Comparative Evaluation of Groundwater Parameters Simulation by Method of Linear & Quadratic Shape Function

C. Ukpaka[a], F. E. Ezeilo[b]

[a]. *Department of Civil Engineering, University of Port Harcourt, P.M.B. 5232 Port Harcourt, Nigeria*

[a]. *Department of Civil Engineering, Rivers State University , Nkpolu, P.M.B. 5080, Port Harcourt, Nigeri***a**

Abstract:-

The investigation presented in this article is aimed at evaluating the selected physico-chemical parameters of ground water and the best approach of simulating the selected water quality parameters migration in Sama community water bearing aquifer, comparison were made between linear and quadratic shape function. Approximation of Finite Element Established by Galerkins's, the linear shape function approximation of finite element approach gives a decrease in the selected physico-chemical parameters as parameters dispersed from a given point to another during the simulation of the One -Dimensional mass transport equation of the groundwater and the result follows an acceptable sequential order as demonstrated in this article while quadratic shape function approximation of finite element results were rising and falling along the considered distances and nodes of interest which do not shows a sound sequential dispersion along the investigated distances. For both method and experimental results, Cl_2^-, SO_4^{2-}, $CaCO_3^-$, pt/co,TSS, Ca^+, K^+,NO_3^-, and Fe^{2+} assessed is within recommended standard by World Health Organization standard for acceptable drinking water.

Keywords: Simulation, finite element, linear shape function Quadratic shape function.

I. INTRODUCTION

A section of rain which falls upon the surface of the earth percolates into the ground and becomes groundwater. During this process, the water comes in contact with many substances both organic and inorganic and some are readily soluble in water. Others such as those generating alkalinity & hardness are soluble in water containing carbon dioxide absorbed from the air or from decomposing organic matter in the soil.

Water resources have been the most exploited or tapped natural component since man strode the planet earth. Since then population growth increasing living standards, wide spheres of human activities and industrialization have giving birth in greater demand of good quality water while on other hand , contamination of water resources is increasing steadily. However, period is not too far when good quality water, particularly in thickly dense, industrialized and water scarce areas, may be inadequate for normal living (Chatterjee, 2010; Ukpaka et al., 2016; Patowary et al., 2015; Suleiman et al., 2006).

Groundwater contamination may be explained as the deterioration in the chemical, physical and biological properties of water brought about mainly by human activities. Pollution can be naturally caused by hydrological processes also in which the decomposed animal, vegetable materials and soil ingredients are brought into the main water resources. All these processes lead to degradation of the natural environment**.** (Sincero et al., 1999; Ukpaka et al., 2016; Garg, 2007; Chatterjee, 2010; Leton, 2007; Ukpaka et al., 2016; Pathak et al., 2012a).

Transport of contaminations from land to Groundwater may be due to one of this phenomena infiltration, percolation and leaching infiltration is the downward entry of water into soil surface. This is controlled by soil properties for a case of compact and clayey soil movement is permeably small. The infiltration is more in soils with a coarse texture having greater number of large pore spaces. It also increases with higher vegetation cover, warm soils, and with increase in organic matter with infiltration of water, the dissolved salt nutrient and pollutions reach into the soil from where they can contaminate groundwater and surface water by percolation and these processes increases water parameters concentration (Goel, 2006; Agunnwaba, 2001; Garg, 2007; Sincero et al., 1999; Gerrad, 1999; Nwaogazie, 2008; Carrol, 1962; Eluozo et al., 2012).

The evaluation in this article is a comparative method of linear shape function and quadratic shape function of finite element method in the simulation of one-dimension mass transport equation of groundwater in predicting the dispersion of groundwater parameters of Sama Community in Sari Toru LGA of Rivers State, 8
Nigeria.

II. MATERIALS AND METHODS

A. One-Dimensional Mass Transport of Groundwater.

The mass transport Equation for groundwater x-direction is given as:

$$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} - U_x \frac{\partial c}{\partial x} \quad (1)$$

Equation (1) can be re-arranged as:

$$\frac{\partial c}{\partial t} - D_x \frac{\partial^2 c}{\partial x^2} + U_x \frac{\partial c}{\partial x} = 0 \quad (2)$$

Where, D_x = dispersion coefficient, C= concentration of water parameters considered and U_x = velocity of the groundwater in the direction –x.

B. Simulation Approach by Gralerkins Finite Element.

Stage-1: Discretization and selection of Approximation function

One – dimensional stretch were assumed and three elements with seven nodes. For the purpose of evaluating groundwater parameters concentration of each mode.

Stage – 2: deviation of element equations. Applying Galerkins Weighted Residuals Method GWRM to the governing one – dimensional mass transport equation (2) is expressed as:

$$\int_o^l N^T \left[\frac{\partial c}{\partial t} - D_x \frac{\partial^2 c}{\partial x^2} + U_x \frac{\partial c}{\partial t}\right] \partial x = 0 \quad (3)$$

***Table 1**: Standard for Measuring the Above Named Parameters*

Parameters	Analytical Method	WHO
Chloride (Mg/l)	APHA 4500Cl-B	250
Sulphate (Mg/l)	APHA $4500SO_4^{2-}E$	250
Total Hardness (Mg/l)	APHA 2350C	150
Colour (Hazen)	APHA 3111B	15
Total Suspended Solid (Mg/l)	APHA 2510B	25
Calcium (Mg/l)	APHA 3111B	75
Potassium (Mg/l)	APHA 3111B	<100
Nitrate (Mg/l)	EPA 352.1	10
Total Iron (Mg/l)	APHA 3111B	0-0.3

Parameters Notation,

Cl_2 = Chloride

Stage 3: Assembling of Element Equations into class Equation.

In Equation (3) one-dimensional stretch were assumed in this investigation in order to establish the assembling equation which will generate the groundwater parameters concentration at each node of interest.

C. Dynamic Groundwater Velocity

In determining the groundwater velocity of the area of study, the developed equation by Darcy's for groundwater velocity given by (Garg,2007) were used.

$$V_a = \frac{V}{\eta} \quad (4)$$

Where , V_a = actual groundwater Velocity, **η**= porosity (%)

V = discharge velocity

Determination of the discharge velocity is as :

$$V = K\frac{\partial h}{\partial x} \quad (5)$$

Where , ∂h= difference between water table of two points

∂x= Difference between distance of two points

k= Permeability of groundwater

D. Experimental Analysis

Cl_2, SO_4^{2-}, $CaCO_3$, pt/co, TSS, Ca, K, NO_3 and Fe

SO_4^{2-} = Sulphate
$CaCO_3$ = Total Hardness
pt/co = Colour
TSS = Total Suspended Solid
Ca = Calcium
K = Potassium
NO_3 = Nitrate
Fe = Total Iron

Water Samples Collection

Water samples were collected in five weeks from a borehole at Sama Community in Asari-Toru Local Government Area, Rivers State of Nigeria. The water specimen was forwarded to Chemical/Petrochemical Engineering Laboratory, RSU for the purpose of determination of selected physico-chemical parameters. The average values determined for each parameters were used for the prediction.

III. RESULTS AND DISCUSSION

A. Approach of Quadratic Shape Approximation Function of Finite Element

$C(x) = N_i^e C_i + N_{i+1}^e C_{i+1} + N_{i+2}^e C_{i+2} = [N][C]$ (6)

Where $N_e = (1 + \frac{x}{l})(1 - \frac{2x}{l})$ (7)

$N_{i+1}^e = \frac{4X}{L}(1 - \frac{X}{L})$ (8)

and

$N_{i+2}^e = \frac{-X}{L}(1 - \frac{2X}{L})$ (9)

Deviation of Element Equations

Individual evaluation of Equation (3)

Evaluate term 1

$\int_o^l N^T \frac{\partial c}{\partial t} dx = \int_o^l N^T \frac{\partial}{\partial t}([N][C])\, \partial x$ (10)

$\int_o^l N^T N \frac{\partial c}{\partial t} \partial x = \int_o^l$

$$\left| \begin{matrix} (1+\frac{x}{L})(1-\frac{2x}{L}) \\ \frac{4X}{L}(1-\frac{X}{L}) \\ \frac{-X}{L}(1-\frac{2X}{L}) \end{matrix} \right| \left| \left[(1+\frac{X}{L})(1-\frac{2X}{L}) \quad \frac{4X}{L}(1-\frac{X}{L}) \quad \frac{-X}{L}(1-\frac{2X}{L})\right] \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \partial x \right| \quad (11)$$

Solving Equation (11) gives:

$$= \frac{L}{30}\begin{vmatrix} 4 & 2 & -1 \\ 2 & 16 & 2 \\ -1 & 2 & 4 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \quad (12)$$

Evaluating term 2 from Equation (3)

$\int_o^l N^T Dx \frac{\partial^2 c}{\partial X^2} \partial x = \int_o^l Dx \frac{\partial N^T}{\partial x} \frac{\partial}{\partial x}([N][C])\, \partial x$ (13)

Putting Equation (7),(8)and(9) into equation (12) gives:

$$= \int_o^l \frac{\partial x}{L^2} \begin{vmatrix} (-1-\frac{4x}{L}) \\ 4(1-\frac{2x}{L}) \\ -1+\frac{4x}{L} \end{vmatrix} \left| [(-1-\frac{4x}{L}) \quad 4(1-\frac{2x}{L}) \quad (-1+\frac{4x}{L})] \right| \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \partial x \quad (14)$$

Solving Equation (14) gives,

$$= \frac{Dx}{3L}\begin{vmatrix} 7 & -8 & 1 \\ -8 & 16 & -8 \\ 1 & -8 & 7 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \quad (15)$$

Evaluating term 3 from Equation (3)

$\int_o^l N^T \; U_x \frac{\partial c}{\partial t} dx = \int_0^l U_x N^T \frac{\partial}{\partial x}([N][C])\, \partial x$ (16)

Substituting equations (7),(8) and (9) into Equation (16) gives:

$$= \int_0^l \frac{U_x}{l} \begin{vmatrix} (1+\frac{x}{L}) & (1-\frac{2x}{L}) \\ \frac{4x}{L} & (1-\frac{x}{L}) \\ \frac{-x}{L} & (1-\frac{2x}{L}) \end{vmatrix} \left[(-1-\frac{4x}{L}) \quad 4(1-\frac{2x}{L}) \; (-1+\frac{4x}{L})\right] \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \partial x \qquad (17)$$

Solving Equation (17) gives,

$$=\frac{U_x}{6} \begin{vmatrix} -3 & 4 & -1 \\ -4 & 0 & 4 \\ 1 & -4 & 3 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \qquad (18)$$

Substituting equation (12),(15) and (18) into Equation (3) gives:

$$\frac{L}{30} \begin{vmatrix} 4 & 2 & -1 \\ 2 & 16 & 2 \\ -1 & 2 & 4 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} - \frac{Dx}{3L} \begin{vmatrix} 7 & -8 & 1 \\ -8 & 16 & -8 \\ 1 & -8 & 7 \end{vmatrix} \begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix} + \frac{U_x}{6} \begin{vmatrix} -3 & 4 & -1 \\ -4 & 0 & 4 \\ 1 & -4 & 3 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} = 0 \qquad (19)$$

Substituting the values ofD_x, U_x, and L and Solving equation (19) to generate seven modes points for three elements based discretization adopted gives:

$$\begin{vmatrix} 26.26 & 17.37 & -6.37 & 0 & 0 & 0 & 0 \\ 11.21 & 114.24 & 17.37 & 0 & 0 & 0 & 0 \\ -6.37 & 11.21 & 57.12 & 17.37 & -7.91 & 0 & 0 \\ 0 & 0 & 11.21 & 114.24 & 17.37 & 0 & 0 \\ 0 & 0 & -6.37 & 11.21 & 57.12 & 17.37 & -6.37 \\ 0 & 0 & 0 & 0 & 11.21 & 114.37 & 17.37 \\ 0 & 0 & 0 & 0 & -7.91 & 11.21 & 30.88 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \end{vmatrix} = 0 \qquad (20)$$

Within water bearing aquifer dispersion values of the studied area is taking as $D_x = 0.03/m^2/day$

Simulating groundwater physico-chemical parameters by application of developed Model matrix Equation (20) gives:

Table1:Prediction of Selected Physico- Chemical Parameters by Quadratic Shape Function Approximation of Finite Element.

Distance (m)	**CL2 (mg/L)**	**SO_42 (mg/L)**	**CaCo3 (mg/L)**	**Pt/co**	**TSS (mg/L)**	**Ca (mg/L)**	**K (mg/L**	**No_3 (mg/L)**	**Fe (mg/L)**
0	84.59	47.5	11.95	1.91	0.95	36.43	24.91	3.00	0.36
250	-10.14	-5.70	-1.43	-0.23	-0.11	-4.37	-2.99	-0.36	-0.04
500	12.11	6.80	1.71	0.27	0.14	5.22	3.57	0.43	0.05
750	-1.46	-0.82	-0.21	-0.03	-0.02	-0.63	-0.43	-0.05	-0.006
1000	1.78	1.78	1.00	0.25	0.04	0.02	0.77	0.52	0.06
0.008	-0.26	-0.14	-0.04	0.006	0.003	-0.11	-0.08	-0.009	-0.001
1500	0.55	0.31	0.08	0.01	0.006	0.24	0.16	0.02	0.002

The negative values in the computations of Cl_2, SO_4^2, $CaCO_3$, Pt/co, TSS, Ca, K, NO_3, and Fe should be neglected. Interest is on the magnitude of simulated results.

B. Approach of Linear Shape Approximation Function of Finite Element

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

Step 1: Linear element approach

$C(x) = N_i^e C_i + N_{i+1}^e C_{i+1} = [N][C]$ (21)

Where,

$N_i^e = 1 + \frac{x}{l}$ (22)

And

$N_{i+1}^e = \frac{x}{l}$ (23)

Substituting Equation (21), (22) and (23) into Equation (3) to evaluate 1st Term of Equation (3)

$\int_o^l N^T D_x \frac{\partial^2 C}{\partial x^2} \partial x = \int_o^l \frac{\partial N^T}{\partial x} \frac{\partial}{\partial x} [N][C] \partial x$ (24)

Solving Equation (24) gives,

$= \frac{D_x}{L} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix}$ (25)

Substituting Equation (21), (22) and (23) into Equation (3) to evaluate 2nd Term of Equation (3)

$\int_o^l N^T U_x \frac{\partial C}{\partial x} \partial x = \int_o^l N^T U_x \frac{\partial}{\partial x} [N][C]$ (26)

Solving Equation (26) gives,

$= \frac{U_x}{2} \begin{vmatrix} -1 & 1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix}$ (27)

Substituting Equation (21), (22) and (23) into Equation (3) to evaluate 3rd Term of Equation (3)

$\int_o^l N^T \frac{\partial C}{\partial t} \partial x$ (28)

Solving Equation (28) gives,

$= \frac{L}{6} \begin{vmatrix} 2 & 1 \\ 1 & 2 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix}$ (29)

Assembling Equation (25), (27) and (29) gives,

$\frac{D_x}{L} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix} - \frac{U_x}{2} \begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix} - \frac{L}{6} \begin{vmatrix} 2 & 1 \\ 1 & 2 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \end{vmatrix} = 0$ (30)

Putting the values of D_x, U_x and L into Equation (30) established the below model matrix

$$\begin{vmatrix} 84 & 42 & 0 & 0 & 0 & 0 & 0 \\ 42 & 168 & 42 & 0 & 0 & 0 & 0 \\ 0 & 42 & 168 & 42 & 0 & 0 & 0 \\ 0 & 0 & 42 & 168 & 42 & 0 & 0 \\ 0 & 0 & 0 & 42 & 168 & 42 & 0 \\ 0 & 0 & 0 & 0 & 42 & 168 & 42 \\ 0 & 0 & 0 & 0 & 0 & 42 & 84 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \end{vmatrix} = 0 \quad (31)$$

Solving Equation (31) gives the results in Table 3,

Table 3: Prediction of Selected Physico- Chemical Parameters by Linear Shape Function Approximation of Finite Element.

Distance (m)	**CL2 (mg/L)**	**SO_42 (mg/L)**	**CaCo3 (mg/L)**	**Pt/co**	**TSS (mg/L)**	**Ca (mg/L)**	**K (mg/L**	**No_3 (mg/L)**	**Fe (mg/L)**
0	84.59	47.50	11.95	1.91	0.95	36.43	24.91	3.00	0.36
250	-22.66	-12.72	-3.20	-0.51	-0.25	-9.76	-6.67	-0.80	-0.09
500	6.07	3.41	0.86	0.14	0.06	2.62	1.79	0.22	0.03
750	-1.63	-0.91	-0.23	-0.04	-0.02	-0.70	-0.48	-0.06	-0.006
1000	0.44	0.25	0.06	0.009	0.005	0.19	0.13	0.02	0.002
1250	-0.13	-0.07	-0.02	-0.003	-0.001	-0.05	-0.04	-0.004	-0.0005
1500	0.06	0.04	0.009	0.001	0.0007	0.03	0.02	0.002	0.0003

The negative values in the computations of Cl_2, SO_4^2, $CaCO_3$, Pt/co, TSS, Ca, K, NO_3, and Fe should be neglected. Interest is on the magnitude of simulated results.

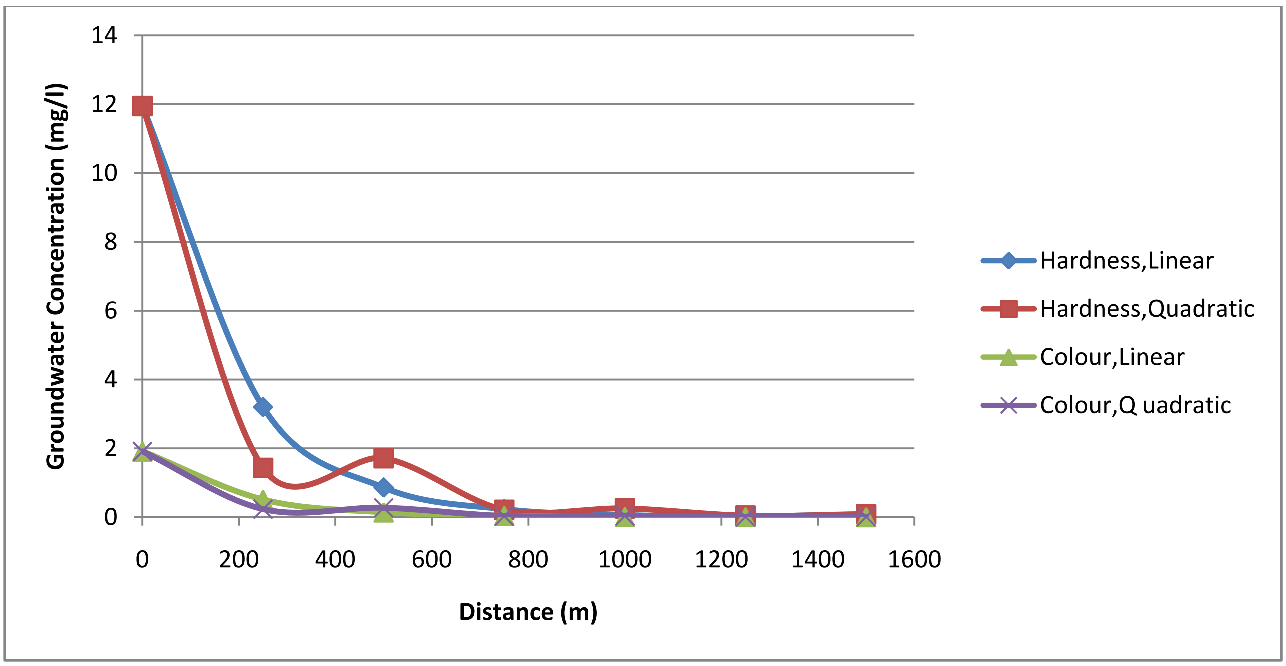

Figure 1: Comparison of Linear & Quadratic Shape Function of Finite Element for Simulation of Groundwater Hardness & Colour

The irons that contribute to hardness in water are Ca^{2+},Mg^{2+}, Cl^-,SO_4^{2-} and HCO_3^-. Hardness is the characteristic of water which hampers the lather formation with soap. Problems of hardness of water much concern is of domestic and industrial use rather than for its health effect and Colors in natural drinking water can be trace from decomposition of organic matter and discharge of certain waste water having interaction with water bodies. Mainly color interferes with penetration of high air affects photosynthesis. Also it may hamper oxygen absorption from atmosphere (Goel, 2006). Water with coloured problem most time are mainly hard to hest, are not used In industry and other purpose, but the investigation of color concentration of sama community indicate good one as value are within acceptable standard. Figure 1 shows the relationship hardness and colour concentration using the of linear and quadratic shape function of finite element in simulating the one dimension mass transport equation of groundwater and results demonstrate that for the purpose of prediction the linear method is the best.

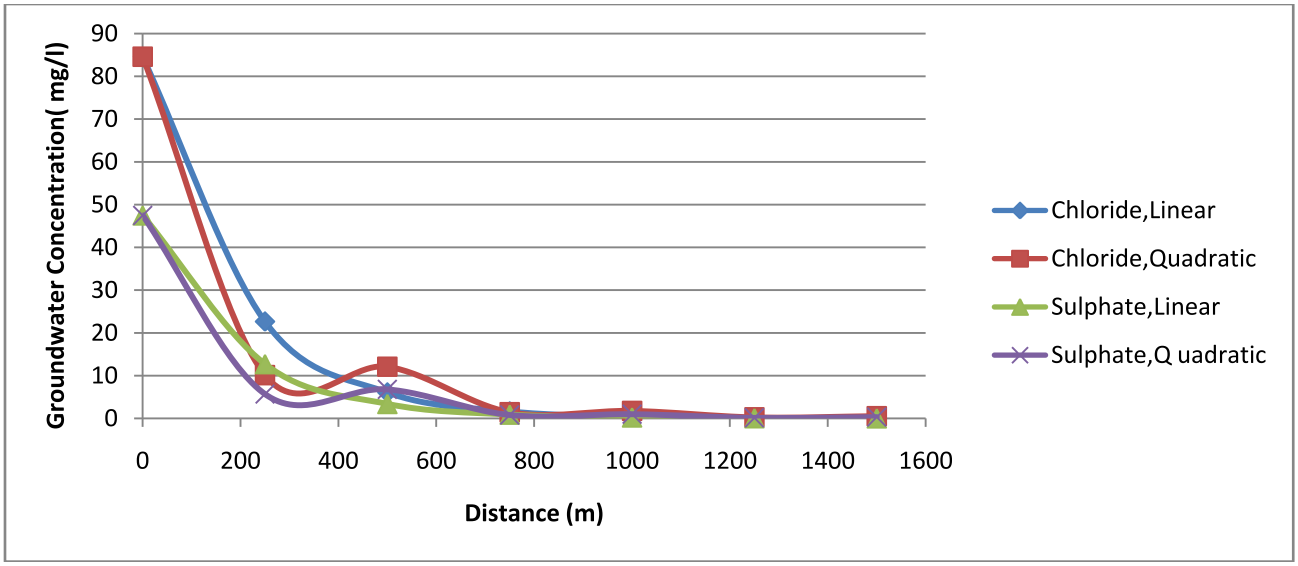

Figure 2: Comparison of Linear & Quadratic Shape Function of Finite Element for Simulation of Groundwater Chloride & Sulphate

Figure 2 illustrate acceptable dispersion spread of chloride (Cl_2^-) and sulphate (SO_4^{2-}) by application of linear approach of Galerkins finite element while that of the quadratic approach, the concentrations was rising and falling. The permissible limit of chloride in drinking water has been kept between 200-250Mg/l in most standard. However, it can be tolerated up to 1500mg/l without any adverse health effect, but produces a salty taste, it can corrode concentrate by extracting calcium in the form of calcide (Goel,2006). Sama community well assessed the chloride concentration are within WHO limit and Sulphates in water can undergo transformations into its reduced state sulphur and hydrogen sulphide and vice-versa depending upon the oxygen level in waters. Sulphate is relatively non-toxic and produces a bitter taste when value determined is above standard. A high value concentration of sulphate may lead to cathartic effects and gastrointestinal disorder in human, but the determined value of sulphate for sama community is within permissible limit.

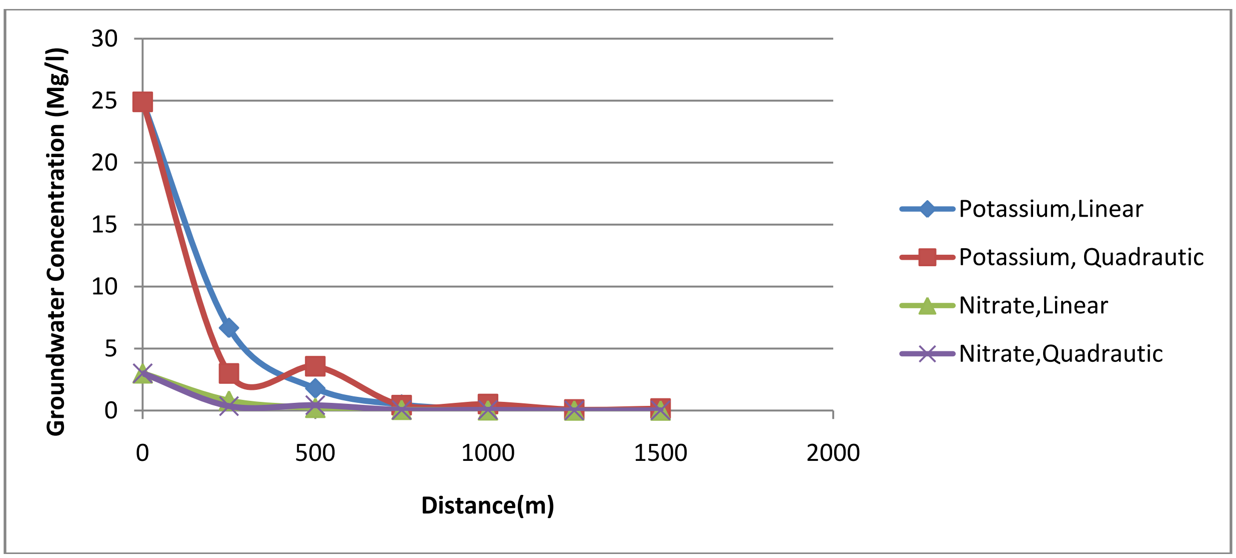

Figure 3: Comparison of Linear & Quadratic Shape Function of Finite Element for Simulation of Groundwater Nitrate & Potassium

Research established that most natural waters are deficient in Nitrate (NO_3^-) having a concentration not more than 5mg/l but some polluted surface and ground waters may report higher quantities it occurrence can be both natural and man-made source, such as fixation of atmosphere nitrogen due to microorganism plant-debris, animal excrement, nitrogenous fertilizers and discharge of sewage and industrial wastes having direct or indirect contact with the groundwater. The time to time investigation of nitrate has gained interest because of it implication in causing infant methaemoglobinaemia, a disease characterized by bluish coloration of human skin. In the case of disease, the normal haemoglobin is transformed into methaemoglobin due to formation of ferric ion in the haem, and loses its capacity to carry oxygen. Areas where Methaemoglobinaemia are reported, it is established that nitrate concentration in the water exceeds 45mg/l. Nitrate concentration of the well evaluated in Sama Community are within permissible limit and Potassium (K^+) and sodium are essential cations occurring naturally in waters. Their major source in water can be attributed to weathering of rocks (Goel, 2006). Figure 3 shows acceptable trend behavior in the spread of the groundwater simulation using linear shape function of Galerkins method of finite element than the quadratic shape function.

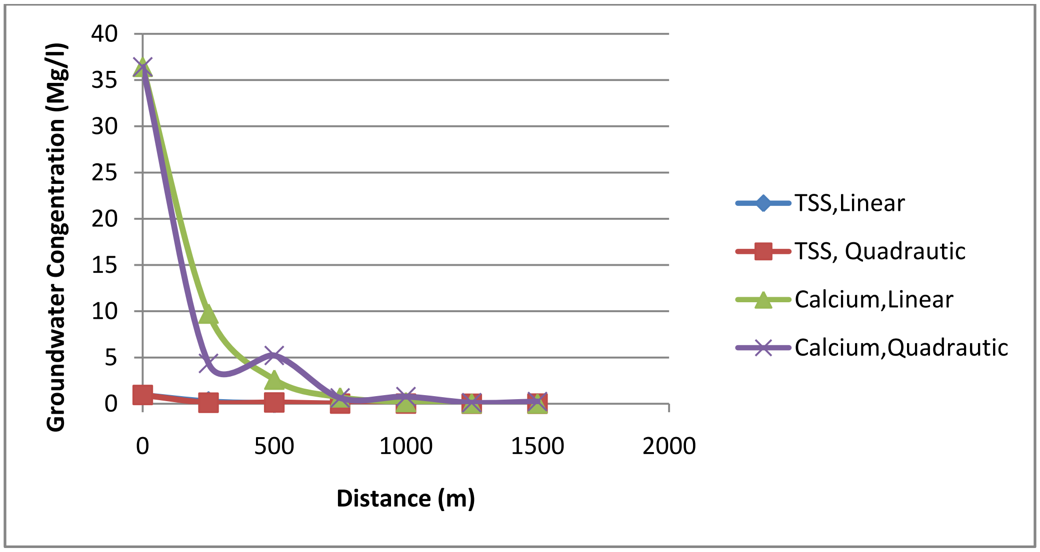

Figure 4: Comparison of Linear & Quadratic Shape Function of Finite Element for Simulation of Groundwater Nitrate & Potassium

Assessment reveals that all the bodies of water contain some quantities of suspended matter that may have been traced naturally as a result of man made activities within the water bodies. This particles remain suspended over time depending on their size and it density. Suspended solids can be said to belong to either organic or mineral category. If excessive corrosion around the water wells that moves from ground to lowest point in the wells this will contribute highly to TSS in the groundwater, However, the TSS and calcium (Ca^{2+}) of Sama Community well examined is within a permissible limit recommended by Nigeria Drinking Water Standard or World Health Organization. The linear shape function gives an acceptable dispersion order than quadratic shape function as in Figure 4.

From Table 1 & 2 established the fact linear shape function results for each node of interest dispersed in an acceptable order more than the quadratic shape function. The occurrence of Fe in water may be due to naturally drive metallic pollutant which owes its source in the water to the sources derived from soil and rocks. Human generation of iron may be confirmed to effluents from certain industries like steel, mills and metal plants. Water contaminated by iron leads to the corrosion of pipes, pumps, and other such structures can also raise concentration of iron in the distribution system that is one of the reason the assessment of iron concentration in water is essential.

IV. CONCLUSION

The comparative study of linear shape function and quadratic shape function of finite element method by Galerkins concept for the prediction of one dimension mass transport of groundwater parameters established the fact that for the aim of groundwater parameters simulation, the linear shape function is the best method to be used since dispersion values at nodes of interest follows an acceptable sequential order than that of quadratic shape function.

REFERENCES

[1] Agunnwaba, J.C (2001): Waste engineering and management tools, 1st edition, immaculate publication ltd, No.2 aku street, Ogui N/layout, Enugu, P.366 – 371

[2] Apha (1981): Standard methods for examination of water & waste water (15ed) America public Health Association, AWWA, WPCF, WASHINGTON DC.

[3] Carrol .D. (1962): Rain water as a chemical agent of geological progress – A review, geological survey, water – spply, 1535-6

[4] Chatterjee, A.K (2010): Water supply, waste disposal and environmental engineering. Romeshchanderkhanna for khanna publisher, 2-B, Nath market, Naisarak, Delhi – 110006. P.1 -201

[5] Dash. J. R., Dash. P. C. and Patra. H. K., (2006), A correlation and regression study on the ground water quality in rural areas around Angul – Talcher industrial zone, international journal of environmental protection, 26(6), pp. 550 – 558.

[6] Eluozo,S.N. and Nwofor, T.C.(2012), Evaluating the variation of transmissivity on groundwater development in Rivers State. International Journal of Applied Environmental Science, 7(2), 141-147

[7] EPA (1990) environmental pollution control alternatives: Drinking water treatment for small communities .EPA /625/5-90/025.

[8] Gajendran C., Thamarai P., and Baskar., (2010), Water quality evaluation for Nambiyar river basin, Tamil, India by using geo – statistical analysis, Asian Journal of Microbiology, Biotechnology and environmental science, 12(3), pp. 555 – 560

[9] Garg, S.K.(2007), Hydrology and Water Resources Engineering, 14th Revised Edition, Romesh Chander Khanna for Khanna publishers 2-B, Nath Market, Nai Sarak, Delhi-110006. pp.700-703

[10] Gerard, K.(1998): Environmental engineering, international edition Mcgraw-Hill, New York, P.200-22g.

[11] Goel, P.K (2006): Water pollution, causes, effects and control. New Age internation (P) Ltd, publishers, P.1 – 300

[12] Kolenbrander, G.J. (1975): Nitrogen in organic matter and fertilizer as a source of pollution in processing of LAWPR conference “Nitrogen as a water pollutant” compenhagen.

[13] Leton, T. (2007): Water and waste engineering, pearl publishers, Port Harcourt, Nigeria, P23-38

[14] Nwaogazie I.L (2008): Finite element modeling of engineering system with emphasis is water resources, 2nd Edition, University of Port Harcourt press, Nigeria, P45 – 177

[15] Ogedengbe A. O., ABBA M. U., (2006), An assessment of Dug – well water quality and uses in Mubi, Nigeria, Journal of Sustainable Development in Agriculture and Development, 2(1), p. 10.

[16] Okeke C. O. Igboanua A. H. (2003), Characteristics and quality assessment of surface water and ground water resources of Akwa Town, Southeast, Nigeria. J. Niger. Assoc. Hydrol. Geol., 14, p. 71 – 77

[17] Pathak H., Limaye S. N. (2011D), A mathematical modeling with respect to DO for environmentally contaminated drinking water sources of Makronia sub-urban area, India: A case study, Ovidius University Annals of Chemistry, Vol. 22(2), 2011. ISSN – 1223 – 7221.

[18] Pathak H., Limaye S. N. (2012A), Assessment of Physico – chemical quality of municipal water samples of Makronia sub – urban RArea of Bundel Khand Region, India, Anaele University din Oradea – Seria Geografie, 2, 122 – 127

[19] Pathak, H., Lirmaye, S. N. (2012B). A water quality index mathematical modeling of water samples of Rajghat, water supply reservoir sagar (M. P.) with respect to total dissolved solids: A regression analysis, the polytechnic institute of Iasi, 2012, vol. 1, ISSN: 0254 – 70104

[20] Patowary, Kabita AND Bhattacharya K. G., (2005), Evaluation of drinking water quality of coalmining area, Assam, Indian Journal environmental protection, 25(3), pp. 204 – 211

[21] Sincero, A.P and Sincero A.G (1999): Environmental engineering, prentence – hall of India pride limited New Delhi ~ 11 0001 P.1~85

[22] Suleiman F. B. (2006), Analysis of some sachet water samples in Katsina, Nigeria, Chem. Class journal of Chemical Society of Nigeria, Zaria chapter, 3, p. 42 – 44

[23] Ukpaka C. P. and Ukpaka C. (2016), Characteristics of Groundwater in Port – Harcourt. Journal of Advances in Environmental sciences. Volume 1 Number 2, pp 59 – 71.

[24] Ukpaka, C., Ify, L.N., Peter, U.C., (2015). Prediction of nitrate interaction for Egi Clan groundwater investigation in Rivers State of Nigeria. CASRP Journal of Applied Sciences, 1(14), 118-132.

[25] WHO (1984): Guidelines for drinking water quality vol.2. Health criteria and other supporting information ch.16. Geneva. PP145-150