Development of Sustainable Ground Water Source Protection Zone as Panacea to Health Hazards from Ground Water Contamination in Abia State

Enyinna Gregory. C

Chair of Environmental Geology, Environmental Resources Management, Brandenburg University of Technology, Cottbus Seftenberg, Germany/ Department of Project Management Federal University of Technology Owerri, Nigeria

***Abstract*:-The disasters associated with groundwater contamination in relation human health hazards are subjective to proper scientific investigation so as to proffer solution through construction of sustainable groundwater source protection zone. Groundwater quality was investigated through sampling of 24 water samples from boreholes in 12 local government areas in Abia state under standard quality assurance for rainy season and dry season samples and laboratory analysis using membrane filtration technique for microbial analysis where 100ml of sample were filtered under vacuum on sterilized Nitrocellulose filter of pore size of 0.45mm with the help of filtration rack and Nitrate was determined by Cadmium reduction method using HI83200 multiparameter bench photometer at a wavelength of 525nm. The results were compared with WHO standard on the graph to show the extent of contamination and graphs showed that 9 samples had total vibrio contamination. 12 samples had contaminated total salmonella contamination, 11 samples had total fecal contamination, 11 samples were had total E coli contamination, and 5 samples had nitrate contamination for rainy season. Dry season samples has 9 contaminated samples of total vibrio count, 9 contaminated samples of total salmonella count, 11 contaminated samples of total fecal count, and 11 contaminated samples of total E coli count and 7 contaminated samples of Nitrate contamination. The variation in results was due to fluctuated increase in rainfall frequency during dry season. Based on the literatures that specified the human health effects of these contaminations I developed Pre-plan and Post-plan in addition to the concept of groundwater protection zone for the sustainability of the concept in Nigeria which will serve as a panacea to disastrous pollution and contamination of groundwater with the damaging health impacts of high morbidity and mortality rate.**

***Key Words:-* Groundwater protection zone, Sustainability, Laboratory, contamination, Health harzads**

I. INTRODUCTION

Groundwater protection zone has been used in several developed countries of the world to reduce the impact of pollution and contamination of groundwater in their states while most developing and underdeveloped countries of the world that have not put the concept of groundwater protection zone into their water management sector policies have suffered tremendous hazards accruing from groundwater contamination through different pollution sources. Nigeria being one of the developing countries of the world with its numerous environmental policies in relation to water resources still lacks the concept of groundwater protection zone in its water sector policies. Therefore it is acceptable to say that lack of this policy of groundwater protection zone in Nigeria has been responsible for the numerous reports of groundwater pollution, contamination and regular epidemics of water related diseases. This has necessitated the research into a possible strategic plan for construction of sustainable groundwater source protection zone in Nigeria aimed at finding out the calculated radius within which boundaries would be created between land use activities and groundwater sources as well as using such boundaries for control of groundwater pollution, contamination and water related disease epidemics in Nigeria.

Balke et al (2000) and Griebler et al (2003) in Zhu et al (2008) specified the need for protection of quality of groundwater from agricultural chemicals and contamination from other forms of pollutants within groundwater sources and catchment areas through creation of groundwater protection zone. Considering how groundwater is importantly rated in the global use of water resources, it is very necessary to carry out an in-depth research on possible way through which it can be conserved with its natural standard quality that makes it valuable for human consumption. Zhu et al (2008) also stated that on a global scale, groundwater is rated best portable water for human consumption. The European Union states depend on groundwater for almost 70% of the piped water supply and 80% of the drinking water while 75% water supply in Baden-Württemberg, Germany is gotten from groundwater sources and over 50% of United States of America's population relies on groundwater a major source of drinking water. Asia is not left out because 20% of water supplied in urban areas in China comes from groundwater but 72% of water supply system in Northern China comes from groundwater sources, 66% in Northwestern China comes from groundwater sources but generally, 80% of cities in China have diverse water resources issues.

According to UN-Water/ Africa vision 2025, about 75% of Africa's continental population is mainly dependent on groundwater for human consumption especially in Libya, Tunisia, Algeria, Morocco, Botswana, Namibia and Zimbabwe. Christiana et al (2014) stated that 2006 house hold census in Nigeria show that about 49.4% of the households interviewed depended on groundwater as their source of drinking water. Therefore since high percentage of the world population is dependent on groundwater for as main sources of water supply for drinking, it becomes imperative to that groundwater protection zone should be constructed in Nigeria to avert the health disaster associated with contamination that regularly occur in the country.

This research has adopted the concept of groundwater protection zone established by Germany in 1957 as German water act which used the zoning system as mode of operation. Zone I is classified as immediate protection zone which should be 10 meters from water well, less than 20 meters in upstream direction of a stream and 30 meters for karst aquifer, zone II is classified as inner protection zone which should be 50 day travel time or less than 100 meters from well or spring which protects groundwater from pathogens that are microbiological and other disastrous contaminations, zone III A is classified as outer protection zone and zone IIIB covers the entire groundwater catchment area and protects groundwater from long distance contaminations like contaminations from radioactivity. ACSAD-BRG Technical Cooperation project (2003). Diagram below will show the different divisions for groundwater protection zone.

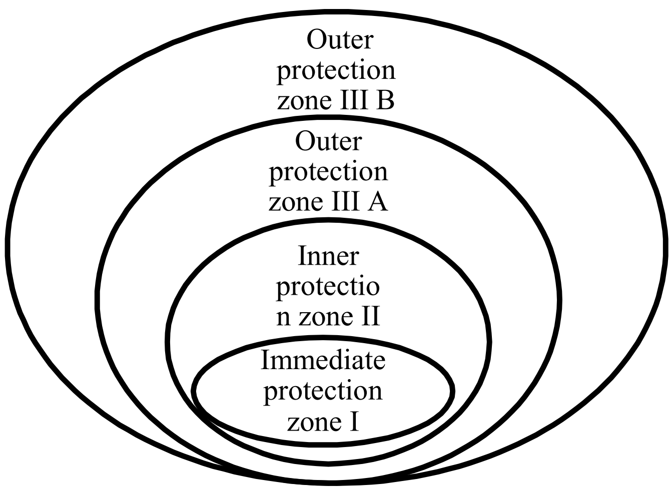

Figure1 Different delineations for groundwater protection zone

Contamination of groundwater water has been connected with the regular epidemics of water related disease which has been disastrous to health of the inhabitants of Nigeria because of lack of enforcement pollution control measures that could save the groundwater from contamination and subsequent occurrence of water borne diseases like Cholera, Typhoid fever, hepatitis and E coli. UNDESA (2014) stated one out of every nine people in the world has no best water quality for drinking and one out of every three persons lack globally acceptable sanitation standard. The organization also stated that major anthropogenic sources of water pollution are from human settlement linked to the disposal of 80% untreated sewage straight into water bodies, annual disposal of industrial waste of about 300-400 million tons in water bodies and agricultural chemical (Nitrate) which is the most common chemical contaminants that distorts the quality of the global groundwater system. Hence all these anthropogenic sources pollute and contaminate groundwater since the river systems serve as catchment areas for the groundwater systems causing approximated annual death rate of 3.5 million people. UN-Water (2014).

II. METHODS

Laboratory analysis was conducted using 24 water samples that were collected from 12 local government areas in Abia state during rainy season and dry season. These samples were collected from well heads that were properly flushed with properly rinsed bottles as quality control measure.

Membrane filtration technique was used for the microbial analysis and 100ml of sample were filtered under vacuum on sterilized Nitrocellulose filter of pore size of 0.45mm with the help of filtration rack. I placed the filter paper 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.

Nitrate was determined in the laboratory by Cadmium reduction method using HI83200 multiparameter bench photometer at a wavelength of 525nm. 10ml of the sample was poured into two separate sample cell bottles. One(1) was used as blank to zero the photometer and one (1) sachet of Nitrate reagent powder pillow was added to the second sample cell bottle and was inserted into the cell compartment and time for 4 minutes and 30 seconds. At the end of the countdown, the READ button was pressed and result was displayed in mg/L of Nitrate.

Excel spread sheet was used in plotting the graphs of temperature and rainfall data as well as plotting the graph showing the extent of contamination of groundwater.

III. RESULTS AND DISCUSSION

Table 1 will display the laboratory results of water analysis conducted during rainy season and dry season for total vibrio count which is linked to cholera epidemics, total salmonella count linked to typhoid fever, total fecal count linked to hepatitis, total E coli count linked to E coli infection and Nitrate contamination linked to methemoglobinemia which is called blue baby syndrome that inhibits the oxygen carrying capacity of the blood cell. Gustafson (1993).

Table 1 Laboratory results for Rainy season and Dry season water samples, measured in cfu/100ml.

Parameter	WHO	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH12
T VC	0	1	1	70	3	1	0	0	59	1	2	0	2
TSC	0	20	29	30	31	22	11	3	12	23	28	39	41
TFC	0	13	24	100	23	49	0	4	41	30	41	50	57
TEC	0	4	12	20	12	19	0	2	21	7	5	9	9
Nitrate	40	107.2	28.1	52	2.1	4.8	196	2.4	49.5	32.6	26.2	6.9	165.6
Dry season													
Parameter	WHO	BHI	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	BH12
TVC	0	0	1	28	5	4	0	1	0	3	24	23	2
TSC	0	1	0	22	5	1	0	0	1	4	11	13	8
TFC	0	3	4	45	2	31	5	2	0	2	45	52	21
TEC	0	1	2	17	1	8	1	1	0	1	27	29	9
Nitrate	40	92.5	36	285	132.8	14.4	57.6	122.5	86.1	0	1.5	80.2	0

The meanings of abbreviations on the table are as follows: Total vibrio count (TVC), Total salmonella count (TSC), Total fecal count (TFC), Total E coli count (TEC), World health organization (WHO) and Borehole 1-12 (BH1-BH12) boreholes where water samples were collected for both rainy and dry season and the result were measured in coliform unit/ 100ml (cfu/100ml). See figure 1 below displaying the laboratory results on graph for analysis.

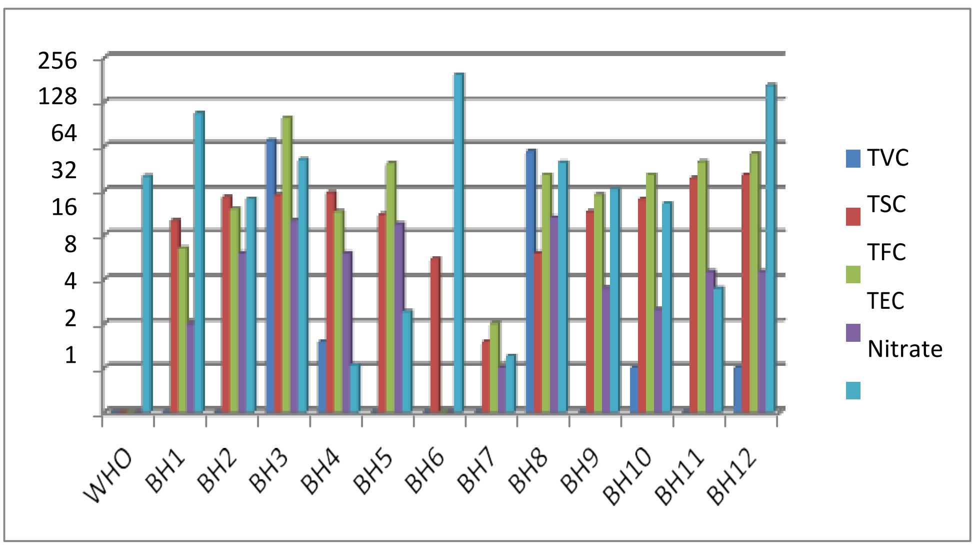

Figure 1-2 Laboratory results for parameters checked during rainy season

The graph was converted from log 10 to log 2 for graphical convenience show very clear variations in level of groundwater contaminations. Therefore all zero values will be represented by 1. All the parameters were compare with WHO standard to verify is a particular water sample is contaminated or not. Total number of water samples above WHO standard for total vibrio is nine (9) therefore 9 samples had total vibrio contamination. 12 samples were contaminated with total salmonella contamination, 11 samples were contaminated with total fecal contamination, 11 samples were also contaminated with total E coli contamination, and 5 samples were contaminated with nitrate contamination.

Graph below shows the results of laboratory analysis done on 12 water samples different parameters in rainy season.

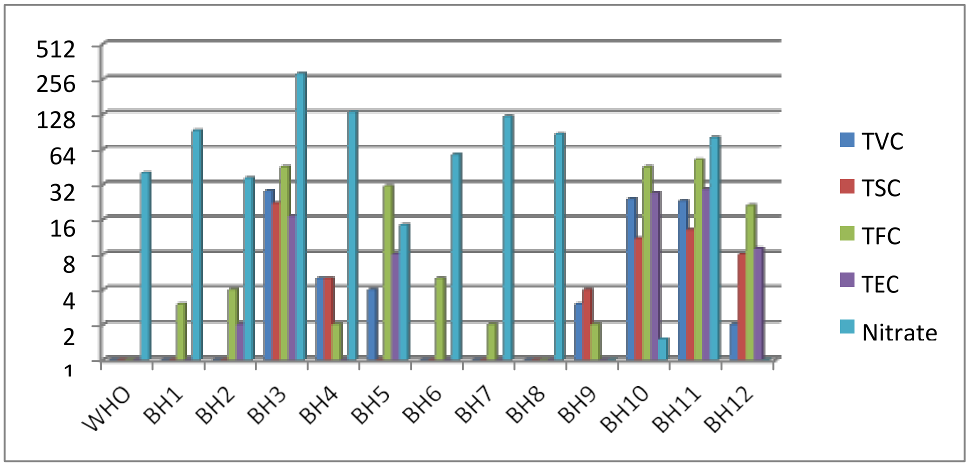

Figure 1-3 Laboratory analysis for water samples collected during dry season

The graph was converted from log 10 to log 2 for graphical convenience show very clear variations in level of groundwater contaminations .Therefore all zero values will be represented by 1. All the parameters were compare with WHO standard to verify is a particular water sample is contaminated or not. Dry season samples has 9 contaminated samples of total vibrio count, 9 contaminated samples of total salmonella count, 11 contaminated samples of total fecal count, and 11 contaminated samples of total E coli count and 7 contaminated samples of Nitrate contamination. These results showing the that groundwater in Abia state is actually contaminated shows that there is need to create sustainable groundwater source protection zone to avert the health hazards associated with groundwater contamination in form of epidemics of water related diseases.

Development of sustainable groundwater source protection zone (SGWSPZ)

Diagram below will show different steps involved in the development of sustainable groundwater sources protection zone. Step 1 is the pre-plan for SGWSPZ, step 2 is the application of the concept of SGWSPZ and step 3 is the Post-plan for SGWSPZ.

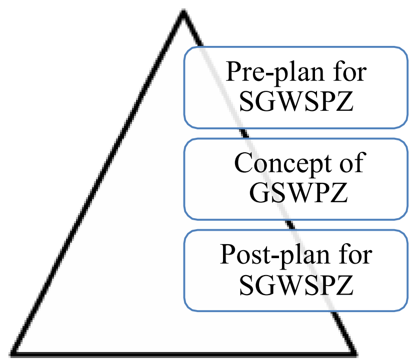

Figure 1-4 Steps taken to achieve sustainable groundwater source protection zone

Figure below shows the different steps involved in the pre-plan for sustainable groundwater source protection zone.

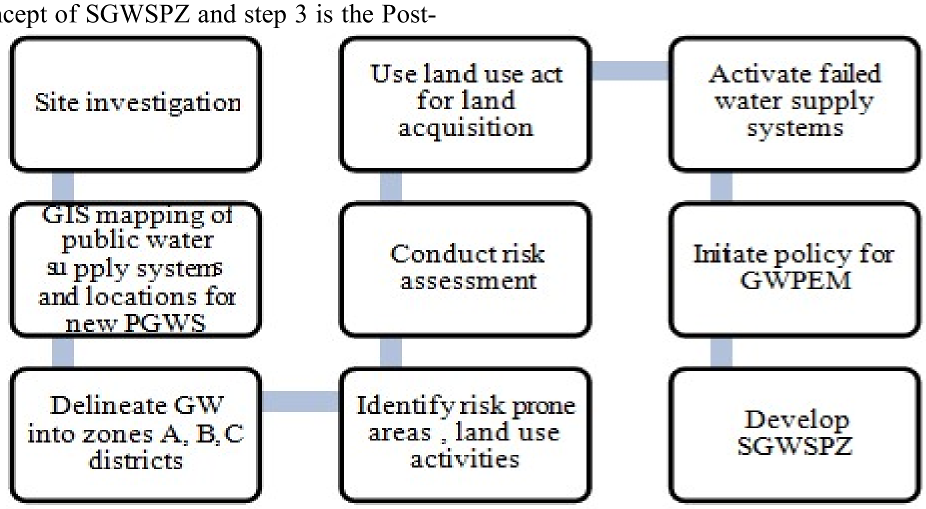

Figure 1-5 Pre-pan for sustainable groundwater source protection zone.

The first step in Pre-plan is project site investigation to enable easy GIS mapping of already public water supply systems and areas for development of new public water supply systems. Furthermore, the mapped area will be delineated into different zones in line with the hydro-geology of the area so as to identify the areas that are prone to risk from land use activities to enable the risk assessment of the area to be done before land use act will be used for land acquisition. Then failed public water supply systems would be activated and possible new ones could be developed in it becomes necessary. This will lead to introduction of policy for groundwater protection, exploitation and management (GWPEM) that will control the pollution and proliferation of water wells in and at last, sustainable groundwater source protection zone (SGWSPZ) will be established.

Application of Darcy's law in estimating groundwater flow velocity

The time of travel of contaminant could be easily calculated when Darcy's law is applied in the estimation of groundwater flow velocity by making use of the mathematical equation; V=Ki/n.

V: Is the average velocity of groundwater flow, calculated in feet per year within a low permeable area and feet per day within the highly permeable area.

K: Is the permeable level of an aquifer which ranges between 100-500 feet per day within aquifer with sandy properties and aquifers with gravel properties.

I: Is the slope of the water table or hydraulic gradient which ranges between 0.2 and 0.3 percent

N: Is the value of aquifer porous medium which is measured in percentage to know the extent of empty space that is occupied by groundwater with value of either 0.25 in sandy aquifer or 0.35 in aquifer made up of gravel. Therefore V= Ki/n = 100× 0.2÷0.25 =80 ft.

1 ft= 0.3048 therefore 80 ft = 80 ×0.3048 = 24.384m/day.

Average water table of Abia south district is 34.4 m. Therefore, travel time of contaminant to water table will be 1.4m days at a flow velocity of 24.3m/day.

Average water table of Abia south district is 55.5m. Therefore, travel time of contaminant to water table will be 2.3days at a flow velocity of 24.3m/day.

Average water table of Abia south district is 70.1m. Therefore, travel time of contaminant to water table will be 3days at a flow velocity of 24.3m/day.

Determination of radius for construction of sustainable groundwater source protection zone in Abia state, Nigeria

Abia state SGWSPZ was divided into Abia south, Abia central and Abia north district in line with the three different senatorial districts that was recognized by the federal government of Nigeria and the diagrams below will show the different radius and zone delineations for SGWSPZ in Abia state, Nigeria for each of these senatorial districts.

Determination of radius for SGWSPZ can be done through hydrological studies or Aquifer modeling but the radius that will be allocated to the diagram for SGWSPW will be based on this mathematical formula used Maria (2001) during workshop on protection of groundwater used as source of drinking water supply.

$$R = \frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$$

Thus, R = radius of groundwater protection zone (m)

Q = pumping rate in (m^3/day), T= the time needed for pollutant to reach the well in (days). N =the effective porosity in (%), H=the well saturated thickness (m).

Table 1-2 Hydro-geology data of Abia state for calculating Radius

Districts	Q (m^3/day)	T1 (days)	T2 (days)	T3 (days)	T4 (days)	N (%)	H (m)	Aquifer property
Abia south	520	1.4	50	365	1825	0.25	1500	sand
Abia central	240	2.3	50	365	1825	0.33	1306	Sandy shale
Abia north	224	3	50	365	1825	0.26	1220	Sand stone

Calculating Radius (R) of SGWSPZ for Abia south district

Zone I: Radius of Immediate is calculated from formula, $R = \frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

Q= 520 m^3/day, T= 1.4days, N= 0.25, π= 3.1416, H= 1500

$$R = \frac{\sqrt{520 \times 1.4}}{3.1416 \times 0.25 \times 1500} = \sqrt{86898.3957} = 294.7\text{m}$$

Zone II: Radius of the Inner protection zone is also calculated with the same formula. $R = \frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

where Q= 520, T= 50days, N =0.25,

π= 3.1416, H= 1500. Therefore $R= \frac{\sqrt{520 \times 50}}{3.1416 \times 0.25 \times 1500}$

= √3013514.13 = 1735.95m ÷ 1000= 1.7km.

Zone III A: Radius of Outer protection will be calculated with the same formula at one year travel time value of 365 days. R = $\frac{\sqrt{Q\,X\,T}}{\pi \times N \times H}$

where Q= 520 m^3/day, T= 365days, N= 0.25, π= 3.1416, H= 1500.

R= $\frac{\sqrt{520 \times 365}}{3.1416 \times 0.25 \times 1500}$

= √2266553.2 =4759.7955m÷ 1000= 4.76km

Zone III B: Radius of the out protection zone that is part of the entire catchment area will be calculated based on 5 years contaminant travel time. Thus, number of days per year (365), Therefore T= 365× 5=1825. Therefore, T=1825 and based on the formula, R = $\frac{\sqrt{Q\,X\,T}}{\pi \times N \times H}$

, the computation will be; R=$\frac{\sqrt{520 \times 1825}}{3.1416 \times 0.25 \times 1500}$

√520 × 1825

= √113278266 = 10643m ÷ 1000 =10.64km

Diagram below shows radius for SGWSPZ in Abia south senatorial district.

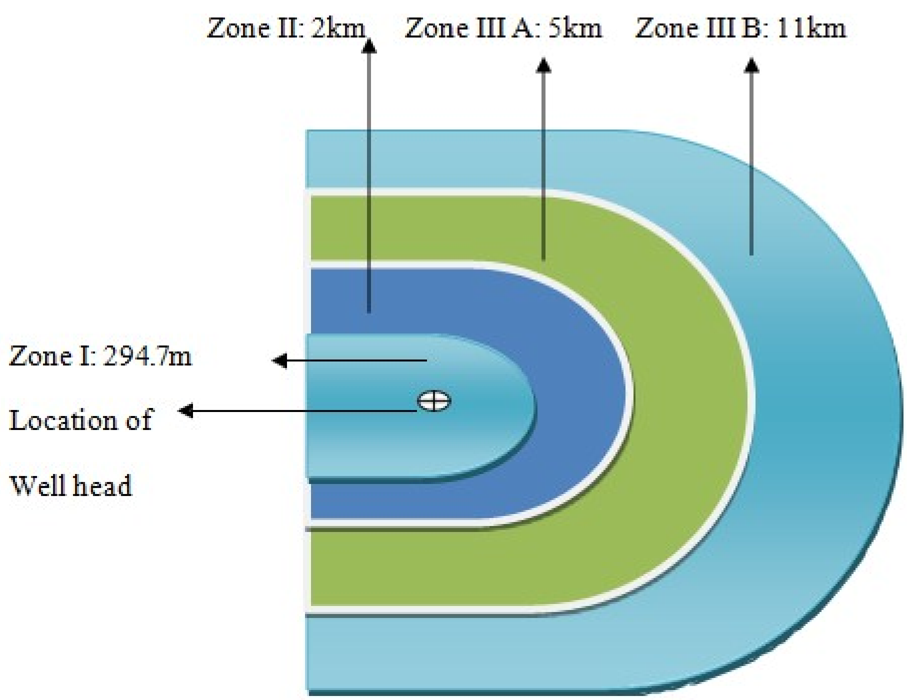

Figure 1-6 Radius of sustainable groundwater source protection zone (SGWSPZ) for Abia south senatorial

Determination of radius for sustainable groundwater source protection zone (SGWSPZ) for Abia central senatorial district

Radius of SGWSPZ for Abia north senatorial district will also be calculated with the same formula R =$\frac{\sqrt{Q\,X\,T}}{\pi \times N \times H}$

R = radius of groundwater protection zone in unit of (m) will be calculated for Zone I, the immediate protection zone below as

Q= pumping rate (m^3/day) = 240. T= the time needed for pollutant to reach the well in (days) = 10 N=the effective porosity in (%) =0.33. H = the well saturated thickness in (m) = 1306

π =3.1416 .Therefore R =$\frac{\sqrt{240 \times 2.3}}{3.1416 \times 0.33 \times 1306}$

=√75726.05 = 275.2m

Zone II calculations follow the same formula, R= $\frac{\sqrt{Q\,X\,T}}{\pi \times N \times H}$

Q = pumping rate (m3/day) =240 . T=time needed for pollutant to reach the well in (days) =50 N=the effective porosity in (%) =0.33 H = the well saturated thickness in (m) = 1306

π =3.1416. Therefore, R= $\frac{\sqrt{240 \times 50}}{3.1416 \times 0.33 \times 1306}$

= √1646218.49 =1283m 1283 m ÷100 = 1.28km =1.3km.

Zone III A calculation also follow the formula R= $\frac{\sqrt{Q\,X\,T}}{\pi \times N \times H}$

R= radius of SGWSPZ calculated in meters (m)

Q = pumping rate (m^3/day) =240 . T=time needed for pollutant to reach the well in (days) =365 N=the effective porosity in (%) =0.33 . H = the well saturated thickness in (m)

= 1306

π =3.1416. Therefore, R= $\frac{\sqrt{240 \times 365}}{3.1416 \times 0.33 \times 1306}$

= √12017395 =3466.6m . 3366.6m ÷ 1000=3.4666 km

=3.5km.

Zone III B calculations were also made based on the formula below.

R= $\frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

where R= radius of SGWSPZ calculated in meters (m)

Q = pumping rate (m^3/day) =240. T=time needed for pollutant to reach the well in (days) =1825 N=the effective porosity in (%) =0.33. H = the well saturated thickness in (m) = 1306

π =3.1416. Therefore, R= $\frac{\sqrt{240 \times 1825}}{3.1416 \times 0.33 \times 1306}$

= √60086974.8 = 7752.6m

7752m ÷ 1000= 7.752km =7.8km.

The radius for zone I – Zone III B will be displayed on Figure 7.4 as calculated radius of SGWSPZ for Abia central senatorial district. This radius will be used for delineation of groundwater sources from land use activities that are capable of causing groundwater contamination.

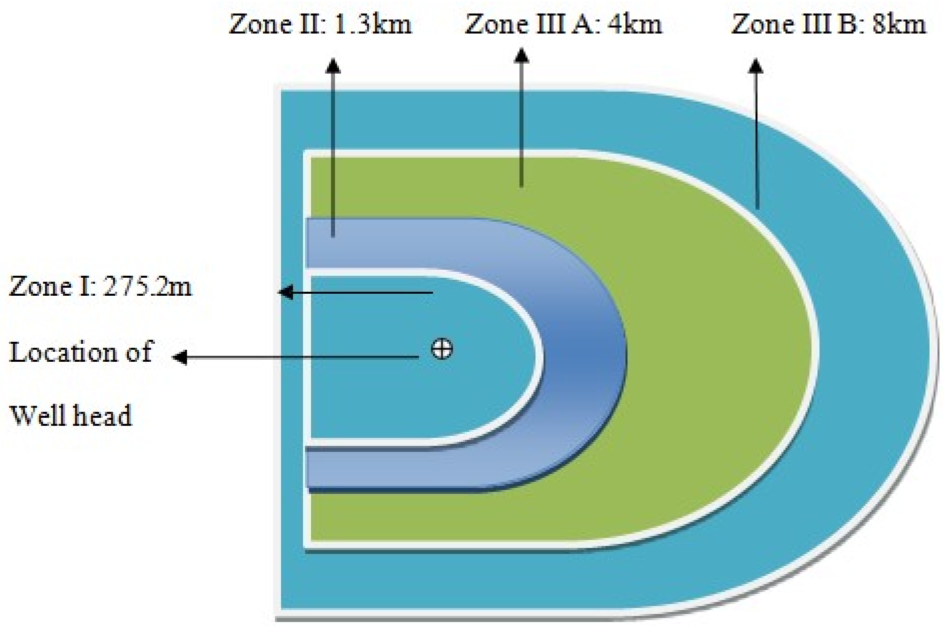

Figure 1-7 Radius of sustainable groundwater source protection zone (SGWSPZ) for Abia central senatorial district.

Determination of radius R of SGWSPZ for Abia north senatorial district

The calculation of radius R for SGWSPZ in Abia north senatorial district will be achieved through this formula, R= $\frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

Zone I: R= Radius of SGWSPZ calculated in meters (m). Therefore R= $\frac{\sqrt{224 \times 3}}{3.1416 \times 0.26 \times 1220}$

= √67850.7 = 260.5m. Therefore R=260.5m

Zone II: The same formula applies where R= $\frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

R= radius of SGWSPZ. Q= pumping rate (m^3/day) =224

T= time needed for pollutant to reach the well in (days) =50. N= the effective porosity in (%) =0.26 H = the well saturated thickness in (m) = 1220

π =3.1416. Therefore R= $\frac{\sqrt{224 \times 50}}{3.1416 \times 0.26 \times 1220}$

1063.408m ÷1000=1.063km = 1.1km

= √1130837.79 = 1063.408

Zone III A: The same formula applies where R= $\frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

R= radius of SGWSPZ. Q= pumping rate (m3/day) =224

T= time needed for pollutant to reach the well in (days) =365. N= the effective porosity in (%) =0.26 H = the well saturated thickness in (m) = 1220

π =3.1416. Therefore R= $\frac{\sqrt{224 \times 365}}{3.1416 \times 0.26 \times 1220}$

2873.17÷ 1000= 2.87km = 2.9km.

=√8255115.86 = 2873.17m

Zone III B: The same formula applies where R= $\frac{\sqrt{Q\ X\ T}}{\pi \times N \times H}$

R= radius of SGWSPZ. Q= pumping rate (m^3/day) =224

T= time needed for pollutant to reach the well in (days) =1825

N= the effective porosity in (%) =0.26. H = the well saturated thickness in (m) = 1220

π =3.1416. Therefore R= $\frac{\sqrt{224 \times 1825}}{3.1416 \times 0.26 \times 1220}$

=√41275579.3 =6424.607m

6424.607m÷1000= 6.4246km = 6.4km.

The radius for zone I – Zone III B will be displayed on Figure 7.5 as calculated radius of SGWSPZ for Abia north senatorial district.

The radius for zone I – Zone III B will be displayed on Figure 7.5 as calculated radius of SGWSPZ for Abia north senatorial district.

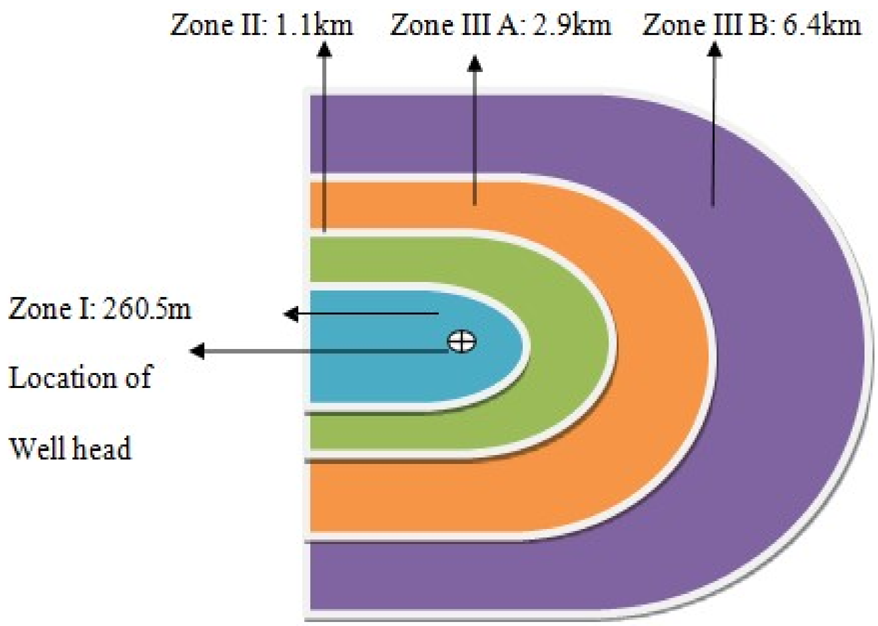

Figure 1-8 Radius of sustainable groundwater source protection zone (SGWSPZ) for Abia north senatorial district

Post-plan for sustainable groundwater source protection zone

Development of post-plan for sustainable groundwater sources protection zone has become inevitably paramount in the sustainability of contaminant free groundwater sources that will drastically reduce the regular epidemics of water related diseases. This post-plan will basically focus on strategies that will integrate all the actors in the water sector into best management practices that will ensure proper coordination of the system so as to enhance efficiency in control of standard groundwater quality that is globally accepted for human consumption, likewise establishment of orientation program, geared towards educating the masses on proper land use measures that are favorable to groundwater protection zone, as well as activating workshops that will focus on training of staff, none staff and interested organizations, on maintenance and management of groundwater protection zone and its related facilities through public private partnership.

Diagram below shows the process of post-plan development for SGWSPZ.

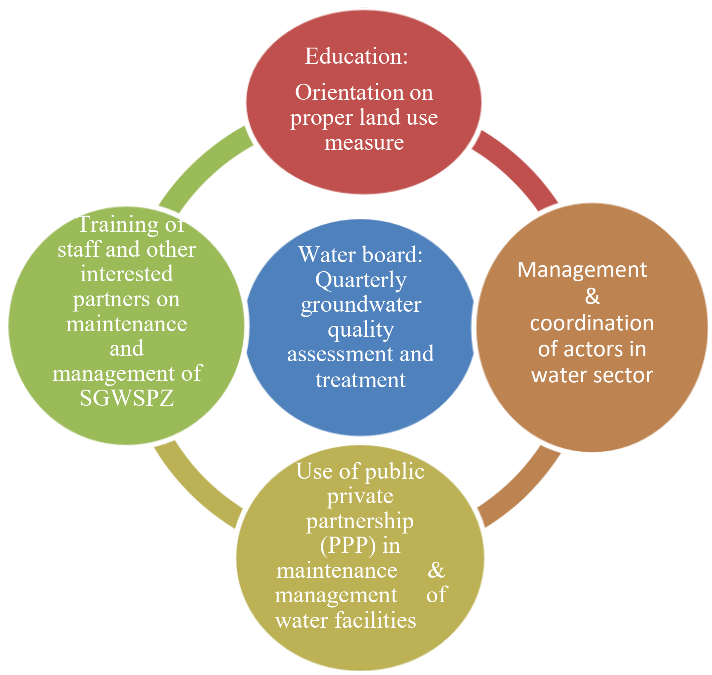

Figure 1-9: Post-plan for management of sustainable groundwater source protection zone

The post-plan for sustainable groundwater source protection zone is built around the water board which is an agency under the federal ministry of water resources. This is done with the aim that this agency will mastermind a quarterly groundwater quality assessment and treatment where necessary and also educate the masses on the legal and environmental implications of developing land use activities within or close to the groundwater protection zone so as to avert pollution of groundwater which is punishable by law.

Water board will also oversee the function of ensuring that all other ministries and agencies that make use of lands will be properly informed about the location of groundwater protection zone facilities so that such agencies will not mistakenly destroy the water facilities in the course of performing their duties.

Therefore, they must be provided with maps indicating where such water facilities are located.

Furthermore the use of Public private partnership is also of importance since the water board can employ such measure through collaboration with private organization in possible groundwater distribution and enforcement of any legally binding framework enshrined in policy of sustainable groundwater source protection zone and finally, water board is expected to carry out regular training of staff and other interested partners at intervals in other to make sure that they are well equipped with all technicalities involved in maintenance and management of the facilities of Sustainable groundwater source protection zone.

In conclusion, it is only on the grounds of completion of development of pre-plan, delineation and development of groundwater protection zone and development of post-plan for groundwater protection zone that I can conclude that sustainable groundwater source protection zone has been achieved or developed and it is only on implementation of this concept that the health hazards which are disastrous to life of the inhabitants of Abia state would be averted.

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