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Bacteriological and Physicochemical Assessment of Drinking Water from wells located in the Industrial Areas of Kano Metropolis

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Abstract
Physicochemical and bacteriological analyses were carried out on well water samples from the eight selected locations within the industrial area of Kano Metropolis namely Bompai, Sharada, Chalawa and Jaba (a non-industrial area) serving as control, using the standard methods. The results obtained were compared with the World Health Organization and Nigerian Standard for Drinking Water Quality. The physicochemical parameters monitored included pH, electrical conductivity, TDS, DO, BOD, Turbidity, chloride, nitrate, phosphate, zinc, iron, lead, manganese and chromium. The mean bacterial counts, coliform and faecal coliform counts ranged from 1.7 x10^3 cfu/ml, 18MPN/100ml, and 11MPN/10ml in BW2, (from Bompai), 3.2 x 10^2 cfu/ml, 33MPN/100ml, and 13MPN/100ml in CW1 (from Chalawa) and 7.0 x 10 cfu/ml, 11MPN/100ml and 4MPN/100ml in NW1 (from Jaba) respectively. Cultural, morphological and biochemical characterization of bacterial genera revealed the presence of *E. coli, Pseudomonas sp., Shigella sp., Proteus sp., Klebsiella sp., Staphylococcus sp., Salmonella sp. and Enterobacter sp.* The samples displayed elevated mean value of lead (0.14mg/l), EC (590.9 us/cm), TDS (119.13mg/l), DO (4.67mg/l), BOD (1.25mg/l), Zinc (1.76mg/l), Iron (0.6mg/l), Manganese (0.44mg/l) and Chromium (0.57mg/l). The result shows that out of the eight (8) wells sampled, only one (1) i.e NW2 is safe for drinking. Hence there is need for improved hygiene and regular hygiene education.
Keywords: Physicochemical parameter, *E. coli,* Wells, Chromium, Groundwater.

INTRODUCTION

Water is one of the most essential elements to life on Earth. In its purest form, it's odorless, colorless and tasteless but due to human and animal activities, it is usually contaminated with solid and human waste, effluents from chemical industries and dissolved gases (Ehlers and Krafft, 2001). Water which occurs below the water table is referred to as groundwater, it supports; drinking water supply, livestock needs, irrigation, industrial and many other commercial activities (Jalali, 2005). The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region (Jalali, 2005). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies (Emmanuel and Nurudeen, 2012). In recent years, due to rapid urbanization and industrialization, the rate of discharge of pollutants into the environment which ultimately finds their way into these water bodies is higher than the rate of purification (Sa'eed and Amira, 2013).

The conventional way of extracting drinking water from the ground is by drilling boreholes and shallow wells through the existing water table to form a well point. In certain regions of Southern Africa, as the water percolates through the soil, harmful physical, biological and chemical constituents (e.g. fine suspended matter, faecal coliform and fluoride) become contained in the water making it unsuitable for human consumption (Pritchard *et al.*, 2008). In Kano, despite the effort of public water agency in providing potable water to the populace, the problem of acute water shortage is still dominant. Low access to safe water in Nigeria has been attributed to the enormous socio-economic development, growing industrial base, poor planning, insufficient funding and haphazard implementation, to mention a few (Oluwasanya, 2009). Consequently, the inhabitants have resorted to the use of wells as alternative sources of water supply. Wells also provide cheap and low-technology solution to the challenges of rural and urban water supply (Ayantobo *et al.*, 2013). Wells could either be protected, unprotected or semi-protected. A protected well is one equipped with a dedicated pump (manual or motorised), concrete lining and platform (or apron), head wall, cover and drainage channel (Murcott, 2007; Oluwasanya *et al.*, 2011).

Un-protected well is without any of the features stated above and a semi-protected well may have one or more of the features found in a protected well (Oluwasanya *et al.*, 2011).

Shimizu *et al.* (1980) have shown that bacteria contaminate well water depending on location. Thus, it is suspected that water from wells in unhygienic areas could be contaminated according to their proximity to sources of pollution. Contaminants such as bacteria, viruses, heavy metals, nitrates and

Salts have polluted water supplies as a result of inadequate treatment and disposal of waste from

humans and livestock, industrial discharges, and over utilization of limited water resources (Adeyemi *et al.,* 2007).

Delivery of safe and portable water to communities in Kano state is the responsibility of the government which in most cases has been inefficient and inadequate. Hence most communities in the state resort to alternate source of water such as wells and boreholes as mentioned earlier, to this effect this study is aimed at investigating the qualities of drinking water from wells located within the industrial estate of Kano Metropolis.

MATERIALS AND METHODS

Study Area

The metropolitan area of Kano lies between latitude 11^0 55' 23.93N to 12^0 3' 53.10N and longitude 8^0 27' 42.26'E to 8^0 36' 41.62'E (Na'Abba, 2002). It covers a land mass of 499km^2 and comprises of eight (8) local government areas; Dala, Fagge, Gwale, Municipal, Nasarawa, Tarauni, Kumboso and Ungogo local governments. It is highly industrialized with the industries concentrated in three industrial estates, namely Bompai, Chalawa and Sharada (Bichi and Anyata, 1999). The activities of these industries have led to the discharge of untreated waste water on land and in rivers and streams. Slightly dense human settlements can be found in and around these industrial areas whose major source of domestic water ranges from pipe-borne water, well water to borehole water.

Sampling Sites

A total of eight (8) wells were randomly selected for sampling in the study. Two wells selected from Sabuwar gandu in Sharada and coded SW1, SW2, two from Tsamawa in Chalawa coded CW1, CW2, two of each from Bompai coded BW1, BW2 and two from a non-industrial area (Jaba) which serves as the control coded NW1, NW2.

Sample Collection

Triplicate samples were collected from each of the eight wells over a period of five months. The water samples were collected in sterile 250 ml capacity non transparent screw caped brown bottles from each of the wells using a sterile stainless steel cup with a 30ft rope. The water samples were transported to the laboratory in a cooler with ice packs within few hours of collection. Samples that were not analyzed immediately were stored in refrigerator at 4^0C (Cheesbrough, 2000).

Physicochemical Analysis of Water Samples

Water samples collected were analysed by both classical and automated instrumental methods prescribed by standard methods for the analysis of water and wastewater and United State Environmental protection Agency (Standard Method, 1999). The physicochemical parameters analysed includes pH, temperature (^{0}C), turbidity (NTU), conductivity (us/cm) dissolved oxygen (DO) (mg/L), biochemical oxygen demand (BOD) (mg/L), total dissolved solid (TDS) (mg/L), chloride (mg/L), nitrate (mg/L), phosphate (mg/L) and five metals which includes zinc, lead, chromium, manganese and iron. Rapidly changing parameters such as temperature, pH, conductivity, DO, BOD and TDS were measured in-situ using a multiparameter bench meter (HI 255). Chloride was determined using the Argentometric method as described by Olajubu and Ogunika, (2014) while phosphate and nitrate was analysed using the colorimetric method with UV spectrophotometer (WAPS 110). Cations, were analysed using atomic absorption spectrophotometer (AAS 3110). All methods used in this analysis were consistent with known standard methods (AHPA, 2005).

Bacteriological Analyses of the Water Samples

The media employed for the bacteriological analyses were all prepared according to the manufacturer's instructions, they include: Peptone water used for serial dilution of water samples, Nutrient agar, lactose broth, Eosin Methylene Blue (EMB) agar used for plate count and multiple tube fermentation. Salmonella-Shigella Agar (SSA) used for the differentiation of *Salmonella* and *Shigella*, Mannitol Salt Agar for the differentiation and isolation of *Staphylococus*. MacConkey agar was used to differentiate between lactose and non-lactose fermenters. Simmon's citrate agar, MR-VP broth, Urea broth, triple sugar iron (TSI) agar for biochemical tests.

Bacteriological Analysis

Bacteriological characteristics of the water samples were determined according to method described by (Dhawale and LaMaster, 2003). The most probable numbers (MPN) multiple tube technique was used for Coliform enumeration. All plates were incubated at 35 ^{0}C for 24 h. Presumptive colonies were confirmed by Gram staining and biochemical reactions and each plate was given to positive or negative score (FDA, 1995).

Characterization and Identification of Bacterial Isolates

Bacterial isolates were characterized on the basis of their colonial morphology (color, texture, odor etc.), cellular morphology through Gram's staining and biochemical tests (Indole, Oxidase, Catalase, Urease, Coagulase, MR-VP, Citrate utilization, Motility, and Sugar fermentation) as reported by previous researchers (Nkwachukwu *et al.,* 2013). To arrive at a probable name for each isolate, references were made to standard texts such as Bucchannan and Gibbon (1974).

RESULTS AND DISCUSSION

Physicochemical Characteristics of Well water

The results obtained for various tests carried out on the physicochemical properties of the well water samples and their comparison with the Nigerian Standard Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standard specified for drinking water (Table 1). The table shows the mean and standard deviation values of the parameters determined in the research along with the recommended standards.

All the Samples appear to be clear, tasteless and odorless except for samples CW1, CW2, SW1 and SW2 which are not so clear in appearance. This could be attributed to materials in solution as opined by Adeyeye and Abulude (2004). Affected wells can be treated by coagulation. Similar result was reported by Oyedele, (2009) in the Physiochemical status of water samples from hand-dug wells in Ajebamidele area of Ado-Ekiti, Nigeria.

The temperature of the well samples ranged from 26.9 – 28.7^{0}C. It should be noted that high water temperature enhances the growth of microorganisms and may increase taste, odour and colour, but for the present research, the temperature of all samples were within the recommended WHO (2006) and NSDWQ (2007) limits.

The study shows the pH range of 6.8 – 8.5 for the water samples. The low pH value might be due to the high levels of free CO_2 which may consequently affect the bacterial counts (Edema *et al.,* 2001). The pH values of all the samples were within the pH range assigned by WHO as the standard for drinking water which ranges from 6.5 - 8.5 (WHO, 2006). Although the values indicated that the well water samples are slightly basic, it is in agreement with what was reported by other researchers in similar study (Ezeribe *et al.*, 2012; Aremu *et al.*, 2011).

The Electrical conductivity (EC) range was 352-893 µs/cm for well samples, which fall within acceptable WHO limit. Conductivity is affected by the presence of dissolved ions in water. The importance of EC is its measure of salinity, which generally affects the taste and therefore, impacts on the user acceptance of the water (Ahmed *et al.*, 2000).

Although all the values recorded for TDS was below the 500mg/L recommended NSDWQ limit, well water samples from Sharada had highest values of 205.22mg/L and 211.10mg/L. this elevated values can be attributed to differences in organic matter that remains as residue in the well water. TDS in drinking water has been associated with natural source, sewage, industrial wastewater, urban run-off and chemical used in water treatment process (Emmanuel and Nurudeen, 2012).

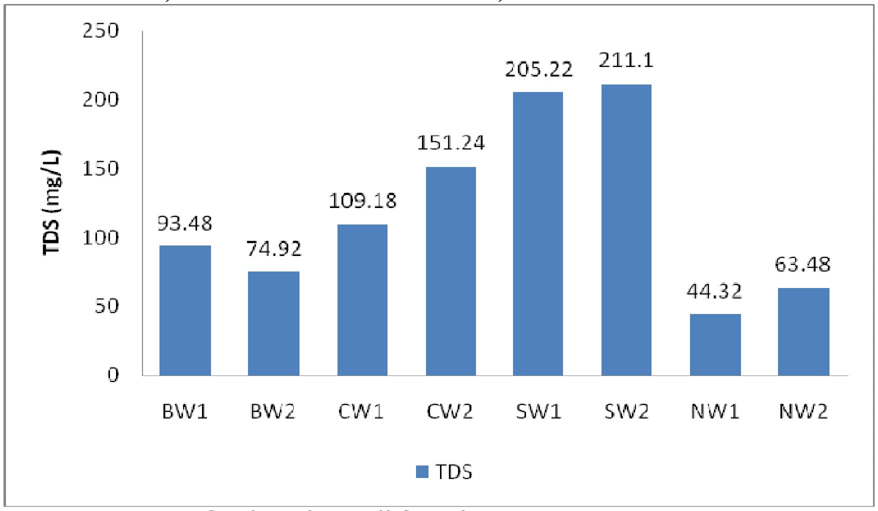

Figure 1: Mean TDS values for Well Samples

Dissolve oxygen (DO) reflects the physical and biological processes prevailing in the water. The DO in this study ranges from 3.48-5.82 mg/l, an increasing trend was however, observed in the water samples from Chalawa and Sabuwar gandu (Table 1) compared to the samples from Jaba and Bompai. All the samples however, were within the limit stipulated by WHO for drinking water. BOD measures the amount of oxygen used by microorganisms, in this case; bacteria, to oxidize organic matter present within the water sample (Edema *et al.*, 2001). This study reports BOD values below standard NSDWQ limits.

The turbidity of water depends on the quantity of solid matter present in the suspended state. It is a measure of light emitting properties of water and the test is used to indicate the quality of waste discharge with respect to colloidal matter. The greater the turbidity, the higher the risk of gastro-intestinal diseases (Ezeribe *et al.*, 2012). This study recorded turbidity value ranging from 2 – 4 NTU, with the highest mean value in samples SW1 and SW2 from Sharada.

Phosphate concentrations tend to increase as a result of the discharge of industrial waste, domestic sewage, agricultural run-off from crops etc. it also occurs naturally, found in rocks as inorganic phosphates and can enter water ways when water runs over and through rocks (Asuquo and Etim, 2012). The values obtained for phosphate in this study (Fig. 2) were very high especially for the well water samples SW1 and CW2 had mean values of 26.88 mg/l and 25.68 mg/l respectively which were the highest values recorded from the well water samples from the industrial area. This can possibly be attributed to the proximity of these wells to waste channels and also to seepage of phosphate rich waste into the water table. The high concentrations of 32.57 mg/l (NW1) in the well from the control sites could be as a result of contact with domestic sewage and/or agricultural run-off. Hence, all values obtained were above standards set by WHO and NSDWQ which may be indicative of pollution.

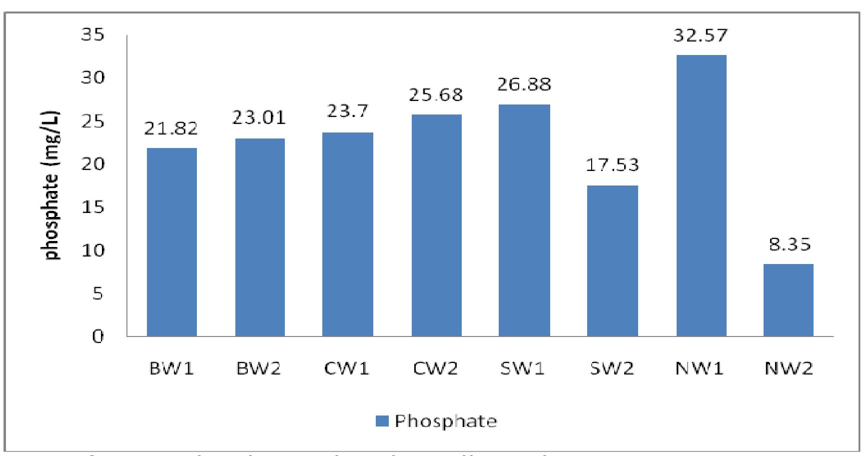

Figure 2: Mean Phosphate Values for Well samples

Chlorides in natural waters such as well water result from the leaching of chloride-containing rocks and soils with which the water comes in contact. The standard deviations and mean values obtained in the samples analysed are within the limits set by WHO (Table 1). Chlorides are the most stable components in water and its concentration is largely unaffected by most natural physiochemical and biochemical processes (Ezeribe *et al.*, 2012). Hence the value of its concentration in water is a useful measure in water sample.

Nitrates indicate the presence of fully oxidized organic matter. The mean values obtained from the eight wells sampled were low except for CW1 (56.04 mg/l), CW2 (70.05 mg/l) and NW1 (52.54 mg/l) which were above the 50 mg/l acceptable limit set by WHO and NSWDQ. Thus, nitrate was found to be higher in the water samples from Chalawa compared to the other sites (Fig. 3). This high value could be attributed to the nature of industrial activities carried out in Chalawa which include cooking gas production and casing, plastic manufacturing etc. The elevated nitrate level in Jaba can be attributed to agricultural activities e.g. gardening. The results obtained in this study is similar to the results obtained by Ezeribe *et al.* (2012) who explained that well water containing high level of oxidized organic matter appears in the form of soluble anions such as nitrates. Excess levels of nitrates can cause Methemoglobinemia as blue baby disease. Although nitrates levels that affect infants do not pose a direct threat to older children and adults, they do indicate the possible presences of other more serious residential or agricultural contaminants such as bacteria or pesticides (Robert, 2006).

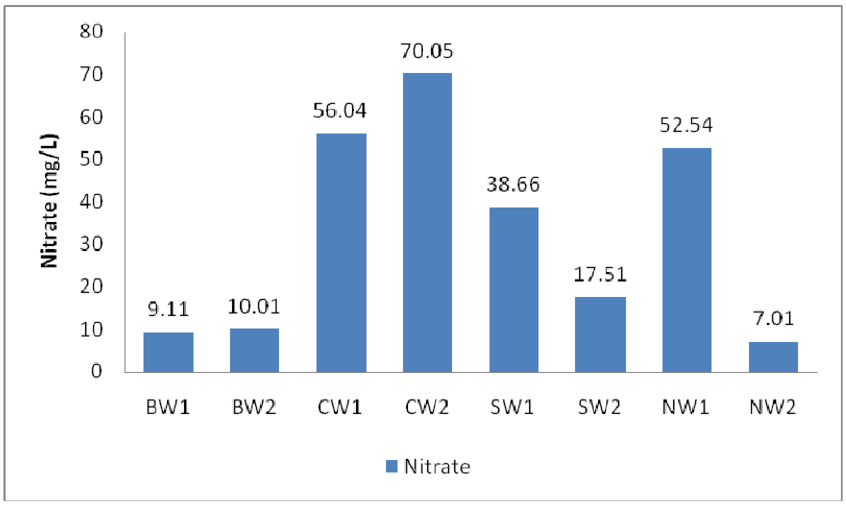

Figure 3: Mean Nitrate Values for Well Samples.

The concentrations of metals (iron, lead, chromium, zinc and manganese) in some of the water samples were generally low compared with the WHO standards. Iron concentration however, was slightly higher with mean values of 0.58 mg/l and 0.68 mg/l obtained from the control wells NW1 and NW2 while 0.92 mg/l and 1.23 mg/l were recorded for CW1 and CW2 from Chalawa respectively (Table1). Furthermore, when comparing the concentrations based on sampling sites, samples from Chalawa showed higher levels of iron compared to the other sites. This can be attributed to naturally occurring iron in basement rocks or to the dissolution of iron bearing rocks and/or soils. It is noted however, that anaerobic groundwater may contain ferrous iron at concentrations of up to several mg/l without discoloration or turbidity in water when directly pumped from a borehole. On exposure to the atmosphere, however the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water (Mohand and Fella, 2014). Iron also promotes the growth of 'Iron bacteria' which derive their energy from oxidation of ferrous iron to ferric iron and in the process deposit a slimy coat on the piping (Mohand and Fella, 2014). Interestingly, the level of Manganese in the water samples showed slight variation when compared to the iron level. All the samples with the exception of BW1, BW2 and CW2 fell below the allocated 0.5 mg/l WHO and NSDWQ standard. The highest values however, were recorded in samples BW1 i.e. 0.92 mg/l and BW2 having 0.61 mg/l.

Elevated lead levels was also observed in both well samples from Chalawa and Sabuwar Gandu with values of 0.32 mg/l, 0.27 mg/l, 0.19 mg/l and 0.11 mg/l in CW1, CW2, SW1 and SW2, respectively. While varying concentrations of Chromium surprisingly higher than the stipulated drinking water limits set by WHO and NSDWQ were observed in some of the water samples. The well samples from Chalawa and Sabuwar Gandu recorded a mean average of 0.92 mg/l, 1.25mg/l for CW1 and CW2; 1.1mg/l and 1.17mg/l for SW1 and SW2 (WHO standard being 0.01mg/l). These findings appear to be similar to some other studies such as Abiola, (2010), Oyeku and Eludoyin (2010) and Oyekunle *et al.* (2012).

Table 1: Result of Physicochemical Analyses for Well Water Samples and WHO/NSDWQ Standards

Parameter	Unit	BW1	BW2	CW1	CW2	SW1	SW2	NW1	NW2	RANGE	MEAN	STD	WHO (2010)	NSDWQ (2007)
Appearance	-	clear	clear	cloudy	cloudy	cloudy	cloudy	clear	clear	-	-	-	Clear	Clear
Taste	-	IO	IO	IO	IO	IO	IO	IO	IO	-	-	-	IO	IO
Odour	-	IO	IO	IO	IO	IO	IO	IO	IO	-	-	-	IO	IO
Temp	^{0}C	27.4	28.1	26.9	27.2	28	28.7	28.1	28.4	26.9-28.7	27.85	0.62	27-28	-
pH	-	7.1	7.4	8.3	8.1	8.5	8.1	6.8	6.9	6.8-8.5	7.7	0.76	6.5-8.5	6.5-8.5
EC	µs/cm	361	338	753	816	858	893	352	356	338-893	590.9	258.7	1000	1000
TDS	mg/l	93.48	74.92	109.18	151.24	205.22	211.10	44.32	63.48	44.3-211.1	119.13	63.6	500	500
DO	mg/l	4.21	3.98	4.97	5.34	4.93	5.82	3.48	4.66	3.48-5.82	4.67	0.76	7.5	-
BOD	mg/l	0.81	0.52	1.34	1.62	1.91	1.83	0.94	1.01	0.52-1.91	1.25	0.5	-	3-6
Turbidity	NTU	2	2	3	3	4	4	2	2	2-4	2.8	0.99	5	5
Phosphate	mg/l	21.82	23.01	23.7	25.68	26.88	17.53	32.57	8.35	8.35-32.57	27.44	9.49	5	-
Chloride	mg/l	40.18	38.92	195.25	195.25	53.25	88.75	124.25	79.25	38.92-195.25	101.89	64.10	250	250
Nitrate	mg/l	9.11	10.01	56.04	70.05	38.66	17.51	52.54	7.01	7.01-70.05	32.62	24.9	50	50
Zinc	mg/l	2.12	2.48	6.24	0.94	0.29	0.17	1.07	0.75	0.17-6.24	1.76	1.98	3	3
Iron	mg/l	0.28	0.35	0.92	1.23	0.38	0.38	0.58	0.68	0.28-1.23	0.6	0.33	0.3	0.3
Manganese	mg/l	0.92	0.61	0.4	0.65	0.2	0.28	0.25	0.22	0.2-0.92	0.44	0.26	0.5	0.5
Lead	mg/l	ND	ND	0.32	0.27	0.19	0.11	ND	ND	0-0.32	0.11	0.12	0.01	0.01
Chromium	mg/l	0.03	0.04	0.92	1.25	1.1	1.17	0.02	ND	0-1.25	0.57	0.59	0.05	0.05

No significant difference (P = 0.772).

Bacteriological Characteristics of the Borehole waters

Table 2 shows the range and mean values of aerobic plate count, coliform count and faecal coliform count of water samples from the sampled wells, collected over a period of five months. Of the Eight wells only one (NW1 i.e control) showed a zero level aerobic plate, coliform and faecal coliform count. The rest were moderately low except for SW1 and SW2 from Sabuwar gandu. The Aerobic plate counts of samples BW1 and BW2 ranged from $4.0x10^2$ - $2.5x10^3$ cfu/ml and $4.8x10^2$- $1.7x10^3$ cfu/ml, with a mean value of 1.4x 10^3 and 1.7x 10^3 cfu/ml, respectively. Samples CW1 and CW2 ranged from 3. $6x10^3$ -$1.1x10^3$ cfu/ml and $5.1x10^2$ -$2.2x10^3$ cfu/ml, with a mean value of $3.2x10^2$ and $1.9x10^3$ cfu/ml. Sample SW1 and SW2 which had the highest ranged from 5.9 x 10^2 – $2.5x10^4$cfu/ml and $6.3x10^2$ – $1.5x10^5$cfu ml^{-1}, with a mean value of $3.6x10^4$ and $5.9x10^4$ cfu/ml and sample NW2, (control) ranged from $2.0x10^1$-$1.2x10^2$ cfu/ml with a mean of $7.0x10^1$ cfu/ml.

Coliform counts had the highest mean values of 88 MPN/100ml and 132 MPN/100ml with ranges between 35-150 and 64-240 MPN/100ml for samples SW1 and SW2 respectively. While samples BW1, BW2, CW1, CW2, and NW2, had mean counts of 17, 18, 33, 44 and 11 MPN/100ml, respectively. Faecal coliform count were also highest for samples SW1, and SW2, with a mean value of 52 and 71 MPN/100ml. Sample BW1, BW2, CW1, CW2 and NW1 had mean values of 11, 11, 13, 25 and 4 MPN/100ml respective.

Water suitable for human consumption (potable water) should be free from disease producing organism or large numbers of non-pathogenic organisms (Ibe and Okplenye, 2005). The study area was observed to be densely populated where boreholes and wells were among the main sources of domestic water supply. Individual house owners used both pit latrine and well on the same plot (Table 3); consequently predisposing ground water to faecal contamination. In this study, all the water collected from the eight (8) sampling sites had varying levels of aerobic plate count, coliform count and faecal coliform count with the exception of one (1) sampling site that had zero aerobic plate count, coliform count and faecal coliform count. Water should have a value of 0.00 cfu/100ml in order for it to be considered safe for human consumption (WHO, 2010).

Table 2: Range and Mean Values of Aerobic Mesophilic, Coliform and Faecal Coliform count of Well Samples.

Sample code	Aerobic Mesophilic Count (cfu/ml)		Coliform Count (MPN/100ml)		Faecal Coliform Count (MPN/100ml)	
	Range	Mean	Range	Mean	Range	Mean
BW1	$4.0x10^2$-$2.5x10^3$	$1.4x10^3$	14-20	17	7.4-16	11
BW2	$4.8x10^2$-$1.7x10^3$	$1.7x10^3$	15-21	18	7.2-14	11
CW1	$3.6x10^2$-$1.1X10^3$	$3.2X10^2$	28-43	33	11-21	13
CW2	$5.1x10^2$-$2.2x10^3$	$1.9X10^3$	23- 75	44	16-28	25
SW1	$5.9x10^2$-$2.5x10^4$	$3.6X10^4$	35-150	88	29-75	52
SW2	$6.3x10^2$-$1.5X10^5$	$5.9X10^4$	64-240	132	48-93	71
NW1	$2.0x10^1$-$1.2x10^2$	$7.0x10^1$	11-6	11	3-7.2	4
NW2	<10	0	<3	0	<3	0

Coliform Count: significant difference (P = 0.011), Faecal Coliform Count: significant difference (P = 0.006).

Based on the cultural characteristics, morphology and result of biochemical test, eight (8) genera of microorganisms (bacteria) were identified from a total of 56 isolates. These genera include *Proteus*, *Esherichia*, *Klebsiella*, *Enterobacter*, *Shigella*, *Salmonella*, *Staphylococcus* and *Pseudomonas* . The sampled wells showed a higher distribution of bacterial isolates with the highest number of bacterial types found in Sharada Well 1 and 2 (SW1 and SW2) i.e. seven (7) genera found in each, followed by Chalawa Well 1(CW1) containing six (6) types. Chalawa Well 2 and Bompai Well 2 (CW2 and BW2) had four (4) types each, (Jaba-non industrial well 2 (NW2) was found to have no single bacterial growth. This is represented in Table 4. Some of these bacteria have been incriminated in various diseases. *Pseudomonas aeruginosa, Staphylococus aureus, Proteus vulgaris* and *Klebsiella pneumoniae* are common causes of urinary tract and wound infections where they cause acute or chronic infections (Olajubu and Ogunika, 2014).

Organisms like *Proteus vulgaris* and *Klebsiella pneumoniae* were also identified to account for up to 55% of nosocomial infections in some parts of Nigeria, while *Salmonella paratyphi* is the causative agent for paratyphoid fever; a mild form of enteric fever (Olajubu and Ogunika, 2014).

Contamination of drinking water by most of these bacteria can occur from many different sources. But more often *E. coli* occurrence in water is associated with failures during treatments and disinfection operations (WHO, 2006). Powell *et al.* (1964) demonstrated that microbial contaminants (both bacterial and viral) derived from sewage can penetrate up to the depth of 90m in some aquifers. These included indicator organisms such as Coliforms which were detected in this investigation. This is also in support of the work of Taura and Hassan (2013), who observed that 89.5% of wells sampled had indicator bacteria above WHO and USEPA standards for safe drinking water in Kano. This was also in concordance with the work of Ibe and Ikplenye (2005), who also found that majority of boreholes in Uli were contaminated by at least one coliform or indicator bacterium. Fattal and Shuval (2003) stated that, of the indicators (Coliform, *Enterococci* and *Escherichia coli*), *E. coli* is the most predictive indicator for enteric disease symptoms. Hence, the ability to detect faecal contamination in drinking water is of public health importance. Likewise, the presence of *E. coli* and other possible bacterial pathogens in these samples show that people that use these water sources may be susceptible to urinary tract infections, bacteremia, meningitis, diarrhoea, acute renal failure and hemolytic anaemia etc. (NSDWQ, 2007).

Table 3: Field Measurement and observation of the sample wells

Sample sites	Distance to pits (m)	Distance to drainage/gutter (m)	Static water level (m)	Covering
BW1	7.1	6.8	7.3	Fully covered
BW2	5.9	7.3	8.0	Fully covered
CW1	3.7	4.2	9.2	Partly covered
CW2	4.1	4.0	8.8	Partly covered
SW1	3.4	1.5	10.7	Not covered
SW2	2.8	2.2	11.2	Not covered
NW1	9.3	4.6	10.6	Covered
NW2	>10	6.2	8.1	Covered

Table 4 Distribution of Bacterial Isolates in the Samples from the Wells

Isolates	BW1	BW2	CW1	CW2	SW1	SW2	NW1	NW2
E. coli	+	+	+	+	+	+	+	-
Proteus sp.	-	+	+	-	-	+	-	-
Pseudomonas sp.	+	-	-	+	+	+	-	-
Klebsiella sp.	-	-	+	-	+	+	-	-
Enterobacter sp.	+	+	+	+	+	+	+	-
Shigella sp.	-	+	+	-	+	-	-	-
Salmonella sp.	-	-	+	+	+	+	-	-
Staphylococcus sp.	-	-	-	-	+	+	-	-

Key:

+ : Isolated; **-** : Not isolated

CONCLUSION

From the result of the assessment of the pH, turbidity, nitrate, iron, phosphate, chlorine, lead, chromium, coliform count and faecal coliform count. It can be concluded that seven out of the eight (8) wells assessed were not fit for consumption.

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