Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2023, 10(5):14-21

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Simulation of Water Quality Parameters and Assessment: Applications of Flow rate and Recharge

C. Ukpaka[1], B.G. Jephter[2]

[1]Jospaka Ventures Nigeria Limited, Port Harcourt, Nigeria.
[2]Department of Civil Engineering, Rivers State University, Nigeria
Corresponding Author's Email: ukpachin@yahoo.com, ukpachin@gmail.com

Abstract The application of groundwater flow rate and recharge was used. Theory in predicting pH, Turbidity, TDS, TSS, Iron, Calcium and Total hardness concentrations. Polynomial model equations of the best fit were established and acceptable coefficient of determination (R^2) for Turbidity, Total dissolved solids, Calcium, Total suspended solid, Total iron and Total hardness concentrations respectively. Results obtained reveals the significance of groundwater parameters distribution from one point to another as a mechanism of contaminants migration. The data obtained from this investigation when compared with the WHO standard shows that pH values determined by the model is a little lower than that of WHO, where as other parameters were within the acceptable limit.

Keywords Physico-chemical parameters, Recharge, Matrix method

1. Introduction

The impact of seasonal change on groundwater quality calls for proper evaluation of groundwater. The rainfall that percolates below the ground surface, passes through the voids of the soils, rocks, and joins the water table. These voids are generally inter-connected, permitting the movement of the groundwater. But in some rocks, they may be isolated, and thus, preventing the movement of water between the interstices. Hence, it is evident that the mode of occurrence of groundwater depends largely upon the type of formation and upon geology of the area [8]. Groundwater is a major resource in terms of fresh water; Groundwater basically moves slowly its rate of movement being distributed due to hydraulic conductivity. Thus, groundwater moves at rates substantially different for different bed material [1-9]. Water table is generally not horizontal, and has high and low points in it or it is not in equilibrium. In order that the equilibrium is approached, water moves inside the ground from the high point on water table to the points lower down and the rate of the movement is dependent upon the ability of the porous medium to pass water through it (permeability) and the driving force or hydraulic gradient [7-11]. The mechanism of pollutant transport depends on hydraulic conductivity of the soil / aquifer. If the hydraulic conductivity is very low as in some aquifers and clays, then the transport mechanism may be primarily by diffusion. For high conductivity, advection is the dominant transport mechanism [10-18].

The effect of recharge on the physico-chemical quality of water cannot be overlooked since this increase or decreases water quality parameters as reveals in prediction of nitrate interaction in groundwater investigation in Egi clan research [17]. The pattern of contamination transport depends on hydraulic conductivity of soil/aquifer interaction [2, 7,13].

Polluted waters contain a high level of pollutants, which is high than the recommended standard by world health organization (WHO) standard for acceptable drinking water and causes problems when consumed by humans [12-18].

This research work is carried out to evaluate the impact of recharge percolation to the groundwater and its effect on the selected physico-chemical parameters of the groundwater.

2. Materials and Methods

2.1 Water Sample Collection

Groundwater specimens of Obite and Ogbogu communities water supply scheme of each community were collected after fleshing the taps for about 15 minutes and put in plastic bottles and were immediately transported to the Chemical/Petrochemical Engineering Laboratory of Rivers State University,Port Harcourt, water specimens collected were packaged in polyethylene bags with ice block for onward analysis. Samples collected for five different weeks and labeled OBWK1, OBWK2, OBWK3, OBWK4 and OBWK5 and OGWK1, OGWK2, OGWK3, OGWK4 and OGWK5 respectively for Obite and Ogbogu, around the month of July and August were investigated to monitor pH, turbidity, total dissolved solid, total suspended solid, calcium, total iron and total hardness physico-chemical parameters of the groundwater.

2.2 Methods of Data Analysis

The analytical chemicals used during the analysis were of good analytical reagent grade. Analysis were carried out for some selected physiochemical parameters and using standard methods.

Table 1: Analytical method for evaluation of different parameters

S/ No	Parameters	Analytical approach	WHO Standard
1	pH	APHA 4500HB	6.5-8.5
2	Turbidity (NTU)	APHA 2130B	5.0
3	TDS (mg/l)	APHA 2130B	250
4	TSS (mg/l)	APHA 2130B	500
5	Total Iron (mg/l)	APHA 3111B	0-0.30
6	Calcium (mg/l)	APHA 3111B	75
7	Total Hardness (mg/l)	APHA 2130	500

2.3 Wells Investigation

The wells monitoring of the concerned communities was carried out to establish the water table elevations of the wells. This is required for proper assessment of wells over months which aim at generating water table elevation contours at different node of interest-because the water table map is a series of contours of equal or different elevations that resemble land topographic contours. Elevations of water table of interest were fully established.

2.4 Unconfined Groundwater Model.

Geological and others assessment reveals that at this point of the assessment, the unconfined groundwater model can be apply in this research taking Obite community as a reference point.

If the flow is assumed to be one dimensional and steady state with a hydraulic conductivity (k). Then the Laplace equation is

$$\frac{d^2 y}{dx^2} = 0 \qquad (1)$$

Recharge is the proportion of rainfall that eventually finds its way into the aquifer and the water level.

If recharge is R, then

$$\frac{dQ}{dx} = R \qquad (2)$$

Solving Equation(1) and substituting Equation(2) into the solution. Finally gives:

$$Q = \frac{k}{2L}(y_R^2 - y_0^2) + \frac{R}{2}(l - 2x) \qquad (3)$$

Equation (3) is equation for flow with the effect of recharge.

Where,

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

K = Aquifer permeability, (m/day)

$y_R =$ Water table height for reference points, (m)
$y_0 =$ Water table height for consideration points, (m)
R = Recharge, (m/day)
x = Any distance along the length, (m)
$l =$ Length apart between the communities, (m)

2.5 Discrete Section of Conceptualization Model

In generating a compartment model of a substantial system, we theoretically separate the system into different numeral of little components between which material is transported. Compartments need not be spatially distinct but must be distinguishable on basis. Considering that the groundwater system is divided in to 2 compartments and after each Δt units of time, parameters are interchanged between compartments. Let assume that a fixed flow rate Qij of the contents of compartment i are passed to compartment j every Δt units of time as shown in figure 2: this hypothesis is known as a linear donor- controlled hypothesis.

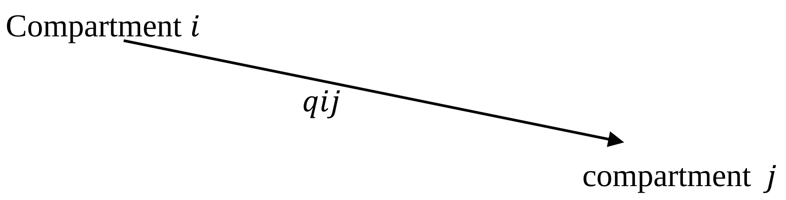

Figure 1: Demonstrate the connection between two Compartments (Communities) Groundwater.

Let the entries S_i in the n x 1 matrix S

Therefore $$S = \begin{vmatrix} S_1 \\ S_2 \\ S_3 \end{vmatrix} \quad C = \begin{vmatrix} C_1 \\ C_2 \\ C_3 \end{vmatrix} \tag{4}$$

Represent groundwater parameter (i), let say that s is the state of parameter of the groundwater tested. The n x1 matrix c is the estimated distributed groundwater parameter over time. This show that s and c are related by

$$C = G S_{ij} \tag{5}$$

In general,

$$\begin{aligned} c_1 &= Q_{11}s_1 + Q_{12}s_2 + - - - Q_{in}s_n \\ c_2 &= Q_{21}s_1 + Q_{22}s_2 + - - - Q_{2n}s_n \\ c_n &= Q_{nis} + Q_{n2}s_2 + - - - + Q_{nn}s_n \end{aligned} \tag{6}$$

The matrix $(Qij)$and it is known as flow rate coefficient matrix. Considering that the sum of the entries in any column the transfer coefficient is equal to 1.

Equation (6) is the used developed model for simulation of physiochemical parameters of groundwater upon the influence of recharge.

2.6 State of Groundwater Model

Physiochemical parameter varies based on groundwater conditions which can be credited to environmental factor. And this variation can influence physiochemical quality or not depending on the environmental impact of the region. In order examine how these parameters is cycled through the groundwater system, let divide the system in to the compartments shown in Figure 2. Suppose that Δt = 1 day and the groundwater parameter (which have been estimated experimentally) are measured. Considering that the water qualities parameter within the compartments are denoted as s_1.

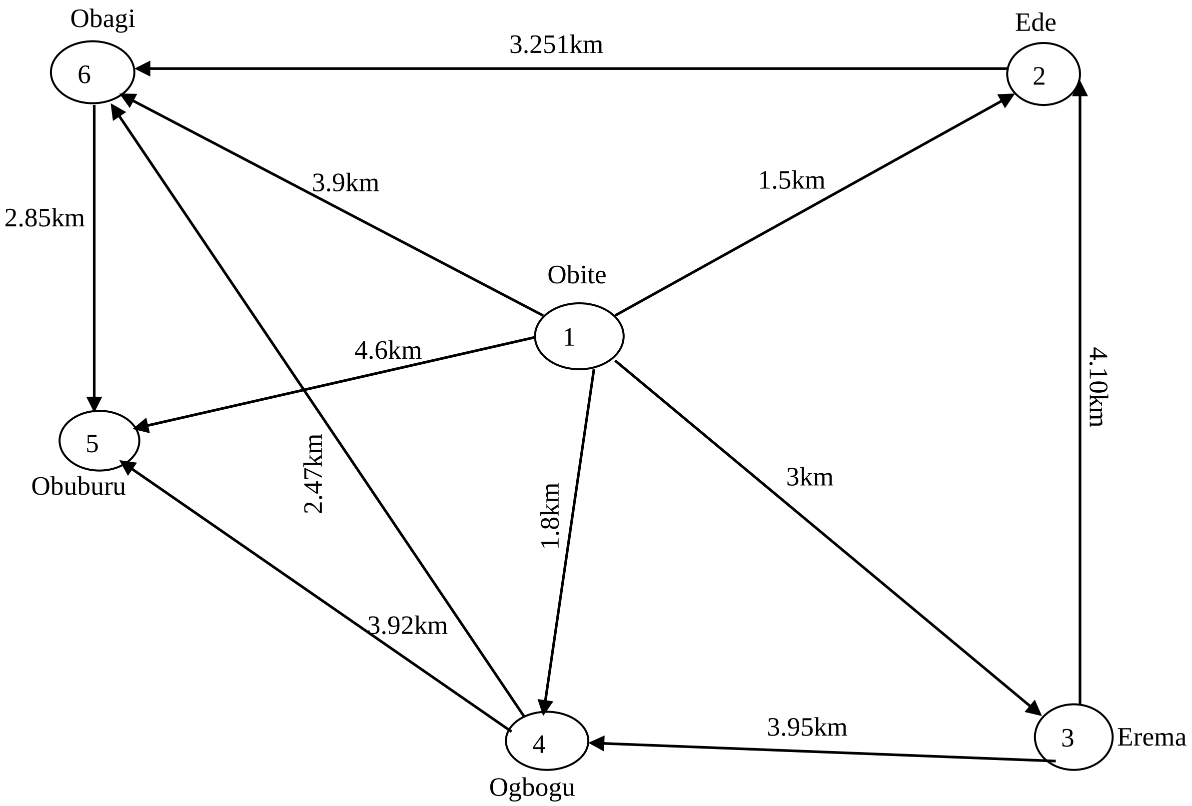

Figure 2: Logical Compartment connection showing Groundwater Movement due to Water Table Levels observed

$$\begin{vmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \end{vmatrix} = \begin{vmatrix} Q_{11} & Q_{12} & Q_{13} & Q_{14} & Q_{15} & Q_{16} \\ Q_{21} & Q_{22} & Q_{23} & Q_{24} & Q_{25} & Q_{26} \\ Q_{31} & Q_{32} & Q_{33} & Q_{34} & Q_{35} & Q_{36} \\ Q_{41} & Q_{42} & Q_{43} & Q_{44} & Q_{45} & Q_{46} \\ Q_{51} & Q_{52} & Q_{53} & Q_{54} & Q_{55} & Q_{56} \\ Q_{61} & Q_{62} & Q_{63} & Q_{64} & Q_{65} & Q_{66} \end{vmatrix} \begin{vmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{vmatrix} \quad (7)$$

Equation (7) is used to determine groundwater physico-chemical parameters spread in (mg/l) of physiochemical parameters due effect of recharge. Qij is calculated through Equation (3). If s_1 denote the initial state of the system.

Where, C_1 = physico-chemical value for Obite community,(mg/l), C_2 = physico-chemical value for Ede community, (mg/l), C_3 = physico-chemical value for Erema community, (mg/l), C_4 = physico-chemical value for Ogbogu community, (mg/l), C_5 = physico-chemical value for Oboburu community, (mg/l), and C_6 = physico-chemical value for Obagi community, (mg/l).

2.7 Assembling Matrix Representation

Representation of Qij characterize the flow rate formed due to functional parameters transmit from compartment i to compartment j. Hence we are given $Q_{11}Q_{12}$, ... e.t.c as in the Equation (7). Matrix G is of form;

$$G = \begin{vmatrix} Q_{11} & Q_{12} & Q_{13} & Q_{14} & Q_{15} & Q_{16} \\ Q_{21} & Q_{22} & Q_{23} & Q_{24} & Q_{25} & Q_{26} \\ Q_{31} & Q_{32} & Q_{33} & Q_{34} & Q_{35} & Q_{36} \\ Q_{41} & Q_{42} & Q_{43} & Q_{44} & Q_{45} & Q_{46} \\ Q_{51} & Q_{52} & Q_{53} & Q_{54} & Q_{55} & Q_{56} \\ Q_{61} & Q_{62} & Q_{63} & Q_{64} & Q_{65} & Q_{66} \end{vmatrix} \qquad (8)$$

3. Results and Discussions

Simulation of physico-chemical parameters distribution for considered communities in Egi Clan groundwater due to recharge is as follows:

For R (Recharge) = 0.1mm/day = 1.0 x 10^{-4}m/d ($^{R}/_{2}$ = 5x10^{-5}m/d)

Within fine sand/coarse sand, k = 62.5m/day = 7.23 x 10^{-4}m/sec, estimation of flow rate based on groundwater gradient from reference point community to others, meaning groundwater parameters determined at Obite Community is used in each of the cases to simulate parameters at Ogbogu Community. Application of Equation (7) and solving for entire lengths and solving Equation (7) gives the following results:

Table 2: Experimental and modeled values of physiochemical quality of Obite –Ogbogu groundwater upon the influence of recharge of 0.1mm/day

	EWO	EW1	EW2	EW3	EW4	MW0	MW1	MW2	MW3	MW4
PH	6.44	6.40	6.35	6.50	6.40	5.00	4.85	4.92	4.97	4.90
Turbidity (NTU)	1.13	1.10	1.10	1.14	1.07	1.05	0.91	1.02	1.08	1.50
TDS (mg/l)	23.80	71.88	50.00	65.00	58.06	18.68	44.38	30.17	34.69	35.76
TSS (mg/l)	4.50	5.20	5.00	4.74	4.79	5.19	3.49	4.52	3.78	3.98
Total Iron (mg/l)	0.36	0.23	0.30	0.29	0.21	0.29	0.14	0.23	0.23	0.23
Calcium (mg/l)	13.80	12.85	12.97	13.00	13.09	8,23	8.36	8.36	8.32	8.16
Total Hardness (mg/l)	8.40	7.88	8.10	8.35	8.00	6.45	4.49	6.02	6.33	6.33

The application of groundwater flow rate and recharge theory in predicting physico-chemical parameters of groundwater were validated using the concept of polynomial regression model. The relationship between the experimental and simulated values of chosen water parameters was examined by concept regression and the following mathematical models are developed and coefficients of determination evaluated as shown in Figure 3-8.

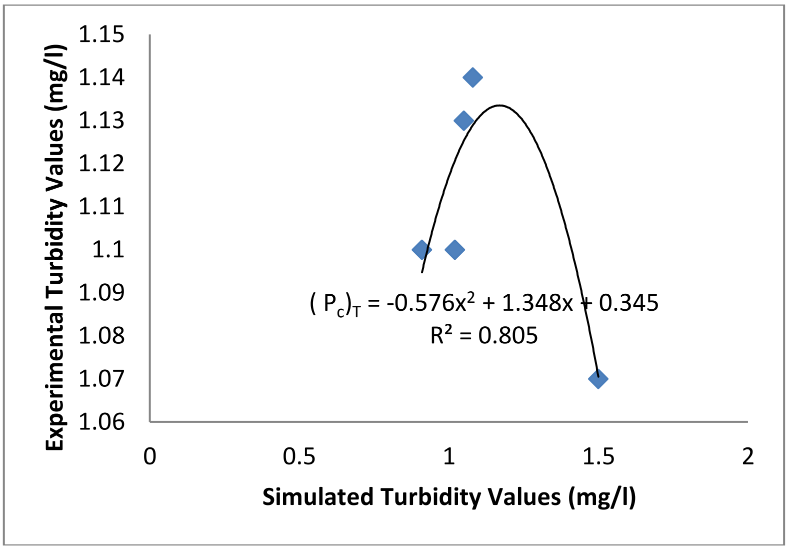

Figure 3: Prediction of turbidity by the simulated turbidity value versus experimental turbidity

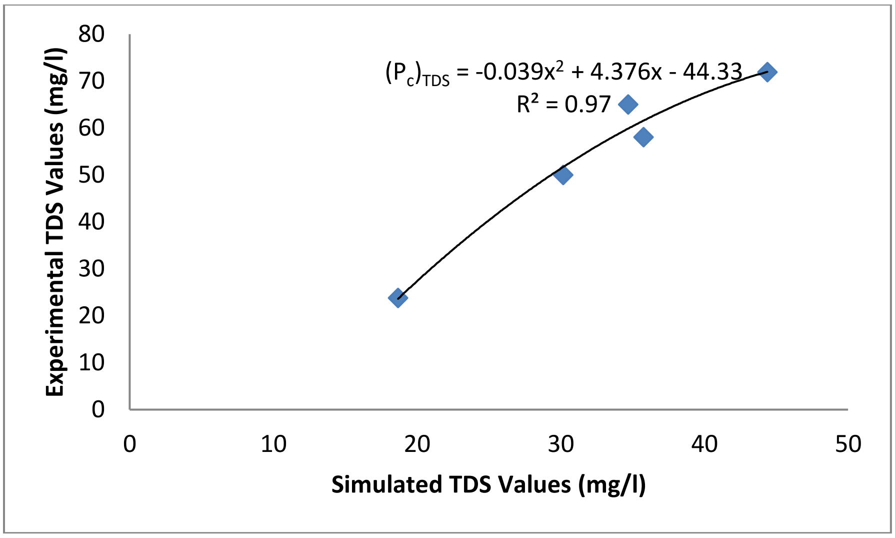

Figure 4: Prediction of TDS by the simulated TDS value versus experimental TDS

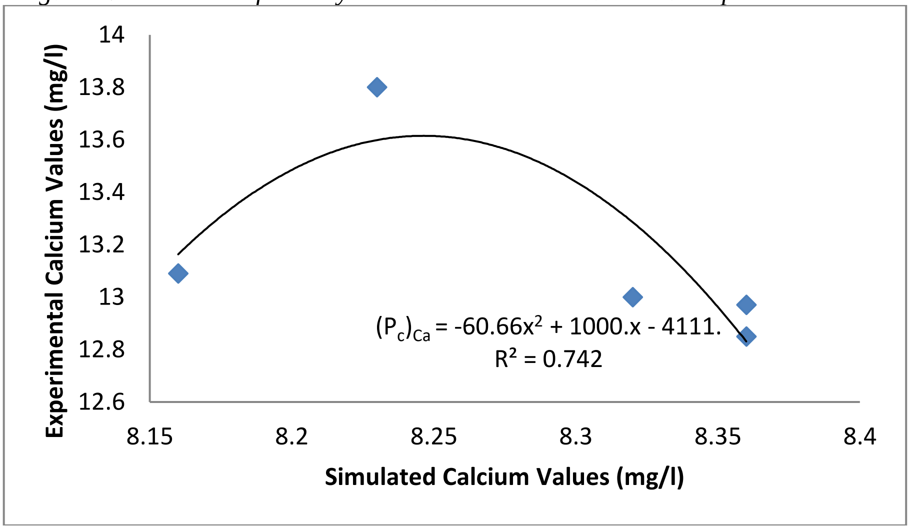

Figure 5: Prediction of calcium by the simulated calcium value versus experimental calcium

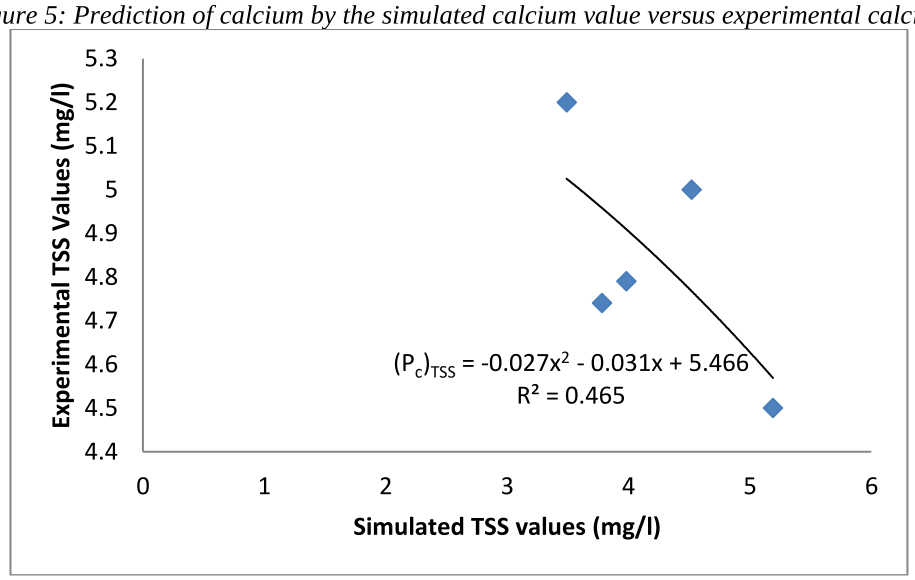

Figure 6: Prediction of TSS by the simulated TSS value versus experimental TSS

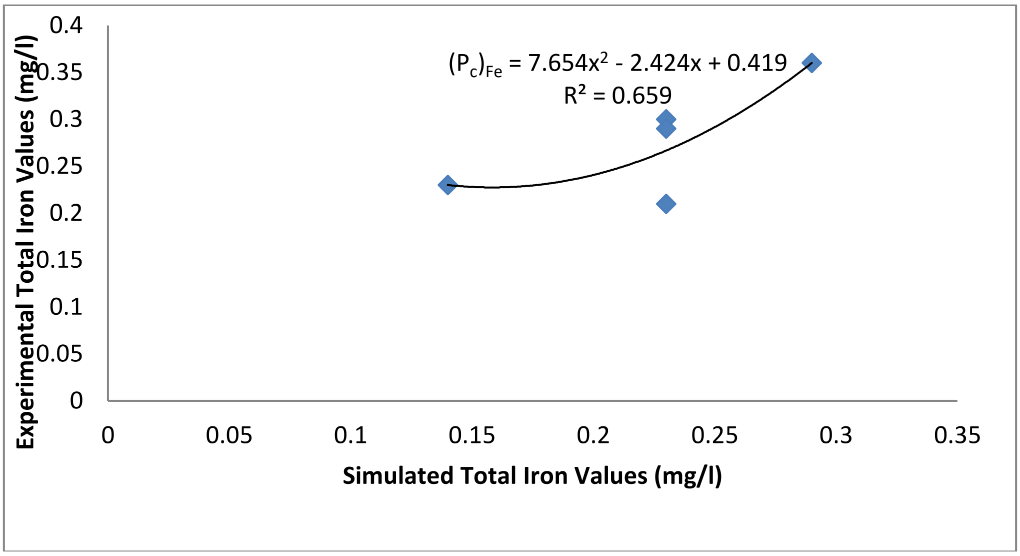

Figure 7: Prediction of total iron by the simulated total value versus experimental total iron

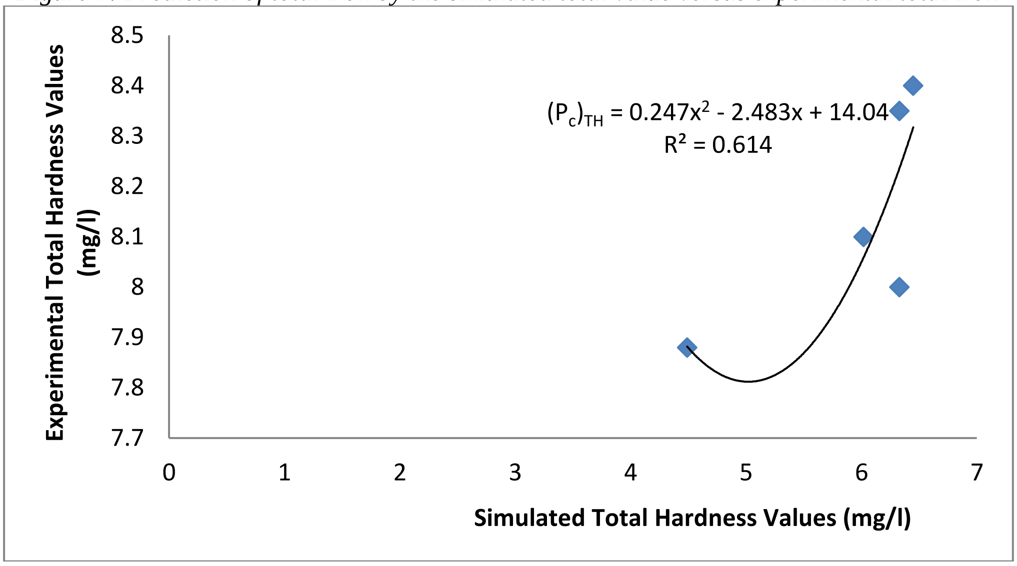

Figure 8: Prediction of total hardness by the simulated total hardness value versus experimental total hardness

4. Conclusion

The following conclusions were drawn from the research work: Theory of groundwater flow rate and recharge is a useful mathematical tool for monitoring and predicting the impact of rainfall recharge on the groundwater parameters considered. Purification of contaminants occurs as migration of pollutants is experienced from one community to another. The comparison of the theoretical and experimental data obtained revealed a good match indicating the reliability of the process. pH values determined by the model is little lower by that of WHO and others parameter is within standard.

Reference

[1]. Adeniyi O. D., & Odigure J. O. (2005). Water quality monitoring: A case study of water pollution in Minna and its environs in Nigeria, Botswana journal of Technology, 14, p. 1

[2]. 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

[3]. Alpha, AWWA, WEF. (1998). standard Methods for the Examination of water and waste waters, 20th Edition America Public Health Association, Washington D. C., 233 pp.

[4]. APHA (1981). standard methods for examination of water & waste water (15ed) America Public Health Associatuin, AWWA, WPCF, WASHINGTON DC.

[5]. Arcadio, P. S. & Gregoria, A. S. (1991). Environmental Engineering: A design Approach, Prentice – Hall of India private Limited New Delhi 110001, p. 2 -52

[6]. Dash. J. R., Dash. P. C., & 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.

[7]. Eluozo,S.N., & 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

[8]. 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

[9]. Gerard, K. (1998). Environmental engineering, international edition Mcgraw – Hill New York, P. 200 – 350

[10]. Goel, P. K. (2006). Water pollution, causes effects and new age internatim (p) Ltd, publishers. P. 1-300

[11]. Masters, G. M. (1991). Introduction to Environmental Engineering and science prentice Hall, englelvood clifts, N. J

[12]. MCGHEE, T. J. (1991). Water supply and sewerage, MCHra Hill, New York.

[13]. Nigeria Industrial Standard, Nigerian Standard for drinking water quality NIS 554, 14, 2007.

[14]. Nwaogazie, I. L. (2008). Finite element modeling of engineering system with emphasis in water resources 2nd Edition, University of Port Harcourt Press, Nigeria, p. 41 – 180

[15]. 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

[16]. Ukpaka, C., Ikebuide, C.F., & Ozota, J.C. (2017). Heavy metals distribution in groundwater: Concepts of flow rate, recharge and matrix approach. Journal of scientific and engineering research , 4(10). 245-250.

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

[18]. 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.

[19]. WHO (2001). Guidelines for Drinking Water Quality. Addendum: Microbiological agents in drinking water. World Health Organization, Geneva.