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Assessment of Groundwater Models in Simulation of Water Quality Parameters

S.N. Eluozo[1] & C. Ukpaka[2]

[1]Department of Civil Engineering College of Engineering
Gregory University Uturu (GUU) Abia State of Nigeria
[2]Jospaka Ventures Nigeria Limited, Port Harcourt Rivers State
Correspondence Author: *Soloeluozo2013@hotmail.com*, *ukpachin@yahoo.com*

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Abstract:

The research presented is a comparative evaluation applying finite element method (FEM) and control system of parameter distribution (CSPD) for predicting aluminum, potassium, arsenic, lead and manganese parameter of Tema Town in Sari-Toru, L.G.A of Rivers State, the simulation was carried out from distance 0-1.8km. The finite element method and control system of parameter distribution method revealed that as parameters dispersed from point zero distance, the concentrations is been reduced as results of soil filtration under homogenous porosity distribution processes within the aquiferous environment, both method developed a reliable order of migration of Al, K, As, Pb and Mn, this conditions established indicates the purpose of investigation and monitoring of water quality parameters within water bearing deposition of Tema Town, both models proof a reasonable agreement as shown from the study. The investigation revealed that groundwater of Tema Town water parameters assessed are within World Health Organizational standard limit in terms of Al, K, As, Pb and Mn.

Key Words: Assessment, Groundwater, Model, Simulation and Quality Parameter

Introduction:

Water is the most considerable resource of a country and of the entire society as a whole as human can hardly deal without water. Water has unique position if compared with other natural resources, like minerals, fuels, forests, lives-stock, etc, because nations can survive in the absence of any other resources, except water. Management of the water resources for different uses should incorporate a participatory approach; by involving not only the various governmental agencies but also the users and stakeholders in an effective and decisive manner, in various aspects of planning, design, development and management of the water resources schemes. There should be a periodical assessment and reassessment of the groundwater potential on scientific bases, taking into consideration the quality of the water available and economic practicality of its extraction. Research carried out on best approach of simulating groundwater parameters using the concept of linear and quadratic shape function given Galerkin's finite element method for Sama Community in Sari- Toru L.G.A, Rivers State in predicting the migration of Cl_2, SO_4^2, $CaCO_3$, Pt/co, TSS, Ca, K, NO_3, and Fe within the water bearing aquifer of Sama established the fact that simulation of groundwater parameters using linear shape function of finite element analysis should be used and the parameters investigated is within acceptable limit (Ukpaka et al, 2017). Poor quality or contamination of groundwater system can be attributed to poor boreholes construction, development and completion practices. Ukpaka et al, 2016 observed in the research of characteristics of groundwater in Port Harcourt that physical and chemical parameters that characterized the groundwater understudy, pH and partly iron are the major problems associated with the groundwater. Contribution of geological formation plays good role in defining quality of water parameters concentration, occurrence of free carbon dioxide in the ground and sea water intrusion on land contribute to acidity of groundwater.

Research Methodology:

Ukpaka, 2015 Technique Approach of Water Parameter Simulation in Groundwater:

Technique of Flow Rate Model of Groundwater of Parameters Distribution:

The consideration of flow rate, recharge and hydraulic gradient in distribution of groundwater parameters interaction within the water bearing aquifer established the mathematical simulation equation for selected wells of six points given by Ukpaka, 2015. This predictive Equation (1) is called Control system of parameters distribution in groundwater network.

$$\begin{vmatrix} C_{GQ1} \\ C_{GQ2} \\ C_{GQ3} \\ C_{GQ4} \\ C_{GQ5} \\ C_{GQ6} \end{vmatrix} = \begin{vmatrix} Q_{11} & Q_{12} & Q_{13} & Q_{14} & Q_{15} & Q_{16} \\ Q_{21} & Q_{22} & Q_{23} & Q_{24} & Q_{25} & Q_{26} \\ Q_{31} & Q_{32} & Q_{33} & Q_{34} & Q_{35} & Q_{36} \\ Q_{41} & Q_{42} & Q_{43} & Q_{44} & Q_{45} & Q_{46} \\ Q_{51} & Q_{52} & Q_{53} & Q_{54} & Q_{55} & Q_{56} \\ Q_{61} & Q_{62} & Q_{63} & Q_{64} & Q_{65} & Q_{66} \end{vmatrix} \begin{vmatrix} C_{E1} \\ C_{E2} \\ C_{E3} \\ C_{E4} \\ C_{E5} \\ C_{E6} \end{vmatrix} \quad (1)$$

Equation (1) is groundwater parameters distribution model for selected six well.

The flow rate at different nodes of consideration in Equation (1) is evaluated by using Equation (2)

$$Q = \frac{k}{2L}(y_R^2 - y_o^2) + \frac{R}{2}(l - 2x) \quad (2)$$

For the purpose of evaluating flow rates in Equation (1), the hydraulic gradient of well 1, 2, 3, 4, 5 and 6 were determined, hydraulic conductivity (k) and a given recharge were considered.

Linear Shape Approximation Function Proposed by Galerkin's:

The mass transport equation of one-dimension flow of groundwater is simulated by approach of linear shape function proposed by Galerkin's residual weighted method.

$$\frac{\partial C_{GQ}}{\partial t} = D_x \frac{\partial^2 C_{GQ}}{\partial x^2} - V_x \frac{\partial C_{GQ}}{\partial x} \quad (3)$$

Applying Galerkin's weighted concept to Equation (3) gives,

$$\int_o^l N^T \left(\frac{\partial C_{GQ}}{\partial t} - D_x \frac{\partial^2 C_{GQ}}{\partial x^2} + V_x \frac{\partial C_{GQ}}{\partial x}\right) \partial x \quad (4)$$

The individual terms of Equation (3) can be calculated by the application of the linear shape functions or finite element method as follows:

Applying the Galerkin's finite element method of obtaining a solution to equation (3) the mass transport functions and the domains arediscretized into elements. A linear shape function was chosen for this research work as given:

Step 1: Linear element approach

$$C_{GQ}(x) = N_i^e C_{GQi} + N_{i+1}^e C_{GQi+1} = [N][C] \quad (5)$$

Where,

$$N_i^e = 1 + \frac{x}{l} \quad (6)$$

And

$$N_{I+1}^e = \frac{x}{l} \quad (7)$$

Evaluating 2nd Term of Equation (4)

$$\int_o^l N^T D_x \frac{\partial^2 C_{GQ}}{\partial x^2} \partial x = \int_o^l \frac{\partial N^T}{\partial x} \frac{\partial}{\partial x} [N][C] \partial x \quad (8)$$

Solving Equation (8) gives,

$$\frac{D_x}{L} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix} \quad (9)$$

Evaluating 3rd Term of Equation (4)

$$\int_o^l N^T V_x \frac{\partial C_{GQ}}{\partial x} \partial x = \int_o^l N^T U_x \frac{\partial}{\partial x} [N][C] \quad (10)$$

Solving Equation (10) gives,

$$= \frac{U_x}{2} \begin{vmatrix} -1 & 1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix}$$

(11)

Evaluating 1st Term of Equation (4)

$$\int_o^l N^T \frac{\partial C_{GQ}}{\partial t} \partial x \qquad (12)$$

Solving Equation (12) gives,

$$= \frac{L}{6} \begin{vmatrix} 2 & 1 \\ 1 & 2 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix} \qquad (14)$$

Assembling Equation (9), (11) and (14) gives,

$$\frac{D_x}{L} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix} - \frac{V_x}{2} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix} + \frac{L}{6} \begin{vmatrix} 2 & 1 \\ 1 & 2 \end{vmatrix} \begin{vmatrix} C_{GQ1} \\ C_{GQ2} \end{vmatrix} = 0 \qquad (15)$$

Data Collection:

Groundwater samples were collected at different intervals in weeks from Tema Village, Sari-Tori L.G.A., Rivers State. And the following parameters was examined,

Experimental Examination:

Samples collected were thoroughly analyzed; the concentration values of water parameter obtained for aluminum, potassium, arsenic and manganese were established using standard methods.

Table 1: Water parameters investigated:

Table 1 describes the parameters investigated; analytical approach used, and all chemical used during analysis is of good analytical reagent, experimental values obtained and world health organization standard.

Parameters investigated	Analytical Approach	Experimental Value	Standard, WHO
Aluminum (Al) Mg/l	APHA 3111D	0.01	0.2
Potassium (K) Mg/l	APHA 311D/ ASTM D3561	16.16	>100
Arsenic (As) Mg/l)	APHA 3030B/3114B	0.01	0.06
Lead (Pb) Mg/l	APHA 3111B	0.01	0.10
Manganese(Mn) Mg/l	APHA 3111B	0.03	0.50

Results and Discussion:

Table 2: Results obtained by method of control system parameter distribution (CSPD) and finite element method (FEM) for Tema Town groundwater.

Distance(m)	Model (CSPD)					Galerkin's Model (FEM)				
	Al	K	As	Pb	Mn	Al	K	As	Pb	Mn
0	0.01	16.16	0.01	0.01	0.03	0.01	16.16	0.01	0.01	0.03
1800	0.08	12.37	0.008	0.08	0.022	0.005	8.05	0.005	0.005	0.014

The results presented in Table 2 were obtained using Equation (1) & (15) for CSPD and FEM by simulating parameter of control well A to get to parameters of other well.

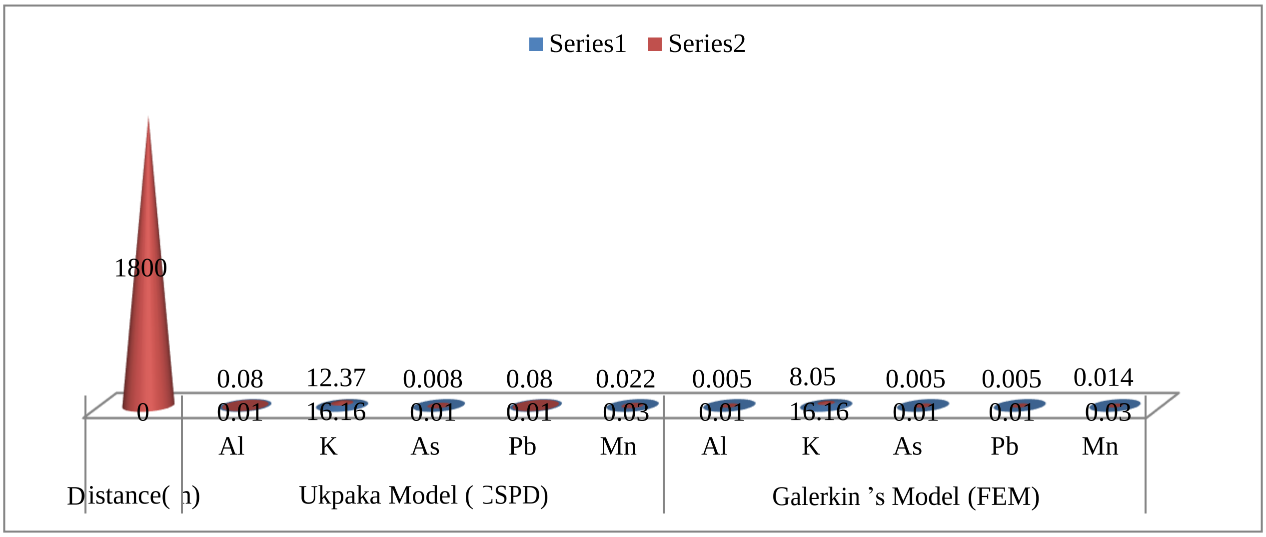

Figure 1: Graph of control system of parameter distribution in groundwater and finite element method

Table 2 and Figure 1 illustrate dispersion and interaction migration order upon distance of 0-1800m of research investigation. Simulating Al from distance zero to 1800 metres the 0.01mg/l concentration spread or dispersed and at 1800m were reduced to 0.08mg/l and 0.05mg/ respectively for CSPD and FEM. K were simulated, the concentration of 16.16mg/l at zero distance was reduced to 12.37mg/l and 8.05mg/l for CSPD and FEM respectively indicating that K parameter interact and moves within the aquifer there is reduction in concentration of K parameter value which can be attributed to soil filtration process and dispersion process and other of process were observed for As, Pb *and* Mn parameters. The results obtained by simulating Al, K, As, Pb *and* Mn parameters by CSPD and FEM revealed either of the method can be use in monitoring and simulating water quality parameter within aquifer zone.

Conclusions:

The following facts were established from this assessment;

[1] The results obtained by simulating Al, K, As, Pb *and* Mn parameters by CSPD and FEM revealed either of the method can be use in monitoring and simulating water quality parameter within aquifer zone.

[2] The developed model applied for comparison with CSPD express faviourable fits, showing the authenticity of the model.

[3] The system was also observed to be influenced by the homogeneity of the formation reflecting on the model.

[4] The application of finite element modeling was to discretize the depositions of all the metals in the formation.

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Nomenclature:

q = Flow rate, (m^3/day)

K = Aquifer permeability, (m/day)

y_R = Water table height for reference point well A, (m)

y_o = Water table height for consideration points, (m)

R = Recharge, (m/day)

x = Any distance along the length, (m)

l = Length apart between the wells of consideration. (Which may be define as l_{AB} , l_{AC} , etc.(m))

C_A = Water parameter of consideration at well A, (mg/l)

C_B = Water parameter of consideration at well B, (mg/l)

C_C = Water parameter of consideration at well C, (mg/l)

C_D = Water parameter of consideration at well D, (mg/l)

C_E = Water parameter of consideration at well E, (mg/l)

C_F = Water parameter of consideration at well F, (mg/l)