0024	236
270	0.0052	108	600	0.0023	240
280	0.0050	112	610	0.0023	244
290	0.0048	116	620	0.0023	248
300	0.0047	120	630	0.0022	252
310	0.0045	124	640	0.0022	256
320	0.0044	128	650	0.0022	260
330	0.0042	132	660	0.0021	264
340	0.0041	136	670	0.0021	268
350	0.0040	140	680	0.0021	272
360	0.0039	144	690	0.0020	276
370	0.0038	148	700	0.0020	280
380	0.0037	152	710	0.0020	284
390	0.0036	156	720	0.0019	288
400	0.0035	160	730	0.0019	292
410	0.0034	164	740	0.0019	296
420	0.0033	168	750	0.0019	300
430	0.0033	172	760	0.0018	304
440	0.0032	176	770	0.0018	308
450	0.0031	180	780	0.0018	312
460	0.0030	184	790	0.0018	316

800	0.0017	320	940	0.0015	376
810	0.0017	324	950	0.0015	380
820	0.0017	328	960	0.0015	384
830	0.0017	332	970	0.0014	388
840	0.0017	336	980	0.0014	392
850	0.0016	340	990	0.0014	396
860	0.0016	344	1000	0.0014	400
870	0.0016	348			
880	0.0016	352			
890	0.0016	356			
900	0.0016	360			
910	0.0015	364			
920	0.0015	368			
930	0.0015	372			

III. RESULT, ANALYSIS AND DISCUSSION

Ten selected values, namely 0, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 from the simulation result are presented for analysis and discussion, using table and graphs.

3.1 Result

The result extracted from the simulation is presented.

Table 1: Presentation of result

L (m)	0	100	200	300	400	500	600	700	800	900	1000
p (kg/m ³)	0.0000	0.0140	0.0067	0.0047	0.0035	0.0028	0.0023	0.0020	0.0018	0.0016	0.0014
T (s)	0.0	40.0	80.0	120.0	160.0	200.0	240.0	280.0	320.0	360.0	400.0

3.1.1 Analysis

By plotting a graph of both the pollutant concentration, and the time of spread and the distance along the creek, we have:

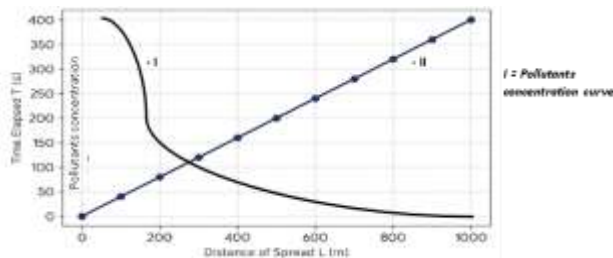


Fig 1. A graph of both the pollutants concentration and the time spread (T) against the distance of spread (L).

3.2 Discussion

Both the pollutants concentration curve and the time of spread curve reveals that hydrocarbons pollutants spread very fast with time, and hence requires urgent intervention once a spill is reported. The extend and time of spread of the spilled crude oil pollutants are clearly shown for a successful clean-up and remediation design.

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Computer simulation of the spread of spilled crude oil pollutants along a creek with time clearly gives us an insight into the nature and extend at spread of hydrocarbon pollutants. This will definitely help us to intervene timely and come up with the appropriate clean-up and remediation design.

4.2 Recommendation

Oil companies operating in the Niger Delta region of Nigeria should learn to respond quickly to spill reports to avoid improper clean-up and remediation design.

REFERENCES

- [1] Alexander K. Hartmann (2009) Practical Guide to Computer Simulation, World Scientific Publishing company, Singapore.
- [2] Ajono M. A. (2007) The law of oil pollution and environmental restoration, Nigerian institute of advanced legal system (NIALS), Lagos, Nigeria.
- [3] Juan Manuel Duran (2018) Computer simulation in science and engineering, springer international publishing, Cham, Switzerland.
- [4] Ike Okonta (2018) Niger Delta paradox, safari books, Ibadan, Nigeria.
- [5] Yinka Omorogbe (2014) Oil and Gas law in Nigeria, Malt house press, 2nd edition, Lagos, Nigeria.