Vol. 4, No. 3 March 2014 ISSN 2225-7217
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

Two Dimensional Flow Transport Modeling of Fungi and Arsenic Deposition on Lateritic and Silty Formation in Coastal Area of Aboluma, Niger Delta of Nigeria

Eluozo, S. N.
Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria
Director and principal consultant Civil and Environmental Engineering, Research and Development

Soloeluozo2013@hotmail.com, solomoneluozo2000@yahoo.com

ABSTRACT

The deposition of fungi and arsenic has been found in the coastal deposition of aboluma, the study were carried to monitor the rate of fungi and arsenic at different direction of flow on the transport system in the coastal environments, the deposition of both parameters were investigated through risk assessment previously carried out in the study area, monitoring and prevention of this contaminants were not done, its deposition in the soil formation has generated high degree of pollution in the coastal environment, the influences from the surroundings of the study area influences fast spread of the pollutants to most part of the study location, this challenges are reflected on the pollution of numerous soil characteristics deposited in the study location, base on this circumstances, mathematical model were find suitable for the study. The develop model will definitely prevent and monitor the transport of fungi and arsenic in coastal area of aboluma.

Keywords: *Two dimensional flow, Fungi and arsenic transport lateritic and silty formation*

1. INTRODUCTION

Soil water establishment is highly affected by soil formation and its steadiness. Various soil arrangement types may cause preferential flow or water immobilization (Kodešová *et al.,* 2006, 2007, 2008). Soil structure breakdown may initiate a soil particle migration, formation of less porous or even water-resistant layers and as a result of decreased water fluxes within the soil profile (Kodešová *et al.,* 2009a, Eluozo, 2013). Soil aggregation is under managed of different mechanisms in different soil types and horizons (Kodešová *et al.,* 2009b). Soil formation and consequently soil hydraulic properties of tilled soil varied in space and time (Strudley *et al.,* 2008). The temporal variability of the soil aggregate stability was shown for instance by Chan *et al.* (1994), and Yang and Wander (1998). While Chan *et al*. (1994) documented that temporal changes of aggregate stability were not positively related to living root length density; Yang and Wander (1998) suggested that the higher aggregate stability was found due to crop roots, exudates microbial by-products and wet/dry cycles. The temporal variability of the soil hydraulic properties (mainly hydraulic conductivities, *K*) were investigated, for instance in following studies. Murphy *et al.* (1993) showed that *K* values at tensions of 10 and 40 mm varied temporally due to the tillage, wetting/drying, and plant growth. Messing and Jarvis (1993) presented that the *K* values decreased during the growing season due to the structural breakdown by rain and surface sealing. Somaratne and Smettem (1993) documented that while the *K* values at tension of 20 mm were reduced due to the raindrop impact, the *K* values at tension of 40 mm were not influenced. Angulo-Jaramillo, *et al*. (1997) discovered that only the more homogeneous sandy soil under furrow irrigation exhibited significant decrease in sorptivity. Petersen *et al*. (1997) documented using the dye tracer experiment that cultivation reduced the number of active preferential flow paths. Azevedo *et al*. (1998) measured tension infiltration from 0 to 90 mm and showed that macropore flow decreased from 69% in July to 44% in September. Bodner *et al.* (2008) discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the structure-related range. Finally, Suwardji and Eberbach (1998) studied both, aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring. The *K* values decreased during the growing season. The goal of this study is to assess the seasonal variability of the soil structure, aggregate stability and hydraulic properties with respect to each other and to varying soil physical and chemical properties, soil management and climatic conditions (Eluozo, 2013).

2. THEORETICAL BACKGROUND

High degrees of deposited fungi and arsenic in lateritic and silty soil structure in coastal environments call for serious concern, the level of deposition were establish through some hazard evaluation carried out on those location, the avoidance were recommended, but could not be carefully achieved, the present of the these two parameters in lateritic and silty soil formation are pressured by coastal surroundings, since it has a few variation through the influences of the coastal formation, the deposition of arsenic and fungi are base on predominant soil deposited structure such as porosity in the study location, thus boost the movement of the contaminants. The deposition of fungi with arsenic are through artificial activities in the study area, some mechanized section produce this type of waste at daily bases, this circumstance developed high deposition of the pollutant in the formation, costal pressures may have also produce spreading of the pollutants in the strata, but one parameter are hypothetical to produce concentration more, but the case of these two parameters the examination generate almost the same concentration at every formation in the strata. The formation setting is through coastal pressure that developed masses of variation as it is expressed in the variation fashioned on formation reports from the risk evaluation. Such condition implies that the expansion of low void ratio and porosity increase the concentration as the pore space between the grain size that generate lower percentage, the development of mathematical modeling on two direction of flow transport are through the condition of the geological surroundings influenced by the coastal arrangement. The expressed derived solution will absolutely generates the directions of transport from this pollutant in the system. it has establish various influenced from strata arrangement characteristics on the deposition of the two parameters in the structure, the expressed derived solution produced various model bearing in mind various behavior of both parameters under the pressure of geological location in the study area.

2.1 Nomenclature

ϕ = Porosity [-]
V = Void Ratio
D = Dispersion Number
Kc = Arsenic Coefficient of inhibition [ML^{-3}]
Kd = Half Concentration of substrate under Aerobic Respiration [ML^{-3}]
C = Concentration of fungi [ML^{-3}]
T = Time [T]
x = Distance [L]

2.2 Governing Equation

$$\phi\frac{\partial c}{\partial t} + V\frac{\partial c}{\partial x} = D\frac{\partial^2 c}{\partial y^2} - K_c\frac{\partial c}{\partial x} + K_d\frac{\partial^2 c}{\partial y} - K_n\frac{\partial^2 c}{\partial x^2} + \lambda(x,y) \quad \ldots\ldots\ldots\ldots \qquad (1)$$

The principal equations that developed the system establish variables denoted with mathematical symbols, the situation of the organization are through the examinations carried out that verify the deposition and migration of fungi including arsenic in coastal area of aboluma in Port Harcourt metropolis. Since the study locations are in industrial layout, manmade activities are practice at high quantity, through the exploitation of our natural resources and other construction activities. The depositions of this pollutant are in two different directions, it is base on this condition the expressed principal equation are generated. The expression will be derived in accordance with the deposition influences of the substances and the microbes at different deposition of the structure.

$$\phi\frac{\partial c}{\partial t} + V\frac{\partial c}{\partial x} = \lambda[x,y] \qquad (2)$$

Let $C = TX$

$$\frac{\partial c}{\partial t} = T^1X \qquad (3)$$

$$\frac{\partial c}{\partial x} = X^1T \qquad (4)$$

$$\phi T^1X + VTX^1 = \lambda \qquad (5)$$

$$\phi\frac{T}{T} + V\frac{X^1}{X} = \lambda \qquad (6)$$

$$\phi\frac{T^1}{T} = \lambda \qquad (7)$$

$$V\frac{X^1}{X} = \lambda \qquad 8)$$

From (7),

$$\phi\frac{dT}{T} = \lambda dt \qquad (9)$$

$$\int\frac{dT}{T} = \int\frac{\lambda}{\phi}dt \qquad (10)$$

$$LnT = \frac{\lambda}{\phi} + a_1 \qquad (11)$$

$$T = \ell^{\frac{\lambda}{\phi}t + a_1} \qquad (12)$$

$$T \;\; C_1\,\ell^{\frac{\lambda}{\phi}t} \qquad (13)$$

$$\frac{V\partial x}{x} = \lambda dx \qquad (14)$$

$$\int \frac{dx}{x} = \int \frac{\lambda}{V} dx \qquad (15)$$

$$Ln\, x = \frac{\lambda}{V} x + a_2 \qquad (16)$$

$$X = \ell^{\frac{\lambda}{V} + a_2} \qquad (17)$$

$$X = C_2\, \ell^{\frac{\lambda}{V} x} \qquad 18)$$

But $C = TX$

$$C_1 = C_1\, \ell^{\frac{\lambda}{\phi} t} \bullet C_2\, \ell^{\frac{\lambda}{V} x} \qquad (19)$$

$$C_1 = C_1\, C_2\, \ell^{\left(\frac{\lambda}{\phi} + \frac{x}{V}\right)\lambda} \qquad (20)$$

$$C_1 = C\, \ell^{\left(\frac{\lambda}{\phi} + \frac{x}{V}\right)\lambda} \qquad (21)$$

The expression here is the exponential phase model; the derived solution establish this phase of the system under the pressure of the soil geological setting in the environment, formation characteristics such as porosity and void ratio influences the structure of the deposited strata, the generation of the exponential phase condition in the system express high concentration of the pollutant at these phase, formation influences are base on the deposited structure of the formation.

$$\phi \frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial y^2} \qquad (2)$$

Let $C = T^1 Y$

$$\frac{\partial c}{\partial t} = T^1 Y \qquad (22)$$

$$\frac{\partial^2 c}{\partial y^2} = TY^{11} \qquad (23)$$

$$\phi T^1 Y = DTY^{11} = \theta^2 \qquad (24)$$

Let

$$\phi \frac{T^1}{T} = D \frac{Y^{11}}{Y} = -\theta^2 \qquad (25)$$

$$\int \frac{dT}{T} = \int \frac{-\theta^2}{\phi} dt \qquad (26)$$

$$LnT = \frac{-\theta^2}{\phi} t + a_3 \qquad (27)$$

$$T = \ell^{\frac{-\theta^2}{\phi} t + a_3} \qquad (28)$$

$$T = C_3\, \ell^{\frac{-\theta^2}{\phi} t} \qquad (29)$$

$$D \frac{Y^{11}}{Y} = -\theta^2 \qquad (30)$$

$$\frac{\partial^2 y}{\partial y^2} + \frac{\theta^2}{D} y = 0 \qquad (31)$$

Auxiliary equation

$$M^2 + \frac{\theta^2}{D} = 0 \qquad (32)$$

$$M = \pm i \frac{\theta}{\sqrt{D}} \qquad (33)$$

$$\therefore Y = ACos \frac{\theta}{\sqrt{D}} y + BSin \frac{\theta}{\sqrt{D}} y \qquad (34)$$

Combine (29) and (34), we have

$$C_2 = TY$$

$$C_2 = C_3\, \ell^{\frac{-\theta^2}{\phi} t}\, ACos \frac{\theta}{\sqrt{D}} y + ASin \frac{\theta}{\sqrt{D}} y \qquad (35)$$

Comparable situation were also measured in these phase of the resultant solution in the develop phase of the system. The generated model of the phase in [35] shows the exponential phase of the condition, but pressured by some deposited minerals that may inhibit both parameters in the study location, the derived model in [35] showcase the condition base on the stratification influences that were considered in the phase of the derived model solution.

Considering

$$\phi \frac{\partial c_3}{\partial t} = K_c \frac{\partial c_3}{\partial x} \qquad (3)$$

Let $C_3 = TX$

$$\frac{\partial c_3}{\partial t} = XT^1 \qquad (36)$$

$$\frac{\partial c_3}{\partial x} = X^1 T \qquad (37)$$

$$\phi T^1 X = KX^1 T \qquad (38)$$

$$\phi \frac{T^1}{T} = K_c \frac{X^1}{X} = \varphi^2 \qquad (39)$$

$$\phi \frac{T^1}{T} = \varphi^2 \qquad (40)$$

$$\frac{T^1}{T} = \frac{\varphi}{\phi} \qquad (41)$$

$$LnT = \frac{\varphi^2}{\phi} t + a_4 \qquad (42)$$

i.e.

$$T = C_4 \ell^{\frac{\varphi^2}{\phi}t} \qquad (43)$$

$$T = \ell^{\frac{\varphi^2}{\phi}t} \qquad (44)$$

$$\phi \frac{T^1}{T} = K_c \frac{X^1}{X} = \varphi^2 \qquad (45)$$

$$\frac{dx}{dx} - \frac{\varphi^2}{Kc} x = 0 \qquad (46)$$

Auxiliary equation

$$M^2 - \varphi^2 = 0 \qquad (47)$$

$$M = \pm i \frac{\varphi}{\sqrt{Kc}} \qquad (48)$$

$$X = K_c \ell^{\frac{\varphi}{Kc}x} + E \ell^{\frac{-\varphi}{Kc}x} \qquad (49)$$

Combining (44) and (49) yield

$$C_3 = TX$$

i.e.

$$C_3 = C_4 \ell^{\frac{\varphi}{\phi}t} \left(K_c \frac{\varphi}{\sqrt{Kc}} x + E \ell^{\frac{-\varphi}{\sqrt{Kc}}x} \right) \qquad (50)$$

The expressed model at these stage shows the level of inhibition that may be establish on the process of deposition in some region of the soil structure, it may deposit transitory flow base on minor deposition of porosity reflecting on the speed of transport flow. The percentage of porosity in this condition determine the tempo of inhibition from arsenic and fungi at this phase of the migration process, the pressure from degree of porosity resolute the deposition of arsenic and other substances inhibiting microbes in the stratification of the soil structure

Let $C = TY$ (51)

$$\frac{\partial c}{\partial t} = T^1 Y \qquad (52)$$

$$\frac{\partial^2 c}{\partial y^2} = TY^{11} \qquad (53)$$

$$\phi T^1 Y = K_d TY^{11} = \alpha^2 \qquad (54)$$

$$\int \frac{dT}{T} = \int \frac{-\alpha^2}{\phi} dt \qquad (55)$$

$$LnT = \frac{-\alpha^2}{\phi} t + a_5 \qquad (56)$$

$$T = \ell^{\frac{-\alpha^2}{\phi}t + a_5} \qquad (57)$$

$$T = C_4 \ell^{\frac{-\alpha^2}{\phi}t} \qquad (58)$$

$$K_d \frac{Y^{11}}{Y} = -\alpha^2 \qquad (59)$$

$$\frac{\partial^2 y}{\partial y^2} + \frac{\alpha^2}{K_d} y = 0 \qquad (60)$$

Auxiliary equation is

$$M^2 + \frac{\alpha^2}{K_d} = 0 \qquad (61)$$

$$M = \pm i \frac{\alpha}{\sqrt{K_d}} \tag{62}$$

$$\therefore Y = A Cos \frac{\alpha}{\sqrt{K_d}} y + B Sin \frac{\alpha}{\sqrt{K_d}} y \tag{63}$$

Combine (58) and (63), we have

$$C_4 = TY$$

$$C_4 = C_5 \ell^{\frac{-\alpha^2}{\phi}t} \left(A Cos \frac{\alpha}{\sqrt{K_d}} y + A Sin \frac{\alpha}{\sqrt{K_d}} y \right) \tag{64}$$

Porosity continues to play foremost roles in the migration system, but at this stage, micronutrients are established to play it roles by displaying their functions on the deposition through the transport system. The influences from micronutrients are found to express thorough deposition, but may be established to deposit an average performance due to its rate of concentration. The expressions in [64] establish the role of half concentration of micronutrients in the transport system.

Considering

$$K_d \frac{\partial^2 c_5}{\partial y^2} = K_n \frac{\partial c_5}{\partial x} \tag{5}$$

Let $C_5 = YX$

$$\frac{\partial c_5}{\partial y} = Y^{11} X \tag{65}$$

$$\frac{\partial c}{\partial x} = X^1 Y \tag{66}$$

$$K_d Y^{11} X = -K_n X^1 Y \tag{67}$$

$$K_d \frac{Y^{11}}{Y} = -K_n \frac{X^1}{X} \tag{68}$$

$$K_d Y^{11} X = -K_n X^1 Y = -Z^2 \tag{69}$$

Let $K_d \frac{Y^{11}}{Y} = -K_n \frac{X^1}{X} = Z^2$ (70)

$$K_d Y^{11} = -Z^2 \tag{71}$$

$$Y^{11} + \frac{Z^2}{K_d} = 0 \tag{72}$$

Auxiliary equation

$$M^2 + \frac{Z^2}{K_d} = 0 \tag{73}$$

$$M = \pm i \frac{Z}{\sqrt{K_d}} \tag{74}$$

$$\therefore Y = A Cos \frac{Z}{\sqrt{K_d}} y + B Sin \frac{Z}{\sqrt{K_d}} y \tag{75}$$

$$K_n \frac{X^{11}}{X} = +Z^2$$

$$\int \frac{dx}{x} = \int \frac{+Z}{K_n} dx \tag{76}$$

$$LnX = \frac{+Z^2}{K_n} x + a_6 \tag{77}$$

$$X = C \ell^{\frac{+Z}{K_n}x} \tag{78}$$

$$C_5 = C \ell^{\frac{+Z^2}{K_n}t} \left(A Cos \frac{Z}{\sqrt{K_d}} y + B Sin \frac{Z}{\sqrt{K_d}} y \right) \tag{79}$$

The behavior of arsenic and micronutrients were considered lastly at this stage of the modeling approach, the structure at this phase were to observed the deposition of micronutrients and arsenic as an inhibitor in the deposition at diverse path of the formation, such circumstance are expressed to determine their behavior at two diverse path of flow influenced by porosity and velocity in the transport system. The derived solution established a model to monitor the behavior of both parameters in the system as it is established in the developed model of [79]. The expressions may develop higher concentration because it is set up to deposit motionless phase of the formation in the developed model Combining (21), (35), (50), (64) and (79) yield

$$C = (x, y) = C_1 + C_2 + C_3 + C_4 + C_5$$

$$C = \ (x, y) \ = C\,\ell^{\frac{t}{\phi} + \frac{x}{v}\lambda} + C_3\,\ell^{\frac{-\theta}{\phi}t}\left(A Cos \frac{\theta}{\sqrt{D}}\,y \ + \ Sin \frac{\theta}{\sqrt{D}}\,y\right) +$$

$$\ell^{\frac{\varphi^2}{\phi}t}\left(A\ Cos\ \frac{\varphi}{\sqrt{Kc}}\,x \ + \ B\,Sin \frac{\varphi}{\sqrt{Kc}}\,y\right) + \ell^{\frac{-\alpha}{K_d}}\left(A Cos \frac{\alpha}{\sqrt{K_d}}\,y \ + \ B\,Sin \frac{\alpha}{\sqrt{K_d}}\,x\right)$$

$$C\,\ell^{\frac{+Z^2}{K_n}x}\left(A Cos \frac{Z}{\sqrt{K_d}}\,y \ + \ B\,Sin \frac{Z}{\sqrt{K_d}}\,y\right) \tag{80}$$

But if $t = \frac{x}{v}$, we have

$$C = \ (x, y) \ - \ C\,\ell^{\left(\frac{t}{\phi} + \frac{x}{v}\lambda\right)\frac{x}{v}} + C_3\,\ell^{\frac{-\theta}{\phi}t}\left(A Cos \frac{\theta}{\sqrt{D}}\,y \ + \ B\,Sin \frac{\theta}{\sqrt{D}}\,y\right)\frac{x}{v} +$$

$$C_5\,\ell^{\frac{-\varphi^2}{\phi}t}\left(A\ Cos\ \frac{\varphi}{\sqrt{Kc}}\,x \ + \ B\,Sin \frac{\varphi}{\sqrt{Kc}}\,y\right)\frac{x}{v}\ C\,\ell^{\frac{+Z^2}{K_n}x}\left(A Cos \frac{Z}{\sqrt{K_d}}\,y \ + \ B\,Sin \frac{Z}{\sqrt{K_d}}\,y\right)$$

$$C_5\,\ell^{\frac{-\varphi^2}{\phi}t}\left(A\ Cos\ \frac{\varphi}{\sqrt{Kc}}\,x + B\,Sin \frac{\varphi}{\sqrt{Kc}}\,y\right)\frac{x}{v}\ C_6\,\ell^{\frac{\alpha}{K_d}}\left(A Cos \frac{\alpha}{\sqrt{K_d}} \ + B\,Sin \frac{\alpha}{\sqrt{K_d}}\right)\frac{x}{v} +$$

$$C\,\ell^{\frac{-Z^2}{K_n}x}\left(A Cos \frac{Z}{\sqrt{K_d}}\,y \ + \ B\,Sin \frac{Z}{\sqrt{K_d}}\,y\right)\frac{x}{v} \tag{81}$$

Numerous segment of the structure were considered in the transport system of the study, the direction of flow were considered at diverse state, base of the geological surroundings in study carried out. The paths of transport flow were in different deposition, this implies means that the flow net are in diverse path as it is state in the principal equation, it may definitely experience diverse level of deposition pressured by formation characteristics, arrangement of the strata deposited influences set up to play major roles in these state of the study, therefore the function of variety parameters were thoroughly at every phase of the model expressed in the system. Such conditions are to guarantee the influential variables detailed in the derived solution, these are expressed from various phase of the transport system. The final expressed model were pooled together to establish the developed model for the transport system of the study as it is expressed in [81].

4. CONCLUSION

The governing equation has produced model in the system, these were derived in different phase considering different conditions from formation characteristics influences and microbial behavior in the soil structural depositions. Fungi generated its behavior as normal, but with minor diverse from other microbes, the behavior of the microbes were considered in the developed system that generated the foremost equation, such circumstance were thoroughly considered in the system generating some influential variables in the study, mathematical modeling approach were found appropriate through this type of mathematical technique, this concept cause to establish all the parameters that produces these results, these represents the depositions and movement of arsenic including fungi in soil and water environment, the expression accommodates every parameter according to their function base on various behavior of the parameter at different direction of flow. The study has express every condition that may have pressured the direction of flow on the transport system of arsenic and fungi in the study location through the final derived model solution for the study.

REFERENCES

[1] Angulo-Jaramillo, R., Moreno, F., Clothier, B.E., Thony, J.L., Vachaud, G., Fernandez-Boy, E., Cayuela, J.A., 1997. Seasonal variation of hydraulic properties of soils measured using a tension disc infiltrometer. Soil Science Society of America Journal 61, 27-32.

[2] Bodner, G., Loiskandl, W., Buchan, G., Kaul, H.P., 2008. Natural and management-induced dynamics of hydraulic conductivity along a cover-cropped field slope. Geoderma 146, 317-325.

[3] Chan, K.Y., Heenan, D.P., Ashley, R., 1994. Seasonal changes in surface aggregate stability under different tillage and crops. Soil and Tillage Research 28, 301-314.

[4] Kodešová, R., Kodeš, V., Žigová, A., Šimunek, J., 2006. Impact of plant roots and soil organisms on soil micro morphology and hydraulic properties. Biologia 61, S339–S343.

[5] Kodešová, R., Kocárek, M., Kodeš, V., Šimunek, J., Kozák, J., 2008. Impact of soil icromorphological features on water flow and herbicide transport in soils. Vadose Zone Journal 7, 798–809.

[6] Kodešová, R., Vignozzi, N., Rohošková, M., Hájková, T., Kocárek, M., Pagliai, M., Kozák, J., Šimunek, J., 2009a. Impact of varying soil structure on transport processes in different diagnostic horizons of three soil types, Journal of Contaminant Hydrology 104, 107-125.

[7] Kodešová, R., Rohošková, M., Žigová, A., 2009b. Comparison of aggregate stability within six soil profiles under conventional tillage using various laboratory tests. Biologia 64, 550-554.

[8] Messing, I., Jarvis, N.J., 1993. Temporal variation in the hydraulic conductivity of a tiled clay soil as measured by tension infiltrometer. Journal of Soil Science 44, 11-24.

[9] Murphy, B.W., Koen, T.B., Jones, B.A., Huxedurp, L.M., 1993. Temporal variation of hydraulic properties for some soils with fragile structure. Australian Journal of Soil Research 31, 179-197.

[10] Petersen, C.T., Hansen, S., Jensen, H.E., 1997. Tillage-induced horizontal periodicity of preferential flow in the root zone. Soil Science Society of America Journal 61, 586-594.

[11] Somaratne, N.M., Smettem, K.R.J., 1993. Effect of cultivation and raindrop impact on the surface hydraulic properties of an alfisol under wheat. Soil and Tillage Research 26, 115-125

[12] Strudley, W.M., Green, T.R., Ascough, I.I.J.C., 2008. Tillage effects on soil hydraulic properties in space and time: State of the science. Soil and Tillage Research 99, 4-48.

[13] Suwardji, P., Eberbach, P.L., 1998. Seasonal changes of physical properties of an Oxic Paleustalf Red Kandosol) after 16 years of direct drilling or conventional cultivation. Soil and Tillage Research 49, 65-77.

[14] Yang, X.M., Wander, M.M., 1998. Temporal changes in dry aggregate size and stability. Soil and Tillage Research 49, 173-183.

[15] Eluozo, S.N. 2013 Modeling and simulation to predict nitrogen deposition influenced by the porosity and the coefficient of inhibition in the coastal area of port Harcourt, Niger delta of Nigeria Health, Safety and Environment (2013) 1(2) 29-40