Productivity and quality analysis of selected boreholes in Osun and Kwara States, Nigeria

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Abstract: A study was conducted on the productivity and quality analysis of borehole water in Offa and Erin-Ile in Kwara State, and in Ilesa and Osogbo in Osun State, Nigeria. Productivity of the borehole was carried out by pumping test to determine the discharge from the boreholes sampled. Data about the boreholes were obtained from Hydrology Department of the Lower Niger River Basin Development Authority Ilorin, Kwara State (LNRBDA) and Rural Water and Environmental Sanitation Agency in Osun State (RUWESA). Ten boreholes were sampled in Offa out of which seven were working. Five boreholes in Erin – Ile were sampled out of which four were functional. 21 boreholes were sampled in Ilesa but only thirteen were working and three boreholes in Osogbo but only one was working. All the boreholes sampled were free from E – Coli bacteria. Most chemicals analyzed were within the permissible limits of the Standard Organisation of Nigeria (SON) Act 2007 but magnesium contents were above the permissible limits (0.20) by a range of 0.09 mg/L, iron (II) above the limits (0.30) by a range of 0.50 mg/L. Water from the boreholes of both states was suitable for human consumption.

Keywords: borehole, water quality, productivity of borehole, aquifers, transmissibility

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1 Introduction

Water is essentially needed for all metabolic processes. About 97.2% of global water resource is salt water mainly in oceans and 2.8% is available as fresh water at anytime on the earth. Out of this 2.8%, about 2.2% is available as ground water (Raghunath, 2006). The world's available fresh water is not evenly distributed through the year. Fresh water is not available all the year round, not available where it is needed and when is available, it is not in sufficient quantity. The basic physiological requirement for drinking water is about 2 L per person per day. However, a daily supply of 140 to 160 L per capita per day is considered adequate to meet the needs for all domestic purposes (Aderibigbe, Awoyemi and Osagbemi, 2008).

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Usually, water from the boreholes is free from danger pathogens for humans like cholera, typhoid, dysentery, guinea worm and many others. Borehole water is groundwater available in an aquifer. Any contaminated surface water with pathogen that infiltrates into the soil and become groundwater would be filtered by the soil profile before the depth of aquifer. An aquifer is saturated water bearing stratum that is capable of holding, transmitting and yield sufficient water in underground to well (Sharma and Sharma, 2007). The major problem of boreholes is chemical contents of the groundwater, which must be analyzed to ascertain if these dissolved products are within the permissible limits for consumption proposed by the authorities, in this case the World Health Organization (WHO) or the Standard Organization of Nigeria (SON).

In Nigeria, dry season is usually between November and February while wet season begins in March and ends in October (Ogunlela, 2001). People in urban and rural areas in some parts of the country usually have problem of potable water especially during the dry season. During dry season the demand for water is high because of irrigation activities and water supply by Water Corporation in urban areas for public use is usually insufficient. Women in rural areas must travel a few kilometres in searching and fetching the available surface water from streams, rivers, ponds and open well that might have been contaminated with pathogens which may cause deadly disease to the population.

The progressive increase in population has also raised the demand for potable water both in the rural and urban areas. Since groundwater has a good quality and boreholes can give appreciable quantity of water for domestic uses, the use of these infrastructures in the rural and urban areas can surely alleviate water problems of the people in Nigeria.

The specific objectives of this research were:

1) to carry out the performance assessment of selected boreholes in Osun and Kwara states, Nigeria.

2) to determine the suitability of the water from boreholes for consumption.

2 Materials and methods

2.1 Site description

This study was conducted in Offa (8°9′N; 4°43′E) and Erin-Ile (8°7′N; 4°42′E) in Kwara state, and in Ilesa (7°37′N; 4°40′E) and Osogbo (7°48′N; 4°37′E) in Osun state, Nigeria between February and April 2011. The population of these towns is 114,000, 70,000, 277,904 and 267,890 respectively. These sites were selected because they usually have problem of water supply especially during dry season.

Locations and data about boreholes in Offa and Erin-Ile in Kwara state were collected from Hydrology Department of the Lower Niger River Basin Development Authority, Ilorin (LNRBDA), while from those in Ilesa and Osogbo were collected from the Rural Water Environmental Sanitation Agency (RUWESA) under the Ministry of Agriculture, Osun State.

The areas in the town where boreholes were drilled were visited to get facts about each borehole in addition to the information given by the two agencies. The people around the area of the borehole were interviewed to know the condition of the boreholes after the construction.

Ten boreholes were sampled in Offa but three were not working and five boreholes in Erin-Ile, with one not working. Twenty one boreholes were sampled in Ilesa but 13 were working and out of the three boreholes sampled in Osogbo only one was functioning. The boreholes sampled in Ilesa and Osogbo in Osun State and their locations were shown in Table 1. The yield of the boreholes was given in litre per second in the data provided by the RUWESA, but converted to cubic metre per day using Equation (1). Data for pumping test of the boreholes in Ilesa and Osogbo were not provided by the agency and the yields of some boreholes were not given as shown in Table 1.

$$Q = 86.4q \tag{1}$$

where, Q is the discharge or yield of the borehole, m^3/d; and q is the discharge from the pumping test/provided by the agency, L/s.

$$Q = 86.4 \times 0.26 = 22.464 \quad \text{m}^3/\text{d}$$

Table 1 Locations of the boreholes sampled in Ilesa and Osogbo in Osun State

Location	Year of construction	Pump	Yield/L · s^{-1}	Yield/m^3 · d^{-1}	Condition
ILESA					
Owa's Palace	9/9/2004	Submersible	—	—	Working
School of Health Technology	9/3/2006	Submersible	0.26	22.464	Working
Orinkinran Isokun	9/3/2006	Hand pump	—	—	Not working
Olatunde Oginni' House	10/1/2006	Hand pump	—	—	Not Working
Chief Esan Street	10/1/2007	Hand pump	—	—	Working
Alhaji Bakare House	17/1/2007	Hand pump	—	—	Working
Palace of peace building	19/1/2007	Hand pump	—	—	Working
Oromu Kayafanda 1	9/1/2007	Hand pump	—	—	Not working
Oromu Kayafanda 2	16/7/2010	Hand pump	—	—	Working

Location	Year of construction	Pump	Yield/L·s^{-1}	Yield/m^3·d^{-1}	Condition
Ayetoro 1	29/1/2007	Hand pump	—	—	Working
Ayetoro 2	29/1/2007	Hand pump	—	—	Working
Ilesa West, L.G.E.A primary School.	1/8/2006	Hand pump	0.51	44.064	Not working
Bolowaduro Baptist School	1/8/2006	Hand pump	0.59	50.976	Not working
School of Health Tech.	9/9/2006	Hand pump	1.40	120.960	Working
Consultant Place	30/1/2007	Hand pump	0.55	47.520	Working
Mr. Ogunsanmi Street	19/02/2010	Hand pump	0.75	64.800	Working
Hon. Timothy Owoeye House	16/3/2010	Hand pump	—	—	Not working
Mr. Adekunle Estate	26/5/2010	Hand pump	—	—	Not working
Adekunle Estate 2	26/5/2010	Hand pump	—	—	Not working
Kunle Jebutu's Site	26/7/2010	Hand pump	1.37	118.368	Working
Bibilari House Ayeni Estate	27/09/2001	Hand pump	1.30	112.320	Working
OSOGBO					
Ogo Oluwa	17/1/2010	Hand pump	—	—	Not working
Engr. Akinnikiye,	26/8/2010	Hand pump	—	—	Not working
Ramp Office, Testing ground	22/10/2010	Hand pump	0.53	45.792	Working

2.2 Pumping test

Pumping test for each borehole was carried by the LNRBDA. Pumping test was conducted to determine the actual discharge of each borehole. Data provided includes static water level, time for pumping test, pumping rate, pumping level and subsequent draw down were determined. A constant rate pumping test involves pumping of a well until it reaches a constant pumping draw dawn. It depends on the aquifer and the pumping rates with time. Water level will "be stabilized" at a constant water pumping level when the aquifer is supplying water to the well at the same rate the pump is extracting water from the well.

2.2.1 Procedures for pumping test

Procedures for pumping test (Gross, 2008) are:

i) Measure the static water level of a borehole or well which has not been pumped for about 24 to 48 h;

ii) Lowering dip meter probe (electrode) into the access pipe to note the static water level on the dip meter;

iii) Pumping the well until an apparent equilibrium level is established; recording the initial time, subsequent time interval, water level. Record the final water level, time and the pumping rate. The reading of a sample of pumping test conducted by LNRBDA at Iyeru – Ira road Offa is shown in Table 2.

Table 2 Readings of pumping test at Iyeru – Ira Road Offa with static water level of 3.0 m and total depth of 37.3 m

Time /min	Static water level /m	Pumping rate /L·s^{-1}	Pumping level /m	Drawdown /m
2	3.00	0.098	3.17	0.17
4			3.84	0.84
6			3.86	0.86
8			3.87	0.87
10			3.88	0.88
20			3.88	0.88
30			3.88	0.88
45			3.88	0.88
60			3.88	0.88
90			3.88	0.88
120			3.88	0.88
125		0.75	4.42	1.42
130			5.37	2.37
135			9.22	6.22
140			11.97	8.97
145			12.97	9.97
150			14.00	11.00
155			14.47	11.47
160			14.93	11.93
165			14.93	11.93
170			14.93	11.93
180			14.93	11.93
190			14.93	11.93
200			14.93	11.93
220			14.93	11.93
240			14.93	11.93
245		1.33	18.79	15.79
250			20.80	17.80
260			22.19	19.19
270			23.38	20.38
280			24.87	21.87
290			24.87	21.87
300			24.87	21.87

Time /min	Static water level /m	Pumping rate /L • s^{-1}	Pumping level /m	Drawdown /m
310			24.87	21.87
320			24.87	21.87
330			24.87	21.87
340			24.87	21.87
350			24.87	21.87
360			24.87	21.87

Source: Hydrogeology Department, Lower Niger River Basin Authority Ilorin, Kwara State (2011).

2.3 Equations governing discharge of a well

Several authors have developed equations for estimating the discharge of an aquifer. In this case, those proposed (Basak, 2004) were:

$$Q = \frac{2\pi Kb(H-h)}{2.303\log_{10}\left(\frac{R}{r}\right)} \tag{2}$$

In terms of draw down $S = H - h$

$$Q = \frac{2\pi KbS}{2.303\log_{10}\left(\frac{R}{r}\right)} \tag{3}$$

In terms of transmissibility $T = Kb$

$$Q = \frac{2\pi TS}{2.303\log_{10}\left(\frac{R}{r}\right)} \tag{4}$$

$$Q = \frac{\pi K(H^2-h^2)}{2.303\log_{10}\left(\frac{R}{r}\right)} \tag{5}$$

In terms of draw down $S = H - h$ and $H = S + h$

$$Q = \frac{\pi S(S+2h)}{2.303\log_{10}\left(\frac{R}{r}\right)} \tag{6}$$

where, Q is the discharge of the well, m^3/s; H is depth of water level from the bottom of the confined aquifer to the static water level, m; h is the depth from the bottom of confined aquifer to draw down or depth from the impervious layer of unconfined aquifer to draw down, m; S is the draw down, m; R is the radius of influence, m; r is the radius of the well, m; K is the hydraulic conductivity of the soil, m/s; T is the transmissibility, m^2/s; b is the thickness of the aquifer, m; and π is 3.142.

The transmissibility of the borehole was determined using Jacob's straight line method. This was done by converting the time used for pumping to logarithmic form. An approximate value of log of time and the corresponding draw down value per one log cycle (h_o - h) in metre was determined from the graph which was substituted into Equation (7) to determine the transmissibility of the aquifer. The value of discharge (Q) used in the following equation was the result of steady state pumping rate (discharge) from pumping test after it has been converted to cubic metre per day using Equation (1). Equation (8) was used to determine the hydraulic conductivity of soil of the aquifer when the thickness of aquifer is known.

$$T = \frac{2.3Q}{4\pi(h_o - h)} \tag{7}$$

$$K = \frac{T}{b} \tag{8}$$

The calculation for the discharge, transmissibility and hydraulic conductivity of the aquifer presented in Table 3 were determined using Equations (1), (7) and (8) respectively. For example, when the value of pumping rate was 1.33 Ls^{-1} at Iyeru - Ira road Offa, the value of discharge was calculated as shown in the following expression and the same equation was used for others.

$$Q = 86.4 \times 1.33 = 114.912 \text{ m}^3/\text{d}$$

$$T = \frac{2.3 \times 114.912}{4 \times 3.142(10.4 - 3.6)} = 3.093 \text{ m}^2/\text{d}$$

$$K = \frac{3.093}{6} = 0.516 \text{ m/d}$$

Table 3 Results of discharge (Q), transmissibility (T) and hydraulic conductivity (K) of theboreholes from pumping test analysis for seven locations in Kwara state

Location	Depth of borehole/m	Pumping rate/L • s^{-1}	Q/m^3 • d^{-1}	T/m^2 • d^{-1}	K/m • d^{-1}
Iyeru–Ira Road, Offa	37.3	1.33	114.912	3.093	0.516
Esa – Compound, Offa	27.80	1.33	114.912	3.447	0.627
Bishop's Court, Offa	18.30	1.33	114.912	4.123	0.687
Ijakadi, Offa	17.62	0.667	57.629	2.511	0.456
Offa Grammar School	27.28	1.33	114.912	3.735	0.467
Ojomudoyin,Offa	18.54	0.391	33.782	0.813	0.163
Oke-Odo, Erin-Ile	29.54	0.596	51.494	5.89	0.841

2.4 Water Quality Test

Water samples were collected from the case study areas for physical, chemical and bacteriological tests. Two samples were randomly picked from Offa, two from Erin – Ile, four from Ilesa and only one sample was working in Osogbo for the quality analysis.

The physical and chemical characteristics were determined using the standard method given by Basak (2004). The physical parameters measured were: colour, turbidity, odour, taste and temperature while the chemical parameters include; Calcium, Magnesium, Iron, Sodium, Chloride, Nitrate, Sulphate, pH, Calcium Carbonate, electrical conductivity, total dissolved solids and total suspended solids.

Bacteriological test is important to determine if the water contain pathogens that can cause diseases to man. Boreholes were sampled for bacteriological test to determine Coli form count (E – Coli bacteria).

3 Results and discussion

The readings obtained from pumping test on the borehole at Iyeru-Ira, Offa in Kwara State conducted by LNRBDA are shown in Table 2. From the pumping test analysis, Iyeru - Ira, Esa – Compound, Bishop's Court and Offa Grammar School have higher discharge (yield) while Ojumodoyin Offa has the lowest discharge as shown in Table 3. The productivity of the boreholes both in Kwara and Osun states can actually supply enough water to those in the areas even the borehole at School of Health Technology Ilesa that has the least discharge in Table 1 is above the recommended minimum yield of a borehole. The low yield of the borehole is to due to the quantity of water available in the aquifer that is supplying water to the borehole. Secondly, the actual depth of the aquifer might not be reached during the construction of boreholes. In addition, some contractors like to maximize profit by using poor quality constructional items (materials) and reducing the quantity of the materials required for the boreholes. Table 3 also contained depth of the borehole, steady state pumping rate, transmissibility and hydraulic conductivity. The readings of pumping test for Ilesa and Osogbo in Osun state were not provided by RUWESA but the yield of the boreholes included in the data given by the agency is shown in Table 1.

The bacteriological test results from the two states shown in Table 4 indicated that all the boreholes sampled were free from Coli form bacteria like E-Coli bacteria.

Results of chemical analysis of the boreholes were shown in Table 5. Most chemicals analyzed were within the permissible limits of the (SON) Act 2007 but magnesium contents were above the permissible level (0.2) by a range of 0.09 mg/L, iron (II) also above the limits (0.30) in two locations in Osun and one location in Kwara State. Magnesium and Iron (II) that were slightly above the recommended values have no effect on health as given by SON Act 2007 of water quality for consumption.

Table 4 Bacteriological test results

Location	CGNA	MPNO	MPNB
Ayeni Estate, Ilesa	40	14	Nil
Bibilari, Ilesa	50	25	Nil
Ido Ijesa, Ilesa	25	32	Nil
Oromu, Ilesa	96	78	Nil
Ramp Office, Osogbo	33	41	Nil
Olorunkuse, Offa	60	18	Nil
Offa Grammar School,Offa	26	20	Nil
Ile Akingbo, Erin-Ile	42	16	Nil
Oke-Odo, Erin-Ile	>100	72	Nil

Note: CGNA - Colonies growing on nutrient Agar at 37^{o}C in 24 h ml^{-1}; MPNO - Most probable number of coli form organism per 100 cc; MPNB - Most probable number of bacteria coli per 100 cc.

Table 5 Chemical analysis of the sampled boreholes in Ilesa and Osogbo, Offa and Erin- Ile

Location	pH	Cl^- /mg·L^{-1}	Electrical conductivity	NO_3 /mg·L^{-1}	SO_4 /mg·L^{-1}	Fe^{+2} /mg·L^{-1}	Na^+ /mg·L^{-1}	Mg^{+2} /mg·L^{-1}	Ca^{+2} /mg·L^{-1}	$CaCO_3$ /mg·L^{-1}	Alkalinity /mg·L^{-1}	Total dissolved solids /mg·L^{-1}	Total suspended solids /mg·L^{-1}	Dissolved oxygen
Ayeni Estate, IIesa	7.0	52.0	92.0	2.9	60	0.30	2.00	0.21	29.0	0.50	0.00	16.8	30.0	51.0
Bibilari, Ilesa	7.0	76.0	96.0	2.7	68	0.31	1.98	0.20	22.0	0.42	0.05	18.1	33.6	51.5
Ido Ijesa, Ilesa	7.0	50.0	94.0	2.8	70	0.30	1.96	0.28	72.0	1.00	0.05	17.0	32.5	52.0
Oromu, Ilesa	7.1	62.0	87.0	3.0	62	0.32	2.00	0.29	54.0	0.83	0.15	50.0	58.6	53.0
Ramp office, Osogbo	7.0	70.0	88.0	2.8	58	0.30	1.80	0.25	17.0	0.42	0.05	31.0	50.0	50.1
Olorunkuse Offa	7.1	50.0	9.60	2.6	69	0.30	2.00	0.22	0.62	0.84	0.10	166	175	51.6
Offa Grammar School	7.0	64.0	9.1.0	2.7	65	0.35	1.96	0.28	0.82	1.10	0.05	180	191	50.8
Ile Akingbo, Erin-Ile	7.0	70.0	9.00	2.9	72	0.30	1.98	0.28	0.84	1.12	0.05	171	189	51.5
Oke-Odo Erin-Ile	7.0	80.0	8.90	2.8	60	0.30	2.00	0.27	0.93	1.20	0.05	168	172	51.1
SON Act, 2007	6.5-8.5	250	1000	50	100	0.30	200	0.20	200	150	500	500	500	---

Note: SON = Standard Organisation of Nigeria.

4 Conclusions

The assessment of boreholes carried out in Offa and Erin – Ile (Kwara State), Ilesa and Osogbo (Osun State) showed that the use of boreholes can alleviate water problem in the rural areas and even in urban areas during dry season in Nigeria because it can give appreciable quantity of water. Borehole that has the least discharge from the study is above the recommended minimum yield.

Boreholes are usually free from E – Coli bacteria and other pathogens that can cause serious diseases to the population. Chemical contents of the boreholes sampled were within the recommended limits of Standard Oganisation of Nigeria Act 2007 but iron (II) and magnesium were slightly above the limits but cannot cause disease to humans as the chemicals usually affect water colour and hardness. Therefore, groundwater of boreholes in Kwara and Osun States is suitable for its consumption.

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