GROUNDWATER FLOW DIRECTION AND POLLUTION MANAGEMENT STRATEGIES FOR IGBO-OLOMU, IKORODU, LAGOS STATE, NIGERIA

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Abstract: *The study used hydrogeological measurements from thirteen wells to illustrate the pattern of groundwater movement in Igbo Olomu area of Ikorodu, Lagos, Nigeria. Data used include information on well coordinates, elevation at well openings, static water level (SWL) and hydraulic head (HH). Data on coordinates of well locations and elevation at well openings with respect to mean sea level were taken using GPS (Garmin 76 csx) while data on static water level in each well was taken with measuring tape. The hydraulic head for each of the thirteen wells was computed as the difference between elevation at well opening and static water level. Findings indicates that hydraulic heads ranges between 33.77 and 36.94m while static water level ranges between 2.35 and 7.36m. The static water level however exhibits greater variability (27.71) than hydraulic head (22.11). The local groundwater flow direction for the study area was subsequently determine manually by triangulation from water table contour map generated from data on static water level. The result of the study further shows that groundwater flow direction in the study area is predominantly towards the north-eastern part of the city. The observed flow pattern thus suggest that groundwater in the south-eastern part of the study area are susceptible to contamination from infiltrated water from sanitary landfills and dumpsites and from underground leakage of sewage and petroleum facilities. The study finally recommended environmental legislation, land-use planning, enforcement and environmental education as management options that can be taken by authority concerned in protecting groundwater from pollution in the study area.*

Keywords: *Groundwater, Pollution, Elevation, Hydraulic head, Management*

INTRODUCTION

Water is a natural resource that is essential for human survival. Access to its safe supply does not only influence health, but also aid in economic productivity and quality of life of the people. According to Nwan Kwoala (2011) potable water is an essential ingredient for sustenance of human life and a vital component for socio-economic development.

Although the supply of water in good quality and adequate quantity has long been a targeted goal of successive governments in Nigeria, the achievement of this goals seems never totally achieved due to a number of reasons; some of which Faniran (1987) listed as far back as over three decades ago to include;

(i) political and bureaucratic pressures arising from government control;
(ii) domination of water resources planning and management by politicians, economists and engineers to the exclusion of other relevant experts;
(iii) dearth of suitable personnel to handle complex water resources projects;
(iv) inadequate funding
(v) craze for large and inflexible (turnkey) projects handled by equally inflexible planners and managers.
(vi) neglect of pilot, experimental projects; and
(vii) inadequate, incomplete and unsatisfactory database for project implementation.

World Bank (2002) observed that water production facilities in Nigeria rarely operate to capacity due to break down of equipment of lack of power or fuel for pumping.

According to Federal Ministry of Water Resources FMWR (2013) apart from Nigeria being among the ten countries in the World that are home to more than 66 percent of the global population without access to improved water supply, the country also has the highest population of number without improved sources of drinking water in Africa. Although, records have shown improvements in accessibility to improved water supply in the country from 47 percent in 1990 to 60 percent in 2012, Sule et al (2016) observed that the rate of progress was not high enough to keep the country on-track for the achievement of the 75 percent drinking water target of 2015.

In the light of the above enumerated problems regarding pipe-borne water supply in most settlements in Nigeria, many private individuals and some government agencies have resulted to the use of groundwater in meeting their domestic demand because of its advantages over other traditional sources of water. Some of the advantages of utilizing groundwater as a source of water supply according to Ayoade (1988) includes:

i. it requires relatively low cost of development, maintenance and operation;

ii. it has relatively higher chemical and bacteriological quality
iii. it requires minimal treatment costs as a result of (ii) above,
iv. it records less fluctuations in water temperature,
v. it has little or no seepage losses
vi. it requires less area of land for its development when compare with surface sources;
vii. it results in little or no loss of farmland or historical sites
viii. it has no resettlement problems
ix. it is available at the of demand; and
x. it has no problem of evaporation losses

However, groundwater which is being heavily relied on because of its numerous advantages over other sources of water supply is now being faced with a number of challenges, amongst which is pollution. Pollution problem especially in developing countries of the world is fast becoming a big problem. Groundwater pollution is caused by many processes which generate pollutants and contaminants that enter the groundwater flow systems. Among such process include physiochemical weathering, mass wasting, erosion, sediment transport and deposition. Other activities through which pollutants enter groundwater include agricultures, mining, waste disposal and oil exploration.

Drinking contaminated groundwater can induce serious health challenges in man. While diseases such as hepatitis, typhoid, cholera, and dysentery may be caused by consumption of contaminated water from septic tank, poisoning may result from intake of toxins that have leached into well water supplies. Other long-term effects such as certain types of cancer may also result from consumption of groundwater that is polluted.

Studies such as Eze (2002), Aremu et al (2002) Akujieze et al (2003) and UN (1988) have revealed impairment of groundwater quality in different parts of Nigeria from leachates outflow, underground petroleum storage infiltration from kind fill over abstraction leaking soak away. Attempt at protecting people from consuming contaminated groundwater calls for effective monitoring of groundwater movement as being currently done in this study. This is germain because, knowledge of both groundwater recharge and discharge are essential for effective management of groundwater resources (Crosbie, et al., 2009). According to Ademila and Salako (2018) detailed knowledge and understanding of groundwater flow patterns is essential to investigating the groundwater potential of an area and finding out the pattern of distribution of contaminants in order to offer dependable recommendation in locating good sites for waste disposal, distribution of vegetation and damn, site selection. Result from this study will not only help in providing vital information on quality status of groundwater in the study area but will also aid in developing protection strategies against groundwater pollution.

THE STUDY AREA

Igbo-Olomu, Ikorodu, Lagos Nigeria is the study area in this investigation (Figure 1). The area is located between longitudes $3^{0}26^{1}$ and $3^{0}\ 30^{1}$ East of Greenwich meridian and between latitudes $6^{0}\ 39^{1}$ and $6^{0}\ 42^{1}$ North of the equator.

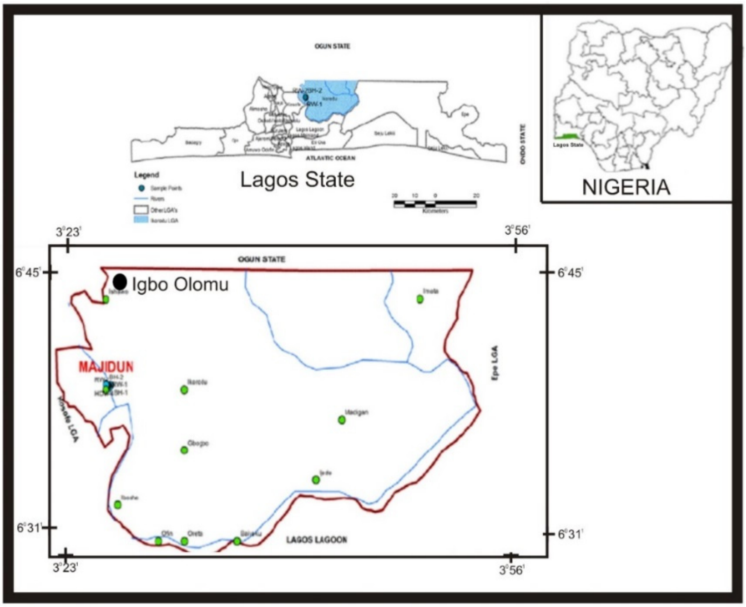

Fig. 1: Map of Ikorodu L. G. A. Showing Igbo Olomu

The area which has wet equatorial climate experience wet season between the months of February and November. The mean annual rainfall for the area is about 1670mm while the month of June usually records the highest rainfall of about 356mm. Temperature in the study area is uniformly high with a mean of 30^{0}c. Relative humidity in the area is usually high and fluctuates between 80 and 100 percent in the rainy seasons. The two main vegetation types identifiable in the area are the swamp forest of the coastal belt and the dry lowland rainforest. Rivers Yewa, Ogun and Ologe are the major water bodies that can be found in the area. The study area is largely underlain by sand/sandstones with lenses of shale and clays. The arenaceous nature of the geology of the study area makes its aquifers susceptible to contamination from anthropogenic sources. The poor socio-economic condition of large number residents in the study area coupled with the pathetic public water supply situation making people to indiscriminately sink wells and boreholes without preliminary geological, hydrogeological and environmental considerations.

MATERIALS AND METHODS

A reconnaissance survey was first carried out to locate all the wells in the study area. Out of the total seventeen (17) wells in the study area, only thirteen (13) were accessible for investigation in this study. The location of the wells are fairly distributed in the study area. A GPS (Garmin 76 csx) was used to take the coordinates of the wells and surface elevations with respect to the mean sea level at each well point. Data on static water levels (SWL) in the wells were taken with measuring tape early in the morning around 6.30am before anyone visit the well to draw. Hydraulic head (HIH) which is the elevation to which water will naturally rise in well was obtained for each well by subtracting the static water level (SWL) from the surface elevation with respect to the sea level (Fig. 2).

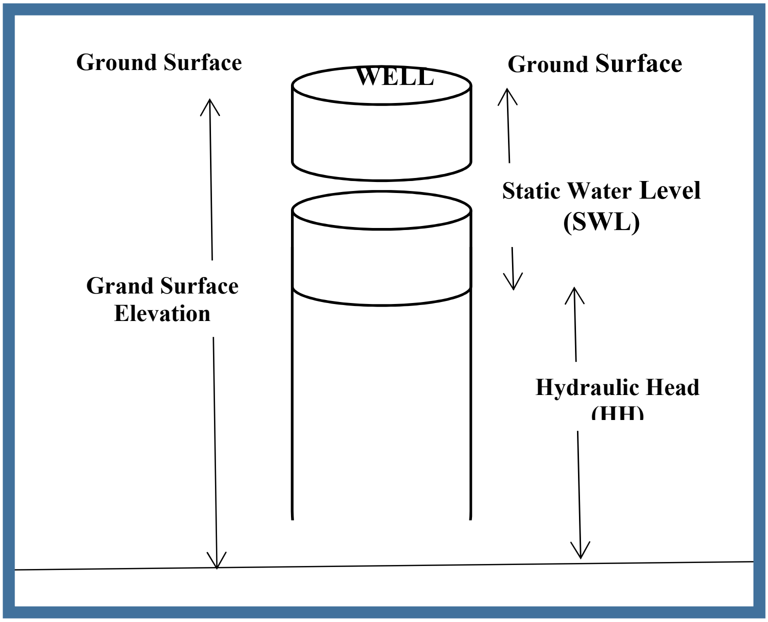

Fig 2Schematic Diagram of Measured Variables

The distribution of hydraulic head at all the thirteen accessible wells were subsequently contoured manually through triangular linear interpolation. This task was carried out by first joining the hydraulic heads of wells at three location with straight lines. Differences in the hydraulic head between the wells were calculated. Elevation head differences were subsequently divided into equal increments by adding to each increment, the initial water level. The straight lines drawn to connect the increments which have the same values represents the water table contours. Because water always move from area of higher elevation to area of lower elevation in the direction of maximum change in elevation, the lines perpendicular to the straight lines connecting the elevation increments thus indicates the direction of flow of groundwater.

RESULTS AND DISCUSSIONS

The relative location of the thirteen wells examined in this study is as shown on Fig 3. The wells are fairly distributed in the study area. Data on well parameters used in determination of groundwater flow in the study area is as presented on table 1.

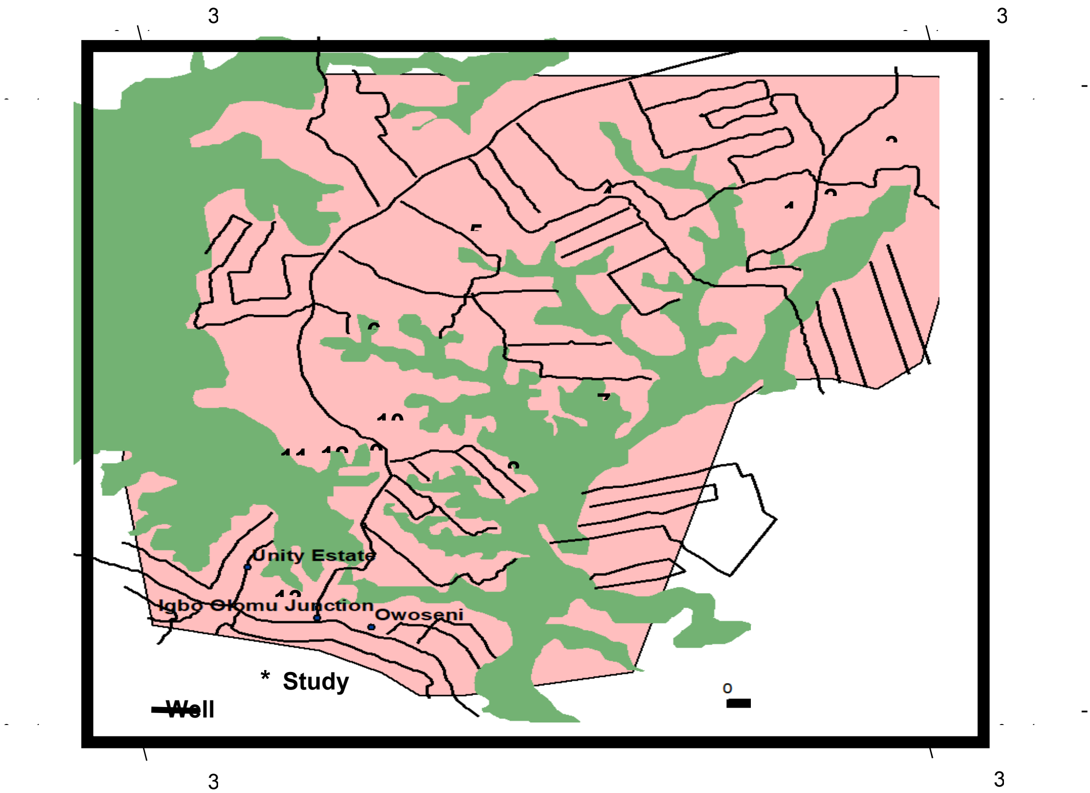

Fig. 3: Map of Igbo Olomu Showing the Study Wells

Table 1: Measured Variables

Serial No of Wells	Longitude (^{O}E)	Latitude ^{O}N	Altitude at Well Opening	Static Water Level (m)	Hydraulic Head (m)
1	$3^{0}\ 27^{1}\ 48^{11}$	$6^{0}\ 40^{1}\ 13^{11}$	40.92	7.16	33.77
2	$3^{0}\ 27^{1}\ 52$	$6^{0}\ 40^{1}\ 13^{11}$	41.12	7.36	33.77
3	$3^{0}\ 27\ 58^{11}$	$6^{0}\ 40^{1}\ 47^{11}$	39.82	3.37	36.45
4	$3^{0}\ 27^{1}\ 40^{11}$	$6^{0}\ 40^{1}\ 16^{11}$	41.24	6.90	34.34
5	$3^{0}\ 27^{1}\ 32^{1}$	$6^{0}\ 40^{1}\ 13^{11}$	40.72	5.64	35.08
6	$3^{0}\ 27^{1}\ 16^{11}$	$6^{0}\ 40^{1}\ 11^{11}$	40.32	5.13	35.19
7	$3^{0}\ 27^{1}\ 40^{1}$	$6^{0}\ 40^{1}\ 10^{11}$	40.53	4.70	35.83
8	$3^{0}\ 27^{1}\ 16^{11}$	$6^{0}\ 40^{1}\ 07^{11}$	39.07	2.75	36.32
9	$3^{0}\ 27^{1}\ 13^{11}$	$6^{0}\ 40^{1}\ 07^{11}$	39.02	4.48	36.54
10	$3^{0}\ 27\ 13^{11}$	$6^{0}\ 40^{1}\ 09^{11}$	38.72	2.35	36.38
11	$3^{0}\ 27^{1}\ 08^{11}$	$6^{0}\ 40^{1}\ 06^{11}$	40.03	3.09	36.94
12	$3^{0}\ 27^{1}\ 10^{11}$	$6^{0}\ 40^{1}\ 07^{11}$	39.63	2.70	36.93
13	$3^{0}\ 27^{1}\ 11^{11}$	$6^{0}\ 40^{1}\ 04^{11}$	39.22	2.37	36.86
Total			**520.36**	**56.00**	**464.39**
Mean			**40.03**	**4.31**	**35.72**
SD			**9.12**	**1.19**	**7.90**
CV			**22.79**	**227.71**	**22.11**

Attitude at well opening range between 38.72 and 41.24m and has a mean value of 40.03 and coefficient of variation of 22.79. The mean statistic water level for the wells is 4.31m; and this parameter exhibit a variability of 27.71%. Hydraulic head which represents the elevation to which water in each well will naturally rise has a mean value of 35.72m; this parameter exhibits the lowest variability among the three well variables investigated in this study. This finding thus shows that groundwater in the study area is likely to be encountered during excavation below a mean depth of 4.5m. However, the rate of inflow into the well will depend on the amount of water in aquifer storage, size and depth of excavation and the hydrogeological properties of the formation being excavated. Data on hydraulic head were subsequently used in generating groundwater contour map for the study area (Fig 4).

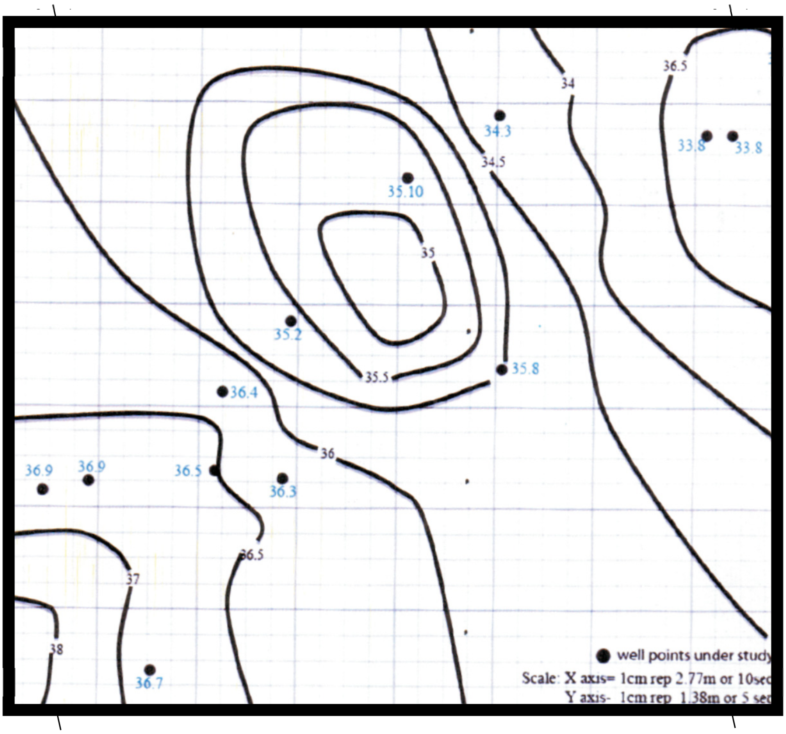

Fig. 4: Watertable Contour Lines

Analysis of the contour map shows that groundwater flow direction in the study area is towards North-East direction. Based on these findings, this research is thus suggesting that location of landfills, waste dumpsites and underground petroleum storage should be restricted to north-eastern and south western parts of the study area.

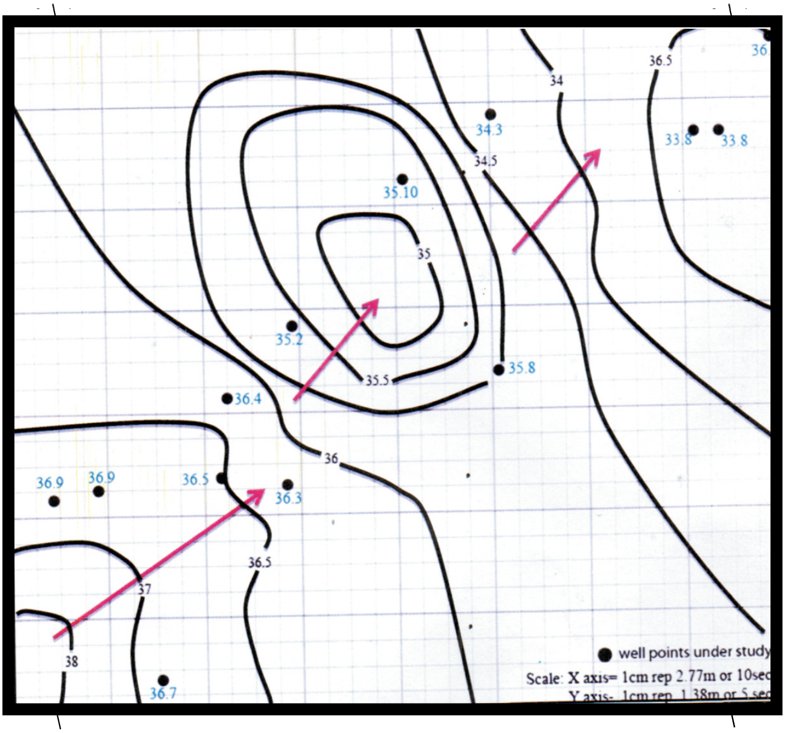

Fig. 5: Groundwater Flow Direction in the Study

MANAGEMENT IMPLICATION FOR GROUNDWATER PROTECTION STRATEGIES

Attempt to manage groundwater pollution problem requires development and implementation of effective policies for groundwater protection. Such policies must however take into account, the institutional and cultural environment of the area where the policy is being proposed, the financial viability of the proposed policy and the acceptability of such policy by the people. Thus, the formulation of such policy by

government agencies concerned must involve the generality of the public and other stakeholders that may be affected by the policy.

Until recently, groundwater in most parts of the world has been considered a dependable source of potable water. However, the increased rate of groundwater extraction without commensurable recharge and leaching of pollutants from underground storage tanks, waste dump site, septic system, landfills pesticides and agricultural practices into aquifers are polluting groundwater sources.

Reasons for the need for protect groundwater are not difficult to discern. Groundwater provides a substantial proportion of the country's domestic and industrial water. More than 63% Nigeria population relies on it as potable water supply with more than 90% of rural households depending on it as their source of drinking water. Not only that, reliance on groundwater in the country is increasing as a proportion of other sources of water, partly due to population growth and urbanization, but also because of greater per capital use. Although withdrawals from all sources of water are daily increasing globally, groundwater use is currently increasing twice as fast as total water use.

Though pollution problem in Nigeria groundwater resources has not yet reached a crisis point, the nature of groundwater and the difficulty associated with its clean-up when polluted suggest that a proactive strategy must be taking to ensure its future integrity. This is because, once an aquifer is polluted, it may remain contaminated indefinitely, even if the source of pollution is removed. In instances where restoration of contaminated groundwater is attempted, clean-up to potable-quality is rarely achieved. Thus it can be strongly argued that efforts to manage and protect groundwater resources should focus more on prevention of pollution, rather than on clean-up exercise. It is thus imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. (RamaKrishnaian et al 2008).

Groundwater pollution control strategies can be achieved, through a number of ways, some of which include;

i. Environmental Legislation

Legislation is an important instrument that can be used in controlling environmental hazards to health. It has being in use over a long time in the control of water quality. Environmental legislation are regulatory in nature. They are usually designed to change private conduct in ways that will help preserve and protect human health and environment. Such laws usually delegate the details of implementation to a regulatory agency that is empowered to set standards, write regulations and issue permits, all of which are designed to protect the environment to some degree. Patrick, et al (1987) observed that the risk of groundwater pollution from commercial or industrial activities and urban development can be reduced through the incorporation of groundwater protection strategies in environmental legislation.

Licensing may be required in environmental legislation on under groundwater for the following;

i.storage, treatment and transportation of harmful toxic wastes;

ii.where effluents with constitutes beyond permissible limits are discharged as an underground injection

iii.when oil in any form is discharged as an underground injection

iv.for an industry or a facility with a new point source of pollution or a new process line.

Environmental legislation on water ensures that all activities concerning water conform to best management practices (BMPs). In order to protect groundwater effectively against pollution in a big geographical area, regional environmental protection policies can be created in some jurisdictions.

Whenever license is given to protect groundwater from pollution, enforcement needs to be carried out by government agencies responsible. And when the need arises, penalties should be given for going against any regulation. However, care must be taken to prevent clashes among government agencies with overlapping responsibilities in area of environmental legislation.

One major problem confronting effective ground water protection measures especially in developing countries is the issue of fund allocation; this is bore out of the fact that the benefits of the groundwater protection measures are not immediate; gaining support for fund allocation to such undertaking thus become very difficult, hence Foster, et al (1992) observation that legislative reform alone may not improve groundwater quality protection unless there is the political will to effectively implement it.

ii.Land use Planning

Land use planning refers to allocation of land to different uses across a landscape in a way that balances, economic, social and environmental values. It purpose is to identify, in a given landscape, the combination of land uses that is best able to meet the needs of the stakeholder while safeguarding resources for the future. Effective land use planning provides direction on the manner in which land use activities should take place and encourages synergies between different uses. Land use planning links social and economic development of an area with environmental protection and enhancement, thus helping to achieve sustainable land management.

The need for land use planning becomes germane because of the relationship between land use and pollution of groundwater. Grifith et al (2002) observed that land use and land-cover remain one of the most significant determinant of water quality. Inappropriate land use, particularly poor land management, causes chronic groundwater quality problem. Thus, land uses and economic activities in sensitive areas, particularly in drinking-water catchments, needs to be subjected to some form of government regulatory control. Such land use regulations can be proposed and implemented at national, state and local government levels with the use of by-laws. While regulations to protect groundwater quality can be implemented by local governments, the issue of groundwater protection can be incorporated into national planning policies.

Land use planning can be implemented at local government level as regulatory control through land use zoning. This is a method of urban planning in which authority concerned divided land into areas called zones, each of which has a set of regulations for new development that different from other zones. Zones may be defined for a single use i.e. residential, industrial etc or they may combine several compatible activities by use. Lefcoe (2005) observed that zoning is the most common urban regulatory urban planning method used by local governments in developed countries. Zoning can be used to direct future development towards groundwater protection; it can come in such form as leaving land as public open space or low residential development with limited use of septic system.

As good as zoning is in protecting groundwater from pollution, its usage in areas that are already developed may not achieve tangible result. However, the method can still be useful in controlling further degradation of groundwater in protected areas. Effort to use zoning to control groundwater pollution will however require continuous monitoring by authority concerned to ensure that the regulations are maintained at all time.

iii.Enforcement

This is the process of ensuring compliances with laws, regulations, rules, standards and social norms. Enforcement of laws can maximize social benefits and protect the public interest. Enforcement action is especially germane, in area of groundwater pollution control to avoid loss of life. Once the legal basis on which groundwater are to be protected has been promulgated, there must be means by which those affected by the policy are made to comply. The enforcement agent has a duty to determine an action that constitute a breach of law and find or if such action has been committed.

Although enforcement is recognized as a key factor for enabling national environmental laws to achieve their objectives of managing and protecting the environment from degradation, the task of enforcement has remained a great challenge especially in developing countries. According to UN (2017) this is due to:

> *"factors such as lack of institutional capacity, lack of competence of relevant enforcement officials to enforce legislation, and lack of information and national guidance materials on enforcement. All of these operate to weaken the effectiveness of the law in regard to protecting and managing the environment and environmental degradation is the results".*

Enforcement mechanism that can be used for environmental protection include permit, license, fine, seizure, arrest and recourse to courts for civil penalties for violation. Although these enforcement mechanisms are already in place in Nigeria, the requisite human and material resources to carry out the enforcement are lacking in the country.

iv.Environmental Education

Environmental education is a process that helps individuals, communities and organizations learn more about the environment, and develop skills and understanding about how to address environmental challenges. Environmental education helps in equipping learners with knowledge, values and skills that promote the protection and conservation of the environment when done right, environmental education can be a helpful tool in the management and prevention of water pollution.

By educating the masses about the importance of good water quality, an awareness of the impact of contaminated water on man, the society and economy will be created; and this can be put to an end, various activities of man that pollute water. Such awareness-raising activities can be carried out through:

i.Interactive Activities: Government agencies, organization and private individuals wishing to promote environmental education can set up interactive activities where people can take part to develop their knowledge informally on issues concerning the environment and water pollution in particular. This kind of program support the transmission model of education where message or information is delivered to a learner, rather than a learner being involved in learning process.

ii.Voluntary Community Work: Residents within a locality can be encouraged to take up voluntary community work. Participants in such activity will have the opportunity to learn, observe and experience different ways by which groundwater can be degraded.

iii.Faith Group: Promotion of water friendly environmental lifestyle can also be carried out through faith groups. This approach was successfully used in 1980s when leaders of the world mayor religious faiths were brought together in Italy to discuss each faith's teaching and principles on environment.

iv.Folk Media: This represents an indigenous method of carrying message to the people. This can be through dance, songs, drama, puppetry and miming. Environmental communicators in developed world have recognized the power of using this medium of communication.

v.Digital Technology: Digital technology, particularly the internet can be of immense assistance in educating people on issues of environment. This can be using YouTube website where people share videos. Such videos place on YouTube will not only serve as reinforcement of a key theme for someone undertaking an environmental project but will also allow other people coming across such video under their own stream to leave their comments and opinions on board for other people to digest.

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