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GROUNDWATER RESOURCES IN NIGERIA: A STRATEGIC OVERVIEW OF MAJOR ISSUES AND TRENDS FOR FUTURE DEVELOPMENT AND PROTECTION

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ABSTRACT

The current groundwater resources development and supply in Nigeria is relatively low and needs a major transformation to supplement other water supply sources currently facing critical challenges. The paper identifies groundwater abstraction as the only road map and affordable means of providing sustainable water supply for the teeming populace in Nigeria. It also carried out extensive review of literatures on the extent and history of groundwater development in Nigeria. The availability of groundwater is considerably large in sedimentary basins, which cover some 50% of the country. But the basic information such as hydrologeological and groundwater maps is limited and investment is often poorly targeted. The sustainable development of the resources depends on many factors including the accurate understanding of the hydrogeology and the availability of skilled groundwater expertises to make better decisions. This paper highlighted some consequences of indiscriminate sinking of boreholes with attendant negative impacts such as earthquake, landslide, and damage to local ecosystems or to human health among others. The paper also provides strategic plans for future groundwater developmental progress and protection given the scale of groundwater development in Nigeria. Such plan must recognise the issue of particular concern to Nigeria, such as: the requirement to develop sustainable and cost effective water supplies across all hydrogeological environments; appropriately managing and protecting groundwater resources given the rate of rapid poorly planned urbanisation and the expansion in on-site sanitation; and the imperatives of water security from household to national levels.

Keywords: *Groundwater Development, Sustainability, Water Supply, Groundwater Potential, Groundwater Resources, Contamination.*

INTRODUCTION

Over the decades adequate water supply to satisfy the fast growing demand has been a global problem (Hesperian foundation 2005). About 2.2 million people die each year due to water borne diseases, usually diarrhoea, guinea worm and other related diseases from consuming unsafe water (Sobsey, 2000; Medema et al. 2003). The situation is mainly pathetic in the developing countries where levels of access to water and water related facilities are very low. The precarious water situation in developing countries motivated the world community in its millennium declaration to include improved provision for water and sanitation in their agenda. One of the targets of Millennium Development Goals (MDGs) designed to ensure environmental sustainability seeks to half the proportion of people without access to portable water and basic sanitation between 1990 and 2015. Presently, it is a known fact that hundreds of millions of urban and rural dwellers in the world are unable to meet their water supply needs for sanitation, health care and other uses and needed to be tackled as a part of meeting the Millennium Development Goals (MDGs) (UN-Habitat, 2003)

Rainfall and surface water supply sources are currently facing critical challenges of not always sufficient; and even when sufficient are not available at right time and place due to seasonal changes and natural phenomena. Surface waters are mainly contaminated with pathogenic microorganisms and various wastewater discharge or runoff from different sources which costs much for enormous treatment before use. According to Eduvie (2006), groundwater is widely used because of its high quality, availability in most areas, portability without treatment and the frequent draught problems enforce the use of groundwater sources as many small intermittent rivers and streams dry out during the dry season.

On a global scale, one third of the population depends on groundwater for their drinking water, in urban as well as rural areas (BGR, 2008). Groundwater also plays a pivotal role in agriculture, and an increasing portion of groundwater extracted is used for irrigated agriculture. It is estimated that at least 40% of the whole world's food is produced by groundwater-irrigated farming, both in low-income as well as high-income (BGR, 2008). In arid and semi-arid areas, the dependency on groundwater for water supply is between 60 and 100%. Therefore, the aim of halving the number of people without sustainable access to safe drinking water and basic sanitation (Millennium Development Goals, MDGs 7) depend very much on how groundwater resources are developed and managed.

In Nigeria, the fourth National Development plan indicates that the problem of water sector in the country includes inadequate supply and distribution and low quality of supply and sanitation (Eduvie, 2006). The current groundwater resource development and supply is very low and needs urgent transformation. With the rapid growth in population, urbanization, industrialization, competition for economic development, drought and flooding events, groundwater resource has become vulnerable to depletion and degradation. Although, Nigeria has substantial groundwater resource availability, its scientific management is necessary both in the short term and long term perspective. However, the large variability in hydrological conditions and geological structures in the country calls for a combination of techniques to identify potential groundwater resources, assess their potential, draw/abstract the water prudently and manage both, its quantity and quality in the long term.

The geophysical survey for exploration of groundwater in Nigeria is still in emerging trend due to the little progress and application of the new techniques. As a result of these problems, many wells and borehole projects are still been sunk in the country to supplement other water supply sources, without these emerging technologies. This has eventually resulted to a lot of uncoordinated, dry and abortive boreholes; and some reported of salinity problem/pollution of the groundwater resources by dissolved contaminants resulting in poor quality of the water. To optimally improve the situation and ensure groundwater sustainability development and disaster management in Nigeria, a thorough understanding of groundwater potential is essential. This study therefore will assist in providing reliable information on the available groundwater resources across all hydrogeological environments and in the selection of appropriate modern technology to be used in delineation of groundwater potential in Nigeria. The study will benefit Nigerians in managing groundwater resource effectively and efficiently.

EXTENT OF NIGERIA'S GROUNDWATER RESOURCES

Nigeria has a total land mass of approximately 925,000km^2 located on the west coast of Africa between latitude 4^{0}1^1 and 13^0 9^{1}N and longitude 2^{0}2^1 and 14^{0}30^1 E (Fig .1). The total replenishable water resource in Nigeria is estimated at 319 billion cubic metres, while the groundwater component is estimated at 52 billion cubic metres (Eduvie, 2006).

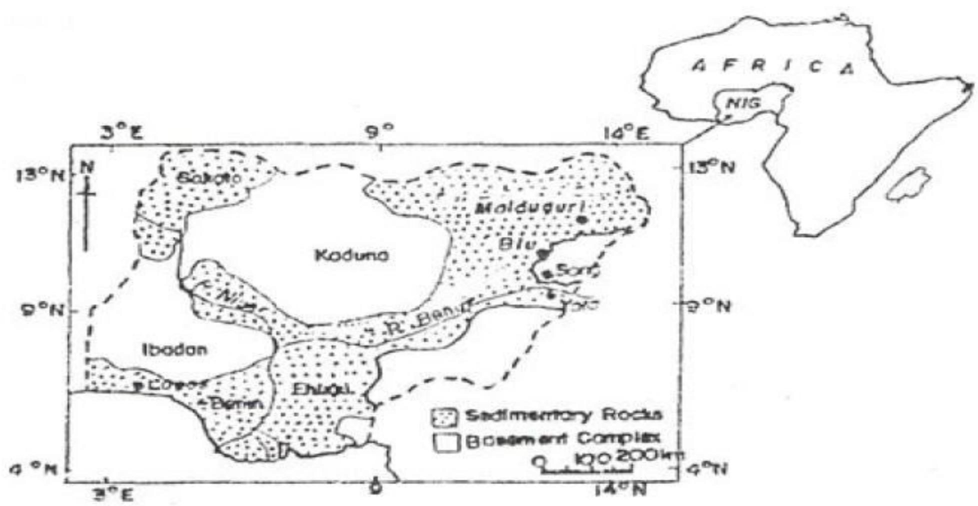

Figure 1. Geological Map of Nigeria. Source: Parker et al. (1964).

The country has abundant groundwater resources to cater for the needs of terming population of about 140million (Nwankwoala, 2011).

There are large groundwater potentials in Nigeria, far greater than the surface water resources, estimated to be 224 trillion L/year (Hanidu, 1990). Rijswlk (1981) estimated groundwater resources at O to 50m depth in Nigeria to be 6x10km^3 (6x10^{18}m^3). However, from the eight aquifers in Nigeria (Akujieze et al., 2003), the Ajali sandstone aquifer yields 7 to 10 L/s, the Benin formation (coastal plain sands) aquifer yields 6 to 9 L/s, the middle aquifer yields 24 to 32 L/s, the lower aquifer with yields of 10 to 35 L/s (of the Chad formation), the Gwandu formation aquifer with yields of 8 to 15 l/s, the kerrikerri sand aquifer with yields of 1.25 to 9.5 l/s and the crystalline fluvio-volcanic aquifer with a 15 l/s in the Jos plateau region; groundwater occurrence is not limited to only 50m b.g.l (below ground level). These mega regional aquifers have an effective average thickness range of 360m, with a thickness region of 15 to 3,000m at a depth range of 0 to 630m b.g.l with an average depth of 220m (Akuji eze at al., 2003).

The availability of groundwater are considerable large in sedimentary basins, which cover some 50% of the country. The potential annual groundwater resources are estimated at 51.93x10^{9}m^3, out of which the sedimentary basins account for 67% (FMWRRD, 1995). The occurrence of groundwater in the areas underlain by crystalline basement rocks depends on the local geological conditions and development of thick soil overburden (overburden aquifers) or the presence of fractures that are capable of holding water (fractured crystalline aquifers) which ultimately controls yields. Despite the huge groundwater resources, water resources development has not been able to keep pace with the phenomenal population growth (Oteze, 2006).

The amount of groundwater storage is not yet known, but according to Eduvie (2006), among the largest water bearing basins are found mainly in Chad, Kerriderri, Nsukka, Benin and Abeokuta formation. This is because they are largely formed from sandstones, alluvial deposits and other related arenaceous sedimentary rocks which cover about 50% of the nation's land mass. The remaining 50% is underlain by crystalline rocks of the basement complex made of shales, clay and limestones are generally poor aquifer due to their argillaceous nature. There is no groundwater in them; expect the ones confined to their fractured and weathered zones. Table 1 shows the static water resources of Nigeria while Table 2 shows the summary of the total static water resources in Nigeria.

Table 1: Static Water Resources of Nigeria, Groundwater and Fresh Meteoric Water

Province	Structural unit	Area (Km2)	TWRS M1 Million (m3)
Crystalline hydrogeological province	N. Nigeria Shield	234516	94979
	W. Nigeria Shield	115529	46789
	Mandara Hills	18460	2492
	Biu Plateau	4418	123.54
	Adamawa Mountains	60152	8121
	Oban Hills	4276	577
	Total Cryst.	437351	166212
Sedimentary hydrogeological province	Sokoto Basin	66424	3188352
	Katsina Basin	3564	28512
	Nupe Basin	36704	1468160
	Coastal Monocl.	12365	296760
	Keri-Keri Basin	22593	101669
	Abakaliki + Mamfe	24945	374175
	Benue Synclinr	96216	1443225
	Niger Delta	104234	2084660
	Borno Basin	119377	2148786
	Total Sedim..W.	486422	11134299
	Total Fresh GWtr	923773	11134299
	Total Water Nig.	923773	36201836

N/B: TWRS = Total static water resources. Source: Schoeneich (2003)

Table 2: Summary of the Total Static Water Resources in Nigeria

TWRS			Percentage	Cubic metres
Rain		Atmospheric water	3.08	$1,117 \times 10^9$
Surface	Fresh water	Fresh surface water	0.03	12×10^9
Ground water		Fresh groundwater	31.23	$11,301 \times 10^9$
	Salty groundwater		65.66	$23,772 \times 10^9$
Total water Nigeria			100.00	36.202×10^9

Source: Schoeneich (2003)

HISTORY OF GROUNDWATER DEVELOPMENT IN NIGERIA

A brief history of groundwater development in Nigeria shows that Geological Survey of Nigeria was established in 1917 to survey groundwater potentials in Nigeria (Eduvie, 2006). The department surveyed many groundwater survey which lead to the exploration and construction of many shallow dug wells mainly in Northern parts of Nigeria up to 1950s. The Nigeria's major intervention on groundwater development was launched in large scale during the first National Development Plan (1962- 1968) which culminated in the establishment of River Basin Development Authorities (RBDs) in 1970s. In 1975, Federal

Ministry of Water Resources (FMWR) was created in line with the Decade of Water and Sanitation by United Nations (1981 to 1990).

During these periods, the Federal Government embarked upon other numerous intervention programmes in water sector, including National borehole Project (1980). Borehole constructions were promoted with improved drilling capacity and technical development of drilling machines. Drilling boreholes with depth of 30m to 50m has become much easier than before in Basement Complex area. Moreover, drilling deep boreholes with depth of 50m to 300m has also become possible in sedimentary rock areas. The main programs so far including groundwater development by Federal and foreign donors are listed in Table 3 with related policies after 1981. It is instructive to note that groundwater development is currently ongoing through MDG budget, targeting the entire nation mainly for rural water supply.

Table 3 Major Groundwater Projects in Nigeria since 1982 to 2011

	Program and Policy	82	83	84	85	86	87	88	89	90	91	92	81	93	94	95	96	97	98	99	0	1	2	3	4	5	6	7	8	9	10	11
A	Program by Federal Government																															
1	National Borehole Programme																															
2	DFRRI RUWATSAN Programme																															
3	Petroleum Trust Fund RWS Project																															
4	Improved Access Programme																															
5	National RWSS Programme																															
6	MDG																															
7	Federal Water Supply Program																															
8	Senatorial Rural Water Supply Program																															
B	Program by Foreign Donors																															
1	UNICEF Assisted WES Programme/Project																															
2	UNDP-World Bank RUSAFIYA Project																															
3	UNDP RWSS Project																															
4	European Union Water & Sanitation Programme																															
5	DFID Water and Sanitation Pilot Project																															
6	Water Aid RWSS Programme																															
7	JICA Rural Water Supply Project																															
8	Development of Local Manufacture of hand pumps																															
9	Chain Assisted Water																															

	Program and Policy	82	83	84	85	86	87	88	89	90	91	92	81	93	94	95	96	97	98	99	0	1	2	3	4	5	6	7	8	9	10	11
	Supply program																															
10	AFDB Assisted Rural Water Sully and Sanitation Initiative																															
11	EU Assisted Water Supply and Sanitation Sector Reform Program																															
C	Main Policy																															
1	Water Supply Sector Memorandum																															
2	RWSS Sector Strategy and Action Plan																															
3	Water Resources Decree 101																															
4	NIS for Hand pumps (1st Edition)																															
5	National Water Supply and Sanitation Policy																															
6	Generic Act for State RWSS Agencies																															
7	Interim Poverty Reduction Strategy Paper																															
8	RWSS Programme Strategic Framework																															

(Sources: Eduvie, 2006)

FACTORS/PROBLEMS MILITATING AGAINST GROUNDWATER DEVELOPMENT IN NIGERIA

The major problems militating against groundwater development in Nigeria have been revolving around underdevelopment and lack of suitable machinery for the effective and sustainable management of groundwater resources and could be grouped as follows among others:

Shortage of Well Trained/Committed Manpower with Appropriate Local Technology

There exist a shortage of well trained/committed manpower in adequate number and quality to cope with the magnitude of planning and management problems. Groundwater expertises are often undervalued in rural water supply programmes. This underlies many of the other reasons why groundwater development has declined. Lack of appropriate training throughout Africa is common. There are few tertiary institutions where hydrogeology is taught. Eduvie (2006) stated that students in the universities in the developing countries offering specialization in these disciplines are usually few compared with other disciplines. This has contributed to a major sociological problem in developing expertises in the water related fields. Application of system analysis and other methods to solve complex problems in water resources planning and management require a good background and expertise in the disciplines of engineering, mathematics, hydrology, water resources and computer technology.

Lack of Relevant Knowledge and Data on Aquifer Characteristics

Existing information on vital data for sound groundwater resources planning and development has not reached a satisfactory level in Nigeria. Lessons learnt from successful or unsuccessful projects are not being used incrementally as a basis for new projects. Basic information, such as geological and groundwater maps are missing or difficult to get. The characteristics of the weathered crystalline basement (with a high proportion of schists) and the superficial unconsolidated aquifers (often of fine grain-size) are such as often to reduce the prospects of shallow water wells (less them 30m deep) providing yields in excess of 0.4 l/s and supporting motorised pumping. The deeper sedimentary aquifers (which offer prospects of much higher well yields) are often geologically complex and with low or uncertain replenishment, and also mainly situated in areas of low rural population density.

Grey literatures, such as consultant reports, are not collated and the knowledge is lost to other projects and future generations. Databases of borehole data, water quantities and qualities, which have proved so useful in many countries, are not adequate. As a result some are drilling boreholes almost blind, with often very poor success rates and poor quality water thereby wasting funds. Even in new projects, the lack of groundwater expertise referred to above often does not allow proper collection of new data, which in its turn would support future work. Apart from data on hydrology, data on socio-economic factors are grossly inadequate.

Inadequate Funding / High Cost of well Water Construction

Funding for research on Nigerian groundwater resources at all time is low. Inadequate funding as shown by poor budget allocations is a major problem common to all developing countries; which Nigeria is not in exception. Development projects are often purposely planned and designed to meet only part of the needs, due to lack of funds. Unless the project has a properly planned phasing programme, such development do not often prove beneficial on the long run. A further generic issue which has impeded groundwater development for poverty reduction is the high cost of water well construction. Although there is no such thing as a typical well; the cause of these high costs is complex, but the following factors come into play.

- Lack of economy of scale and competition in water well construction, due to absence of a large private sector market for domestic and irrigation water wells.
- High excise duties on imported drilling equipment and pumping plant, and no significant local manufacture even of spares.
- Corruption in the letting and execution of water well drilling contracts.
- Inappropriate well design and excessive drilling depth for some hydrogeological conditions, with insufficient use of low-cost technology options.

Problem of Acceptance

There is always lack of acceptance (and suspicion) of mathematical or sophisticated approaches to the solution of water resources problems by older nationals superiors in top management. Their attitudes tend to frustrate the efforts of the few younger management personnels who have acquired expertise in systems analysis. Unfortunately, those who could or should use the results of systems analysis should acquaint themselves with the new tools and what it can do for them.

Lack of Joint Effort by Government and Water Consumers in the Country

After initial development of groundwater, water consumers in the community and Government always pay less concern with the presence or functionality of public wells in the community. Most of the privileged citizens that are supposed to facilitate the maintenance of public water wells in their communities resort to have their private shallow wells and therefore not always concerned with functionality of public wells in their communities. As a result, most public wells are neglected contributing to inefficiency of water supply and collapses of water systems.

Time Factor

Time is a vital factor that needed special consideration when planning to develop groundwater resources. Little time is always apportioned for design study and groundwater analysis in Nigeria. Nigerians are always in hurry and these results short periods of planning at the initial stages for project operation and management. If groundwater development must work effectively, it is necessary to plan and design water resources projects such that they can be used to obtain data for updating the project and for future project design.

Political Interests

Many a time, execution of groundwater project is politically motivated. Politicians in power do divert water projects designed for specific area to another area of their personal interest without minding whether the project is visible in the area or not; thereby thwarting the original list of areas it was formally planned for during geophysical investigation studies.

STRATEGIC PLANS FOR FUTURE GROUNDWATER DEVELOPMENT PROGRESS AND PROTECTION IN NIGERIA

For an effective groundwater development program plan to be a reality, it is very essential to have full knowledge of the following number of insights which can be summarized as follows:

i. All the available data (reports, maps etc) pertaining to the project area should be reviewed before the drilling programme commences. Despite the fact that today there are various methods available for predicting the nature of sub-surface formations, there is still only one sure way of finding out and that is drilling. The most frequently used and reliable descriptor of underground strata and groundwater are drilling contractor's records commonly referred to as well logs. The relevant contacts in Germany are the Federal Institute for Geoscience and natural resources (BGR, www.bgr.de), Germany development service (DED, www.ded.de), Deutshe Gesellschft fur Technische Zusammenarbell (GTZ, www.gtz.de), German Development Bank (KFW, www.kfw.de), and consultant (www.vubic.de). Further information can be obtained from the appropriate organizations in other donor countries, and the local water authorities as well as the geological surveys in the partner country. Detailed information about groundwater in developing countries can be reviewed at the BGR websites, which has one of the largest collections of geoscientific literature.

The use of geophysical techniques presently is taking upper hand for assessing data concerning groundwater potentials. Many geophysical methods such as Resistivity log, Spontaneous Potential log, Radio Active log, Temperature log, Caliper log, Fluid Conductivity and fluid velocity log, Induction log, Sonic log, Close circuit television log, Environmental Isotope log, Leismic, Downhole logging etc. abound, but many authors including (Ekine and Osobonye, 1996; Ako and Olorunfemi, 1989; Etu-Efeolor and Akpokodje, 1990; Okolie et al., 2005) have proved the use of vertical electrical resistivity (VES) as the best method for assessing groundwater potentials presently in Nigeria. This method is reasonably cost effective way of obtaining a broad coverage of sub-surface formations. It involves inducing a known electrical current into the ground via two electrodes, and evaluating the resistivity of the ground material based on the measured potential difference in two other electrodes.

Vertical electrical resistivity (VES) is a relatively cheap method and suited to the gravel type aquifers, although the results it provides are a simplification of nature. An interpretation of resistivity soundings provides an indication of the sub-surface sediments and the associated groundwater characteristics. However, it is not a direct measure, and relies on a high degree of interpretation. A consultant with significant experience in applying the technique locally concluded that it was best at measuring relative changes of silt content (Ground search-1984). It provides a more objective assessment of the sub-surface geology than the observations of different drillers who may interpret and describe their drilling cuttings differently. Remote sensing is always used to complement surface geophysical techniques in groundwater exploration. Remote sensing provides a noninvasive, regional and economic way of compiling reconnaissance data for groundwater development.

ii. Identification of the current status of water extraction and replenishment in the area, third-party water rights and the effects of the new well must be considered. Furthermore, the direction of the groundwater flow should be known. The option of the local community must be considered regarding the location of the proposed well, as well as the detail planning of the project. Valuable supplementary information about location of the planned water well can be derived from the experience of the local community. The existing technological hydrogeological knowledge, as well as an understanding of the necessity of measures to protect the groundwater must be elaborated. The operation of technical facility must be guaranteed, for example by means of a well committee.

iii. The decision as to whether the well will be constructed by hand-digging or drilling depends on the depth to the aquifer and the local hydrogeological conditions. Water wells that are hand-dug with assistance of the local residents are commonly less expensive. However, drilled wells are more hygienic, but require more capital investment.

iv. The planning of water well should always be undertaken by experienced hydrogeologists and water well construction engineers. The drilling contractor or the consultant must survey the location of the water well by GPS (Global Positioning System) and document important information about the well (profile of penetrated strata, well design). This document must be filled at the local and / or regional water authority so that they can be referred to in the future.

v. During the preparation of the tender documents, it is necessary to estimate the costs of carrying out a pumping test to determine the quantity of groundwater that is available, the well carrying capacity and to undertake chemical and bacteriological water analysis. Furthermore, analysis of water from wells in the neighbourhood can provide information about the necessity for purification of the groundwater. If necessary, the financial cost for the required purification should be included in the planning. For deep drill holes the quality of the samples obtained during fluid assisted drilling techniques is often inadequate to provide sufficiently detailed information about the rock sequence necessary to determine the optimal depth of installing the screen. In such cases, borehole geophysical surveys are required.

vi. The requirements and responsibilities of the local community must be emphasized and integrated into the planning phases of a water well construction programme. The establishment of a well committee is very good for implementing this participation. The committee participates in the planning phase, and takes responsibility for financing the running costs as well as the maintenance of the water well, its pump and other facilities. It should also take responsibility for instructing the local population in matters concerning water hygiene.

Implementation

vii. The well should be sited by an experience hydrogeologist, and the final decision on the location be made in agreement with the local community, including the women. The construction of the well must be carried out and supervised by an experience water well engineer.

In order to ensure the long-term operation of the well, a specialist should determine the depth of the screen interval, the material used for the screen, the screen slot size and the gram size of the gravel pack. The well head must be strengthened and secured. The well head must be designed so that water cannot flow from the ground surface into the well. This is particularly important for wells that are constructed in the bed of a dry river. Animals must be kept away from the vicinity of the well by a fence. Water trough for cattle must be located several tens of metres away from the well. If shade is required at the well site a simple shelter should be built (e.g with corrugated iron). Trees and bushes should never be planted near the well, since roots can damage both the well and the surface construction.

viii. Impermeable strata (e.g clay beds) must be re-established during the construction of the well in order to prevent contamination of the groundwater from the surface. This can be achieved by installing a cement or clay barrier in the annulus of the well.

ix. The pump should be selected on the basis of pump performance curve that are provided as diagrams by the manufacturer. The essential input data includes, for example, the desired pumping rate, the required depth (in other words the pump head pressure required to lift the water to surface), the desired pressure at the well head and the efficiency of the pump. Operating the pump under conditions outside the ideal curve leads to waste of electricity and to rapid degradation of the pump. The well is equipped either with a hand-operated pump or with a motor pump that must be continuously and well maintained. The motor can either be installed on the surface (drive shaft pump) or at depth (submersible motor pump).

Post – Supervision

x. An appropriate maintenance schedule must be implemented as a part of the project. The efficiency of the wells and pumps should be controlled and documented at regular intervals. The local users of a well should maintain and upkeep the water well facility. The ability and willingness of the local community to pay for long-term maintenance should be examined before the commencement of the project, as this is especially relevant to the maintenance plan, as well as the determination of any future need for a subsidy.

More importantly, one of the important strategies for sustainable management of groundwater is regulation in critical areas. This is because over exploitation / development of groundwater resources is increasingly being recognized as a major problem, especially in Niger Delta region of Nigeria (Nwankwoala and Mmom, 2006). The tendency towards over exploitation of groundwater resources is rooted in the rapid spread of energized pumping technologies, resource characteristics, demographic shifts and incoherently inconsistent government policies. There are very little effort to check over exploitation and regulation of groundwater resource.

DANGERS OF INDISCRIMINATE SINKING OF BOREHOLES

The exploitation of groundwater involves the sinking of boreholes at sites which sometimes are chosen arbitrarily and this issue continues to threaten residents in the borehole sites. The short and long terms effects of indiscriminate sinking of boreholes could be traced and grouped as follows:

- Boreholes sunk arbitrarily have long term environmental impacts such as pollution and degradation. Through the movement of polluted groundwater and sediments on environment could spread further contamination into neighbouring communities and cause damage to local ecosystems or to human health.
- Indiscriminate sinking of boreholes can result to abortive boreholes, extreme low yield and total failure of supply wells in an area. This leads to wastage of large sums of money invested in the project. Abortive and non-functional wells are direct source of groundwater pollution and degradation.
- Incessant drilling of boreholes within sedimentary environment could lead to induced earth and landsides. Over a period of time, it can also lead to man-made earthquakes, because the abandoned boreholes are not always properly covered.
- Drilling of boreholes in a random way is capable of contaminating the interconnection of underground water regime.
- Proximity of boreholes causes interferences.
- Boreholes indiscriminately sunk could result in silt/sand/clay pumping and eventually affect the tube seals in the hand pumps or the impellers in the case of submersible pumps.
- It leads to hydrogeological failures due to the problems of boreholes tapping aquicludes and seasonal fluctuations.

PREVENTION AND CONTROL MEASURES FOR GROUNDWATER CONTAMINATION FROM VARIOUS SOURCES

Groundwater contamination happens when naturally occurring or man-made substances seep into groundwater. Man-made groundwater contamination may develop through accidental or deliberate release of chemical products into the subsurface.

Groundwater contamination is detrimental to water supplies not only because of its potential health effects, but because the contamination itself ("plume") tends to migrate and spread throughout the aquifer, thereby impacting a larger volume of groundwater over time. Ideally, groundwater contamination should be prevented in the following ways:

- Improved well siting,
- Good control design, construction, siting, and management of potential contamination sources.
- Land-use planning (including environmental impact assessment), integrated pollution control licensing, waste licensing, water quality management planning and water pollution legislation, etc., should be interated as a means of protecting groundwater against contamination.
- Elimination of contamination sources (e.g., maintaining the integrity of pipelines and storage tanks) prevents worsening of problems but does not clean-up aquifer. If these controls are not effectively employed and contamination reaches the point of discharge condemnation of the water supply or expensive treatment is required.
- Monitoring of individual bodies and local plumes of contaminated groundwater in order to determine the success of prevention techniques to apply.
- Removal of conduits to groundwater (e.g., properly destroying unused water wells in accordance with state well destruction standards).
- Preparation of vulnerability maps, based on distribution of travel times, chemical parameters, types of topsoil, subsoil and land use.
- Periodic inspection of underground storage tanks for leakages by city water agencies
- Installation of public sewers to collect and treat wastewater at a central facility.

- Pollution control laws have to be enacted banning people from indiscriminate disposal of storm runoff and excess irrigation water in shallow wells.
- Inventory of aquifers, their characteristics and classification.
- Control of groundwater withdrawals
- Regulation of sinking of boreholes by relevant authorities to ensure that water from boreholes are safe for drinking and for other domestic purposes
- Sinking of well waters /boreholes far away from polluted surface water sources and contaminated lands.
- Restricting the disposal of industrial discharges to the ground in vulnerable areas through introduction of discharge permits and appropriate charges to encourage recycling and reduction.
- If contaminants have been released to groundwater, the federal and/or state regulatory agencies typically should manage and enforce for site investigations and cleanups.

CONCLUSION

- Nigeria has substantial groundwater resource availability and its scientific management is necessary.
- In order to purse large scale development of groundwater, it is essential to have reliable information on the past and present advances made so far on groundwater potentials and development in Nigeria.
- Due to large variability in hydrological conditions and geological structures in the country , The research calls for a combination of techniques to:

✓ identify potential groundwater resources,
✓ assess their potential,
✓ draw/abstract the water prudently and manage both, its quantity and quality in the long term.

For an effective groundwater development program plan to work well, Such plan must sort a way to:

➢ develop sustainable and cost effective water supplies across all hydrogeological environments in the country;
➢ appropriately manage and protect groundwater resources given the rate of rapid poorly planned urbanisation and the expansion in on-site sanitation;

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