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Depth of Hand Dug Wells and Water Chemistry: Example from Ibadan Northeast Local Government Area (L.G.A.), Oyo-State, Nigeria

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ABSTRACT The paper attempts an examination of the relationships between water chemistry and depth of hand-dug wells in a densely populated (16,679-people/km^2) part of Ibadan, Nigeria. Multivariate procedures of multiple and stepwise regression analyses were adopted. Results of the multiple regression and correlation shoed that Coliform count., pH , total hardness (TH), calcium (Ca^+),magnesium (Mg^+), iron (Fe^+) and chloride (Cl^-)increase with increasing depth while nitrate (NO_3^-)and bicarbonate $(CO_3^-)_2$ reduce with depth. All the examined parameters were significant at 0.05. Further, the result of R^2 showed that the relationship explains 68.88% of the variance; while, the stepwise regression suggest chloride to be the most important chemical parameter (R^2 of 38.11%). That is related to well's depth. The paper calls for further research.

INTRODUCTION

Pollutants in groundwater can be from various sources mainly municipal (i.e. leakages, liquid, waste and solid wastes from land fill), industrial (i.e. liquid wastes, tank and pipeline leakages, oil field and brines) and agricultural sources (i.e. irrigation return flow which are sometimes saline). Alternatively it may also be from spills, surface discharges in form of hydrocarbons in groundwater table or rather from stockpiles in industrial, construction or agricultural sites. It may be as a result of contamination from cesspools, septic tanks, saline water intrusion and interchange through wells. All these are sources of leachates or contaminants in groundwater.

Dispersion plays an important role in groundwater pollution. This is because some pollutants spread out and change in volume due to molecular diffusion and mechanical dispersion beneath the ground. Dispersion of pollutants is controlled by permeability and porosity. In addition, Proximity of the source of pollutants plays a prominent role in groundwater pollution, for example a study in India showed that the percentage of polluted wells significantly increases with distance to sources of pollution. For instance, 76.80% of the sampled wells got polluted when located close to open drains, 64.40% were polluted when located near a pool of stagnant wastewater, while, 32.3% got polluted when garbage dump was nearby (Mahedeven and Krishamswamy, 1984). In a similar study Asimi (1998) in Ilorin concluded that effluents from slaughtering slab increases groundwater COD, total water hardness, total solids, turbidity and other water quality variables in the immediate vicinity of these slabs. These conditions decrease in importance with depth of water table and depth of well.

Studies of groundwater pollution become imperative when it is considered against the background of the processes leading into it. Unlike its surface water counterpart, once an aquifer is polluted it may remain so for years of centuries because of its slow rate of flushing. For example, in Long Island there are instances when pollution were discontinued and at least 10 years passed before polluted water became discharged from the aquifer (Perlinutter et al., 1963). This becomes more important particularly in areas with rocks having low porosity and permeability such as the crystalline basement complex rocks of the study area. Cases of water contamination have been reported particularly in the study area (Sangodoyin, 1993). Also in Nigeria, there are evidences of fresh out break of water borne diseases (see; Sadiq, 1991 and William, 1991).

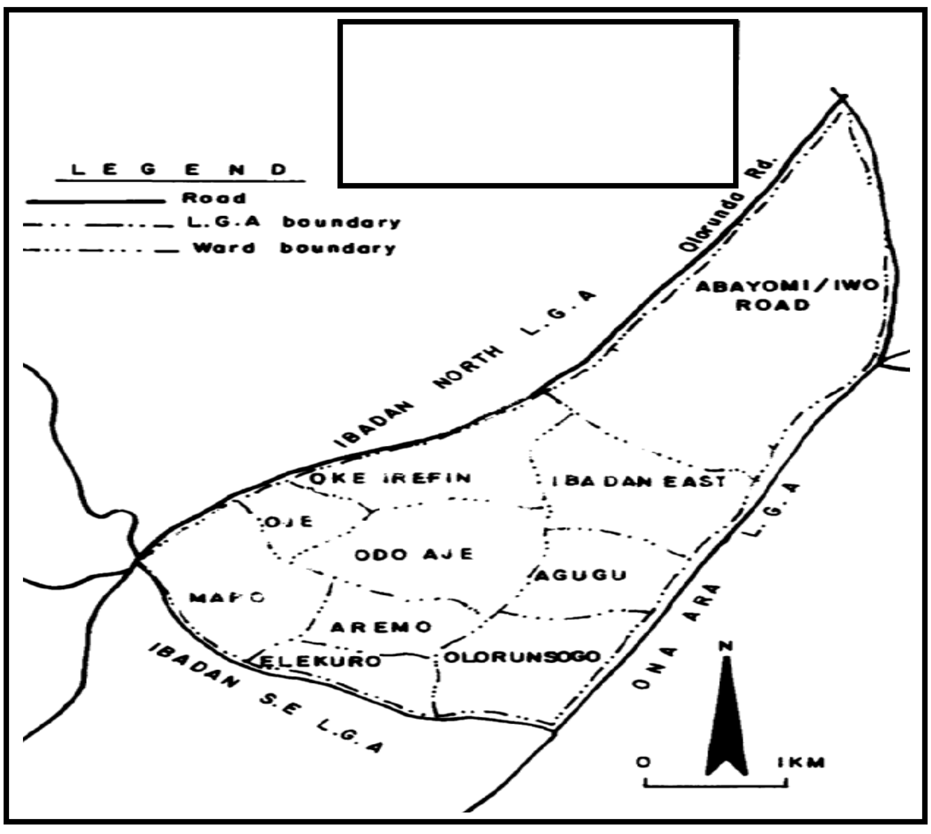
Ibadan suffers serious water supply problems; cases of dry taps are common in virtually every part of the city. Sights of children/women searching for water are common experience. Many parts of the city are not connected with government water supply system. This problem of acute water shortage is compounded by difficult terrain (which has prevented water flow by gravity) and management problems. To this end, inhabitants of the city have turned to hand-dug wells as an appropriate alternative. Furthermore, the study area is densely populated with about (16,679 persons/km^2). Individual houses are closely parked together in an in orderly fashion. Refuse dumps, pit latrines and open sewers are common. All these suggest possible chances of pollutants entering these relatively shallow wells.

There is therefore a need to examine relationships between depth of these shallow hand-dug wells and some water quality parameters with a view to improving the health status of every household in the study area who depend on hand-dug well as an alternate source of water supply. This will assist in improving health care delivery system of this community. Hence, this paper attempts to examine the relationship between depth of hand-dug wells and quality of water in the study area.

The Study Area

Ibadan Northeast Local Government Area (L.G.A.) has a land area of about 15.5km^2. It is situated between longitude 3^{0}45 and 4^{0}00 East and Latitude 7^{0}15’ and 7^{0}30’ North, with an altitude ranging from 150-210 above MSL (Fig.1).

Rain season starts from April and ends in early October (about 6 months rainy season) Rainfall is between 1,115mm to 1450mm with June as the wettest month and December as the driest. Temperature is moderately high throughout the year with a low range. The mean annual maximum and minimum temperature are 30.5^{0}C and 24.2^{0}C respectively. Duration of rainy season has a



Map of the study area (Ibadan North East L.G.A.)

Fig. 1. Ibadan Northeast Local Government Area.

positive effect on the wells while during the dry season (October – March) the reverse is the case. The study area has rainforest vegetation. The topography is highly undulating, characterized by swells. The area is underlain with crystalline Basement Complex rocks consisting of mainly folded gneiss, schist and quartzite complexes, which belong to the older intrusive type. Soil is highly ferallitic with brownish red colour. Depth of regolith is appreciable.

The study area is one of the most populated areas in Nigeria (16,679/km^2). Dwellings are compacted together. Buying and selling is an important economic activity. Many markets are located within the area (i.e. Oje, Orita-Aperin, Agodi and Oranmiyan markets). Besides; some industries are also found, all of which generate wastes. Due to problem of physical planning wastes are not properly disposed off. They are dumped indiscriminately along streets, open places and inside river channels.

The population of the study area is 258,519 people (NPC 1991). The condition of the public water supply situation is deplorable and inefficient as pipe stand are characterized by long queues, and dry taps, also sights of women and children searching for water are common.

METHODS OF STUDY

Sampling Framework: The study area was divided into 10 units, along the political wards boundary. In each of these ten wards two water sample points (shallow wells) were carefully selected for observation. This make a total of 20 sample points altogether. The well water samples were taken once in the dry season month of March, when the well must have been under stress and free from seepage from water percolation. (March 1998). The single sampling is however acceptable for groundwater quality simply because of the low rate of flushing and mixing compared to its surface water counterpart (Perlnutter et al., 1964). In addition, the study area is on Precambrian a crystalline Basement Complex rock that is well known for its poor level of permeability, consequently rate of mixing should be least expected.

Water samples were collected in plastic water bottles and stored at low temperature to minimize physico-chemical reactions. The water samples were taken to the laboratory same day for analyses. The samples parameters were, Coliform count (Cc), Calcium (Ca^+), Magnesium (Mg^+), Iron (Fe^+), Chloride (Cl^-), Nitrate (No_3^-), bicarbonate (Co_3^-), total water hardness (TH) and pH.

Laboratory Methods: Standard laboratory procedures were adopted, cat ions and anions (i.e. Calcium, Iron, Magnesium, Chloride and bicarbonate) were determined with atomic absorption spectrometer method using cadmium reduction method. Water hardness was also determined by volumetric method using solution, while Ph was determined with glass electrode Ph meter, while coliform count was done through total plate count method.

RESULTS AND DISCUSSION

a. Descriptive Characteristics of Sample: Among the examined variables, TH has the highest mean (236.04mg/L) followed by Cl^- (135.60mg/L) while Fe^+ remained the least (0.58mg/L). Also, TH recorded the highest standard deviation (103mg/L), this is followed by Cl^- (57.18mg/L) while Fe^+ record the least value (0.2mg/L). Furthermore, TH also remains the most absolutely varied parameter among the examined

Table 1: Descriptive characteristics of water samples

S. No.	*Parameter*	*Mean (Mg/L)*	*SD (Mg/L)*	*Coefficient of variation (%)*
i	Coliform (Colf)	7.45	10.60	70.28
ii	pH	7.83	0.47	1664.9
iii	Total hardness (TH)	236.04	103	28.8
iv	Calcium (Ca^+)	53.85	12.41	197.70
V	Magnesium (Mg)	23.85	12.41	192.20
Vi	Iron (Fe^+)	0.58	0.2	259.70
vii	Chloride (Cl^-)	135.60	57.18	237.10
viii	Nitrate ($N0^-_3$)	8.01	14.89	53.8
ix	Bicarbonate (Co_3^-)	108	47.95	225
	Depth (Y)	22.65	5.28	428.60

Source: Author’s 2000.

Table 2: Relationship between depth of well and water quality parameters.

S. No.	*Variable*	*Coliform count*	*pH*	*Total hardness*	*Ca^+*	*Mg^+*	*Fe^+*	*Cl^-*	*No_3^-*	*$(Co_3^-)_2$*	
1	Coliform count	1.00									
2	pH	-0.4220	1.000								
3	Total Hardness	-0.4230	0.1750	1.000							
4	Ca^-	-0.0197	0.0199	0.9044	1.000						
5	Mg^+	0.4929	0.3557	0.8331	0.5877	1.000					
6	Fe^+	-0.02566	-0.1494	-0.3816	-0.3638	- 1811	1.000				
7	Ch^-	-0.2214	0.2093	0.6547	0.5713	0.6875	0.2888	1.000			
8	NO_3^-	0.0536	-0.1239	-0.5715	-0.6027	-0.3618	0.1493	-0.6106	1.000		
9	$(Co_3^-)_2$	-0.4050	0.3430	0.4102	0.1831	0.5915	0.7339	0.3747	-0.2255	1.000	
10	Depth	0.0678	0.1379	0.5665	0.6111	0.4756	0.0800	0.6174	-0.5064	-.076	1.00

Source: Author's 2000.

water characteristics within the study area. On the pattern of relative variation, the result of the coefficient of variation shows that all the examined variables with the exception of TH are heterogeneous. pH for example tops the list with a value of 1664.9%, this was followed by depth of well (428.60%), while TH, the only homogeneous characteristic has a value of 28.80% (Table 1).

The above analysis shows that all the examined water chemical characteristics were highly varied both absolutely and relatively. Hence, this indicate that these properties do not exhibit a clear cut pattern, therefore for the purposes of environmental management there is a need for a close monitoring of the water quality parameters in these shallow wells from time to time especially in view of the role it plays in water supply in the study area.

b. Relationship Between Water Quality Parameters: The results of the correlation matrix presented in Table 2 showed that only a few significant correlations exist in the data .For example, coliform count increases with Mg^+ (r=0.49). This increase is expected, first because Mg^+ is an important element to coliform growth. Second, it is required for the activities of enzymes especially those involved in phosphate transfer and thirdly it stabilizes ribosome cell membrane and nucleic acid. All these conditions are required in the growth of coliform in water. Ph on the other hand displayed a weak association with all examined water chemical characteristics. Total hardness on the other hand, increased with increasing Ca^+(r=0.90), Mg^+(r=0.83), and Cl^- (r=0.65) but decreased with increasing concentration of No_3^- (r=0.57). The increasing proportion of Ca^+, Mg^+, and $Cl^-$is normal because these properties are responsible to a large extent for hardness of water .For example, the concentration of Ca^+ and Mg^+ will dictate how hard a given volume of water will be. Chloride may aggravate water hardness on a lighter mood .The inverse relationship between total hardness and nitrate (0.53) is expected because the concentration of bacteria and other biological activities will expectedly decrease with increasing hardness of water. Calcium increases with increasing chloride (0.57) and Mg^+(0.59).

Finally, as $(CO_3)_2$ increases Mg^+(r=0.59) and Fe^+ (r=0.73) increases. This is normally the situation in hard water .For example, when Mg^+ and Fe^+ increases there is the tendencies for such water to be hard.

c. Relationship Between Depth and Chemical Parameters: Table 2 revealed that as depth of well increases CC, P^h, Ca^+, TH, Mg^+, Fe^+ and Cl^- increased. Although CC, pH and Fe+ have low correlation which are less than 0.50.This probably suggests that with increase in depth of holes this relationship might be reversed .As the depth of hole increases concentration of No_3^- and $(Co_3^-)_2$ decrease this is however normal as No_3^- is normally introduced from the surface

The result of the F-statistics suggests that, a significant relationship exist between depth and all the examined parameters. In further analysis, the coefficient of determination, which is the percentage of the regression plane explained by the variance, suggests that the relationship explains as much as 68.88% of the variance. This is relatively strong. However, the association between all chemical variables is better explained with equation 2 below.

$$Y = 1.131732 + 0.138411\mathbf{col} + 2.16231\mathbf{p^h} - 0.005776\mathbf{TH} + 0.74203\mathbf{Ca^+} + 0.207028\mathbf{Mg^+} + 1.745266\mathbf{Fe^+} + 0.020691\mathbf{Cl^-} - 0.45635\mathbf{NO3^-} - 0.48148\ (Co3_-)_2 \quad \text{.........(eq.2)}$$

$$(\mathbf{R^2 = 68.88\%})$$

In attempt to determine, which of the examined

Table 3: Characteristics of the stepwise regression

ChemicalParameter	*Number in*	*Partial R^2*	*Model R^2*	*F*	*Prob > F*
Chloride	1	0.3811	0.3811	11.0858	0.0037

variable is better determined by the depth of the well. The result of the stepwise regression statistics (equation 3) shows that amongst all the variables, chloride has the highest relationship with depth of well.

The $\mathbf{R^2}$ of the stepwise statistics indicates that this variable (Chloride) alone explains 38.11% of the variance in this association. Hence, one can therefore conclude that chloride is the only variable that possesses the strongest relationship with depth of hole. This is further, described by equation 3 below

$$Y= 14.91331610 + 0.05705519_{cl} - \ldots\ldots\ldots\ldots \text{eq. 3}$$
$$(R^2 = 38.11\%)$$

The above equation implies that for every 14.91% increase in depth of hand dug well the value of chloride will increase by 1mg/L in the study area. This agrees with the findings of Perlinutter, et. al. (1964); Mahadeven and Krishaswamy, (1984) and Asimi, (1998) where they all concluded that groundwater pollution is affected by depth of well .However, Sangodoyin (1993) has earlier pointed out the high values of chloride in the aquifer of the study area in a study of hand pump and hand-dug wells. Generally, there is a need for further research particularly; determining the depth that concentration of chloride becomes appropriately deleterious.

Implication of the Study

The relationships between depth and chemical parameters are discussed. For example, some parameters have positive relationship with one another, while others are negative. The result indicates that significant relationship exists between depth and all the examined parameters. Further, the multiple regression equation explained 68.88% of the variance in the data set. However, stepwise regression shows that chloride is the only chemical parameter having the strongest relationship (38.11% of the variance) with depth of shallow wells in Ibadan north East L.G.A. (Table 3). Hence, for the purpose of primary health care delivery the depth of well should be taken into consideration before embarking on shallow ground water development exercise in the study area.

According to the analysis above, chloride in the wells of the study area has a strong association with well depth. For example, a high correlation exists between chloride and depth. According to table 2, as depth of well increases the level of chloride concentration also increases. This suggests that excessive well depth may indicate chloride contamination of water. There is therefore a need to determine the actual depth at which this relationship is reversed or rather ceased. This is however, important in view of the fact that excessive consumption of chloride may lead to various health problems particularly when it contains undissolved metal ions such as copper, zinc, mercury, silver etc, its excess concentration can results to cancer. When chloride contains other form of salts such as calcium, magnesium, sodium and potassium its excess concentration can lead to other problems such hypertension, high blood pressure, corrosion, water hardness etc.

However, in the mean time people residing in the study area are advised to boil and flocculate water obtained from these shallow wells as these are simple and appropriate strategies by which this can be resolved, such that the effects of this chemical and other parameters, which may be found in water of these wells, are reduced to the affordable minimum.

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