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Effect of seasonal drawdown variations on groundwater quality in Nigeria

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Water samples from twenty (20) shallow wells in Akure were analyzed during the wet and dry seasons in 2009 to ascertain the effect of drawdown on their qualities. Twenty (20) parameters consisting of five physical, twelve chemical and three heavy metals were tested for in the samples. The parameters included dissolved and suspended solids, turbidity, the pH, alkalinity, calcium, sulphate, nitrate, magnesium, electrical conductivity, lead, iron and manganese, were determined using standard procedures. Preliminary findings showed that 40% of the wells had poor drainage system and water levels expectedly varied significantly with seasonal change. However, most of the analysis showed significantly negative and weak correlations for the observed parameters during the two seasons of study. The revealed water quality was independent on drawdown but dependent on other parameters such as hygiene, pollution due to usage, underlying rock formation materials and proximity to polluting sources peculiar to emerging African cities.

Key words: Shallow well, pollution, water level, seasonal change, parameters.

INTRODUCTION

Lack of clean water and fresh water pollution are among many plausible causes of potable water shortage and outbreak of water related infections especially in the developing nations. Increase in pollution and its necessities have led to deterioration in both surface and sub-surface water (Shyamala et al., 2008). In Nigeria for instance, Jaji et al. (2007) reported that only 48% of the inhabitants of the urban and semi urban areas and 39% of rural areas inhabitants have access to potable water supply. This confirms the World Health Organization (WHO) report which stated that one-fifth of the urban dwellers in developing countries and three quarters of their rural dwelling population do not have access to reasonably safe water supplies (WHO, 2004). This has placed tremendous pressure on groundwater supplies as alternative to the shortage being experienced, thereby resulting in rapidly-changing drawdown in most wells (Howard and Bartram, 2003).

Moreover, due to this pressure, increased usage has not only put pressure on the rate of drawdown but also responsible for pollution (Ikem et al., 2002). Groundwater pollution is believed to be mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010). However, recent studies have shown that poor drainage especially around wells, over-exploitation, high hydraulic conductivity of soil and indiscriminate use of herbicides and inorganic fertilizers for subsistence agricultural practices also played prominent role in its pollution (Kannan, 2008). Igbinosa and Okoh (2009) reported the damaging consequences of leachate infiltration into groundwater bodies on life expectancy of such water consumers, while Quinn et al. (2006) enumerated its effect and that of delayed drawdown on moist plant productivity and wetland ecology.

Several studies have been conducted by Al-Awad (2004), Paredes and Lund (2006), Quinn et al. (2006), Kannan (2008) and Al-Sabahi et al. (2009) on excessive

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pressure rate of drawdown on groundwater qualities and quantities, aquatic biota, recharge-discharge relationships and health implications with little or no consideration on the probable effect of seasonal drawdown variation and its associated factors on water quality. The objective of the study therefore was to access probable effects of seasonal drawdown variation on groundwater quality in Akure, Nigeria. The study would also consider other associated factors that may be responsible for groundwater contamination within the region of interest.

MATERIALS AND METHODS

Study area

The study area was Akure, Ondo State, Nigeria. Akure is located on latitude 7° 15' 0" N and longitude 5° 12' 0" E, Southwestern part of Nigeria. It has a tropical humid climate with two distinct seasons: a relatively dry season from November to March and rainy season from April to October, though now modified and unpredictable due to the effects of climate change. Akure has an average annual rainfall within the range of 1405 and 2400 mm of which rainy season accounts for over 90% and the month of April marks the beginning of rainfall.

Experimental procedure

Twenty (20) shallow wells in Akure were randomly selected for use in this study which indicated two well in one zone. Their depths and diameters were measured using measuring rule and line sinker. Physical inspection of wells was carried out to gather information such as well development and completion. Type of completion whether ringed or not, age of well, distance from polluting source example abattoir, landfill, etc and information on diurnal fluctuation and differential local discharges were collected. Oral interviews and structured questionnaires were employed in collecting these and other information about the wells. A zonal classification based on district location was done for easy data collation and reporting. The description and associated information on the selected wells are shown in Table 1. The selected wells were measured in the two distinct seasons in Nigeria; dry and wet. The first round measurements were conducted in February 2009, while second round measurements took place in August, 2009.

Sampling and analysis techniques

Water sample collection was done using standard techniques described by AOAC (2000). The physical analyses conducted included, temperature, turbidity and dissolved solids (DS). For chemical analysis, the following parameters were analyzed: pH, electrical conductivity (EC), chloride (Cl), sulphate (SO_4), nitrate (NO_3), Iron (Fe), suspended solids (SS), total solids (TS), potassium (K), total alkalinity (TA), total hardness (TH), sodium (Na), calcium hardness (CH) and magnesium hardness (MH). Manganese (Mn) and lead (Pb) were also investigated for heavy metals and free carbon dioxide (CO_2) was also determined in all the samples considered using standard methods for the examination of water (APHA, 2005; AOAC, 1990). The pH was determined using a Mettler Toledo pH meter by direct measurement, analog mercury thermometer was used in making temperature measurements and a Hach 2100A turbidimeter was used for turbidity determination.

To ensure a high degree of accuracy, samples collection was done in the morning before the wells were put into use and laboratory sampling bottles were used for sampling. The samples were covered with cork to prevent spillage and contamination and were kept in the laboratory at 4°C before the commencement of analysis. The wells under construction or development were not considered, two well-spaced (20 m distance) wells were chosen in each of the 10 selected zones and special attention was given to two abattoirs in Akure during the investigation.

Statistical analysis

Paired sample t-tests were used to analyze significant differences between the observed parameters during different seasons and also between the drawdown rates observed. The probability levels used for statistical significance were $P < 0.05$ for the tests.

RESULTS AND DISCUSSION

From the preliminary observations and structured questionnaire, the following were observed (Table 1); Forty percent (40%) of the zones where water samples were collected had poor drainage system. Seventy percent (70%) of the wells whose water samples were analyzed were being used for domestic purposes. Eighty percent (80%) of the wells were protected with iron lids; ten percent (10%) were covered with wooden cover, while the other ten percent (10%) had no cover at all. Eighty-five percent (85%) of the wells had ring-shaped concrete as support and the number of the rings depended on the depth of the well, while fifteen percent (15%) had no casing.

The mean temperature value for all locations during the dry season (Table 2) was 28.4°C, with the highest temperature value of 30°C recorded in samples from FUTA 1 and FANIBI 1 locations, respectively. The mean temperature during wet season (Table 3) was 22.87°C, while the highest value was recorded in sample B1 (FUTA 2). The mean temperature during the dry season was higher due to the prevalent atmospheric conditions. Higher number of sunshine hours would naturally implied lower relative humidity, temperature increase of water bodies due to conduction and convection processes by the earth crust. These were, however, different from the World Health Organization (WHO, 2004) values of 32°C high average value and 27°C ambient temperature under the same conditions. On the other hand, this was similar to the findings reported by Jaji et al. (2007) in his study. Pollutants, among many other factors may cause temperature increase in water in the present situation and similar result was also recorded by Al-Sabahi et al. (2009).

Furthermore, the well depths remained the same in the two seasons but water levels in the well fluctuated due to variation in weather during the seasons. In all the wells sampled, less than 5% had water depth above 2 m, indicating that the wells were mostly shallow wells whose yield was small. The average depth of the wells ranged between 4 and 12 m (Figure 1). The drawdown in water

Table 1. Locations and features of wells form the study area.

Sample	Location	Depth (m)	Diameter(m)	Casing/Lining	Cover type	Well use	Remark
1	FUTA Zone						
A	FUTA 1	10.99	0.85	Ringed concrete	Iron	Domestic	Clean environment
B	FUTA 2	8.29	0.82	Ringed concrete	Iron	Domestic	Dirty environment
2	LEO Zone						
C	LEO 1	6.70	0.85	Ringed concrete	Iron	Domestic	Dirty environment
D	LEO 2	5.21	0.93	Ringed concrete	Iron	Domestic	Clean environment
3	IJOKA Zone						
E	IJOKA 1	5.57	0.82	Not ringed	No cover	Domestic	Dirty environment
F	IJOKA 2	6.14	0.92	Ringed concrete	Iron	Domestic	Clean environment
4	SIJUWADE Zone						
G	SIJUWADE 1	8.82	1.05	Ringed concrete	Iron	Domestic	Dirty environment
H	SIJUWADE 2	5.67	0.73	Ringed concrete	Iron	Domestic	Clean environment
5	FANIBI Zone						
I	FANIBI 1	3.91	0.91	Ringed concrete	Iron	Domestic	Clean environment
J	FANIBI 2	4.88	1.04	Ringed concrete	Iron	Domestic	Clean environment
6	OKE-OGBA Zone						
K	OKE OGBA 1	9.12	0.82	Not ringed	Iron	Domestic	Erosion around well
L	OKE OGBA 2	7.28	0.70	Ringed concrete	Iron	Domestic	Clean environment
7	OBA NLA Zone						
M	OBA NLA 1	3.65	0.91	Ringed concrete	Iron	Domestic	Dirty environment
N	OBA NLA 2	5.33	0.95	Ringed concrete	Wood	Domestic	Clean environment
8	OSHOKOTI Zone						
O	Oshokoti 1	5.79	0.91	Ringed concrete	Wood	Domestic	Clean environment
P	Oshokoti 2	4.22	0.73	Ringed concrete	Iron	Domestic	Clean environment
9	ARAROMI Zone						
Q	Araromi 1	4.30	1.04	Not ringed	No cover	Domestic	Dirty environment
R	Araromi 2	3.59	0.73	Ringed concrete	Iron	Domestic	Erosion around well
10	OKE-ARO Zone						
S	Oke aro 1	5.91	0.67	Ringed concrete	Iron	Domestic	Clean environment
T	Oke aro 2	3.47	0.85	Ringed concrete	Iron	Domestic	Clean environment

levels during the two seasons was also shown in Figure 1. There were pronounced reduction in water levels during the dry season and obvious increase in water level during the wet season in all the wells; it ranged from 0.2 to 1.8 m between the two water levels in the two seasons considered (Table 4). The changes in water levels may be due to the yield of the aquifer, location of a deep well close to the vicinity, depth and diameter of the wells. This was corroborated by Mohammed et al. (2009). Smaller diameters and deeper wells tend to have higher change in water level than the current observations.

More also, turbidity values ranged from 1.1 to 10 NTU in dry season (Table 2) samples and from 1.2 to 18 NTU in wet season samples (Table 3). Some were higher than 5 NTU, the WHO stipulated values particularly in areas such as H1 (Sijuwade 2), L1, (Oke-ogba 2) and M1 (Obanla 1) during the dry season. In wet season, only M2 (Obanla 1) had values higher that 5 NTU. More locations had higher turbidity values during dry season due to higher demand for water as a result of its shortage. More users had contact with the wells using locally-made fetchers to draw water. This in turn detach the soil

Table 2. Analysis of results from field samples taken during dry season in February, 2009.

Sample	Well depth (m)	Water depth (m)	Temp (°C)	Turbidity (NTU)	EC (µmho/cm)	pH	TDS	SS	TS	TA	TH	CH	MH	Cl^-	SO_4	NO_3	Fe	K	Na	Mn	Pb	CO_2
A1	11	1.5	30	1.5	400	6.8	280	ND	312	122	106	74	38	27	ND	0.5	2.5	ND	20	10	ND	50
B1	8.3	1.1	28	1.1	340	6.5	231	ND	311	110	118	84	32	29	ND	0.4	0.2	20	10	ND	ND	30
C1	6.7	0.9	26	4.3	410	6.6	245	22	287	46	88	64	24	39	0.6	ND	0.3	ND	30	ND	ND	45
D1	5.2	0.6	30	2.2	550	6.4	232	ND	195	35	76	50	26	41	ND	ND	0.1	ND	0.2	0	ND	30
E1	5.6	0.4	27	4.5	180	6.4	77	13	90	58	76	70	46	42	60	ND	ND	10	0.1	ND	ND	60
F1	6.2	0.5	30	3.8	450	6.7	203	ND	190	40	80	45	35	35	ND	ND	0.2	91	0.2	ND	ND	80
G1	8.8	0.4	27	5.1	280	6.6	280	ND	312	12	88	62	26	39	ND	0.1	0.3	ND	30	0	ND	84
H1	5.7	0.3	27	10.0	520	6.1	210	ND	280	16	86	30	50	20	170	ND	ND	ND	18	0	ND	63
I1	3.9	0.7	30	2.5	420	6.0	140	44	294	58	92	70	22	48	ND	ND	0.2	ND	13	ND	ND	80
J1	4.9	0.4	30	2.7	600	6.8	194	ND	287	45	150	80	70	30	ND	ND	0.2	44	12	0	ND	95
K1	9.1	1.1	29	2.0	280	6.4	208	ND	316	49	73	50	20	33	ND	ND	0.1	ND	18	ND	ND	80
L1	7.3	0.6	29	15.0	220	6.5	134	ND	280	17	91	63	53	29	ND	0.1	ND	ND	11	ND	ND	60
M1	3.7	0.9	29	10.1	200	6.8	196	30	140	284	404	262	133	47	ND	ND	0.1	10	0.2	ND	ND	80
N1	5.1	0.7	29	8.0	180	6.4	280	19	130	200	350	150	100	25	ND	ND	0.2	198	0.2	0	ND	70
O1	5.8	1.0	27	1.5	200	6.8	120	10	140	154	356	88	26	23	300	ND	ND	20	10	ND	ND	50
P1	4.2	0.6	28	1.6	150	6.7	234	6	900	120	310	26	60	51	ND	0.5	0.2	0.4	26	ND	ND	60
Q1	4.3	0.6	29	3.8	220	6.4	154	27	154	84	420	296	124	60	135	135	1.3	ND	0.2	ND	ND	30
R1	3.6	0.2	29	2.9	685	6.8	150	2	170	326	76	58	18	58	0.3	ND	ND	70	0.2	ND	ND	85
S1	5.9	0.9	28	1.8	380	7.2	280	7	287	142	318	174	144	119	1.6	ND	ND	170	130	ND	ND	30
T1	3.4	1.1	28	2.1	720	6.6	370	ND	128	180	200	180	120	98	1.0	ND	ND	ND	0.1	ND	ND	60
WHO Standard				5 -10	1000	6.5- 8.5	500		1000	300	300	75	30	250	200	45	0.3	200	200	0.1	0.1	

Unless otherwise stated all measurements are in mg/l pH- dimensionless. ND. Not detected.EC.Electrical conductivity; TDS, total dissolved solid; SS, suspended solids; TS, total solid; TA, total alkalinity; TH, total hardness; CH, calciu, hardness; MH, magnesium hardness.

Table 3. Analysis of results from field samples taken during wet season in July, 2009.

Sample	Well depth(m)	Water depth(m)	Temp (°C)	Turbidity (NTU)	EC (µmho/cm)	pH	DS	SS	TS	TA	TH	CH	MH	Cl^-	SO_4	NO_3	Fe	K	Na	Mn	Pb	CO_2
A2	11	2.5	24	1.5	450	6.9	280	ND	280	140	138	76	62	58	6	0.5	2.5	10	20	0.1	ND	70
B2	8.3	2	26	1.2	360	6.5	239	7	246	120	84	46	38	20	ND	0.4	0.2	30	12	ND	ND	50
C2	6.7	1.6	22	1.5	620	6.9	324	ND	324	48	137	96	41	41	0.6	ND	0.3	10	30	ND	0.01	45
D2	5.2	1.1	23	2.3	780	7.2	200	ND	200	50	100	54	46	62	0.1	0.2	0.1	ND	15	0.1	ND	80
E2	5.6	0.9	22	3.8	200	6.7	50	ND	94	13	89	25	64	42	0.3	ND	ND	10	0.1	0.1	ND	60
F2	6.2	1.1	20	3.6	420	7.6	210	ND	210	50	80	41	39	38	ND	0.1	0.1	90	30	0.1	ND	80
G2	8.8	2.2	25	7	290	6.8	400	13	413	12	100	29	71	40	2.1	0.1	ND	ND	10	ND	0.1	87
H2	5.7	1.1	21	1.5	340	6.9	194	44	238	100	122	84	38	27	173	0.4	0.4	20	60	ND	ND	34

Table 3. Contd.

I2	3.9	2.3	23	3	620	7.3	434	ND	434	122	176	128	48	41	ND	0.1	0.1	ND	ND	ND	ND	25
J2	4.9	1	23	4.0	600	6.7	211	11	222	176	140	83	57	30	ND	ND	ND	45	30	0.1	ND	95
K2	9.1	2.5	24	2.6	250	6.8	280	133	413	51	80	52	28	30	ND	ND	0.1	ND	18	ND	ND	80
L2	7.3	1.9	25	12	270	6.5	79	19	98	152	99	51	48	20	ND	0.2	ND	ND	11	ND	ND	95
M2	3.7	1.8	21	18	360	6.8	232	22	254	291	291	192	99	58	ND	ND	0.4	10	20	ND	ND	20
N2	5.1	1.7	24	3.5	190	6.9	314	11	325	200	328	247	81	35	ND	ND	0.7	203	0.1	ND	ND	75
O2	5.8	2	22	1.5	290	7.2	130	ND	130	120	221	184	37	23	300	ND	ND	20	10	ND	ND	40
P2	4.2	2.1	23	3.0	480	6.7	256	3	920	111	420	285	135	20	ND	ND	ND	0.4	26	ND	ND	60
Q2	4.3	0.9	24	4.1	700	6.4	172	41	213	80	410	287	123	40	135	0.5	1.3	ND	0.2	ND	ND	30
R2	3.6	0.5	21	3.7	690	7.1	140	21	161	326	81	54	273	38	0.3	ND	ND	70	20	ND	ND	85
S2	5.9	2.2	24	1.8	400	6.5	291	17	308	130	321	181	140	118	113	ND	ND	167	130	ND	ND	45
T2	3.4	2.9	21	2.1	810	6.6	170	ND	170	128	293	191	102	98	1	ND	ND	ND	0.4	ND	ND	60
WHO Standard				5 -10	1000	6.5-8.5	500		1000	300	300	75	30	250	200	45	0.3	200	200	0.1	0.1	

Unless otherwise stated all measurements are in mg/l pH – dimensionless. ND. Not detected.EC.Electrical conductivity; TDS, total dissolved solid; SS, suspended solids; TS, total solid; TA, total alkalinity; TH, total hardness; CH, calciu, hardness; MH, magnesium hardness.

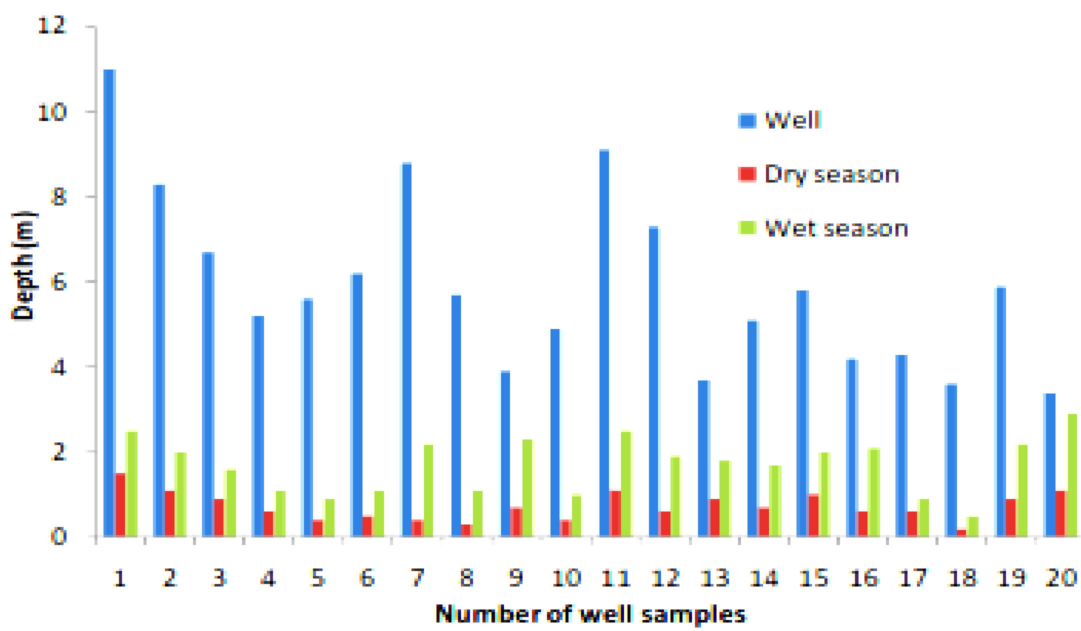

Figure 1. Comparisons of well depths with water depths in dry and wet seasons during the experiment.

Table 4. Water drawdown between the water levels in dry and wet seasons.

WELL	WD	DSD	WSD	DD
A1	11	1.5	2.5	1
B1	8.3	1.1	2	0.8
C1	6.7	0.9	1.6	0.7
D1	5.2	0.6	1.1	0.5
E1	5.6	0.4	0.9	0.5
F1	6.2	0.5	1.1	0.6
G1	8.8	0.4	2.2	1.8
H1	5.7	0.3	1.1	0.8
I1	3.9	0.7	2.3	1.6
J1	4.9	0.4	1	0.6
K1	9.1	1.1	2.5	1.4
L1	7.3	0.6	1.9	1.3
M1	3.7	0.9	1.8	0.9
N1	5.1	0.7	1.7	1
O1	5.8	1	2	1
P1	4.2	0.6	2.1	1.5
Q1	4.3	0.6	0.9	0.3
R1	3.6	0.2	0.5	0.2
S1	5.9	0.9	2.2	1.3
T1	3.4	1.1	2.9	1.8

particles from the unstable sidewalls of the well, mostly unlined which increased sediment deposit and turbidity values. These were lower than the values of Longe and Balogun (2002). When the turbidity values for both dry and wet seasons were subjected to statistical test (Figure 2), same pattern was observed in their behavior and significant (r = 0.69) at 95% confidence level (Table 5). However, when the well drawdown was compared with the turbidity values during two seasons, there was no significance with r- values 0.01 and 0.07 respectively (Table 6). The weak correlation showed that the well drawdown did not have any effect on the change in turbidity values observed.

Total hardness (TH) values ranged from 73 mg/L in K1 (Oke-ogba 1) to 420 mg/L in samples Q1 (Araromi1) (abattoir) during the dry season (Table 2) and from 80 mg/L in F2 (Ijoka 2) to 420 mg/L at P2 (Oshukoti 2) in wet season (Table 3), respectively. The WHO value of 300 mg/L is the maximum permissible standard for potable water, hence samples M1, N1, O1, P1, Q1, S1 and N2, Q2, P2 and S2 both in dry and wet seasons exceeded the standard and were adjudged as hard. Samples from Obanla 1 and 2, Oshokoti 1 and 2, Araromi 1 and Oke-aro 1 were hard having exceeded the permissible limit. Underlying rock formations, presence of calcium and magnesium carbonates may be present in the identified samples. The WHO (2004) reported that encrustation in water supply structure and an adverse effect on domestic use was probable in wells above its recommended value. The values were however higher than those obtained by Shyamala et al. (2008). Higher values of TH were observed in wet season when compared with the values in dry season which expectedly was due to higher volume of precipitation, infiltration and runoff which would subsequently have found its way into the aquifer thereby recharging the wells (Figure 3). Analyzing the comparisons, a strong significance (r= 0.91) existed between the values but weak correlation (P< 0.05) existed when the hardness values were compared with well drawdown in all the locations with r-values 0.10 and 0.21, respectively (Table 6).

Meanwhile, the electrical conductivity (EC) values ranged from 180 to 720 µmho/cm in dry season (Table 2) and 180 to 810 µmho/cm in wet season (Table 3) and all were still below 1000 µmho/cm recommended by the WHO for potable water. The EC values were, however, lower than the findings of Al Sabahi et al. (2009) since his groundwater samples were located near landfill and leachate infiltration would be high and hence the very high values. The EC values were surprisingly higher during the wet season when compared with the values obtained during the dry season (Figure 4) and the correlation relationships during the two season (r =0.69) showing relatively high variation. Traditionally, EC values should be lower in wet season due to dilution by increased volume of water. This reason for this observation is unknown; hence further study is suggested on it. Moreover, there was no significance (P< 0.05) when drawdown values were compared with EC values during dry and wet seasons, -0.15 and -0.18, respectively (Table 6), indicating

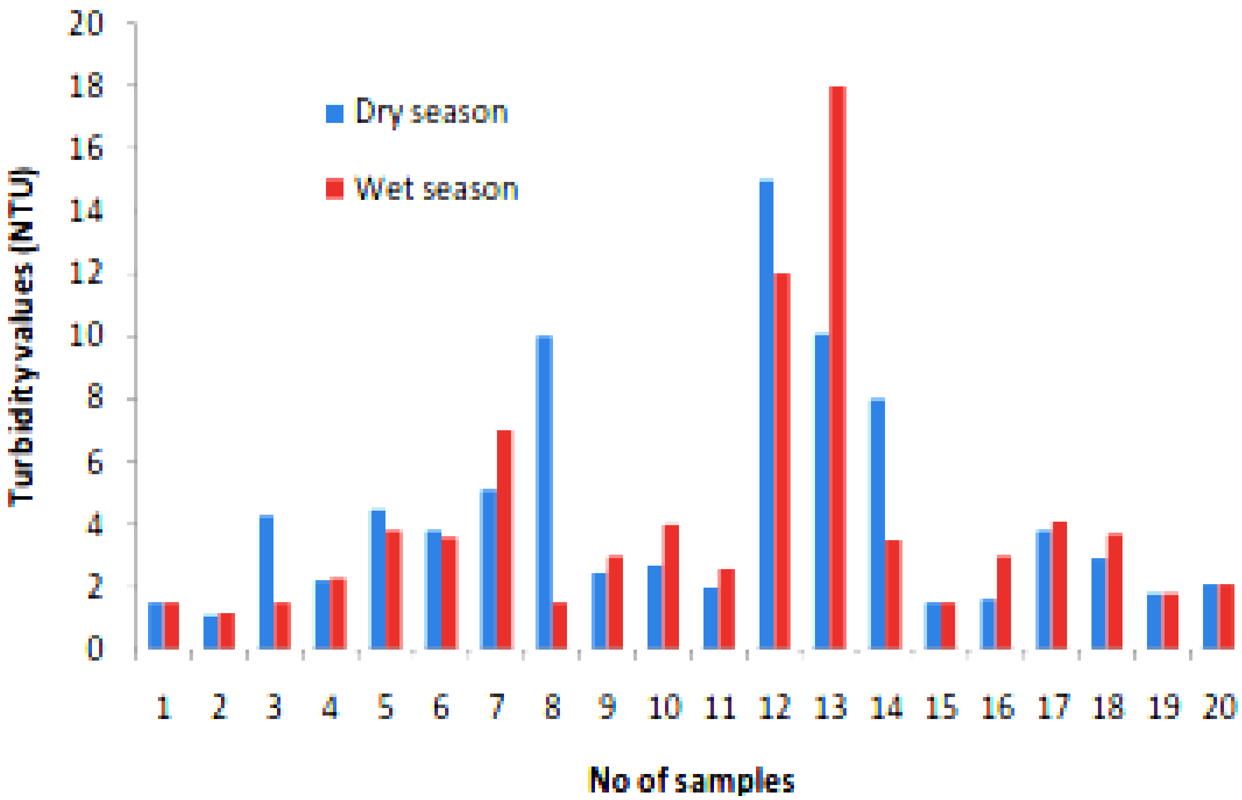

Figure 2. Comparisons of well samples with turbidity values in dry and wet seasons.

Table 5. Correlation analysis of water parameters analyzed in wet and dry seasons with water depth in dry season.

Parameter	WSD	WSTBD	WSTH	WSEC	WSCH	WSC
DSD	0.75	-0.14	0.15	-0.04	0.16	0.31
DSTBD		0.69	-0.06	-0.40	-0.06	-0.24
DSTH			0.91	0.03	0.91	0.27
DSEC				0.69	-0.32	0.36
DSCH					0.63	0.45
DSC						0.85

$P < 0.05$. WSD, Wet season depth; WSTBD, wet season turbidity; WSTH, wet season total hardness; WSEC, wet season electrical conductivity; WSCH, wet season calcium hardness; WSC, wet season chloride. DSD, dry season depth; DSTBD, dry season turbidity; DSTH- dry season total hardness; DSEC, dry season electrical conductivity; DSCH, dry season calcium hardness; DSC- dry season chloride.

Table 6. Correlation analysis of well water drawdown with selected parameters

Parameter	Dry season	Wet season
TH	0.10	0.21
C	0.26	0.22
CH	-0.08	0.16
EC	-0.15	-0.18
pH	-0.16	-0.04
TBD	0.01	0.07

Probability level is $P < 0.05$. TH, Total hardness; CH, calcium hardness; EC, electrical conductivity; TDB, turbidity.

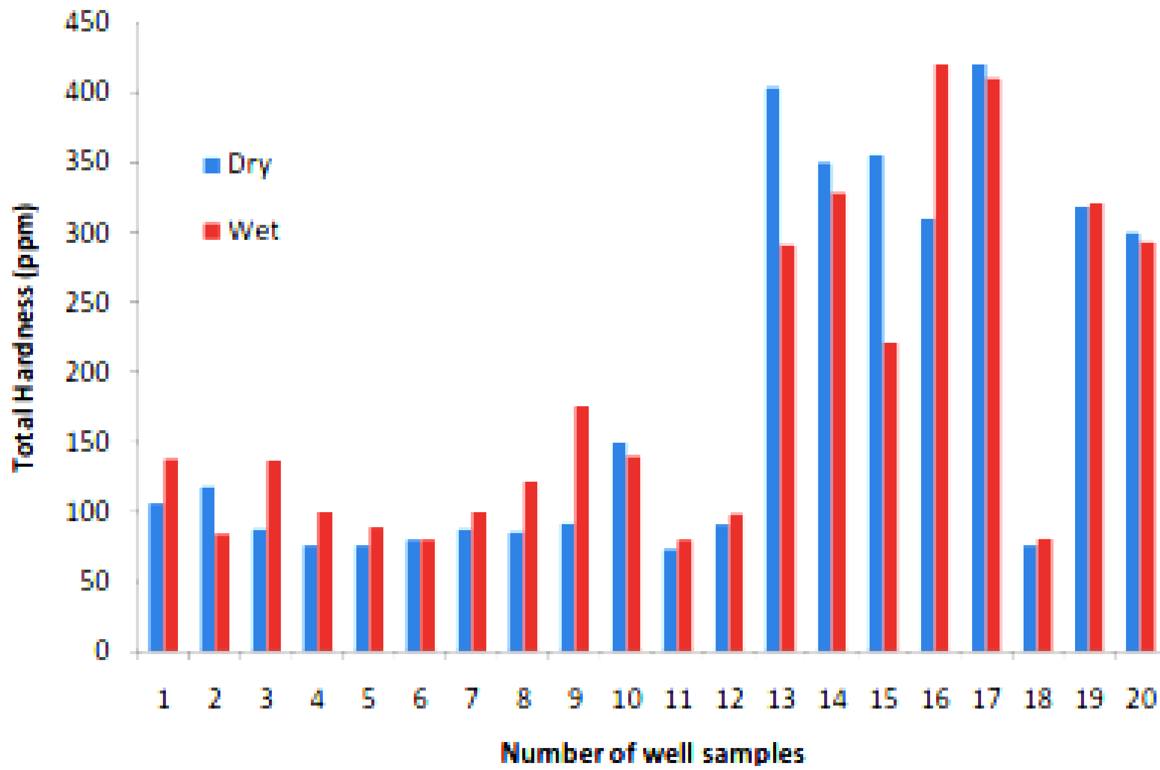

Figure 3. Comparisons of well samples with total hardness values in dry and wet seasons.

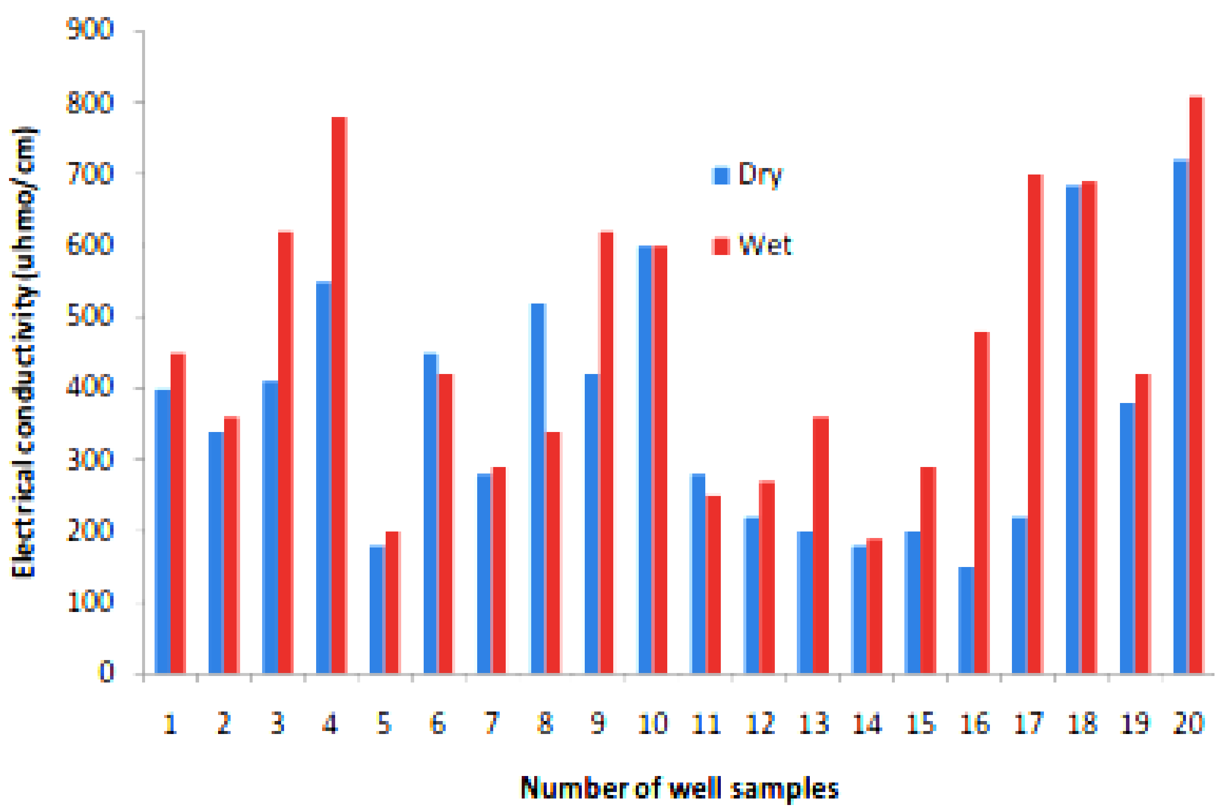

Figure 4. Comparisons of well samples with electrical conductivity values in dry and wet seasons.

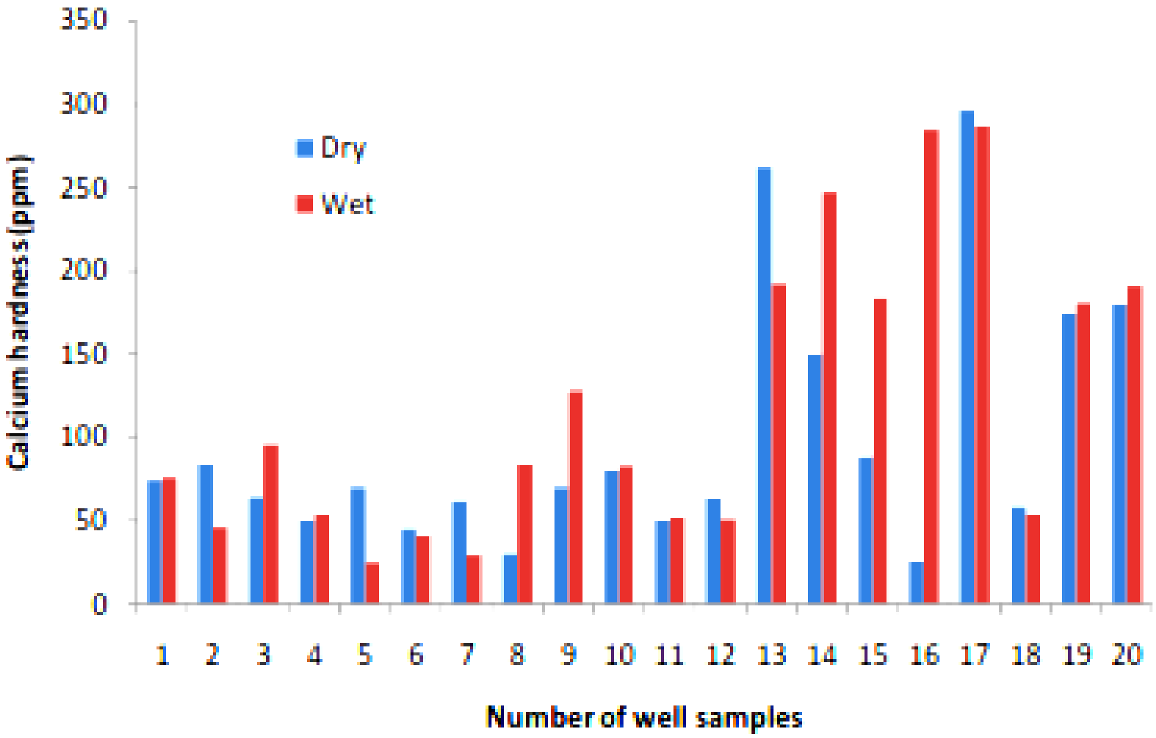

Figure 5. Comparisons of well samples with calcium hardness values in dry and wet seasons.

that the drawdown had no influence on the quality of water samples.

Figure 5 shows the comparisons of well samples with calcium hardness values in dry and wet seasons. As for chloride ion, all the samples were below the WHO limit of 250 mg/L, however, values observed from S1 and S2 (Oke aro 1 and Oke aro 2) had high values 119 and 118 ppm during the dry and wet season, respectively (Figure 6). The values were much lower than the findings of Ikem et al. (2002) and Al-Sabahi et al. (2009), but similar and agreed with the findings of Longe and Balogun (2002). There was significant difference (P< 0.05) between the two pairs with correlation value r = 0.85 (Table 5) and insignificant difference between the chlorides values in dry and wet seasons when compared with well water drawdown (r = 0.26 and 0.22) (Table 6) at P < 0.05. Other parameters analyzed such as sulphate, potassium, magnesium, nitrate and sodium were within the WHO (2003) permissible level for potable water, hence do not pose health risk to the consumers. Heavy metals such as lead, manganese and iron had very low concentration and some were not even detected in all the samples analyzed (Tables 3 and 4).

The bacteriological assay conducted also did not show presence of any pathogenic organisms and/or total bacteria count, which inferred that pollution due to feces either from humans or animals were less likely to occur. This was probably due to the fact that all but one well was covered and none was located near a stream or river which may be carrier of any bacteria organisms (Table 1). The analyses between each sample within the two seasons were significant (P < 0.05), while their correlation with the drawdown in all the wells were not significant at the same confidence level (Table 5). Some were negatively–weak correlated, showing that there was no relationship whatsoever between the samples with respect to drawdown of water level experienced during the dry season in all the wells (Table 6); Al-Awad (2004) and Paredes and Lund (2006) findings in their studies pointed to this fact.

A major factor that may be responsible for pollution could be lack of functional drainage systems around the well. Forty percent (40%) did not have drainage and this would result in polluted water finding its way back into the well by infiltration. Though, the concentration of the contaminants may have been reduced by the infiltration process, this however does not prevent pollutants from getting into the well thereby compromising the quality. The mode of wells usage could also be responsible for the pollution observed in the water samples. Since the wells were cited among the communities, indiscriminate domestic usage and discharging used water near the wells in an unhygienic manner could also be responsible for the contamination. Also, location of pit latrines, septic tanks and other polluting sources such as landfills and abattoirs within the communities were most probable sources of pollution of the surrounding wells. Leachate from these pollution sources would easily have found

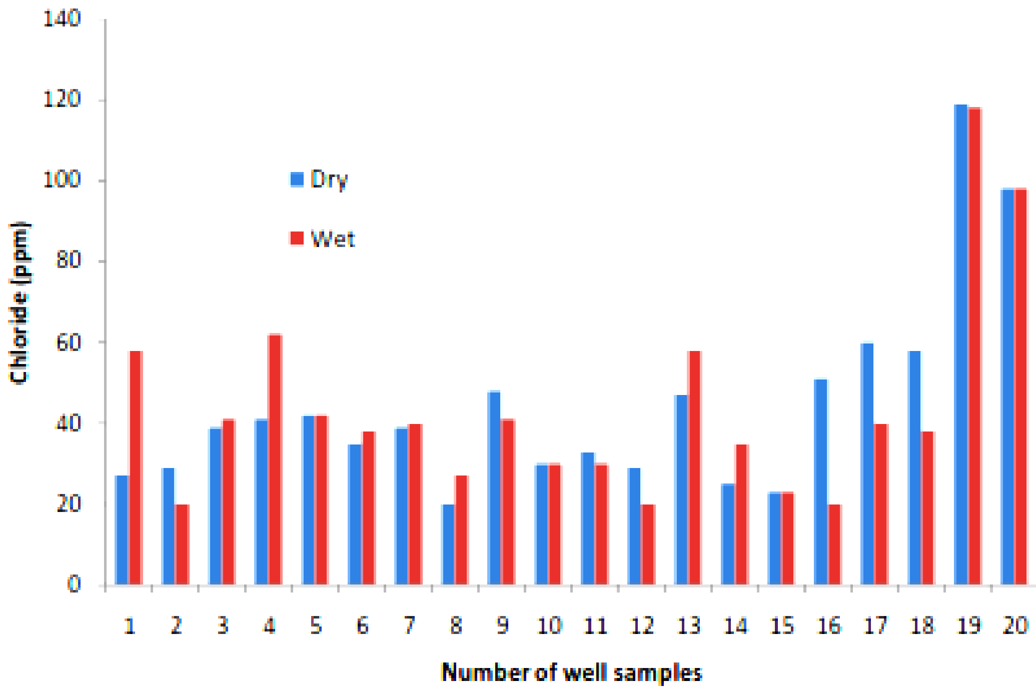

Figure 6. Comparisons of well samples with chloride values in dry and wet seasons.

their way into these wells unnoticed. Sangodoyin (1991) therefore suggested the location of domestic wells to be 30 m radially away from any polluting source. The pollution from the underlying rock formation and agricultural pesticides used for subsistence farming could also be responsible for the change in water quality in the area.

Conclusion

An attempt was made to establish the effect of well water drawdown variations on the quality of water in Akure and its environs, and 20 different parameters were analyzed from samples of 20 wells chosen for the study. Preliminary findings indicated that most of the inhabitants within the well locations depended on it for domestic purposes despite the unhygienic state of some of the wells, such as lack of cover and casing. All the parameters analyzed showed significant differences at 95% confidence interval when compared between the two seasons considered, but were not significant at the same interval when compared with the water drawdown observed during the dry season. The marginal potability of the water was never in absolute doubt, giving the number that had casings and lid covers since almost all the parameters tested were within the permissible limit by the WHO for portability. However, concern exists when the water quality fluctuates due to diurnal changes in water levels occasioned by change in weather pattern.

This study revealed the independence of drawdown on water quality in the area but on factors such as the hygiene, as less than 40% had poor drainage which will permit inflow of polluted water back into the well, thereby compromising the quality. Other factors could be the mode of usage, proximity to polluting sources such as pit latrines, septic tanks, landfills and abattoirs, which were common occurrence in the city before Government's intervention. This has led to cholera outbreaks and other water-related infections. The pollution from the underlying rock formation and agricultural pesticides used for subsistence farming could also be responsible for the change in water quality in the area.

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