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Mathematical model of inverse transport of bacterial in fine sand column in deltaic environment

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ABSTRACT

Bacterial migration in soil and water environment under the influence of various soil characteristics has been expressed, the concepts is to monitor the transport process at various condition, bacterial known to have a lot of variety of behaviour, these condition were considered when the system are developed, the major variables in the system are porosity of the soil, these parameters determine the rate of bacterial deposition at every formation, degree of porosity also has a lots of variation, therefore bacterial behaviour are influenced by the rate of soil porosity, the system developed an equation considering this parameters as a major role in fast migration of bacterial under the influence of this variables, other variables were considered that played other role in the transport were expressed .in the system, the developed mathematical equation that expresses this study of bacterial were derived, applying slit method techniques and Bernoulli's method of separation of variables, the developed equation are derived applying these concept were the equation express the parameters at various state with their functions at different phase of the transport process expressed denoted with mathematical tools, the model express base on the behaviour of the bacterial at different phase on the transport process to soil and water environment.

1. Introduction

The riverine area of the Niger Delta is a coastal belt of swamps nearby the Atlantic Ocean. The swamps are vegetated tidal flats formed by a reticulate pattern of interconnected meandering creeks and distributaries of the River Niger. The forests are of two types: nearest the sea is a belt of saline/ brackish mangrove swamp separated from the sea by sand beach ridges (except west of Benin River). Within the mangrove swamp forest, numerous sandy islands occur with fresh water vegetation (Allen, 1965; 1970; Nedeco, 1961; Weber, 1971). Fresh water swamps gradually supersede the mangroves on the landward side. About 70% of Nigeria's crude oil and gas production is from this area. The riverine area is home to a large population living mainly in small villages scattered along the banks of rivers and creeks. Rainfall in this coastal belt is heavy varying from 2400 to 4000 mm annually. One of the most serious problems of the region concerns the availability of fresh water. Inhabitants of sandy beach ridges, river point bars or islands obtain fresh water from shallow wells or earth pits. However, most of the people depend on rainwater collected during the rainy season; but this hardly suffices in the dry season. The alternative lies in the development of groundwater Fresh water occurs in shallow unconfined aquifers, in sands of the coastal beach ridges and river point bars, as well as in sandy islands within the mangrove belt. It also occurs in confined aquifers at varying depths. Drilling for water in the coastal belt Fresh water occurs in shallow unconfined aquifers, in sands of the coastal beach ridges and river point bars, as well as in sandy islands within the mangrove belt. It also occurs in confined aquifers at varying depths. Drilling for water in the coastal belt has been carried out by both federal and state governments. These boreholes were drilled without detailed hydro geological studies, resulting in a large number of the wells having brackish water (Akomeno, 1984).

Water is of fundamental importance to plants and animals particularly man. It is then very vital in maintaining life processes and growth (Ogbe, 2003). Potable drinking) water is not commonly found and its provision limits the setting up of villages and towns to the places where supply exist (Shankar, 1994 and Huisman, 1966). In most part of Niger delta like aboh and environs, the residence depend on the slow running water from river Niger and its tributaries such as Ase creak and hand dug wells for their domestic water needs but today, increased activities within the study area which includes gas flaring at Kwale/Okpai gas plant, dead and decayed organic matter in contact with the rivers, streams and lakes, the drilling activities and the effect of buried pipes (rust) as well as the numerous oil spillages especially that of August 2002 in River Niger, the Ashaka 1 location spills of 1978 and 1983 respectively and the recent fire and oil spillage at Abalagada in have drastically polluted the source of water supply to the region and rendered it unhygienic and unsafe for drinking (Oseji et al, 2005). Unfortunately, these were the only available source of water, despite the increased demand for potable water in the region due to increase in the population within the last few years A better knowledge of the near surface aquifer distribution, formation and type in this area is therefore important so as to ascertain whether the aquifer is prone to contamination or not since the surface water have been polluted. (Oseji et al 2006). Most of the side effects of oil production are the possible pollution of water and the destruction of aquatic lives. Water pollution occurs when rainwater combines with the by-products of gas flaring in the atmosphere, (Ebeniro et al 1996). In most cases, air oxides such as nitrogen and sulphur become acidic contaminant during rainfall and the water flows into surface water that has been further polluted as a result of decaying organic matter. Some of the water on the land surface infiltrates underground and becomes groundwater, one of our most valuable natural resources. In fact, most freshwater on earth exists beneath the land and its geologic occurrence is the subject of many misconceptions. In the past, it was believed that groundwater occurs as large lakes or pools beneath the land. According to Bernard et al, 1994 groundwater occurs in pore spaces and fractures within sedimentary rocks. Underground Water sustains and maintains stream flow when it is close to the surface, but where it intersects the surface, a spring or watering hole is formed. Okolie et al, (2005) carried out the determination of the source of River Ethiope in Delta State of Nigeria (Oseji, 2011).

Groundwater has been described as the main source of potable water supply for domestic, industrial and agricultural uses in the southern part of Nigeria especially the Niger Delta, due to long retention time and natural filtration capacity of aquifers (Odukoya et al., 2002; Agbalagba et al., 2011; Ehirim and Ofor, 2011). Water that is safe for drinking, pleasant in taste, and suitable for domestic purposes is designated as potable water and must not contain any chemical or biological impurity (Horsfall and Spiff, 1998). Pollution of groundwater has gradually been on the increase especially in our cities with lots of industrial activities, population growth, poor sanitation, land use for commercial agriculture and other factors responsible for environmental degradation (Egila and Terhemen, 2004). The concentration of contaminants in the groundwater also depends on the level and type of elements introduced to it naturally or by human activities and distributed through the geological stratification of the area It has been reported that petroleum refining contributes solid, liquid, and gaseous wastes in the environment (Ogbuagu, et al., 2011). Some of these wastes could contain toxic components such as the polynuclear aromatic hydrocarbons (PAHs), which have been reported to be the real contaminants of oil and most abundant of the main hydrocarbons found in the crude oil mixture (El-Deeb and Emara, 2005). Once introduced in the environment, PAHs could be stable for as short as 48 hours (e.g. naphthalene) or as long as 400 days (e.g. fluoranthene) in soils (Martens and Frankenberg, 1995). They thus, resist degradation and, remain persistent in sediments and when in organisms, could accumulate in adipose tissues and further transferred up the trophic chain or web (Decker, 1981; Boehm et al., 1981, Gordon, 2012).

2. Theoretical background

Over the past years in deltaic environment ground water are known to have a lots of qualities, these complies in the raw state, these include drinking water standard, however, in definite areas, the natural ground water chemistry is such that it does not comply with the standard for human utilization, the pollution source are arsenic nitrates fluorides iron manganese, further more the number and variety of microorganism in natural waters in different place are under different conditions. Bacterial are washed into the water from air, the soil from almost every conceivable object. Significant numbers of bacterial can move through media even when the percentage retained is very high. The faeces of animals contain vast numbers of bacterial and enter many natural water systems, the size of opening in subsurface material can be assumed to be variable and are generally not measured, but porosity and permeability measurement on aquifers sediments indicate that adequate, even in some dense porous rocks. Spaces for bacterial exist in many sediments types.. These conditions experienced on bacterial migration in soil and water environment, the developed equation considered the variables in formulating the system. The inverse transport of bacterial are influence on the stated variables, the study area is deltaic environment and the influence from the geologic history are base on the deltaic nature of the soil, these were expressed in the parameters considered in the system, the mathematical expression will be derived to express various condition of bacterial transport to ground water aquifer,

$$\beta \frac{\partial C}{\partial T} = \frac{1}{Pe} \frac{\partial^2 C}{\partial Z^2} - \frac{\partial C}{\partial Z} - w(C-S) \qquad \text{......................} \qquad (1)$$

3. Nomenclature

Dimensionless Equation Parameters

- C = Concentration of bacterial
- β = Fraction of equilibrium sorption site
- μ = Deposition coefficient
- T = Time
- Z = Distance
- w = Coefficient of mass transfer
- S = Bacterial concentration on kinetic adsorption

$$\frac{1}{Pe} \frac{\partial^2 C_1}{\partial Z} = \frac{1}{Pe} \frac{\partial^2 C_1}{\partial Z} \qquad \text{......................................} \qquad (2)$$

$$\left.\begin{aligned} & x = 0 \\ & t = 0 \\ & C_{(o)} = 0 \\ & \left.\frac{\partial C_1}{\partial Z}\right|_{\substack{x=0\\t=0}} = 0 \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

$$\beta \frac{\partial C_2}{\partial T} = \frac{\partial C}{\partial Z} - w\,C - S \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

$$\left.\begin{aligned} & t = 0 \\ & x = 0 \\ & C_{(o)} = 0 \\ & \left.\frac{\partial C_2}{\partial T}\right| \; t = 0,\ \beta \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (5)$$

$$\frac{1}{Pe}\ \frac{\partial^2 C_3}{\partial Z^2} = -\ \frac{\partial C_3}{\partial Z} - w\,C - S \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

$$\left.\begin{aligned} & x = 0 \\ & C_{(o)} = 0 \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

Applying direct integration on (2)

$$\beta \frac{\partial C}{\partial T} = \frac{1}{Pe}\,C + K_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

Again, integrate equation (8) directly, yields

$$\beta = \frac{1}{Pe} CZ + K_1 z + K_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (9)$$

Subject to equation (3), we have

$$BCo = K_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (10)$$

And subjecting equation (8) to (3)

At $\left.\dfrac{\partial C_1}{\partial Z}\right|_{x = 0,\ C_{(o)} = C_o} = 0$

Yield

Inverse transport or bacteria in fine sand column developed an equation, split method techniques were applied to monitor the inverse bacteria in fine sand column. In equation seven the split method techniques expressed different boundary volume were by parameters were splited to determine their relationship and their various function in the system, integrating directly in equation eight, it express a constant in subject to the equation determining their relationship in with respect to concentration and distance, boundary values were developed yielding to equation ten correlating with anther constant under the influence of the boundary concentration and distance

$$0 = \frac{1}{Pe} C_o + K_2$$

$$\Rightarrow \quad K_1 = \frac{1}{Pe} C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (11)$$

So that, we put (10) and (11) into (9), we have

$$\beta C_1 = \frac{1}{Pe} C_1 z - \frac{1}{Pe} C_o z + \beta C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (12)$$

$$\beta C_1 = \frac{1}{Pe} C_1 z = \beta C_o - \frac{1}{Pe} C_o z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

$$\Rightarrow \quad C_1 \left(\beta - \frac{1}{Pez} \right) = C_o \left(\beta - \frac{1}{Pez} \right)$$

$$\Rightarrow \quad C_1 = C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

Hence equation (14), entails that at any given distance, x, we have constant concentration of the contaminant in the system

$$\beta \frac{\partial C_2}{\partial T} = \frac{\partial C_2}{\partial Z} - w \bullet C - S \qquad \ldots\ldots\ldots\ldots \quad (4)$$

We approach this system by using the Bernoulli's method of separation of variables

$$C_2 - ZT \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

$$\frac{\partial C_2}{\partial T} = ZT^1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

$$\frac{\partial C_2}{\partial Z} = Z^1 T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$$

Put (16) and (17) into (15), so that we have

$$\beta XT^1 = w \bullet C - S \; X^1 T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

i.e. $\beta \frac{T^1}{T} = w \bullet C - S \frac{X^1}{X} = -\lambda^2$ ……………………………… (19)

Hence $\beta \frac{T^1}{T} + \lambda^2 = 0$ ……………………………… (20)

That is,

$$\frac{X^1 + \lambda}{\beta} X = 0 \qquad \text{..................................} \qquad (21)$$

$$w \bullet C - S \; X^1 + \lambda^2 T = 0 \qquad \text{..................................} \qquad (22)$$

From (21), $X = \frac{A Cos \lambda}{\sqrt{\beta}} t + \frac{B Sin \lambda}{\sqrt{\beta}} x$ .... (23)

And (16) gives

$$\boxed{T = C \ell^{\frac{-\lambda^2}{W \bullet C-S} t}} \qquad \text{.............................} \qquad (24)$$

By substituting (23) and (24) into (15), we get

Equation 14 expressed similarity like equation eight were by parameters like coefficient of mass transfer and bacteria concentration and absorption were expressed Bernoulli's method were applied deriving the equation from 14 to 24 gives a model that expressed the concentration with respect to time, a constant were developed interacting with coefficient of mass transfer bacteria coefficient and the concentration of bacteria

$$\boxed{C_2 = \left[A Cos \frac{\lambda}{\sqrt{\beta}} t + B Sin \frac{\lambda}{\sqrt{\beta}} x \right] C \ell^{\frac{-\lambda}{W \bullet C-S} t}} \qquad \text{....................} \qquad (25)$$

Subject equation (25) to conditions in (5), so that we have

$$C_o = AC \qquad \text{......................................} \qquad (26)$$

Therefore, equation (26) become

$$C_2 = C_o \ell^{\frac{-\lambda^2}{w \bullet C-S} t \quad Cos \frac{\lambda}{\beta} x} \qquad \text{......................................} \qquad (27)$$

Again, at

$$\left. \frac{\partial C_2}{\partial T} \right|_{x = 0, \; B} = 0, \; t = 0$$

Subject to Equation 23 and 24 substituted in to 15 it express a model with respect to time and distance that integrated the express model of 25 to the condition in 5, will have initial concentration at equation 26 where by high rate of concentration may be decreasing with respect to time and distance under the increase of formation , through the structural deposition of the soil influencing the bacterial transport to ground water aquifer, for further interaction with other parameters experience an expression from 27 were by coefficient of mass transfer bacteria and concentration of the bacteria were integrated were the constant expressed inverse transport of the microbes, under the influence of fluctuation of velocity of transport between the aquiferous zone, boundary values were also integrated to determine their limit between the time and distance under the influence of concentration with respect to time and distance

Equation (27) becomes

$$\frac{\partial C_2}{\partial t} = \frac{\lambda^2}{\beta} C_o \ell^{\frac{\lambda}{w \bullet C-S}} \quad Sin \frac{\lambda}{\beta} \quad \text{..................................} \quad (28)$$

$C_o \dfrac{\lambda}{\beta} \neq 0$ Considering NKP

Which is the substrate utilization for microbial growth (population), so that

$$0 = -C_o \frac{\lambda}{\beta} Sin \frac{\lambda}{\beta}^{B} \quad \text{..................................} \quad (29)$$

$$\Rightarrow \frac{\lambda}{\beta} = \frac{n\pi}{2}, n = 1,2,3 \quad \text{..................................} \quad (30)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{\beta}}{2} \quad \text{..................................} \quad (31)$$

So that equation (27) becomes

$$C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S} t \; Cos \frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}} x} \quad \text{..................................} \quad (32)$$

$$\therefore \Rightarrow C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S} t \; Cos \frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}} x} \quad \text{..................................} \quad (33)$$

The derived mathematical equation reflect on when the bacterial experiences relocation process in some stratum, and those formation does not deposit substrate in the formation, the bacterial may experience sluggish in transport; due to degradation in some region of the stratum, the concept absolutely considered these conditions were by the bacterial may experienced degradation, if the bacterial become accustomed to the condition of the soil, even if the bacterial travel to another soil formation, during the process of transport, the bacterial may reducing its inhabitants through death.

Now, we consider equation (6) which is the steady-flow state of the system

$$\frac{1}{Pe} \frac{\partial^2 C_3}{\partial x^2} = -\frac{\partial C_3}{\partial Z} - w \bullet C - S$$

Applying Bernoulli's method, we have

$$C_3 = ZT \quad \text{..................................} \quad (34)$$

$$\frac{\partial^2 C_3}{\partial Z^2} = Z^{11}T \quad \text{..................................} \quad (35$$

$$\frac{\partial C_3}{\partial Z} = Z^1 T \quad \text{..................................} \quad (36)$$

Put (35) and (36) into (6), so that we have

$$\frac{1}{Pe} Z^{11} T \;=\; -\, w \bullet C - S\, X^{1} T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (37)$$

That is,

$$\frac{1}{Pe} \frac{Z^{11}}{Z} \;=\; -\, w \bullet C - S \frac{Z^{1}}{Z} \;=\; \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (38)$$

$$\frac{1}{Pe} \frac{Z^{11}}{Z} \;=\; \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (39)$$

$$-\, w \bullet C - S \frac{Z^{1}}{Z} \;=\; \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (40)$$

That is $Z \;=\; A \ell^{\frac{\varphi}{\frac{1}{Pe}} Z}$ $\qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (41)$

And

$$T \;=\; B \ell^{\frac{\varphi}{\frac{1}{Pe}} t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (42)$$

Put (41) and (42) into (34), gives

$$C_3 = A \ell \frac{\varphi}{w \bullet C - S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (43)$$

$$C_3 = AB \ell^{(x-x) \frac{\varphi}{w \bullet C - S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (44)$$

Initial concentration were integrated as a constant that denote the whereby assumption was made when there is no substrate utilization for microbial growth this expression from equation 29 were disintegrated to were a model were establish at equation 33 initial value were integrated considering a condition when there is no substrate utilization of the soil stratification, steady state flow of the equation were considered were an assumption were made when the system are on steady state. In this condition the microbes are observed a lag phase influenced by inhibitors including in permeable layers like clay zone this expression were disintegrated from equation 34 to 44 were equation 41 and 42 were integrated into 34 that denote an expression condition of the microbes assuming in the next formation that porosity of the soil has been increase in this regard coefficient of mass transfer were observed, bacteria concentration and assumption played a major role including finally concentration in respect to distance. Subject to equation forty four integrated to 7 yields another concentration that expressed initial concentration with respect to of the microbial distance under the influence of porosity

coefficient of mass transfer and final concentration. Assumptions were expressed where there is no substrate utilization in that condition the concentration were decrease.
Subject equation (44) to (7), yield

$$C_3 = (0) = C_o \qquad \ldots\ldots\ldots\ldots \qquad (45)$$

So that equation (45), becomes

$$C_3 = C_o \,\ell^{(x-x)\frac{\varphi}{w \bullet C-S}} \qquad \ldots\ldots\ldots\ldots \qquad (46)$$

Now assuming that at the steady state flow, there is no NKP for substrate utilization, our concentration here is zero, so that equation (46) become

$$C_3 = 0 \qquad \ldots\ldots\ldots\ldots \qquad (47)$$

Therefore, solution of the system is of the form

$$C = C_1 + C_2 + C_3 \qquad \ldots\ldots\ldots\ldots \qquad (48)$$

We now substitute (14), (33) and (47) into (48), so that we have the model

$$C = C_o + C_o \,\ell^{\frac{-n^2\pi^2 \frac{1+fP_bK_d}{\theta}}{2Vd\frac{P_b}{\theta}1+fK_dC-Sk}t} \; Cos\,\frac{n\pi}{2}x \qquad \ldots\ldots\ldots\ldots \qquad (49)$$

$$\boxed{C = C_o\,1+\ell^{\frac{-n^2\pi^2\frac{P_b}{\theta}1+fK_dC-Sk}{2Vd\frac{P_b}{\theta}1-fK_dC-Sk}t} \; Cos\,\frac{n\pi}{2}x} \qquad \ldots\ldots\ldots\ldots \qquad (50)$$

The split expression at equation 6 has become zero this conclude the expression at equation forty seven the solution of the system express were the initial concentration that were split in different state from c_1 to c_3, subject to the models by substitute equation 16, 33, 47, into equation 48 developed an expression, integrating all the parameters that the yield the final model equation that express the impact of bacteria in fine sand column at equation 50 the model develop were to determine the influence that result to bacteria in fine sand column in deltaic environment. High rate of porosity express the coefficient of mass transfer fraction of equilibrium sorption will respect to time and distance, bacteria concentration on kinetic assumption played a major at difference developed model expression this will determine the inverse transport of bacteria in fine sand column

4. Conclusion

The generations of bacterial are through human and animal activities these are unsewered settlement, through the onsite sanitation. Including cemeteries waste dump, site and feedlots, such area, microorganism will definitely be predominant in those locations, the condition implies that in soil and water environment, they will accumulated to a very high concentration, in the case of ground water aquifers, it will absolute deposition with high concentration under the influence of constant regeneration in those waste dump locations, the concept is peculiar in bacterial deposition, and the behaviour of the microbes varies in terms of transport process, under the influence of the variation in soil stratification. The influenced of geochemistry and geomorphology of the formation is not left behind, as this also play A major role in some condition on the transport process, in this situation, the inverse transport of microbes occur in the transport process, because in some instant, the deposition of the soil base on the intercedes of the particle grain size, influenced the behaviour of transport from one formation to the other, therefore inverse transport of bacteria are determined through these influence, the developed mathematical equation considered these experience as variable in the formulation of the system. There inverse transport of bacterial definitely should be considered in transport for thorough predictive model, the developed model will definitely provide a précised management method for bacterial transport in soil and water environment.

References

Akomeno, U., 1984. OI Electric logs for groundwater exploration in the Niger Delta Challenges in African Hydrology and Water Resources (Proceedings of the Harare Symposium, July 1984). IAHS Publ. no. 144.

Allen, J.R.L., 1965. Late Quaternary Niger Delta and adjacent areas: sedimentary environments and lithofacies. Bull. Am. Ass. Petrol. Geol. 49, 547-600.

Allen, J.R.L., 1970. Sediments of the modern Niger Delta: a summary and review. In: Deltaic Sedimentation (ed. by J.P.Morgan), 138- 151. Spec. Publ. Soc. Econ. Paleont. Miner, no. 15.

Nedeco (Netherlands Engineering Consultants), 1961. The Waters of the Niger Delta. Nedeco, The Hague

Ogbe, M.G., 2003. A Seminar on Wetlands, Water and Poverty Eradication in a water short world

Okolie, E.C., Osemeikhian, J.E.A., Oseji, J.O., Atakpo, E., 2005. eophysical Investigation of the source of River Ethiope" in Ukwuani Local Government area of Delta State. Nigeria Institute of Physics. Vol. 17.

Oseji, J.O., Atakpo, E., Okolie, E.C., 2005. "Geoelectric Investigation of the Aquifer Characteristics and Groundwater Potential in Kwale, Delta State, Nigeria Journal of Applied Sciences and Environmental Management Vol. 9 (1) Pp (157 – 1600) ISSN 1119 – 8362 www. Bioline. Org.br.ja.

Ebeniro, J.O., Avwiri, G.O., 1996. "Environmental Pollution due to Gas Flaring at Oyigbo Area of Rivers State". Nigeria Journal of Physics Vol. 85. Pp (7 – 10).

Oseji, J.O., Asokhia, M.B., Okolie, E.C., 2006. "Determination of Groundwater Potential in Obiaruku and Environs Using Surface Geoelectric Sounding". The Environmentalist, Springer Science + Business Media, DO1 10.10669-006-0159-x Vol. 26 Pp (301 – 308), Netherlands

Huisman, L., 1966. "Groundwater in Deltas" in scientific problems of the humid tropical zone deltas and their implications. Pro.dacca symp. Pp (157 – 168). UNESCO

Shanker, R.K., 1994. "Selected Chapters in Geology". Shell Petroleum Development Company, Warri. Pp (10 – 148).

Oseji, J.O**.,** 2011**.** surface geoelectric sounding for the determination of aquifer characteristics in aboh and environs delta state

Amangabara, G.T., Gordon J.D.N., Amangabara, T., Njoku, J.D. 2012. Assessing Groundwater Vulnerability to the Activities of Artisanal Refining in Bolo and Environs, Ogu/Bolo Local Government Area of Rivers State; Nigeria British Journal of Environment & Climate Change 2(1), 28-36, 2012

Boehm, P.D., Fiest, D.L., Elskus, A., 1981. Comparative weathering patterns of hydrocarbons from Amoco Cadiz oil spill observed at a variety of coastal environment. International Symposium on the fate and effects of oil spill. Brest, France, pp. 159-173.

Decker, J.C., 1981. Potential health hazards of toxic residues in sludge. In sludge-health risk of land application. Ann. Arbon. Sci. Publ. Inc., pp, 85-102.

Egila, J.N., Terhemen, A., 2004. A preliminary investigation into the quality of surface water in the environment of Benue Cement Company Plc. Gboko, Benue State. Nigeria. Int. J. Sci. Tech., 3(1), 12-17.

Ehirim, C.N., Ofor, W., 2011. Assessing Aquifer vulnerability solid wastes landfill Sites in a Coastal Environment, Port Harcourt, Nigeria. Trends in Applied Sciences Research, 6(2), 165 –173.

El-Deeb, M.K.Z., Emara, H.I., 2005. Polycyclic aromatic hydrocarbons and aromatic plasticizer materials in the seawater of Alexandria Coastal area. Egyptian J. of Aquat. Res., 31, 15-24.

Horsfall, M., Spiff, A.I., 1998. Principles of environmental Chemistry. Metrol Prints Ltd, Nigeria, pp. 107–118.

Martens, D.A., Frankenberger, Jr.T., 1995. Enhanced Degradation of Polycyclic Aromatic Hydrocarbons in soil treated with an Advanced Oxidative Process—Fenton's Reagent. Journal of Soil Contamination, 4(2), 175-190.

Odukoya, O.O., Arowolo, T.A., Bamgbose, O., 2002. Effect of Solid Waste. Landfill on underground and surface water quality at Ring Road, Ibadan. Global J. Environ. Sci., 2(2), 235–242.

Ogbuagu, D.H., Okoli, C.G., Gilbert, C.L., Madu, S., 2011. Determination of the contamination of groundwater sources in Okrika Mainland with Polynuclear Aromatic Hydrocarbons (PAHs). British Journal of Environment & Climate Change, 1(3), 90-102.