Application of Modflow in Modeling Groundwater Flow Direction for Abia State, Nigeria

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Abstract: **- Developing groundwater flow model for Nigeria was achieved in this research for 12 out of 17 local government areas in Abia state. The model was designed to show the groundwater flow direction using MODFLOW version of Arc hydro software with a realistic output that displayed groundwater flow direction and flow path in each of the local government areas. The water wells where water samples were collected and analyzed in the laboratory showS that out of the 48 water samples that were scientifically analyzed for microbial contamination in water, 85.4% was contaminated with total bacterial contamination when compared with world health organization (WHO) standard, 85.5% was contaminated with total coliform contamination, 95.8% was contaminated with total fecal contamination, 95.8% was contaminated with total E coli contamination, 77.1% was contaminated with total vibrio contamination, 87.5% was contaminated with total salmonella contamination, 58.3% was contaminated with total pseudomonas contamination and 97.9% was found with total fungal contamination. The laboratory technique that was used for water analysis to achieve the above results was the membrane filtration techniques where 100ml of sample were filtered under vacuum on sterilized Nitrocellulose filter of pore size of 0.45mm with the help of filtration rack. Groundwater protection zone concept, water treatment strategies, development of recycling plants, immunization against water related diseases and public orientation on pollution reduction strategies have been recommended as groundwater contamination and water related health disaster control in Nigeria.**

Key Words**: Contaminant Transport, Groundwater Flow, Health Disaster, Microbial Analysis.**

I. INTRODUCTION

Groundwater quality assessment has become a global research issue because of the high relevance of groundwater to the global community and its corresponding human health impact that manifest several forms of water related diseases epidemics. Clinton. (1992), Chima et al (2008). Groundwater can be regarded highest in rating of importance water resources since it makes up some 2/3 of global freshwater resources but if the polar icecaps and glaciers are eliminated from the evaluation, groundwater can be said to cover almost all freshwater systems. Freeze et al (1979) in Clinton (1992) stated “The dominant role of groundwater resources is clear and their use and protection is, therefore, of fundamental importance to human life and economic activity” Thus groundwater should be protected from contamination to avoid the numerous morbidity issues that will arise as a result of human consumption of contaminated groundwater. Though the process of attenuation could resolve such contamination problems where pollution sources are located far from groundwater sources or well heads, Chima et al (2007).

Groundwater flow for contaminant transport model is developed with the help of hydro geological and climatic data to show the flow direction of groundwater and the manner in which contaminants are deposited into the water table and individual water wells. According to Kumar et al (2015) there are different means of achieving a model development in other to predict contaminant transport for risk evaluation of groundwater and investigation of groundwater flow direction for verifying if groundwater movement is along the contaminant pathway which makes it possible for the contaminant to be transported into the water table or not. They also specified that field data should be gathered to determine the type of modeling and the specific software that could be applied to achieve this objective which will lead this process into data computation and adjustment of calibrated model for possible identification and correction of observed errors. This will clarify the doubt in authenticity of the parameters leading to forecasting of future groundwater flow and contaminant transport. Kumar et al. (2015) also identified hydraulic conductivity and transmissivity and aquifer media, model grid size and spacing, layer elevations, boundary conditions and recharge the parameters required for groundwater flow and contaminant transport model. Thus solute transport through the soil pores and burrows move contaminants of bacteriological and chemical constituents into groundwater. Crane at al. (1984) in Nwachukwu et al. (2010) indicated that there are two main reasons that affect movement of Bacteria through the soil and they include: (a) Soil factors (b) Bacteriological factors. The soil factors are; distribution of different sizes of particles, distribution of pore sizes, content of clay, and moisture regime while Bacteriological factors that cause Bacteria to die off include; Temperature, PH, content of moisture, and availability of nutrient.

Development of groundwater flow model could also help actors in the water sector to determine certain aquifers that could that should be protected from pollution because of their prolific nature and vulnerability to contamination since they are highly dependable for drinking water supply sources. Arizona department of environmental quality (1997) stated that groundwater flow is regulated by spatial variations in hydraulic head and water sustains equilibrium by flowing from an elevated hydraulic head to a depressed hydraulic head. Furthermore Arizona department of environmental quality (1997) stated that "total hydraulic head is height of bottom of column of water above sea level while the pressure head is the energy exerted by mass of water column itself".

The development of groundwater flow and contaminant transport involved the application of MODFLOW, a numerical model formulated by the US geological survey which has a three dimensional property for simulating groundwater flow and the application involves development of grid that will be allocated to different group of aquifer parameters to each node of the grid and with this it is possible have greater accuracy for predicting variations in water table contours in relation to time as a result of varying conditions. Aquifer boundaries simulations can be done using the node USGS (1985). This research will therefore use MODFLOW to model groundwater flow and contaminant transport which will be overlaid on the water table of different depths in the 17 local government areas of Abia state showing how contaminants flow into the water table and reduced the quality of groundwater below standard for human consumption and for recommending solutions to groundwater contamination problem in Nigeria. The model also compliments the fact from laboratory results showing the number contaminations for each parameter from the water samples.

II. METHODS

MODFLOW version of Arc Hydro was used as groundwater tool from Arc GIS 10.2 software to store control and view groundwater parameters like water table, groundwater contamination and groundwater flow direction which will be displayed as 2D geological models as well as geo- reference some water wells that are located within the area under study, Bear et al (1987).

Groundwater flow was overlaid on the water table in the 17 Local Government Areas of Abia state for easy visualization of the contaminant movement into the water table and the water well locations were also indicated on the model to show whether the contaminants flow into the wells or not.

See diagram below for different steps taken to develop groundwater flow for contaminant transport model, Kumar et al (2015).

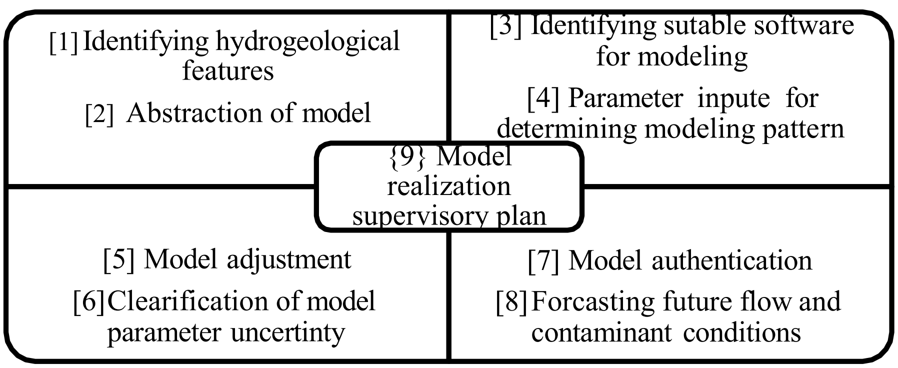

Figure 1 Processes involved in development of groundwater flow and contaminant transport model

Laboratory analysis was initiated by field investigation and collection of 48 groundwater samples from 24 wells observing all quality assurance procedures and taken to the laboratory for scientific analysis of microbial constituent of collected water samples. This study location was delineated into three different areas. The first is *Abia south*, made up of *Aba North, Aba South, Ugwunagbo, Obingwa, Ukwa East, Ukwa West & Osisioma,* second is *Abia central* , made up of *Umuahia North, Umuahia South, Ikwuano, Isiala Ngwa North, Isiala Ngwa South* and third is *Abia North*, made up of *Umunneochi, Isukwuato, Ohafia, Arochukwu, Bende* and this was done in line with the three different senatorial districts in the state. Groundwater samples were collected in 12 local government areas out of 17 local government areas LGA„s in the state. The first phases of rainy season samples were collected between 02/09/2014-25/09/2014 while the second phase of the rainy season samples were collected between 04/10/2014-10/10/2014. The first phase of dry season samples were collected between 26/01/2015-04/02/2015 while the second phase of dry season samples were collected between 06/02/2015-13/02/2015.These LGA„s are spatially distributed within the three zones. 24 water samples were collected during the rainy season while 24 samples were also collected during the dry season. Therefore, total number of water samples that were collected summed up to 48 samples. These 48 water samples were collected from distance of 5-7 meters from pollution sources.

The laboratory technique that was used for water analysis was the membrane filtration techniques where 100ml of sample were filtered under vacuum on sterilized Nitrocellulose filter of pore size of 0.45mm with the help of filtration rack. Filter paper was placed on a prepared Marcokey agar, Nutrient ager Eosin Methylene blue ager, Salmonella Shigella agar, centrimide ager and Sabrouse dextrose ager. I inverted the petri dish in an incubator at 37-41.5^{O}C for 24hrs for bacterial growth and between 72hrs-120hrs for fungi growth. At the end of the incubation, growth of colonies was counted with a colony counter and results were recorded. The results were extracted and converted to percentages. for Total bacterial count (TBC), Total coliform count (TCC), Total fecal count (TFC), Total E coli count (TEC) Total vibrio count (TVC) Total salmonella Count (TSC), Total pseudomonas count (TPC), Total fungal count TFGU.

III. RESULTS AND DISCUSSION

Table1: Percentage rate of microbial contamination of groundwater and formula used for its calculation.

Parameters	TBC	TCC	TFC	TEC	TVC	TSC	TPC	TFGU
PNC	85.4	85.5	95.8	95.8	77.1	87.5	58.3	97.9
PNC= ∑RW1+RW2+∑DW1+DW2÷∑ WS× K. Percentage number of contamination =PCN, Rainy season water samples=R1, R2, Dry season water samples DW1,DW2, Total number of water samples= WS , Percentage value , K=100 constant value.								

The meaning of abbreviations on table 1: Total bacterial count (TBC), Total coliform count (TCC), Total fecal count (TFC), Total E coli count (TEC) Total vibrio count (TVC) Total salmonella Count (TSC), Total pseudomonas count (TPC), Total fungal count TFGU and PNC is percentage number of contamination. The diagram below will display the graph plotted from the data on table 1.

The results show percentage rate of contamination from the sum of microbial contamination from water samples that were collected during the rainy season and dry season. The result from each parameter was compared with world health organization standard (WHO) to verify if it exceeded the globally acceptable standard or if it did not exceed such standard. Therefore for each parameter the values that exceeded the WHO standard are said to be contaminated. See figure 1, for the percentage number of microbial contamination of water samples in Abia state collected during rainy season and dry season.

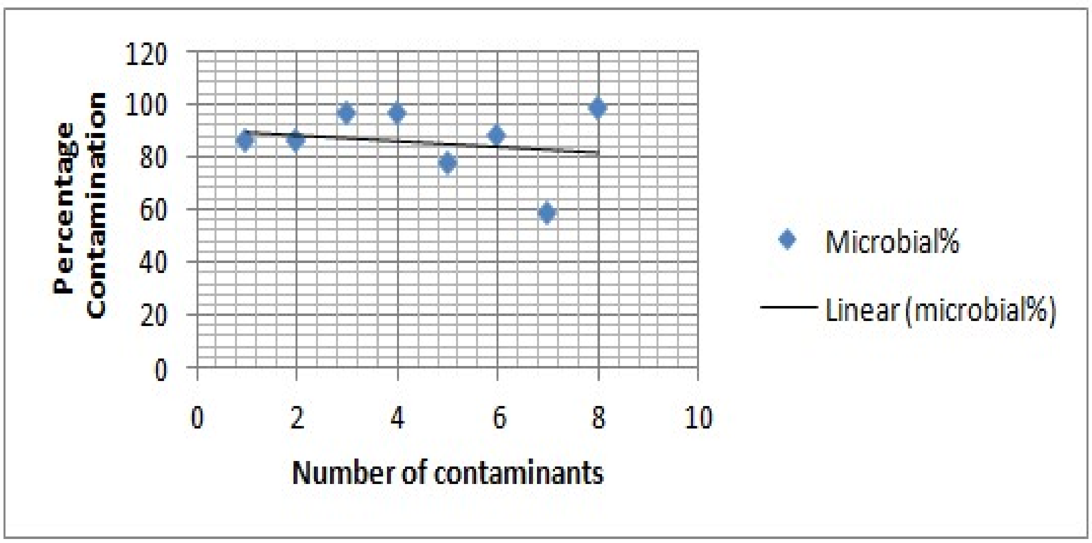

Figure 2: Percentage numbers of contaminations for microbial contamination in water samples

The graphical representation of water samples in figure 2, shows that 85.4 % of the 48 water samples had total bacterial count value that was more than WHO standard value, 8.5% of water samples had total coliform count value that was more than WHO standard value, 95.8% had total fecal count value that was more than WHO standard value, 95.8% of 48 water samples also had total E coli count value that was more than WHO standard value, 77.1% of the 48 water samples had total vibrio contamination more than Who standard value, 87.5% of the 48 water samples had total salmonella count more than WHO standard value, 58.3% of the 48 water samples had total pseudomonas count more than WHO standard value and 97.9 % of the 48 water samples had total fungal count more than WHO standard value for drinking water. Therefore, all the samples the water samples that were scientifically analyzed in the Laboratory for all microbial parameters that had higher values than the WHO standard value for drinking water are all contaminated samples.

Table 2 : Hydrogeological data groundwater flow for contaminant transport model in Nigeria.

L.G.A	WTD	RWD	TCK	RES	LIT	XCD	YCD	YLD
Aba north	120	360	240	1242	sand	5.333333	7.316666	P
Aba south	100	300	200	1109	sand	5.100001	7.350001	P
Arochukwu	240	240	320	3020	Shale- sandstone	5.416667	7.500001	L-D
Bende	230	230	320	3500	Shale-sand	5.566667	7.633333	M
Ikwuano	200	200	320	3280	Sandstone	5.433333	7.566666	M
Isiala Ngwa north	130	130	300	1210	sand	5.116667	7.366666	P
Isiala Ngwa south	100	100	300	1287	sand	5.185278	7.601944	P
Isikuato	250	250	360	2100	Sandstone	5.533333	7.483333	L-M
Obi Ngwa	120	120	320	1250	sand	5.149722	7.330277	P
Ohafia	180	180	280	3050	Sandy shale	5.616667	7.833333	L-D
Osisioma	130	340	210	1150	Sand	5.416667	7.500001	M-H
Ugwunagbo	100	300	200	962	Sand	5.185278	7.601944	P
Ukwa west	120	320	200	850	Sand	5.116667	7.366666	P
Ukwa east	100	320	220	840	Sand	5.104722	7.142501	P
Umuahia north	300	400	100	3280	Sandy shale	5.533333	7.483333	L-M
Umuahia south	180	300	120	1720	Sand	5.508056	7.481666	M-H
Ummunochi	250	400	150	2270	Sandstone	5.104722	7.142501	L-M

Source: Abia state water corporation and Anambara-Imo river basin rural development authority in Nawcukwu et al (2013)

The meanings of abbreviations displayed on table 2 above will be explained below.

LGA= Local government areas. WAT= Water table (feet). RWD= Recommended well depth.

TCK= Thickness of prospective horizon. RES= Mean resistivity. LIT= Lithology. XCD= X coordinate. YCD= Y coordinate. YLD= Aquifer yield, P= Prolific. M-H= Medium to high yield.

L-M= Low to medium yield. L-D= Low yield to dry well.

Groundwater flow for contaminant transport model has been developed for the 17 local government areas in Abia state, the water tables for each of them and the water wells where sample were collected for laboratory analysis to verify the quality of groundwater in the area. The diagram below shows this hydro geological model for Abia state.

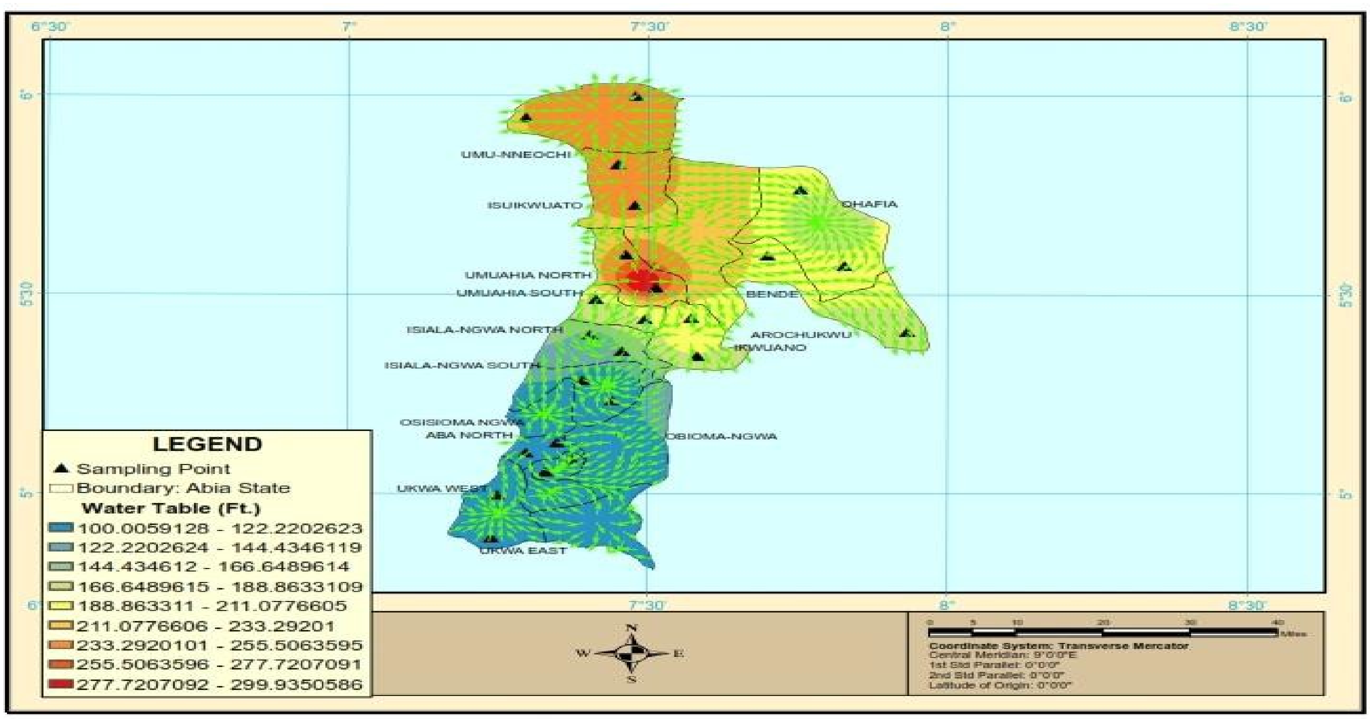

Figure 1-2 Overlay of Groundwater flow and contaminant transport model on water table

Groundwater flow for contaminant transport model on figure 1-2 has achieved the development of flow direction of contaminants which follows the same path with groundwater movement to the water tables located in all the local government areas. Furthermore it has also shown the status of the water quality in Abia state by displaying contaminants transport and groundwater flow pathway into water wells as well as the water table. Therefore groundwater flow and contaminant transport model was overlaid on water table to verify if actually contaminants flow into the water table so as to prove that Abia state inhabitants are bound to be exposed to the use of poor water quality. Finally, this model has been able to identify the water wells that are supposed to be under regular water assessments and treatments for human consumption as well as water wells that should be protected from pollution so as to reduce the rate of groundwater contamination in the state.

The displayed model used small lemon color arrows to show groundwater flow direction, 24 tiny black triangles to show water wells where groundwater samples that were analyzed in laboratory were collected while different color patches displays the ranges of the water table within the 17 local government areas in the state. Furthermore it is observed that the arrows which show the flow direction of groundwater and contaminant transport passed across the 24 water wells where the water samples were collected from and converged into the water tables represented by the different color patches on the model. Therefore, since these contaminants flow into the water wells and water table as shown from the flow direction of groundwater , the water samples collected from the wells are bound to be contaminated which correlates with laboratory results on figure 1-2.

IV. CONCLUSION

Modeling of groundwater flow for contaminant transport in Nigeria has served as a very important management tool for hydrogeology, environmental and water related health disaster control that have been major sources of concern for the research community in that region. The model has solved the problems of Identifying contaminated water wells and confirmation of groundwater contamination in the state through the flow direction which passed through all the sampled water wells and contaminant flow that emptied into the water table in all the local government areas since the model was overlaid on water table. This research has through the same model, identified groundwater sources that need to be protected from pollution and consequently treated before human consumption. Furthermore the results of laboratory analysis have shown high level microbial contamination in groundwater and the model also confirmed and displayed the path way of contaminant flow. Therefore it is recommended that groundwater protection zone should be developed for the state to drastically reduce the rate of groundwater contamination and water related health hazards associated with contamination of groundwater. Enyinna (2016). The residents should also be given proper orientation on how to quarterly treat the water before human consumption and possible, government should organize an Immunization program for all water related diseases through its public private partnership and collaboration with world health organization and other international agencies that might be willing to assist in this regard. This research would not be concluded if the recommendation is not made for building a sustainable recycling plant that could recycle the waste collected in the state thereby reducing the rate of pollution and subsequent contamination of groundwater resources in Nigeria.

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