INVESTIGATION OF CONCENTRATION PROFILE OF CONTAMINANTS IN OGINIGBA CREEK, PORT HARCOURT

BY

Ujile, Awajiogak A. and Nsor, T.
Department of Chemical/Petrochemical Engineering
Faculty of Engineering
Rivers State University of Science and Technology
Nkpolu-Oruworukwo, Port Harcourt

ABSTRACT

The concentration profile of contaminants in Oginigba creek, Port Harcourt has been investigated. The key parameters considered are based on the existing industrial activities in the area. Application of the two-dimensional dispersion and convection equations on the contaminants shows a gradual penetration of the dissolved molecules into the water body. However, the sources of pollutants to the creek are not monitored/controlled, therefore it is concluded that hardness, COD, BOD, TSS, Lead and other contaminants concentration will continue to increase. This increase is more predominant in the dry season than in the rainy season. Total hardness values in (mg/l) at the industrial effluent channel are101 and 45.3 for dry and wet seasons respectively.

1.0 INTRODUCTION

Oginigba Creek is located in the Trans Amadi area of Port Harcourt. It separates part of Obio/Akpor local government area from Port Harcourt City local government area with a link bridge between Slaughter and Woji town. The various communities around the western part of the creek are Trans Amadi industrial area, Azubie, Okujagu Ama, Okuru –Ama, Kalio-Ama, Abuloma etc. and Woji Town is found on the eastern part. Residents of these communities whose main occupations are trading, butchery, dealers in auto parts, fishing use the creek for domestic and commercial activities. Some industrial activities from companies like Nigerian Bottling Company, Schlumberger Base 2000, Dowell Schlumberger, Halliburton, New China Rubber Plastic Company, Michelin Nigeria Ltd., Slaughter etc. located in the Trans Amadi industrial area generate wastes on daily basis. These wastes are discharged into the creek leading to the contamination of the water body (Oginigba creek). Figure 1 shows the aerial view of the location of the creek and the adjourning communities (Goggle Earth, 2006).

The impact of pollutants at various distances away from their source of origin varies greatly depending on the rate of pollutants distribution/dispersion vis-à-vis concentration.

This paper considers the laboratory analysis of the systematic water samples collected from main water bodies based on certain parameters that constitute water quality. The objectives are:

- To evaluate the laboratory investigations of the parameters on the creek
- Simulate the concentration profile of the pollutants based on previous work carried out by other authors on similar environment.
- Compare the laboratory/analytical results with the simulations.
- Evaluate impacts of pollutants in the creek and proffer sustainable solution(s) to the environmental effects.

The aim of the investigation therefore is to establish sources of contaminants to the creek and proffer solutions to the existing pollution problems.

The general characteristics of surface water are considered based on the following parameters: varying composition, low mineralization, high turbidity, presence of colour, and presence of micro-organisms, medium hardness, presence of taste and odours, and possible chemical toxicity.

Oginigba creek water is brackish. It is also tidal in nature. It becomes imperative to monitor the characteristics of wastewater discharge from exploration, development, producing and other processing industries from the following parameters: pH, temperature, density, turbidity, salinity (Cl^-), oil and grease, total suspended solid, total dissolved solids, chemical and oxygen demand, biological oxygen demand, lead, Iron, sodium, cyanide, sulphide (as H_2S), sulphate (as SO_4), ammonia (as NH_4), total phosphorous (as PO_4), total nitrogen (as NO_3), zinc, chromium, copper, colour and odour, discharge rate, and hardness.

The detailed analysis and implications of these parameters could be obtained from the Federal Ministry of Environment report, 2002. However, it should be noted that the greater the dilution of the receiving waters, the less the negative impact of the discharge.

Limitations

The main limitations to the work are:

- Inability to ascertain the treatment method(s) adopted by the adjourning companies in Trans Amadi industrial area for their effluents
- Inability to sample all discharge points from all companies in Trans Amadi area. The sampling point for this work is only from one source (one of the oil servicing companies involved in oil well cementing process).

These limitations would be considered in further studies to enhance the correlations of all sources of pollutants to the creek. Then the appropriate controlling measures can be ascertained.

2.0 THEORY OF CONVECTION/ DISPERSION OF POLLUTANTS IN WATER

A – Two dimensional convective/dispersion equation which describes the distribution/dispersion of a pollutant introduced into a flow system is given as:

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - V_x \frac{\partial C}{\partial x} - V_y \frac{\partial C}{\partial y} \qquad (1)$$

The solution to an equation similar to equation 1 by the Taylor and Neumann method (Ujile, 2003) on modeling groundwater contaminants due to transient sources of pollutants with the boundary conditions

$$C\ (x,\ y\ o) = 0,\ \ 0 \leq x \leq \alpha;\ 0 \leq y \leq \beta \ \ldots \qquad (2)$$

$$\frac{\partial c}{\partial x}\ (o,\ y,\ x) = 0 \qquad t > 0 \qquad (3)$$

Yielded

$$\ln \frac{C_x}{C_o} = \ln \left[K_L\ (1 + \rho_b\ Kd/\phi) + \frac{M}{h} \right] - \left\{ \left[K_L\ (1 + \rho_b\ Kd/\phi) + \frac{M}{h} \right] \Big/ (1 + \rho_b\ K_d/\phi) \right\} t \quad (4)$$

The modification of equation 1 as applicable to Oginigba creek with the boundary conditions

$$0 \leq x \leq 500;\ 0 \leq y \leq 6.9 \qquad (5)$$

$$C(x,y,t) = 0; \qquad t \geq 0$$

becomes,

$$\frac{C}{C_o} = \frac{M}{(P+Q)} \{1 - \frac{1}{t^{\frac{(P+Q)t}{h}}}\} \qquad (6)$$

where Co = initial concentration

$$P = \left(\frac{2D_x}{h} + aV_x \right) \frac{1}{(a+1)} \quad \ldots(7)$$

$$Q = \left(\frac{2D_y}{h} + V_y b \right) \frac{1}{(1+b)} \quad \ldots.(8)$$

$$M = \left(\frac{2D_x}{h} - (1-a)V_x \right) \frac{1}{a} + \left(\frac{2D_y}{h} - (1-b)V_y \right) \frac{1}{b}$$

$\ldots..(9)$

Equation 6 is applied in this investigation with the boundary conditions, h = 6.2m, a = 80.6452, b = 1.1129

Where a = horizontal distance, (meters)

b = vertical distance, (meters)

The relationships between a, b and x, y have been shown by (Ujile, 2003) with the use of MATHCAD SOFTWARE.

3.0 METHODOLOGY

Sampling - Four sampling points were established for the investigation. Three of the points were at the upstream, discharge point and down stream sections of the creek; while the fourth one was at the industrial effluent channel that empties into the creek. The effluent channel and discharged points samples collection were collected within 0.5m depth, while at the upstream and downstream sampling points samples collection were at 0.5m and 3.0m depth respectively. A proper design sampling programme was established as not only to preserve the samples, but also to achieve the best characteristics of the collected samples.

The above standpoint has prompted the choice of the grab (catch) sample method which was utilized to carry out the sampling exercise. This consists of a portion of water samples taken at one time in a random manner. The samples collected at the centre of the river (away from the bank) for the upstream and downstream sampling points and at different depths, within 0.5m and 3.0m depths for each of the sampling locations.

At 0.5m depth: Before taking samples, the water surface was slightly stirred and then sample collected.

At 3.0m depth: The Niskin bottle sampler was used to collect samples within 3.0m river depth. The bottle was connected to a calibrated cord and lowered to about 3m water depth with both ends open. A messenger weight dropped on the line activated a mechanical trigger on the bottle which caused the bottle to close, thereby trapping some water. On retrieval to the surface, the water samples were transferred directly into appropriate containers for different analysis of the specific parameters and later preserved accordingly. However, in-situ measurements were carried out for unstable (fast changing) parameters as, pH, temperature, dissolved oxygen, total dissolved solids, conductivity and turbidity. These were carried out with the help of dissolved oxygen (DO) pH/TDS/conductivity meters and results recorded on sampling data sheet.

All samples collected were transported to International Energy Services Limited (IESL) laboratory, located at No. 3 Rumuokoro Street, Rumuomasi, Port Harcourt, in iced packed coolers and later transferred into a refrigerator until required for analysis. Standardizations of test procedures for monitoring physico-chemical parameters were strictly followed.

The following calibrated equipments were used for all the analysis: Gas Chromatography, Atomic Absorption Spectroscopy, UV/Visible Spectrometer, Portable Microprocessor, Turbidity Meter, Conductivity/TDS Meter (Model Hanna Instrument HI 93703) and others. The detailed analytical methods and procedures for all the parameters could be obtained in an unpublished work of (Nsor, 2006). However, the results obtained are shown in tables 1 and 2 for dry season and wet season of 2005 respectively.

4.0 RESULTS AND DISCUSSIONS

The results in the tables show that Biochemical Oxygen Demand value in the two seasons exceeded the Rivers State Ministry of Environment (RSMENV) limits. In fact the value obtained was more than four times the acceptable limit at the down stream during the rainy season. Similar concentration profile was observed for **lead** at downstream sampling point. While the values at 0.5m & 3.0m depth were 3.01 and 1.14 respectively for dry season, the values at the same depths were 2.67 and 3.38 (mg/l) for rainy season. These changes may be as a result of high velocity and turbulent flow. The same flow pattern was experienced in Total Suspended Solid (TSS).

Basic pollutants parameters such as dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, oil and grease, total suspended solids, barium, lead, and total hardness were assigned for the investigations carried out for this study.

For the sake of simplification, and time factor, the convective-dispersion model equation was applied on only one of these parameters, total hardness. The concentrations of total hardness in the two (2) seasons sampled in the period under survey (year 2005) are applied in the model equation. However, concentrations of other parameters of interest could be used for further investigations to describe pollutants distribution in the creek.

Pollutants dispersion in Oginigba creek in the wet and dry seasons of the period under survey was determined and described using plots of concentration (C) and concentration/ initial concentration (C/Co) against time determined with total hardness.

The extent of curvature and downstream length of a creek affected by introduced pollutants/ contaminants depends on the level of pollution.

The shape of the curve also depends on the flow and can change seasonally e.g. under low flow periods or conditions, minimum pollutants level can prevail over longer distances while the reverse is also applicable. The degree of impact of pollutants in this environment depends on such parameters as temperature, dilution of effluent, concentration of pollutant in discharge and in the receiving water system, etc. Thus, the shape of pollutants curve greatly affects the biology and quality of a water system as in severe cases of pollution they could be total elimination of biota. However, in most cases, the level of pollution is not as serious as this as was observed in Oginigba creek during this study. Under continuous outfall of pollution as is applicable here, the effect on water quality is such as to impose a clear downstream zonation of animals, plants and microbial populations.

Total hardness can be introduced into a water body from sources such as animal wastes, municipal sewage, decomposition of dead animals and plants, chemicals from man's washing activities, agricultural activities, oil spillage as well as from effluent from industries. This study concentrated on the impact of pollutants introduced from effluents from industries located around the creek.

Total hardness (both temporary hardness caused by presence of hydrogen trioxocarbonate (iv) ions of calcium, magnesium, $Ca(HCO_3)$ or $Mg(HCO_3)$ and permanent hardness caused by the presence of tetraoxosulphate (vi) ions of calcium, magnesium or iron, $CaSO_4$, $MgSO_4$, or $FeSO_4$) in water renders it unfit for drinking, kills off aquatic life, thereby reducing man's source of protein. It leads to the indirect poisoning of man through the distortion of the food chain.

The graph is based on the developed model equations and the input data from the analytical results. The graphical representation as in Figure 2 shows that the concentration decreases with time sharply and over a period increases and later becomes asymptotic. Application of dispersion/ convective equations has shown that even when the concentration becomes steady the level (value) is higher than the allowable limit as established by the Rivers State Ministry of Environment (RSMENV). The increase in value of the hardness is above the threshold limit. The case under consideration shows that the concentration of most parameters in the rainy season is less than that in the dry season. This also agrees with the tabular results as shown in tables 1 and 2, for instance, the total hardness (mg/l) values at the industrial effluent channel are 101 and 45.3 for dry and wet seasons respectively.

It is observed that the values of the total hardness increases with time at the discharge, upstream, and downstream points. These values are not in agreement with those of the model equations for dispersion/convection systems of pollutants. This perhaps is as a result of non existence of monitoring/controlling procedure of effluent discharge into the creek. The MATHCAD Software printout for the simulation is shown in Appendix 1. The increase in concentration may be as a result of complex compounds formed due to the reaction of pollutants with other contaminants (yet to be identified) in the water body.

5.0 CONCLUSION AND RECOMMENDATIONS

The investigation has shown that there is an increase in total hardness among other parameters in the creek. The results obtained from dispersion/convective equation represented graphically show further increase in concentration levels of pollutants.

The upward variations in the concentration profiles of pollutants in the creek affect the economic lives of the inhabitants.

From the above standpoint, it becomes imperative that the cause(s) of the arbitrary increase in pollutant concentrations in the creek may be as a result of indiscriminate dumping/discharge of wastes into the creek. The procedure applied in this work can be utilized in other creeks/water bodies receiving wastewater. It is therefore recommended that further research work on the analysis of the parameters at various discharge points into the creek should be carried out. The mechanism of the complex compound formed could then be ascertained. This will enable comprehensive and macro dispersion processes of the entire pollutants in the Oginigba creek to be compiled. The existing enabling laws to restrict contaminant levels of effluents discharge to water bodies should be enforced. Regular routine checks of all effluents from industries in Trans Amadi industrial area in Port Harcourt should be carried out by the State Ministry of Environment as not only to sustain/maintain the environment but also to prevent the degradation of our environment.

NOMENCLATURE

C = Concentration of contaminant at time t, (mg/l)

Co = Initial concentration of contaminant, (mg/l)

Dx, Dy = directional hydrodynamic dispersion coefficient in the x and y direction respectively, (m^2/s).

Vx, Vy = directional velocity in the x and y direction respectively, (m/s)

x = horizontal linear distance between source and sink of pollutant, (m)

y = vertical distance between water surface and depth at which sample was taken,(m)

pH = degree of acidity and alkalinity

e = exponent

REFERENCES

1. **Goggle Earth.**: National Geographic Society. Europa Technologies. Image © Digital Globe. 2006.

2. **Nsor, T.**: ''Impact of Industrial Wastewater on Receiving Water Quality''. A case study of Oginigba Creek. M. Tech. Thesis RSUST, 2006.

3. **RSMENV** –Interim Effluent Limitation Guidelines in Nigeria for all Categories of Industries. Guidelines and Standards on Environmental Pollution Control and Management in Rivers State, 2002 p 11.

4. **Ujile, A.A**: ''Modeling Groundwater Contaminants due to Transient Sources of Pollutants'' PhD Thesis, RSUST, 2003 pp 280

APPENDIX 1

$a = 80.6452$

$b = 1.129$

$h = 6.2$

$Vx = 0.06$

$Vy = 1.3\cdot 10^{-3}$

$Dx = 0.021$

$Dy = 0.0086$

$Co = 101 \qquad t = 400$

$$P = \left(2\cdot\frac{Dx}{h} + Vx\cdot a\right)\cdot\frac{1}{(a-1)}$$

$P = 0.059$

$$Q = \left(2\cdot\frac{Dy}{h} + Vy\cdot b\right)\cdot\frac{1}{(b-1)}$$

$Q = 1.992\cdot 10^{-3}$

$$M = 2\cdot\frac{Dx}{h}\cdot(1-a)\cdot Vx\cdot\frac{1}{a} + 2\cdot\frac{Dy}{h}\cdot(1-b)\cdot Vy\cdot\frac{1}{b}$$

$M = 0.062$

$$C = \left(\frac{M\cdot Co}{(P-Q)} - 1\right)\cdot\frac{1}{e^{\frac{(P-Q)}{h}t}}$$

$C = 111.478$

$\frac{C}{Co} = 1.104$

This program when run on MATHCAD SOFTWARE yields simulation of the entire concentration profile.

FIG. 1: AERIAL VIEW OF PORT HARCOURT SHOWING OGINIGBA CREEK.

TABLE 1: AVERAGE VALUES OF DRY SEASON WATER SAMPLES (FEBRUARY- APRIL 2005)

Test Parameters	Industrial Effluent Channel	Discharge Point (Creek)	Upstream (Creek) 0-0.5m	Upstream (Creek) 3m	Down stream (Creek) 0-0.5m	Down stream (Creek) 3m	RSMENV Limit
Temperature (°C)	26.6	26.1	30.2	26.1	34.6	31.0	<40 °C
Ph	7.46	8.38 -	6.45	6.49	26.7	6.32	6.0-9
Dissolved O_2 (mg/l)	5.34	4.19	6.57	7.22	5.59	4.82	-
BOD (mg/l)	74.4	90.2	63.4	64.3	83.6	98.5	50
COD (mg/l)	126	184	114	78.2	145	146	-
Oil &grease (mg/l)	22.5	34.5	3.25	2.19	23.7	24.4	10.0
TSS (mg/l)	20.0	28.6	45.8	37.1	71.7	54.9	30.0
Total hardness (mg/l)	101	148	127	132	166	184	-
Barium (mg/l)	<0.03	2.52	<0.03	<0.03	2.55	2.07	5.0
Lead (mg/l)	<0.20	1.30	0.90	1.07	3.01	1.14	1.00

TABLE 2: AVERAGE VALUES OF WET SEASON WATER SAMPLES (JUNE - AUGUST 2005)

Test Parameters	Industrial Effluent Channel	Discharge Point (Creek)	Upstream (Creek) 0-0.5m	Upstream (Creek) 3m	Down stream (Creek) 0-0.5m	Down stream (Creek) 3m	RSMENV Limit
Temperature (°C)	25	28.5	26.0	22	28.6	29.7	<40 °C
pH	7.12	7.15	6.88	6.23	6.45	6.45	6.0-9.
Dissolved O_2 (mg/l)	4.39	5.49	5.64	5.26	5.23	6.94	-
BOD (mg/l)	113	220	109	120	224	207	50.0
COD (mg/l)	78.5	149	406	84.6	131	214	-
Oil &grease (mg/l)	<1.00	5.40	0.89	0.15	4.29	2.94	10.0
TSS (mg/l)	22.4	48.7	57.5	49.0	103	82.9	30
Total hardness (mg/l)	45.3	104	105	97.6	162	130	-
Barium (mg/l)	1.00	1.81	<0.03	<0.03	1.30	1.53	5.00
Lead (mg/l)	<0.20	0.93	<0.20	0.53	2.67	3.38	1.0

TSS-Total suspended solid, BOD-Biochemical oxygen demand, COD-Chemical oxygen

TABLE 3: INPUT DATA AND RESULT FROM MODEL EQUATION
(see algorithm in appendix)

Time(s)	C1 (mg/l)	C1/Co	C2 (mg/l)	C2/Co
1	4600	45.336	3895	38.56
60	176.35	1.746	165.206	1.636
100	65.71	1.4	139.922	1.385
200	55.7	1.23	120.96	1.198
300	52.32	1.155	114.638	1.135
400	50.65	1.12	111.478	1.104
500	49.65	1.1	109.58	1.085
600	48.98	1.08	108.32	1.07
700	48.5	1.07	107.42	1.064
800	48.14	1.06	106.74	1.057
900	47.86	1.057	106.211	1.052
1000	47.64	1.052	105.789	1.047

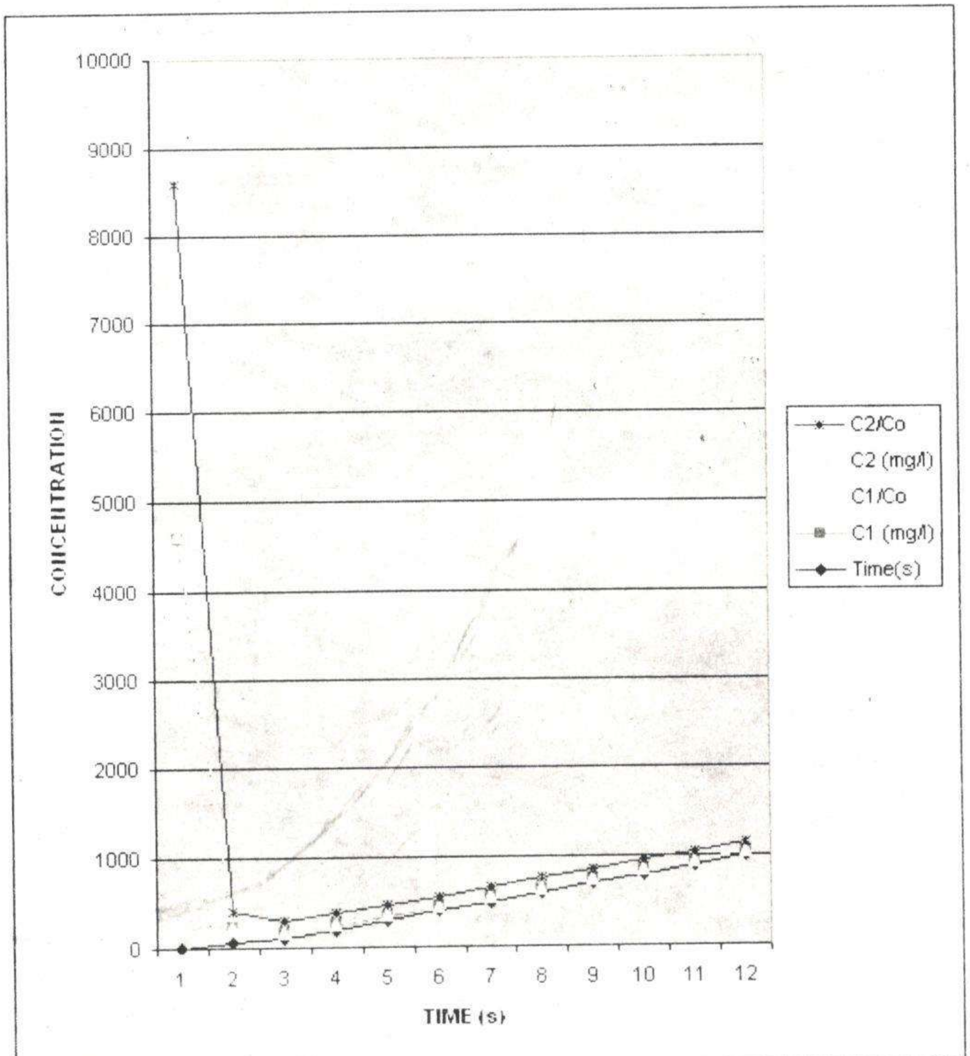

FIG. 2: EFFECT OF CONCENTRATION OF HARDNESS C (mg/l) & C/Co WITH TIME.