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***Journal of Scientific and Engineering Research*, 2017, 4(10):245-250**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Heavy Metals Distribution in Groundwater: Concepts of Influence of Flow Rate, Recharge and Matrix Approach

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Abstract The investigation in this research is centred on assessing selected heavy metals distribution within the groundwater bearing aquifer of Ogbogu and Obagi City in Ogba/Egbema/ Ndoni L.G.A, Rivers State taking Obite City as reference point of migration of water parameter to be predicted. The solution of Laplace equation of one-dimension flow were used to developed the flow rate model and the contribution of recharge was taking into consideration since research were carried out during wet season. The computed flow rate were fitted into the developed distributing matrix model and heavy metals; arsenic, copper, zinc, lead, cyanide, selenium, cadmium, nitrate, manganese, total mercury and reactive silica distribution in the groundwater were predicted. Comparing experimental and predicted heavy metals assessed to WHO, results revealed that both are within acceptable limited. Distributing matrix model used simulating the distribution of heavy metals in this article is considered useful in monitoring and predicting groundwater quality of the research area.

Keywords Heavy metal, flow rate, Recharge, Matrix method, Obite, Oboburu, Obagi

Nomenclature,

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)
C_A = Heavy metal value for Obite community,(mg/l)
C_B = Heavy metal value for Ede community, (mg/l)
C_C = Heavy metal value for Erema community, (mg/l)
C_D = Heavy metal value for Ogbogu community, (mg/l)
C_E = Heavy Metal value for Oboburu community, (mg/l)
C_F = Heavy Metal value for Obagi community, (mg/l)

1. Introduction

The hazard due to pollution to the environment with heavy metals is a serious problem because of industrial and sewage sludge applications to our environment there by been a major contribution to the rapid spread or heavy metal to our domain. Wang et al., [1], also reported that the occurrence of heavy metals in industrial and urban waste water result to contamination of water and soil pollution. The presence of heavy metals causes a serious threat to human health and ecological environment [2-3]. More occurring metals as effluent are lead, arsenic, zinc, cadmium, chromium, copper and mercury resulting from heavy metals or metals. Natural levels of heavy metals are caused by rocks by weathering process.

In addition to the organic pollution of water bodies, there is a added load of heavy of metals to groundwater source which can be attributed to sewage and industrial waste. Metals like copper and zinc in sewage often become bound to the sediments of the estuary. These metals are not biodegradable and persist in the environment. Groundwater may be polluted by either point of source or diffuse sources. In an farmyards area where there are wells, there is always possibility of wastewater runoff and other agricultural contaminants entering the groundwater directed or percolation process [4-8].

The mass transport processes evaluate the extent of plume spreading and the geometry of the distribution of concentration. Some pollutants may attenuate or aggregate depending on the biological, chemical or nuclear processes occurring. The transport mechanism is essentially advection, with diffusion and / or hydrodynamic dispersion being insignificant. The magnitude of parameters concentration distribution transport are governed by three-dimensional hydraulic conductivity, the water level and its gradient, the existence of sources (groud streams) and shape of the flow domain [9-14].

The investigation in this study is carried out to assess the distribution of heavy metals parameter in the chosen Cities in Egi Clan groundwater been influenced by water table, hydraulic gradient and flow rate.

2. Materials and Methods

2.1. Method of Data Collection

Water samples from chosen communities, Obite, Ogbogu and Obagi Cities in Rivers State, Nigeria were collected from the groundwater source distributing water across the entire communities (water scheme) and were labeled as OEW0, OWE1, OEW2, OEW3, OEW4, OUW0, OUW1, OUW2, OUW3, OUW4, OIW0, OIW1, OIW2, OIW3 and OIW4 respectively for Obite, Ogbogu and Obagi for better identification of water specimens collected. Water samples collected in each city were put in cleaned plastic bottles bagged in polyethylene bags with ice block and transported immediately for laboratory examinations of heavy metals concentration.

2.2. Data Analysis

Table 1: Analytical method for heavy metal parameters

S/ No	Parameters	Analytical approach	WHO Standard
1	Arsenic (mg/l)	APHA 3111B	0.06
2	Nitrate (mg/l)	EPA 3521	10.0
3	Zinc (mg/l)	APHA 3111B	3.0
4	Ammonium (mg/l)	APHA 4500 NH_3	1.50
5	Reactive Silica (mg/l)	APHA 4500 $S1O_2$	0-0.30
6	Manganese (mg/l)	APHA 3111B	0.50
7	Total Mercury(mg/l)	APHA 3111B	0.04
8	Copper (mg/l)	APHA 3111B	1.0
9	Cadmium (mg/l)	APHA 3111B	0.10
10	Lead (mg/l)	APHA 3111B	0.10
11	Cyanide (mg/l)	APHA 4500 CN	0.07
12	Selenium	ASTMD 3859	0.01

2.3. Borehole Assessment

Borehole assessment was carried out to establish required parameter need for the research such as water table elevations of the wells. Elevations of water table of interest were fully established after several weeks of study.

2.4. Formulation of Model.

Geological evaluation indicates that at this point of the examination, the unconfined groundwater model can be used in this research taking Obite community as a reference point.

If the flow is considered to be in x- dimensional and steady state with a hydraulic conductivity (k) in distributing or studying groundwater interaction of heavy metals. Then the Laplace equation is

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

Recharge is the ratio of rainfall amount that sooner or later finds its way into the bearing aquifer due infiltration processes and then influence 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.

2.5. Formulation Pattern of Discretization of Flow Groundwater

Let consider compartment i and compartment j as show below indicating flow groundwater movement from i to j having a flow rate q_{ij}. In formulation of compartment model of a substantial system, we theoretically separate the system into different numeral of little components between which material is to distribute.

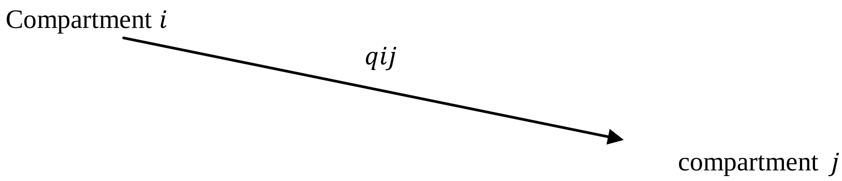

Figure 1: Formulated connection between two Compartments (Communities) Groundwater.

Let the entries S_i in the n x 1 matrix S defined the laboratory concentration of heavy metals at initial state and C present the responding distributed heavy metals in groundwater.

Therefore, $$S = \begin{vmatrix} S_A \\ S_B \\ S_C \end{vmatrix}, \quad C = \begin{vmatrix} C_A \\ C_B \\ C_C \end{vmatrix} \qquad (4)$$

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

$$C = GS_{ij} \qquad (5)$$

In general,

$$\begin{aligned} c_A &= Q_{AA} S_A + Q_{AB} S_A + --- Q_{in} S_{in} \\ c_2 &= Q_{BA} s_A + Q_{BB} s_B + --- Q_{2n} s_n \\ c_n &= Q_{n1 s_A} + Q_{n2} s_B + --- + Q_{nn} s_n \end{aligned} \qquad (6)$$

(Qij) 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 the distribution of heavy metals concentration of groundwater upon the influence of recharge.

2.6. Formulated Discritization Flow of Groundwater

Heavy metals parameter distribution in groundwater varies based on geological formation, its natural occurrence, hydraulic conductivity, etc. This variation can sway heavy metals quality. For the purpose of the study distribution or migration of heavy metals in the chosen communities, the flow pattern in Figure 2 were assumed for selected communities groundwater system,

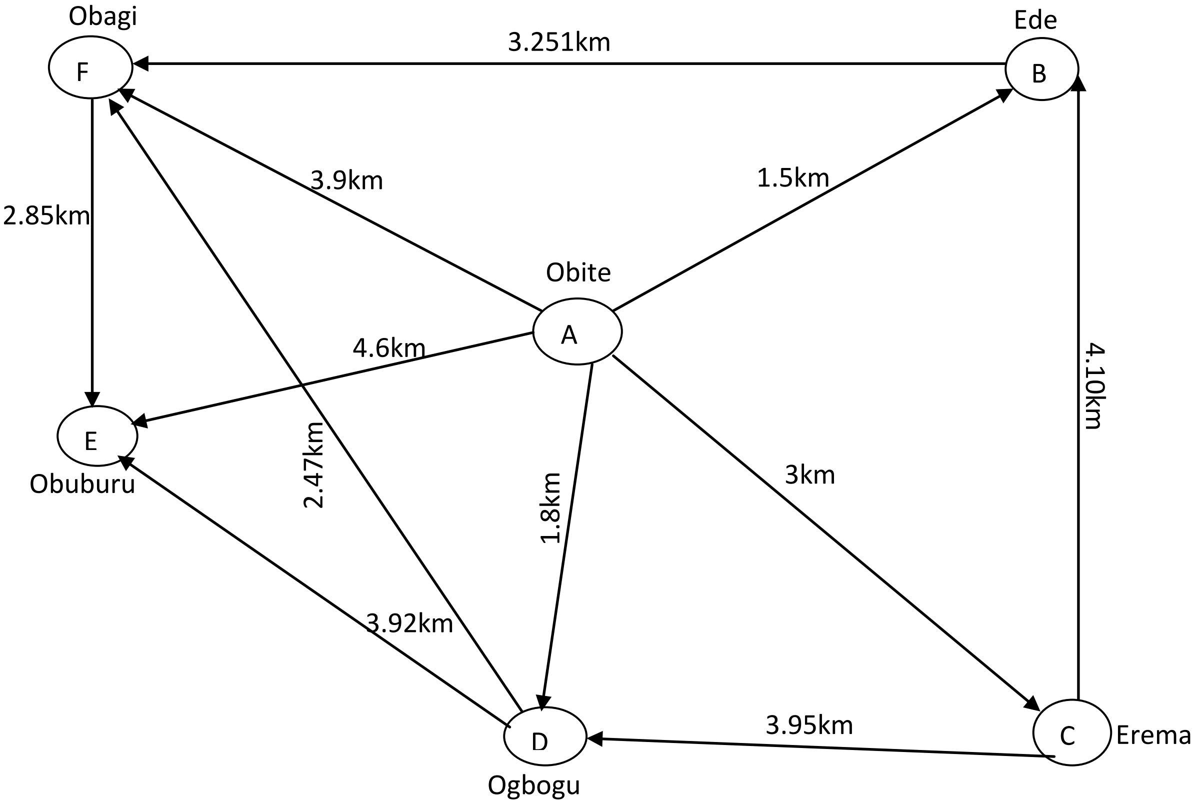

Figure 2: Formulated Compartment connection indicating flow of groundwater movement due water gradient observed

$$\begin{vmatrix} C_A \\ C_B \\ C_C \\ C_D \\ C_E \\ C_F \end{vmatrix} = \begin{vmatrix} Q_{AA} & Q_{AB} & Q_{AC} & Q_{AD} & Q_{AE} & Q_{AF} \\ Q_{BA} & Q_{BB} & Q_{BC} & Q_{BD} & Q_{BE} & Q_{BF} \\ Q_{CA} & Q_{CA} & Q_{CC} & Q_{CD} & Q_{CE} & Q_{CF} \\ Q_{DA} & Q_{DC} & Q_{DC} & Q_{DC} & Q_{DE} & Q_{DF} \\ Q_{EA} & Q_{EB} & Q_{EC} & Q_{EC} & Q_{EE} & Q_{EF} \\ Q_{FA} & Q_{FB} & Q_{FC} & Q_{FC} & Q_{FE} & Q_{FF} \end{vmatrix} \begin{vmatrix} S_A \\ S_B \\ S_C \\ S_D \\ S_E \\ S_F \end{vmatrix} \quad (7)$$

Equation (7) is used to evaluate groundwater heavy metals parameter migration in (mg/l) due effect of recharge. The computation of Qij can be carried out through Equation (3). Where S_A is the initial concentration of heavy metal to be simulated through the system for a considered water quality parameter.

3. Results and Discussion

Distribution of heavy metal parameters for chosen communities due to recharge and flow rate were evaluated using developed predictive Equation (7). Taking R (Recharge) = 0.2mm/day = 2.0 x 10^{-4}m/d ($R/2$ = 1x10^{-4}m/d).

Within the water bearing aquifer, sand/coarse, k = 62.5m/day = 7.23 x 10^{-4}m/sec, flow rate based on groundwater gradient from reference point community to others, Obite Community is used in each of the cases to study and predict the distribution of parameters at others Communities using Equation (7) and solving for their entire lengths.

The summary of results of heavy metals distribution using Eqn. (7) gives;

Table 2: Experimental and predicted value of heavy metals quality for Obite to Ogbogu groundwater parameter

Parameters	EO	E1	E2	E3	E4	P0	P1	P2	P3	P4
Arsenic(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate(mg/l)	6.87	5.85	6.0	5.04	5.90	3.13	2.99	3.28	2.89	3.06
Zinc(mg/l)	0.09	0.10	0.22	0.11	0.05	0.06	0.07	0.06	0.05	0.08
Ammonium (mg/l)	0.06	0.03	0.04	0.07	0.06	0.03	0.05	0.06	0.06	0.07
Reactive Silica (mg/l)	17.83	16.78	17.00	17.07	16.90	11.17	11.42	11.34	10.98	10.98
Manganese (mg/l)	0.13	0.02	0.01	0.09	0.11	0.18	0.04	0.25	0.38	0.15
Total Mercury (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Copper(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cadmium(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lead(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cyanide (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Selenium (mg/)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 3: Experimental and predicted value of heavy metals quality for Obite to Obagi groundwater parameter

Parameters	EO	E1	E2	E3	E4	P0	P1	P2	P3	P4
Arsenic(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate(mg/l)	4.60	3.30	4.49	4.61	4.58	3.64	3.48	3.82	3.37	3.57
Zinc(mg/l)	0.03	0.01	0.04	0.01	0.01	0.21	0.05	0.30	0.44	0.18
Ammonium (mg/l)	0.08	0.05	0.07	0.06	0.08	0.04	0.06	0.06	0.07	0.08
Reactive Silica (mg/l)	15.66	15.01	14.97	15.65	15.65	11.17	11.42	11.34	10.98	10.98
Manganese (mg/l)	0.01	0.01	0.04	0.01	0.01	0.21	0.05	0.30	0.44	0.18
Total Mercury (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Copper(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cadmium(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lead(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cyanide (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Selenium (mg/)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 2 &3 presents the experimental (E0-E4) and predicted (P0-P4) heavy metals assessed for five different weeks for Obite, Ogbogu and Obagi Cities. Heavy metal parameters of Obite city were used to predict the distribution or migration of the considered parameter to other communities.

4. Conclusion

The research established the following conclusions;

1. Concepts of flow rate in predicting heavy metals used in developing the simulating matrix model of Equation (7) is considered fit for use in monitoring and predicting parameters interaction within the studied area.
2. Hydraulic gradient, hydraulic conductivity, assumed flow movement and recharge were functional parameter in the prediction of heavy metals distribution within the water bearing aquifer.
3. The experimental and predicted values of the assessed heavy metals are within acceptable limit of WHO standard indicating reliability of method used in studying parameters distribution.

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