EFFECT OF THE SEASONS IN THE BACTERIOLOGICAL AND PHYSICOCHEMICAL PROPERTIES OF WELL WATER IN BIDA TOWN, CENTRAL NIGERIA

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ABSTRACT

Bacteriological and physicochemical studies of 72 well water samples were carried out over two successive dry and wet seasons in Bida town. Membrane filtration technique, Cultural and Biochemical tests were used for Bacteriological analysis while the methods of the American Public Health Association (APHA) were used for the physicochemical analysis. One way Analysis of Variance (ANOVA) was used to analyze all data generated. Bacterial counts of well samples tested were all above the limits specified by the Nigerian Standards for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO). Only the mean feacal coliform counts (FCC) for the wet seasons were significantly different (P<0.05) from the dry seasons values. Mean THC and TCC showed no significant difference over the dry and wet seasons. All physicochemical parameters recorded values in the wet seasons that were significantly different (P<0.05) from the values obtained in the dry seasons, except Turbidity, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS). The most frequently occurring bacterial isolates for the dry and wet seasons were Streptococcus faecalis (24.6% and 20.9% respectively) and Salmonella paratyphi (22.1% and 14.7% respectively), while Klebsiella pneumoniae, Shigella dysenteriae and Bacillus subtilis recorded frequencies of 0.7% , 0.9% and 1.5% respectively. Periodic sanitary surveillance and proper siting of wells should help mitigate groundwater contamination in Bida, Niger State.

KEYWORDS: *Physicochemical Parameters, Coliforms, Correlation.*

Introduction

Groundwater forms a major source of drinking water and plays a crucial part in the maintenance of plant and animal life (Ranjana, 2009). However, groundwater is increasingly being polluted in the wake of urbanization and population growth, poor land- use system, agricultural activities, that had led to the fast degradation of ground water quality as well as several other anthropogenic activities that are impacting daily across most parts of Niger state

(Yisa ***et al.,*** 2012).

In many developing countries, availability of potable water has become a critical and urgent problem. It is a matter of great concern to families and communities depending on non-public water supply system. Conformation with physicochemical and microbiological standards is of special importance because of the capacity of water to spread disease within a large population (Faparusi *et al*., 2011). Variations in groundwater physico-chemical characteristics are more pronounced during the dry season probably due to evaporation (Muhammad, 2012).

Dug wells are generally the worst groundwater sources in terms of faecal contamination, and bacteriological analysis serves primarily to demonstrate the intensity of contamination and hence the level of the risk to the consumer (Chiroma *et al*., 2007). It has been observed that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies (Yerima *et al*., 2008).

MATERIALS AND METHODS

Location and Description of Study Area

Bida is located within longitude 9^0 10E and latitude 5^0 10N and occupies an estimated land area of about $38km^2$ with a population of around 185000 (NPC, 2006). The geology of the wells is mostly sedimentary with depth ranges of 3.0 – 10 m. Some hydromorphic soils occurred in a few locations within dominant ferosols that characterize the soil of the area. Bida has a tropical climate with mean temperature of 30.2^oC, relative humidity of 61.0% and mean rainfall of 1334mm. The climate presents two distinct seasons; a rainy season that lasts between April and October and a dry season that lasts between November and March of the following year.

Collection and Analysis of Samples:

72 well samples were collected between 10.00a.m and 3.00 p.m over a period of 24 months (spanning two dry and wet seasons). The samples were divided into 250.0 ml and 500.0ml amounts in glass and plastic bottles for bacteriological and physiochemical analysis respectively. Cluster sampling technique was the method of sampling used, according to the Rapid Assessment of Drinking Water Quality (RADWQ) survey protocol of Howard *et al*. (2003) and as modified by Ince *et al*. (2010).

Bacteriological Analysis

Bacterial counts were carried out to determine Total Heterotrophic Counts (THC) as well as Total Coliform and Faecal Coliform Counts (TCC and FCC): THC was determined by the Pour Plate method, while TCC and FCC were determined by the Membrane Filtration method, using Membrane Lauryl Sulphate Broth (MLSB) medium (APHA, 2005).

Morphological and biochemical tests were carried out for the identification of bacterial isolates by comparing their characteristics with those of known taxa, according to Cowan and Steel (1974). Biochemical tests included Gram staining, motility, catalase, urease production, methyl red, Voges Proskauer, H_2S production, coagulase, starch hydrolysis, oxidase and indole tests, lactose and citrate utilization, mannitol, sucrose and glucose tests.

Physicochemical Analyses of Water Samples

Physicochemical analyses were carried out on well samples according to the methods of the American Public Health Association (APHA, 2005). Total hardness (mg/l) was determined by titrimetric method while gravimetric method was used to determine total dissolved and total suspended solids (mg/l). Ferrous iron was determined by atomic absorption spectrophotometry. Dissolved oxygen (mg/l) was determined by the Winkler's test, while Turbidity (mg/l), nitrite and sulphate (mg/l) were determined by UV spectrophotometry.

Statistical Analysis of Data

Data generated were subjected to statistical analysis, using one way analysis of Variance (ANOVA) for the treatments. Probability level was maintained at 0.05 (i.e 95% confidence limits) and used for the test of significance of variations between the sample areas and the months of each study year. Percentage data was transformed by arc sin transformation according to Zar (1984).

RESULTS AND DISCUSSION

An assessment of well water in Bida over a twenty four month period revealed that the groundwater source harbour diverse bacterial contaminants. The bacterial load recorded counts well above the levels recommended by the Nigerian Standards for Drinking Water Quality (NSDWQ, 2007) and the World Health Organization (WHO, 2012). Mean THC for both dry and wet seasons were much higher than the mean FCC and TCC. The generally high bacterial counts could be attributed to the poor well protection and the poor waste management and sanitation protocols as well as the ease with which debris and impurities are washed into the wells. These results are supported by the findings of Muhammad (2012) who reported high bacterial load in well water in the low-income high density areas of Kaduna metropolis.

There was no significant difference ($p > 0.05$) between mean THC and TCC for the wet and dry seasons although mean FCC for the wet seasons was significantly higher ($p < 0.05$) than the values for the dry seasons . The variations observed in the THC and FCC is at variance with those of Shridha (2009) as well as Adekunle *et al*. (2007) who reported significant changes in total heterotrophic bacterial counts between the dry and wet seasons in South Western Nigeria. The higher wet season feacal coliform counts could be attributed to the higher temperatures and effluent discharges which characterizes the season as well as stormwater runoffs that could have gained entry into the water body through cracks or crevices. This assertion is supported by the findings of Abdo *et al*. (2010) who reported higher coliform counts in the Ismailia canal of the River Nile in Egypt during the wet season which witnessed a reduction towards the period preceding the dry season.

Table 1. Mean Variation of Bacterial Count of Well Water for two successive Dry and Wet Seasons.

Bacterial Count	**Season**	
	Dry	**Wet**
THC (cfu/ml)	$2192.50^{ab} \pm 373.65$	$2380.56^{ab} \pm 321.75$
TCC (cfu/100ml	$36.97^{a} \pm 3.64$	$47.72^{a} \pm 3.55$
FCC (cfu/100ml	$5.92^{b} \pm 0.52$	$12.47^{a} \pm 1.29$

Data on the same row carrying the same superscript do not differ significantly (P<0.05) from each other.
Values are ± Standard Error of Mean.

With the exception of TDS and Ferrous Iron, all physicochemical parameters tested recorded higher concentrations for the wet seasons. However, values recorded for Nitrite, Sulphate ions and pH were significantly different ($p < 0.05$). Wet season mean value for Ferrous iron also differed significantly ($p < 0.05$) from the value obtained for the dry season. With the exception of Turbidity, Total Hardness, nitrite and pH, all the parameters were either within the limits specified by NSDWQ (2007) or have no specified limits (Table 2).

The relatively higher turbidity in the wet season could be attributed to suspended organic matter, soluble coloured organic compounds, painktons and other microscopic organisms. It may also be due to reduction in transparency due to the presence of particulate matters. These results are corroborated by those of Abdo *et al*. (2010), Mahananda *et al*. (2010) as well as Adekunle *et al*. (2007) with more or less similar observations. Although the NSDWQ (2010) attributes no direct health impact to consumption of turbid water, Abdo *et al*. (2010) have pointed to the level of turbidity of a groundwater source as an indication of its degree of pollution.

TSS concentrations which were significantly different ($P < 0.05$) from the other values could be attributed to turbidity due to silt and organic matter. Results from the current study though at variance with those of Efe (2005) is in general agreement with the results obtained by Mahananda *et al*. (2010) and Kumar *et al*. (2011) on the ground waters of Kharicut Canal of Ahmedabad, Gujurat, India. Elevated TSS concentrations could also be due to heavy rainfall events which according to Gimba (2011) may reach as high as 1335mm during the peak of the rainy season in some parts of Niger State.

High TDS concentration recorded for the dry season may be an indication of pollution and corroborates those of Agbaire and Obi (2009) who recorded higher dry season TDS concentrations during the dry season in the ground waters of River Ethiope, Abraka in Delta State of Nigeria. Although high TDS concentration in groundwater usually indicates pollution, (Adetunde *et al*. 2011), well waters overlying calcite-rich bedrock could cause the release of carbonate and bicarbonate ions which in solution could increase TDS in the groundwater source (Mahananda *et al*., 2010). Although high TDS concentrations in groundwater used for drinking have not been linked directly

No significant variation ($P > 0.05$) was observed in the mean TTH-CO_3 values between the two seasons. However, higher wet season values could be attributed to increased chemical dissolution (occasioned by high precipitation) and the lower values obtained due to longitudinal dissipation of metallic ions on standing. The results corroborates findings of Pritchard *et al*. (2006) from their assessment of groundwaters in several districts of Malawi but is at variance with the results recorded by Efe (2005) in a study of well water sources in the Western Niger Delta Region of Nigeria.

The low concentrations of ferrous iron recorded from the study corroborates results obtained by Adetunde *et al*. (2011) who also recorded ferrous iron concentrations well below the recommended limits from groundwater sources in Ogbomosho Township of Oyo State, Nigeria. The results also agree with the findings of Yisa *et al*. (2012) who investigated groundwaters in Doko Community of Suleja in Niger State, Nigeria. The results are however at variance from those reported by Aremu *et al*. (2011) from their assessment of well water sources in Kubwa, Bwari Area Council of the Federal Capital Territory, Abuja. The low wet season ferrous iron concentrations could be attributed to the probable absence of any build-up of dissolved iron under anaerobic conditions of the aquifer recharging the groundwater sources in the study areas (Idoko, 2010).

The generally low levels of DO encountered in the well water sources tested across the study areas (particularly during the dry seasons) may have been due to increased levels of nutrients in the water sources or the concentration of dissolved and suspended solids present in the water. This assertion is supported by the findings of Muhammad (2012) on the studies of ground water sources in the densely populated parts of Kaduna metropolis. Ololade and Ajayi (2009) who attribute low DO content of groundwater to biological degradation of organic matter. The investigators believe that decomposition of organic

matter might be an important factor in the consumption of DO by aquatic organisms, as more vigorous deposition could be likely during dry weather.

Table 2. Mean Variation of Physicochemical Properties of Well Water for two successive Dry and Wet Seasons.

Parameter	**Season**		
	Dry	**Wet**	**NSDWQ Standard**
Turbidity (ftu)	$4.90^{c} \pm 0.32$	$6.78^{c} \pm 0.68$	5.00
Total Suspended Solids (mg/l)	$0.07^{d} \pm 0.01$	$0.13^{c} \pm 0.01$	NS
TotalDissolved Solids (mg/l)	$58.16^{e} \pm 1.12$	$52.89^{e} \pm 4.74$	500
Total Hardness – as $CaCO_3$ (mg/l)	$47.01^{d} \pm 1.26$	$76.44^{c} \pm 5.19$	150
Ferrous Iron (mg/l)	$0.19^{a} \pm 0.08$	$0.06^{d} \pm 0.00$	0.3
Dissolved Oxygen (mg/ml)	$2.41^{ab} \pm 0.18$	$3.42^{ab} \pm 0.22$	NS
Nitrite (mg/l)	$0.03^{b} \pm 0.00$	$4.91^{a} \pm 2.73$	0.2
pH	$6.90^{c} \pm 0.05$	$7.78^{a} \pm 0.34$	6.5-8.5
Sulphate (mg/l)	$5.88^{abc} \pm 0.34$	$9.14^{ab} \pm 0.88$	100

Data on the same row carrying the same superscript do not differ significantly ($P<0.05$) from each other. Values are ± Standard Error of Mean.

NS: Not Specified.

Oxygen depletion in the groundwaters tested could also have resulted from the oxidation of nitrogen and phosphorus (which are chemically combined in organic compounds) to nitrates and phosphates.

Reoxygenation during the rainy season could be the cause of the increase in the DO concentration of the well samples which according to Adeyemo *et al*. *(* 2008) may be due primarily to circulation and mixing by inflow after wet season rains. The result may also be due to greater agitation and influx of water into the wells. However, lower DO could be attributed to decrease in temperatures associated with the dry season which according to Abdo *et al*. (2010) and Parashar *et al*. (2006) typically encourages phytoplankton activity or the circulation of cold water as well as the increased solubility of oxygen associated with low temperatures.

The higher concentrations of nitrite encountered in well samples during the wet seasons could be attributed to the disposal of municipal effluents by sludge and stormwater run-offs during and after rainfall episodes in addition to the location of well water sources close to pit latrines or soakaways. This assertion is supported by Eni *et al*. (2013) who recorded higher nitrite concentrations in their investigation of groundwater sources in different part of Calabar, Cross River State of Nigeria. High nitrite concentration could also be due to variation in phytoplankton excretion, oxidation of ammonia and reduction of nitrate to nitrites and by the recycling of nitrogen and bacterial decomposition of planktonic detritus in the environment. Yisa, *et al*. (2012) however relates the presence of nitrites generally in drinking water to leguminous bacterial organisms.

The low concentrations of nitrite during the dry season could be attributed to its relative instability and rapid conversion to nitrate. The results are corroborated by Adekunle *et al*. (2007) who recorded low nitrite concentrations (0.06 mg/l) from the groundwaters of a rural settlement in South Western Nigeria. High nitrite levels in both well (which were above the limits of 0.2 mg/l recommended for long time exposure to nitrite) highlights the danger to health consumers in the area likely to be exposed to following long term consumption of the water sources. Such health concerns according to Yisa *et al*. (2012) involve the development of infant mathaemoglobinaemia and other physiological distress such as stomach cancer in adults.

pH

The higher mean concentration of pH during the wet seasons could be attributed to the higher photosynthesis of micro and macro vegetation, occurring during the period, which usually results in increased production of free carbon dioxide, causing a shift of the pH equilibrium toward alkalinity. This observation is corroborated by Verma *et al*. (2006) in their assessments of the groundwaters of lower Lake Bhopal in India.

Mean higher wet season concentrations of sulphate which were well below the guideline of 100 mg/l limit approved by the NSDWQ (2007) and WHO (2012) could be attributed to the ease with which sulphate precipitates and settles. These assertions are supported by Adetunde *et al*. (2011) and Oluseyi *et al*. (2011) who investigated groundwaters of Ogbomosho Township of Oyo State and those of Ewekoro and Sagamu in Ogun State, Nigeria respectively. However, the relatively higher wet season values should be a cause for further investigation. This is because of the report by WHO (2004) which linked the occurrence of catharsis in adult males to ingestion of drinking water containing small amounts of sodium and magnesium sulphate.

The presence of the bacterial isolates (particularly *E. coli* and *Streptococcus faecalis*) is an indication that the well water sources investigated are faecally contaminated and reflects the unsanitary practices prevalent in the study areas. These practices usually include location of wells to toilets, soakaways, septic tanks or refuse dump sites as well as poor well construction. Chronic unhygienic practices of the inhabitants of the areas investigated in addition to the abilities of some of the isolates to survive for long periods in water may also have contributed to the presence of the organisms in the well water sources. These results are corroborated by Muhammad (2012) and Ibiene *et al*. (2012).

Table 4. Mean Frequency of Occurrence (%) of Bacterial Isolates in Well Water for two successive Dry and Wet Seasons.

	Organism	Frequency (%)	
		Dry	Wet
1.	*Escherichia coli*	14.7	19.3
2.	*Klebsiella pneumoniae.*	0.5	1.1
3.	*Pseudomonas aueroginosa.*	8.6	5.4
4.	*Salmonella typhi*	4.8	13.8
5.	*Salmonella paratyphi.*	10.7	6.4
6.	*Proteus mirabilis.*	4.4	4.5
7.	*Citrobacter freundii.*	3.4	2.8
8.	*Enterobacter aerogenes*	4.1	6.1
9.	*Staphylococcus aureus*	4.5	13.1
10	*Serratia marcecens.*	5.5	6.7
11	*Streptococcus faecalis*	25.6	6.0
12	*Micrococcus luteus*	0.5	13.0
13	*Bacillus cereus*	11.1	1.2
14	*Bacillus subtilis*	0.8	0.6
15	*Shigellla dysenteriae*	0.9	

Similar observations were made in previous studies by several investigators such as Okonko *et al*. (2009) as well as Onifade and Ilori (2008) who also identified most of the isolates encountered in the current study in their investigations of groundwater sources in different parts of Nigeria.

Higher *E.coli* prevalence during the wet seasons could be attributed to the higher temperatures and effluent discharges which characterize the wet season as well as stormwater runoffs that could have gained entry into the water body through cracks or crevices. This assertion is supported by the findings of Abdo *et al*. (2010) who reported higher coliform counts in the Ismailia canal of the River Nile in Egypt during the wet season and Pritchard *et al*. (2007) who identified the predominance of coliforms in well water in some parts of Malawi during the wet season and relatively lower coliform counts during the dry season.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The assessment of well water sources in Minna metropolis over the dry and wet seasons revealed bacterial counts well above the limits specified by the NSDWQ and the World Health Organization.

Most physicochemical parameters tested recorded higher concentrations in the wet seasons, with some values well above the limits specified by the guidelines for drinking water quality. Correlations of physicochemical properties with the THC of well samples were heterogeneous for both seasons (in terms of positive and negative correlations).

Recommendations

Periodic sanitary risk surveillance of the bacteriological and physicochemical properties of wells should be instituted to help address the prevailing dearth of information on their level of contamination and potability.

Siting of wells or boreholes should be done from potential point sources of pollution such as refuse dumps, sewage channels or areas where effluent discharges are common.

Coverings should be provided for wells in order to minimize contamination from anthropogenic and airborne sources.

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