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Assessment of Water Quality and Yield Capacity of Artesian Wells in Okada and its Environs

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Abstract: *Provision of water adequate and suitable for human use and consumption is one indices of a good life. The research focuses on assessing and evaluating the quantity and quality of three (3) artesian wells located in Okada and its Environs for provision of water supply to the community. Laboratory analysis for the determination of water quality parameters were performed on the samples collected from the three study artesian wells. The result of the water analysis was compared with the Nigeria Standard of Drinking Water Quality (NSDWQ) and were found to be within the recommended limit excluding pH and Magnesium. The volume rate of flow of the artesian wells were investigated and the measured mean yield capacity were as follows 75.7296m³/day for location A,77.7m³/day for location B and 55.31328m³/day for location C. The combined total yield for the three artesian wells is estimated at 208.72m³/day and when compared to the present estimated water demand (13,429 m³/day) and 25 years target water demand (19,485 m³/day) is grossly inadequate as its result into huge deficit of 13,220.21 m³/day and 19,276.21 m³/day respectively. Therefore, more boreholes are needed to provide an adequate viable water supply scheme for Okada and its environs.*

Keywords: *Artesian Well, Yield Capacity, Water Quality, Water Demand*

Nomenclature

Q = Rate of Discharge (m^3/s)
V = measured volume rate of flow over time interval
T_2 = Stop Time when the can is full (s)
T_1= Start Time immediately the can was placed on the flowing water pipe(s)
T = Period of flow (s)
Q_{AV} = Average rate of Discharge measured over several volume of flow against their interval
Q_1, Q_2, Q_3…..Q_n= number of measured rate of flow at its specific volume and time interval
n= number of times measurement was carried out.
$Q_{AVhourly}$ = Mean hourly Discharge
$Q_{AVdaily}$ = Mean daily Discharge

$Q_{AVmonthly}$ = Mean monthly Discharge
$Q_{AVyearly}$ = Mean yearly Discharge
P_o = population count at the initial year (2006)
P_t = estimated population at the present year (2018)
t_o = initial year of count (2006)
t_f = present year or estimated year of count (2018)
r = assumed growth rate for semi-urban areas within the 1st ten years =1.5% (0.015)
P = population at any year of study
$0.12m^3/p/day$ = unit water demand per person per day

INTRODUCTION

Water is one of the most important natural substances that profoundly affect and influence life of both plants and animals. The importance of water to man and his environment cannot be overemphasized. The provision of water is very essential especially water of good quality for human health. Increase in human population has exerted enormous pressure in the provision of safe drinking water especially in developing countries such as Nigeria. There is no availability and functioning water supply scheme in Okada and a lot of people depend on a few domestic boreholes owned by individuals which are commercialized. There are also artesian wells situated in the area.

A lot of residents who cannot afford to patronize the commercialized private boreholes owners' resort to these artesian wells because of its free gift of nature.
An artesian well is a well that taps into a confined aquifer and under artesian pressure, water in the well rises above the top of the aquifer. A flowing artesian well is one that has been drilled into an aquifer where the pressure within the aquifer forces the groundwater to rise above the land surface naturally without using a pump. Flowing artesian wells can flow on an intermittent or continuous basis and originate from aquifers occurring in either unconsolidated materials such as sand and gravels or bedrock, at depths ranging from a few meters to several thousand meters. This research attempts to evaluate the water quality of these artesian wells and also determine the yield capacity of the wells for the provision of constant water supply within the area.

Description of Project Study Area

Okada Town is the administrative headquater of Ovia North East Local Government Area of Edo state with geographical coordinates of 6^0 44^0 North and 5^0 22^0East. It is a semi-urban area with the prospects of transforming rapidly into urban because of the presence of the first indigenous private University in Nigeria Igbinedion University Okada,(IUO), Edo state NYSC orientation camp, banks and other governmental offices and establishments. All these developments attract all kinds of businesses, commercial activities and people to Okada, thus, increasing the population and their quest for water demand and satisfaction. The three project study areas are the artesian wells located in Old Boys Crown Estate, Okada (Location A), and its environs namely NYSC Permanent Camp in Iguomo Ovia-North East Local Government Area (Location B), and Iguedo in Ovia South-West Local Government Area (Location C). The geographical coordinates of the three project study location sites given in Table-1 were determined using GPS (Global Positioning System) Garmin 72 receiver shown in Fig. 1. The sites of the flowing artesian wells are shown in Fig. 2 – Fig. 4.

Table-1 Address and G.P.S. Coordinates of artesian wells under study.

SAMPLE/ LOCATIONS	ADDRESS	G.P.S CO ORDINATES	
		Latitude	Longitude
A	Campus 2, Old boys, Crown Estate, Igbinedion University, Okada	$6^{0}43^{1}14.0''$N	$5^{0}23^{1}45.0''$E
B	NYSC Permanent Site, Iguomo.	$6^{0}44'4.64''$N	$5^{0}23'35.04''$E
C	Iguedo Town (MDGS) project	$6^{0}43^{1}49.3''$N	$5^{0}23'44.8''$E

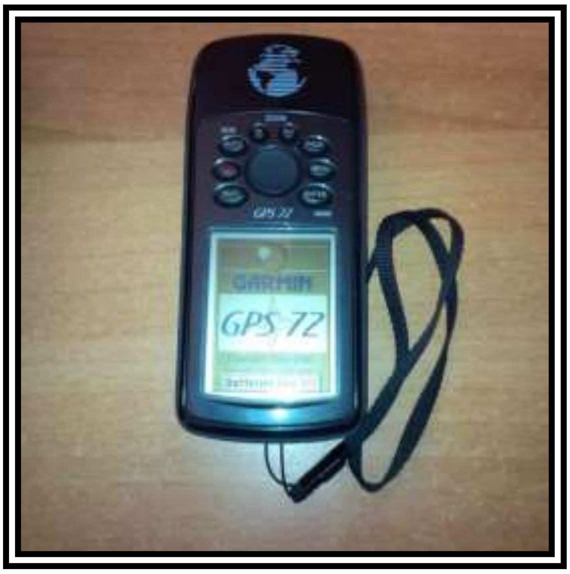

Fig.1 Garmin GPS 72 receiver used for geo-location of sampling points


Fig. 2 Artesian well in Location A


Fig. 3 Artesian well in Location B

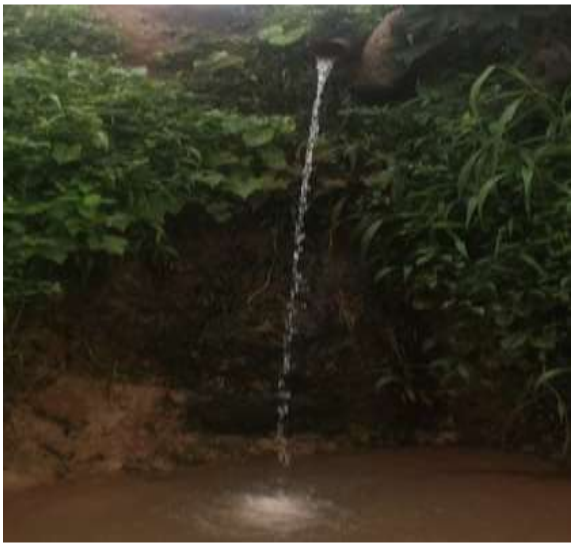
Fig. 4 Artesian well in Location C

MATERIAL AND METHOD

2.1. Laboratory Investigation of Water Quality Parameters

Samples were collected from the three sources of artesian wells in the different locations mentioned. The samples were collected as early as 6.30am on 2nd March 2018 for the determination of water quality of the artesian wells. Collection, preservation and transportation of the water samples to the laboratory followed the standard guideline recommended by WHO (1996). Samples were properly labeled to avoid mix up. At any point of collection, the sterilized sample bottles were rinsed, three times thoroughly with the artesian well water to be sampled before the main water sample was collected. The black bottles were air tightened for the analysis of BOD after five days, to prevent photosynthetic oxygen generation. Samples were also collected for the analysis of other chemical parameters.

MacGill Engineering and Technical Services located at No 234 Murtala Mohammed Way; Benin City is the laboratory used for the water quality analysis. For the Electrical Conductivity (EC), Total dissolved solids (TDS), pH, Temperature and Dissolved Oxygen (DO) water quality parameters, on-site measurements were carried out because the parameters change with storage time (WHO, 1996). pH, EC, temperature and TDS were all measured using multi-portable meter (HI 9813-6) while DO was examined using DO meter (Lutron DO-5509, Range 0 – 20mg/l). These water samples were analyzed in triplicates to obtain the mean value of the parameters. The physico-chemical parameters tested were pH, Electrical conductivity (EC), Salinity, Total Dissolve Solids (TDS), Dissolved Oxygen (DO). Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Bicarbonate (HCO_3), Sodium (Na), Potassium (K), Calcuim (Ca), Magnesium (Mg), Chloride(Cl^-), Phosphorus (P), Ammonium(NH_4), Nitrite (NO_2), Nitrate (NO_3), Sulphate (SO_4), Iron (Fe), Manganese (Mn), Zinc (Zn),and Copper (Cu), Color, Turbidity, Total suspended solid (TSS), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Lead (Pb).

2.2. Measurement of Volume of Flow in the Various Locations and Data Analysis

Equipment used were 25 (twenty-five) litre (0.025m^3) container, stop watch and funnel. Immediately the container is placed under the flowing water with a guide of a funnel to enable accurate inflow of water to the can, the stop watch was started simultaneously. Immediately the can was filled the stop watch was stopped. The volume of water was recorded over the time interval of water flows. Rate of discharge in m^3/s was now estimated as given in equation 1

$$Q = \frac{V\,(m^3)}{T_2 - T_1(s)} = \frac{V(m^3)}{T(s)} \quad (1)$$

Measurement of the yield capacity of the artesian wells were carried out during morning (7 – 9am) and evening hours (4 – 6pm) starting from 1st April, 2018 for one month in each location. Average rate of discharge (Mean Discharge) was determined using volume of flow taken over severally interval of time given by equation 2. Mean hourly discharge, mean daily discharge, mean monthly discharge and Mean yearly discharge were also calculated using equation 3, 4, 5 and 6 respectively.

$$Q_{AV} = \frac{Q_i}{n} = \frac{Q_1 + Q_2 + Q_3 + \cdots \ldots\ldots\ldots + Q_n}{n} \quad (2)$$

$$Q_{AVhourly} = Q_{AV}\ x\ 3600\ \left(\frac{m^3}{h}\right) \quad (3)$$

$$Q_{AVdaily} = Q_{AV}\ x\ 3600\ x\ 24\ \left(\frac{m^3}{day}\right) \quad (4)$$

$$Q_{AVmonthly} = Q_{AV}\ x\ 3600\ x\ 24\ x\ 30\ \left(\frac{m^3}{month}\right) \quad (5)$$

$$Q_{AVyearly} = Q_{AV}\ x\ 3600\ x\ 24\ x\ 365\ \left(\frac{m^3}{yearly}\right) \quad (6)$$

2.3 Estimation of Population of Water Consumers and Water Demand

2.3.1. Estimation of Population of Water Consumers

The combined total population of Okada with its environs was 78,000 (Iguomo and Iguedo, 2006), extracted from National population Commission, 2006 and then projected. The projected population of water consumers for the present year of study (2018) using geometric growth rate, r = 1.5% was estimated using equation 7 which was still used to project water consumers for the next twenty-five (25) years being the design service period for the water supply scheme.

$$P_t = P_0(1+r)^{t_f - t_0} \qquad (7)$$

2.3.2. Estimation of Water Demand of the Population.

The unit water demand or basic water consumption standard for small town and semi urban area is 120L/p/day or 0.12m^3/p/day according to the national water supply and sanitation policy (NWSSP) further 10% of total water demand may be added as water losses. The water demand for the community is calculated using equation 8.

$$Total\ water\ demand = P\ x\ \left(\frac{0.12m^3}{p/day}\right) x\ 1.2 \qquad (8)$$

where,

1.2 = Peak value /day (Agunwamba, 2000)

RESULTS AND DISCUSSION

3.1 Laboratory Result of Water Quality Parameters

The obtained laboratory results of water quality analysis of the three (3) artesian wells and the maximum permitted limit set by NSDWQ for each water quality parameter are given in Table 2.

Table-2 Results of the laboratory water quality test of the artesian wells in comparison with NSDWQ recommended value.

WATER QUALITY PARAMETERS	Unit	SAMPLE A	SAMPLE B	SAMPLE C	NSDWQ	REMARK
pH	mg/l	5.1	5.3	5.6	6.5 – 8.5	Acidic
EC	US/cm	66.3	76.1	82.5	1000	Ok
Salinity	g/l	0.030	0.034	0.037	-	-
Color	Pt.co	ND	ND	ND	15	ok
Turbidity	NTU	ND	ND	ND	5	ok
TSS	mg/l	ND	ND	ND	-	ok
TDS	mg/l	32.9	38.1	41.3	500	ok
DO	mg/l	6.9	6.5	7.1	-	ok
BOD	mg/l	1.5	1.1	9.2	-	ok
COD	mg/l	8.3	7.9	9.2	-	ok
HCO_3	mg/l	9.7	10.5	12.4	-	ok
Na	mg/l	0.47	0.32	0.56	200	ok
K	mg/l	0.11	0.08	0.14	-	ok
Ca	mg/l	1.57	1.38	1.90	-	ok
Mg	mg/l	0.68	0.54	0.79	0.2	Not ok
Cl	mg/l	17.7	25.4	35.5	250	ok
P	mg/l	0.11	0.19	0.18	-	ok
NH_4N	mg/l	0.007	0.005	0.006	-	ok
NO_2	mg/l	ND	ND	ND	0.2	ok
NO_3	mg/l	0.67	0.94	0.7	50	ok
SO_4	mg/l	0.13	0.18	0.24	100	ok
Fe	mg/l	0.21	0.19	0.26	0.3	ok
Mn	mg/l	0.013	ND	0.017	0.2	ok
Zn	mg/l	0.08	0.05	0.10	3	ok
Cu	mg/l	ND	ND	0.004	1	ok
Cr	mg/l	ND	ND	ND	0.05	ok
Cd	mg/l	ND	ND	ND	0.003	ok
Ni	mg/l	ND	ND	ND	-	ok
Pb	mg/l	ND	ND	ND	0.01	ok

*ND – Not detected

Excluding pH and Mg, all other water quality parameters are within the recommended limit established by NSDWQ. pH of all the samples shows acidic which means it could be soft and corrosive. And such water can leach metals such as iron, copper, lead, zinc, etc., which are detrimental to health. Magnesium violated the recommended limit established at 0.20mg/L. Consumption of high concentration of magnesium in drinking water causes laxative effect and osmotic diarrhea (USEPA, 2009). Nine (9) parameters including some heavy metal were not detected in the samples and they are color, turbidity, TSS, NO_2, Cu, Cr, Cd, Ni and Pb. Therefore, the artesian well have no significant threat from heavy metals.

3.2 Discharge (Yield Capacity) of the Different Artesian Wells

Measurement and calculation of rate of discharge for location A during morning hours on the first day is given in Table 3, while for location B and C are given in Tables 4 and 5 respectively. The daily, hourly, monthly and yearly mean discharges are summarized in Table 6.

Table-3 Measured volume (V) and discharge (Q) of artesian well in location A,

No. of Test	Time Start T_1 (s)	Stop Time T_2 (s)	Period of flow $T = T_2 - T_1$ (s)	V (Volume of water) m^3	Discharge Q $Q = \frac{V}{T}\ (m^3/s)$
1.	00:00	00:30	30	0.025	0.000833333
2.	00:00	00:27	27	0.025	0.000925926
3.	00:00	00:28	28	0.025	0.000892857
4.	00:00	00:27	27	0.025	0.000925926
5.	00:00	00:30	30	0.025	0.000833333
6.	00:00	00:28	28	0.025	0.000892857
7.	00:00	00:30	30	0.025	0.000833333
8.	00:00	00:27	27	0.025	0.000925926
9.	00:00	00:27	27	0.025	0.000925926
10.	00:00	00:29	29	0.025	0.000862069
11.	00:00	00:30	30	0.025	0.000833333
12.	00:00	00:28	28	0.025	0.000892857
13.	00:00	00:29	29	0.025	0.000862069
14.	00:00	00:28	28	0.025	0.000892857
15.	00:00	00:29	29	0.025	0.000862069
16.	00:00	00:28	28	0.025	0.000892857
17.	00:00	00:30	30	0.025	0.000833333
18.	00:00	00:28	28	0.025	0.000892857
19.	00:00	00:27	27	0.025	0.000925926
20.	00:00	00:29	29	0.025	0.000862069
				Total Discharge =	**0.017601715**

Total discharge for twenty (20) test carried out is 0.017601715 m^3/s

Table-4 Measured volume (V) and discharge (Q) of artesian well in location B.

No. of Test	Time Start T_1 (s)	Stop Time T_2 (s)	Period of flow $T = T_2 - T_1$ (s)	V (Volume of water) m^3	Discharge Q $Q = \frac{V}{T}\ (m^3/s)$
1.	00:00	00:29	29	0.025	0.000862069
2.	00:00	00:28	28	0.025	0.000892857
3.	00:00	00:29	29	0.025	0.000862069
4.	00:00	00:28	28	0.025	0.000892857
5.	00:00	00:27	27	0.025	0.000925926
6.	00:00	00:27	27	0.025	0.000925926
7.	00:00	00:27	27	0.025	0.000925926
8.	00:00	00:27	27	0.025	0.000925926
9.	00:00	00:27	27	0.025	0.000925926
10.	00:00	00:28	28	0.025	0.000892857
				Total Discharge =	0.009032339

Total discharge for ten (10) test carried out is 0.009032339m³/s

Table-5 Measured volume (V) and discharge (Q) of artesian well in location C.

No. of Test	Time Start T_1 (s)	Stop Time T_2 (s)	Period of flow $T = T_2 - T_1$ (s)	V (Volume of water) m^3	Discharge Q $Q = \frac{V}{T}\ (m^3/s)$
1.	00:00	00:39	39	0.025	0.0006410256
2.	00:00	00:39	39	0.025	0.0006410256
3.	00:00	00:39	39	0.025	0.0006410256
4.	00:00	00:39	39	0.025	0.0006410256
5.	00:00	00:39	39	0.025	0.0006410256
6.	00:00	00:38	38	0.025	0.0006578947
7.	00:00	00:41	41	0.025	0.0006097561
8.	00:00	00:40	40	0.025	0.0006250000
9.	00:00	00:39	39	0.025	0.0006410256
10.	00:00	00:39	39	0.025	0.0006410256
11.	00:00	00:40	40	0.025	0.0006250000
12.	00:00	00:40	40	0.025	0.0006250000
13.	00:00	00:38	38	0.025	0.0006578947
14.	00:00	00:39	39	0.025	0.0006410256
15.	00:00	00:39	39	0.025	0.0006410256
16.	00:00	00:38	38	0.025	0.0006578947
17.	00:00	00:39	39	0.025	0.0006410256
18.	00:00	00:38	38	0.025	0.0006578947
19.	00:00	00:39	39	0.025	0.0006410256
20.	00:00	00:39	39	0.025	0.0006410256
				Total Discharge =	**0.0128086427**

Total discharge for twenty (20) test carried out is 0.0128086427m³/s

Table-6 Yield Capacity of the Artesian Wells.

Locations	Discharge				
	Q_{AV} (m³/s)	**Q_{AVh} (m³/h)**	**$Q_{AVdaily}$ (m³/day)**	**$Q_{AVmonthly}$ (m³/month)**	**$Q_{AVyearly}$ (m³/year)**
Artesian well A	0.0008765	3.1554	75.7296	2271.888	27641.304
Artesian Well B	0.0008999	3.23964	77.75136	2332.5408	28379.2464
Artesian Well C	0.0006402	2.30472	55.31328	1659.3984	20189.3472
Total yield Capacity of the artesian well			**208.7942**		

The combined yield capacity of the three artesian wells studied is 208.294m³/day.

3.3 Population of Water Consumers and Water Demand

3.3.1 Population of Water Consumers

Using equation 7, population of water consumers were projected as given in Table 7.

Table-7 Projected population of water consumers

S/N	Year	Initial Population P_0	Projected Population $P_t = P_0(1+r)^{t_f - t_0}$
1.	2006	78000	78000
2	2018	78000	93258
3.	2028	78000	108230
4.	2038	78000	125605
5.	2043	78000	135313

Population of water consumers in 2018 is Nine-three thousand, two hundred and fifty-eight (93,258) while for the next twenty-five years, the population is estimated to have increased to one hundred and thirty-five thousand, three hundred and thirteen (135313).

3.3.2 Water Demand of Consumers

Using equation 8, the total water demand of the community is summarized in Table 8.

Table-8 Total estimated water Demand of the consumers in the Community.

Year	Population	Unit Demand	Peak Value	Estimated Water Demand (m^3/day)
2018	93258	0.12	1.2	**13429**
2028	108229	0.12	1.2	**15585**
2038	125605	0.12	1.2	**18087**
2043	135313	0.12	1.2	**19485**

The estimated water demand for 2018 is 13,428m^3/day while for the projected 25 years is 19,485m^3/day.

3.4 Assessment of Adequacy of the Yield Capacity of The Artesian Wells As Proposed Viable Source of Water Supply.

Adequacy of yield capacity of the artesian wells as proposed viable source of water supply is assessed or carried out by comparing it with estimated present year (2018), 2028, 2038- and 25-year projected water demand (2043) as summarized in Table 9.

Table-9 Artesian well yield capacity and projected target water demand

Year	Population	Estimated water Demand (m^3/day).	Total Yield capacity of artesian wells (m^3/day).	Comment
2018	93258	13429	208.79	-13220.21 Deficit
2028	108229	15585	208.79	-15376.21 Deficit
2038	125605	18087	208.79	-17878.21 Deficit
2043	135313	19485	208.79	-19276.21 Deficit

The combined total yield of the three artesian wells (208.72 m^3/day) when compared to the present water demand for 2018 (13,429 m^3/day) and 25 years target water demand (19,485 m^3/day) is grossly inadequate as its result into huge deficit of 13,220.21 m^3/day and 19,276.21 m^3/day respectively. Therefore, the three artesian wells cannot meet up the estimated water demand. More boreholes are required to be provided within the projected study area in other to serve as source of water supply for Okada and its environs.

CONCLUSION

Water quality parameters analyzed were within the recommended standard excluding pH and Magnesium that exceeded the recommended limit in the three artesian wells sampled. The measured mean yield of the three artesian wells respectively are 75.7296m^3|day for location A,77.7513m^3|day for location B and 55.3132m^3|day for location C. The combined total yield of the three artesian wells (208, 72 m^3/day) when compared to the present water demand (13,429 m^3/day) and 25 years target water demand (19485 m^3/day) is grossly inadequate as its result into huge deficit of 13,220.21 m^3/day and 19,276.21 m^3/day respectively. When the estimated total combined yield of the artesian wells for the present year (2018) and ultimate target year (2043) is compared with the estimated water demand for the present year and projected ultimate year, the yield is found to be grossly inadequate to meet up the water demand. Therefore, more artesian wells are needed to be dug in order to provide an adequate viable water supply scheme for Okada and its environs.

RECOMMENDATION

There is need to also assess the bacteriological nature of the artesian wells to determine the degree of microbial pollution especially for drinking purposes. Secondly treatment is needed to reduce pH and Magnesium level of the well for the provision of clean water supply for the people living within this Community. More boreholes are needed to be provided within this project study area in other to meet their water demand.

CONFLICT OF INTEREST

We hereby state that no conflict of interest will arise in any form from the publishing of this research work.

REFERENCES

Agunwamba, J.C (2000) "Water engineering systems" Immaculate publications limited N0 2 akustreet, N/layout, Enugu, Nigeria 1stedition, Page 42 – 44.

American Public Health Association (APHA) (1999): "Standard Methods for the the Examination of Water and Wastewater", 20th edition. American Water Works Association, Water Environment Federation, Washington, DC

Ezomo, F.O.; Biose, O and Ajieh, M. U. (2013): "Evaluation of Groundwater in Uromi, Edo State, Nigeria."International Journal of Scientific & Engineering Research, Vol. 4, Issue 3. ISSN 2229 – 5518. www.ijser.org. Accessed on 8th April,2016.

National Population Commission Report, 2006.

National Water Supply and Sanitation Policy.

WHO/UNEP (1996): "Water Quality Assessment a guide to use of biota, sediments and water in environmental monitoring" 2nd edition. Chapman @ Hall Publishers. ISBN 0419215905 (HB), 0419216006 (PB)

USEPA (2009) "Groundwater and Drinking water" www. Epa.gov. Accessed on 7th February, 2017.