International Journal of Pathogen Research

4(1): 34-43, 2020; Article no.IJPR.55977
ISSN: 2582-3876

Ascertaining the Bacteriological Quality of Water Drawn from Cast and Non-cast Wells in Zaria, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author DFY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OAI and OJO managed the analyses of the study. Author DYP managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPR/2020/v4i130104
Editor(s):
(1) Khadiga Ahmed Ismail Eltris, Ain Shams University, Egypt.
Reviewers:
(1) Ashish Kumar, Agra College, Agra, India.
(2) Olukayode, Oluwakemi Omolara, Ogun State College of Health Technology, Nigeria.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55977

Original Research Article

Received 02 February 2020
Accepted 09 April 2020
Published 22 April 2020

ABSTRACT

Lack of access to safe drinking water is a threat to public health and wellbeing of the people as it exposes them to risk of waterborne diseases. This study assessed the bacteriological quality of well water samples obtained from Zaria communities and compared the level of contamination between wells with internal wall casting (cast wells) and wells without internal wall casting (non-cast wells). Water samples from 142 wells were collected for a period of six months encompassing both rainy and dry seasons (July to September for rainy season and November to January for dry season). The water samples were collected and analysed for faecal contamination using membrane filtration technique. The water samples contained high density of bacterial counts ranging from $1.73x10^3 \pm 2.73x10^2$ – $2.02x10^2 \pm 1.85x10^2$cfu/100ml during the raining season and

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$4.17x10^2 \pm 3.07x10^1$ – $1.39x10^3 \pm 3.27x10^2$cfu/100ml during the dry season. Coliforms and *E. coli* were present in all the samples with total coliform counts ranging from 1.06×10^3 – 2.12×10^4 cfu/100 ml and *E. coli* counts ranging from 5.10×10^2 – 5.0×10^4 cfu/100 ml Counts were higher during the raining season in all the locations compared to the dry season. Faecal coliform counts were higher in wells without casting (91.9%) compare to wells with casting (91.2%) while *E. coli* counts were higher in wells with casting (77.9%) compared to wells without casting (66.2%). There was no significant difference in the bacterial counts between cast and non-cast wells (p-values were all greater than 0.05).A total of 168 organisms were isolated from this study and they include; *E. coli*(48.3%), *Klebsiella pnuemonaie*(11.8%), *Klebsiella ozanae*(13.2%), *Enterobacter agglomerans*(11.8%), *Enterobacter gergoviae*(14.7%), *Enterobacter aerogenes* (8.8%), *Citrobacter freundii*(8.8%), *Proteus mirabilis* (5.9%), *Serratia liquefaciens*(10.3%) and *Acinetobacter lwoffii* (2.9%). *E. coli*was isolated more frequently (48.3%) compared to other species and was more frequent in non-cast wells (50.0%) compared to cast wells (47.1%). Other species were more frequent in cast wells. The bacteria isolated from this study are mostly of enteric origin; these organisms acquire public health significance under certain conditions, therefore, their removal in drinking water should be given moderate priority. The wells in this study fail to meet the minimum standard for safe drinking water and are therefore not safe for domestic purposes especially for drinking purpose without adequate treatment.

Keywords: Water quality; cast wells; non-cast wells; internal wall casting; bacteria; coliform; Zaria.

1. INTRODUCTION

Water scarcity and the frequency of pollution of existing water sources create very serious health problems for people living in developing countries like Nigeria. Water covers 70.9% of the earth's surface and is vital for the growth and survival of all living things including man [1]. However, the availability and accessibility to safe drinking water has been a serious issue evidenced by high frequency of water borne infections reported [2,3]. Potable water accessibility and supply is limited due to fluctuating climatic conditions and environmental pollution that lower the wholesomeness of most water sources [4].

Water is highly susceptible to both microbial and chemical contaminants regardless of the source [5]. Significantly, microbial contaminants such as coliforms, *E. coli, Cryptosporidium parvum,* and *Giardia lamblia* has been of great concern to public health. The Presence of *Escherichia coli, Klebsiella* and *Enterobacter* species in water is a likely indicator of the presence of pathogenic organisms such as *Clostridium pafringens, Salmonella* and Protozoa [6,5]. These pathogens cause diarrhea, giardiasis, dysentery and gastroenteritis, which is common among the rural dwellers of developing nations [4]. Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion do not have access to adequate sanitation [7].

Generally, groundwater is considered to be cleaner and safer than surface water because it is less susceptible to microbial contamination due to the lengthy time of their travel in subsurface environment, and the soils and rocks through which groundwater flows screens out microorganisms, especially bacteria and protozoa. However, contaminants may enter the water and change its quality [8,9]. Several factors such as discharge of industrial, agricultural and domestic wastes, land use practices and rate of infiltration affect the quality of ground water and once contamination occurs, it can persist for hundreds of yearsbecause water movement in aquifers is very low [10]. Well water is the major source of groundwater supply in rural communities. Wells are categorized based on the nature of construction: open dug wells are generally considered the worst type of groundwater sources in terms of faecal contamination and bacteriological analysis [11,7].

The isolation and characterization of enteric bacteria are of primary importance in the microbiological quality of water. The use of indicator organisms particularly the coliform group as a means to assess the potential presence of waterborne pathogens is of importance to public health [8]. Water has been a common vehicle for disease transmission, and the health risks associated with consumption of contaminated water are of great interest [12,13]. Therefore, assessing the quality of these water sources through frequent monitoring is therefore

extremely necessary for effective maintenance of water quality through control measures. The aim of this study was to assess the bacteriological quality of well water samples obtained from Zaria communities and compared the level of contamination between wells with internal wall casting (cast wells) and wells without internal wall casting (non-cast wells).

2. MATERIALS AND METHODS

The study was conducted in Zaria. Zaria is a major city in Kaduna state in Northern Nigeria and is home to the popular Ahmadu Bello University. It was one of the original seven Hausa city-states, formally known as Zazzau. It occupies an area of about 300 Km^2 at latitude 11°07'51''N and longitude 7°43'43''E with a population of 408198 according to the 2006 census. Water samples were collected from three locations namely; Samaru, Sabon-gari and Tudunwada.

2.1 Sample Collections

A total of 142 wells (53, 44 and 45 wells from Samaru, Sabon-gari and Tudunwada respectively from both cast and non-cast wells) were sampled for a period of six months encompassing both rainy and dry seasons (July to September for rainy season and November to January for dry season).

Well water samples from the three different locations were collected in 100 ml sterile capacity bottles and transported to the Department of Microbiology, Ahmadu Bello University, Zaria for examination of bacteria.All samples were collected during the early hours of the day (between 8am and 10am) and analyzed within 6hours from the time of collection (APHA, 1992).

2.2 Bacteriological Analysis

2.2.1 Standard plate count

One milliliter of the water sample was diluted in 99ml sterile distilled water and filtered through 0.45µm sterile membrane filter paper. The filter paper was then placed on pre-sterilized and solidified standard plate count agar (SPCA) and incubated at 37°C. Colonies were counted and expressed as colony forming units per 100 ml (cfu/100 ml) after 24 hours of incubation.

2.3 Total Coliforms and *E. coli* Counts

One milliliter of the water sample was diluted in 99 ml sterile distilled water and filtered through 0.45 µm sterile membrane filter paper. The filter paper was then placed on pre - sterilized and solidified Membrane Lactose Glucoronide agar (mLGA) plate and incubated at 37°C for 24 hours. The result was read within 15minutes after removal from the incubator because the yellow coloration of colonies changes on cooling and standing. Green colonies were regarded as presumptive *E. coli* while the yellow colonies were regarded as other coliforms. The total coliform counts were counts of both the green plus the yellow colonies and expressed as cfu/100 ml.

2.4 Thermotolerant Coliforms

One milliliter of the water sample was diluted in 99 ml sterile distilled water and filtered through 0.45µm sterile membrane filter paper. The filter paper was then placed on pre-sterilized and solidified Membrane Lactose Glucoronide agar (mLGA) plate and incubated at 45°C for 24 hours. The result was read within 15minutes after removal from the incubator because the yellow coloration of colonies changes on cooling and standing. Green colonies were regarded as presumptive *E. coli* while the green plus the yellow colonies were regarded as thermotolerant coliforms and expressed as cfu/100 ml.

2.5 Biochemical Characterization of the Bacteria Isolates

After enumeration of total bacteria count, coliforms counts and *E. coli* counts, 2 colonies were randomly picked from countable plates of mLGA that were incubated at 45°C. The colonies were Gram stained and Gram negative isolates were transferred onto nutrient agar slants and stored at 4°C for biochemical characterization.

The following biochemical tests were carried out on the isolates;

2.6 Motility Test

Motility medium was prepared according to manufacturer's instruction and dispensed in bijou bottles. Using a sterile needle, a colony of 24 hours culture of the organism was picked and stabbed into the medium to within 1 cm of the bottom of the tube. The medium was then incubated at 37°C for 24 hours and was observed for evidence of growth.

2.7 Citrate Utilization Test

Simmon citrate agar was prepared according to manufacturer's instruction and dispensed in bijou bottles and sterilized at 121°C for 15minutes. The bottles were inoculated with 24 hours culture of the test organism and incubated at 37°C for 24 hours. The tubes were then observed for colour change from green to blue.

2.8 Indole Test

One colony of a 24 hours culture of the test organism was inoculated into bijou bottles containing 3ml of sterile peptone water and incubated at 37°C for 24 hours. 0.5 ml Kovac's reagent was then added and examined for red colour on the surface within few minutes.

2.9 Urease Test

Urea agar was prepared according to manufacturer's instruction and sterilized at 121°C for 15 minutes. Glucose and phenol red were added to the medium and steamed for 1hour. A filter sterilized urea solution was added and mixed properly and dispensed into sterile bottles. The bottles were inoculated with 24 hours culture of the test organism and incubated at 37°C for 24 hours, then observed for pink colour in the medium.

2.10 Methyl Red and Voges-Proskauer (MR-VP) Test

A tube was inoculated with a single colony from a 24 hours culture of the test organism and incubated at 37° for 24 hour. After incubation, using a sterile pipette, two aliquots were removed and placed into small tubes; one for methyl red test and the other for Voges-Proskauer test. 5 drops of methyl red were added to one tube and the result was read immediately. For the Voges- Proskauer test, 15 drops of Voges-Proskauer reagent A was added and mixed well. 5 drops of Voges-Proskauer reagent B was also added and mixed well.

Methyl red: A red colour at the surface was considered a positive test while a yellow colour at the surface indicated a negative test.

Voges-Proskauer: A positive test was indicated by a pink-red colour developing within 5 mins.

2.11 Characterization of the Bacteria Isolates Using Microgen Test Kit

The isolates were further characterized using microgenGnA ID system.

2.12 Preparation of Suspension of the Test Organism

A single colony from a 24 hours culture of the test organism was emulsified in 3 ml of 0.85% NaCl solution, making sure that the suspension was homogenous and without clumps of floating bacteria.

2.13 Inoculation of the Organism and Incubation

The back of the adhesive tape sealing the microwells test strips was peeled. One hundred mililitre of the suspension of the test organism was inoculated into each well with a sterile micro pipette. After inoculation, wells 1, 2, 3 and 9 were overlaid with 3 drops of mineral oil. The top of the microwell test strip was sealed with the adhesive tape removed earlier and incubated at 37°C for 24 hours.

Table 1. Distribution of samples across the sampling locations

Sampling location	Number of cast wells	Number of non-cast wells
Samaru	30	23
Sabon-gari	20	24
Tudunwada	12	27
Total	68	74

2.14 Reading and Addition of Reagent

The wells were read after 24 hours of incubation. The proper reagents were added to the compartments accordingly as described in the chart. Using the identification colour chart, results were recorded in the recording sheets. The substrate reactions were organized into triplets with each substrate assigned a numerical value. The sum of the positive reactions for each triplet formed a single digit of octal code that was used to determine the identity of the isolate. The octal code was entered into the microgen identification software, which generated a report of five most likely organisms in the database. The software provided identification based on the probability, percentage probability and likelihood with an analysis of the quality differentiation. Potential organism was recorded based on the percentage probability.

3. RESULTS

Table 2 presents the result for total bacterial count of cast and non-cast wells according to season and sampling location. Bacterial counts range from ($2.02x10^2 \pm 1.85x10^2$ - $1.73 \times 10^3 \pm 2.73x10^2$ cfu/100ml) during the raining season and $4.17x10^2 \pm 3.07x10^1$ – $1.39x10^3 \pm 3.27x10^2$cfu/ 100 ml (mean ± standard error of mean).

Coliforms and *E. coli* were present in all the samples with total coliform counts ranging from 1.06×10^3 – 2.12×10^4cfu/100 ml and *E. coli* counts ranging from 5.10×10^2 – 5.00×10^4cfu/100 ml (plates incubated at 37^0C). Counts were also higher during the raining season in all the locations compared to the dry season (Table 3).

Faecal (thermotolerant) coliforms and *E. coli* (plates incubated at 45°C) counts were present in most of the samples with values ranging from $1.70 \times 10^2 \pm 6.10 \times 10^1$ – $6.16 \times 10^3 \pm 1.60 \times 10^3$cfu/100 ml (Table 4).

Table 5 is the percentage occurrence of faecal coliforms and *E. coli* in the well water samples. Faecal coliform counts were higher in wells without casting (91.9%) compare to wells with casting (91.2%) while *E. coli* counts were higher in wells with casting (77.9%) compared to wells without casting (66.2%).

Table 6 shows the comparison of the mean values of the bacterial counts of the well water samples drawn from the three sampling locations. There were no statistical difference in all the bacterial counts between the locations (p-values were all greater than 0.05). Also, there were no significant differences in the bacterial counts between well water drawn during the rainy and well water drawn during the dry season and shown in Table 7(p-values were all greater than 0.05).

The effect of casting on the bacterial counts in the well water is presented in Table 8. However, there was no significant difference in the bacterial counts between wells with internal wall casting and wells without internal wall casting (p-values were all greater than 0.05).

Table 9 presents the percentage occurrence of the bacterial species isolated from the sampling location. A total of 168 organisms were isolated and 98(69.0%) were isolated from cast wells while 76(53.5%) were isolated from non-cast wells. *E. coli* was isolated more frequently (48.3%) compared to other species and was more frequent in non-cast wells (50.0%) compared to cast wells (47.1%). Other species were more frequent in cast wells.

Table 2. Mean values of total bacterial count of cast and non-cast well according to season and sampling location (mean ± standard error of mean)

Location		No. of samples		Total bacterial count (cfu/100 ml)	
		Cast	Non-cast	Cast	Non-cast
Tudunwada	R	7	13	$2.13x10^2 \pm 4.01x10^2$	$1.96x10^3 \pm 1.98x10^2$
	D	11	14	$4.03x10^2 \pm 4.9 \pm 10^1$	$4.27x10^2 \pm 3.97 \pm 10^1$
Samaru	R	15	13	$1.94x10^3 \pm 4.60x10^2$	$4.04x10^2 \pm 5.00x10^1$
	D	15	10	$1.61x10^3 \pm 5.27x10^2$	$1.07x10^3 \pm 2.18x10^2$
Sabon-gari	R	10	14	$1.44x10^3 \pm 3.18x10^2$	$2.37x10^3 \pm 3.50 \pm 10^2$
	D	10	10	$5.31x10^2 \pm 5.7x10^1$	$3.54x10^2 \pm 8.31x10^1$

Key; R = Rainy season
D = Dry season

Table 3. Mean values of total coliform count and *E. coli* count of cast and non-cast well according to season and sampling location (mean ± standard error of mean)

Location		No. of samples		Total coliform count (cfu/100 ml)		*E. coli* count (cfu/100 ml)	
		Cast	Non-cast	Cast	Non-cast	Cast	Non-cast
Tudunwada	R	7	13	$1.56x10^4±2.94x10^3$	$2.00x10^4±4.22x10^3$	$1.05x10^4±2.31x10^3$	$1.60x10^4±4.20x10^3$
	D	11	14	$3.65x10^3±4.31x10^2$	$3.71x10^3±5.10x10^2$	$1.41x10^3±3.00x10^2$	$1.05x10^4±2.91x10^2$
Samaru	R	15	13	$2.20x10^4±4.21x10^3$	$3.65x10^3±4.32x10^2$	$9.92x10^3±3.01x10^3$	$1.41x10^3±3.00x10^2$
	D	15	10	$3.50x10^3±4.80x10^2$	$1.06x10^3±9.20x10^1$	$1.27x10^3±2.84x10^2$	$5.10x10^2±1.54x10^2$
Sabon-gari	R	10	14	$1.37x10^4±4.24x10^3$	$6.16x10^3±1.10x10^3$	$2.06x10^3±4.41x10^2$	$8.57x10^2±2.98x10^2$
	D	10	10	$2.29x10^3±4.69x10^2$	$2.97x10^3±7.23x10^2$	$3.50x10^2±1.19x10^2$	$1.09x10^3±6.09x10^2$

Key; R = Rainy season
D = Dry season

Table 4. Mean values of faecal coliform count and *E. coli* count of cast and non-cast well according to season and sampling location (mean ± standard error of mean) (plates incubated at 45°C)

Location		No. of samples		Faecal coliform count (cfu/100 ml)		*E. coli* count (cfu/100 ml)	
		Cast	Non-cast	Cast	Non-cast	Cast	Non-cast
Tudunwada	R	7	13	$4.63x10^3±1.35x10^3$	$6.10x10^2±3.07x10^2$	$2.89x10^3±1.23x10^3$	$1.88x10^3±7.70x10^2$
	D	11	14	$6.41x10^2±2.05x10^2$	$3.71x10^3±5.10x10^2$	$6.10x10^2±1.19x10^2$	$4.79x10^2±1.20x10^2$
Samaru	R	15	13	$2.55x10^3±6.99x10^2$	$3.65x10^3±4.32x10^2$	$6.42x10^2±2.05x10^2$	$2.14x10^2±6.10x10^1$
	D	15	10	$1.05x10^3±1.66x10^2$	$1.06x10^3±9.92x10^1$	$3.42x10^2±9.00x10^1$	$1.72x10^2±6.10x10^1$
Sabon-gari	R	10	14	$2.26x10^3±4.02x10^2$	$6.16x10^3±1.61x10^3$	$1.38x10^3±3.45x10^2$	$4.30x10^2±1.19x10^2$
	D	10	10	$3.60x10^2±1.38x10^2$	$2.97x10^3±7.23x10^2$	$5.10x10^2±1.81x10^2$	$1.39x10^2±7.70x10^1$

Key; R = Rainy season
D = Dry season

Table 5. Frequency of occurrence of faecal coliform and *E. coli* in cast and non-cast well according to season and sampling location

Location		Faecal coliform (%)		*E. coli* (%)	
		Cast	Non-cast	Cast	Non-cast
Tudunwada	R	7(100)	11(86.6)	7(100)	8(61.5)
	D	11(100)	14(100)	8(72.7)	12(85.7)
Samaru	R	14(93.3)	10(76.9)	14(93.3)	9(69.2)
	D	15(100)	10(100)	13(86.7)	6(60)
Sabon-gari	R	9(90)	14(100)	7(70)	9(64.3)
	D	6(60)	9(90)	4(40)	5(50)
Total		62(91.2)	68(91.9)	53(77.9)	49(66.2)

Key; R = Rainy season; D = Dry season

Table 6. Comparison between mean values of bacterial counts of the well water samples drawn from the three sampling locations (mean ± standard error of mean)

Bacterial count	Samaru	Sabon-gari	Tudunwada	P-value
Total bacterial count	$1.2x10^2±0.8x10^1$	$1.4x10^3±1.2x10^2$	$7.7x10^2±3.3x10^2$	0.43ns
Total coliform count	$2.1x10^2±1.6x10^1$	$5.5x10^3±3.2x10^2$	$6.8x10^2±3.2x10^2$	0.53ns
E. coli count	$3.7x10^3±2.0x10^2$	$1.1x10^3±3.7x10^2$	$7.2x10^3±6.0x10^2$	0.56ns
Faecal coliform count	$2.1x10^3±1.0x10^2$	$2.9x10^3±1.2x10^2$	$2.4x10^3±2.2x10^2$	0.82ns

Key; ns = not significant

Table 7. Seasonal influence on the bacterial count of the well water samples drawn from the three sampling locations (mean ± standard error of mean)

Bacterial count	Rainy season	Dry season	P-value
Tatal bacterial count	$1.4x10^3±2.6x10^2$	$9.5x10^3±8.6x10^2$	0.40ns
Total coliform count	$7.5x10^3±1.9x10^3$	$2.1x10^3±9.0x10^2$	0.7ns
E. coli count	$6.8x10^3±3.5x10^3$	$1.2x10^3±3.0x10^2$	0.10ns
Faecal coliform count	$3.3x10^3±4.7x10^2$	$1.6x10^3±3.2x10^2$	0.10ns

Key; ns = not significant

Table 8. Effect of casting on the bacterial counts in the well water drawn from Zaria (mean ± standard error of mean)

Bacterial count	Cast	Non-cast	P-value
Total coliform count	$9.9x10^3±1.4x10^2$	$7.2x10^3±1.1x10^3$	0.18ns
Faecal coliform count	$4.1x10^3±8.5x10^2$	$3.9x10^3±9.8x10^2$	0.15ns
E. coli count	$1.0x10^3±6.4x102$	$7.4x10^2±1.6x10^2$	0.13ns
Total bacterial count	$1.3x10^3±1.7x10^2$	$1.3x10^3±1.7x10^2$	0.09ns

Key; ns = not significant

4. DISCUSSION

Raw water may contain a wide variety of harmless heterotrophic and pathogenic micro-organisms. The standard plate count also called heterotrophic plate count (HPC) is used to estimate the total amount of bacteria in the water and indicates the overall status of the water. Heterotrophic microorganisms include both members of the natural microbial flora of water environments and organisms in water pollution sources [14,1]. Increase in heterotrophic microorganisms in water can influence of microbial growth in the distribution system and presence of biofilm [15], and this may increase the risk of gastroenteritis [16]. The total bacterial count of the sample range from $2.02x10^2±$ $1.85x10^2$ - $1.73 x 10^3 ± 2.73x10^2$ cfu/100 mlfu/ 100 ml during the raining season and $4.17x10^2$ $±3.07x10^1$ – $1.39x10^3±3.27x10^2$cfu/100 ml during the dry season. HPC has no health effect, however, the lower the concentration of bacteria in the water the better maintained the water system [17].

Table 9. Percentage occurrence of the bacterial species isolated from the sampling location

Organism	Number of isolates (%)		Total (%)
	Cast	Non-cast	
E. coli	32(47.1)	37(50.0)	69(48.6)
Klebsiella pneumoniae	8(11.8)	6(8.1)	14(9.9)
klebsiella ozaenae	9(13.2)	6(8.1)	15(10.6)
Enterobacter agglomerans	8(11.8)	8(10.8)	16(11.3)
Enterobacter gergoviae	10(14.7)	5(6.8)	15(10.6)
Enterobacter aerogenes	6(8.8)	4(5.4)	10(7.0)
Citrobacter freundii	6(8.8)	3(4.1)	9(6.3)
Proteus mirabilis	4(5.9)	0(0)	4(2.8)
Serratia liquefaciens	7(10.3)	7(9.5)	14(9.9)
Acinetobacter lwoffii	2(2.9)	0(0)	1(1.4)
Total	98(69.0)	76(53.5)	168 (100)

Key; % = percentage occurrence

Total coliforms, thermotolerant coliforms and *E. coli* were detected at 100%, 91.5% and 71.8% respectively in the water samples. These are bacteria whose presence indicates faecal contamination from human or animal sources [18,19]. Pathogens from these sources in water can cause diarrhea, cramps, nausea, headaches and other symptoms. These pathogens may pose a special health risk for infants, young children and the immuno-compromised [14,20].

According to Nigeria standard for drinking water quality, there should not be more than 10cfu/100 ml of total coliforms in water, and zero tolerance for thermotolerant coliforms and *E. coli* [21]. The presence of significant amount of coliforms and *E. coli* in the water samples in both cast and non-cast wells is indicative of inadequacy of the depths of the wells and/or a breach of the sanitary intergrity of the wells.

Total coliform count, faecal coliform count and total bacterial count were higher in wells with internal wall casting than in wells without internal wall casting. Bacterial species were also more frequently isolated in wells with internal wall casting than in wells without internal wall casting. But analyses of variances on the data obtained showthe differences were not significant. This could mean that internal wall casting does not have a direct impact of the bacteriological quality of the water obtained from them.

Furthermore, 168 faecal coliform organisms belonging to 7 Genera and 10 species of bacteria were isolated in this study. *E. coli* was isolated more frequently from the water samples (48.6%). The presence of *E. coli* in drinking water sources often indicates recent faecal contamination. That means there is a higher risk that other pathogens are present. *E. coli* is usually a normal flora of the gastrointestinal tractof humans and warm-blooded animals. However, some strains can cause illness [22].

The presence of*Enterobacter*, *Klebsiella, Citrobacter, Proteus, Serratia and Acinetobacter* species in the water sources is of public health importance. The presence of *Enterobacter* in water sources may be indicative of faecal contamination. Other sources could be soil, polluted water and plants [23,24]. Although these organisms have been isolated in drinking water sources and have been found to colonize distribution systems, no outbreaks of associated human disease have been conclusively reported. However, they have been associated in nosocomial infections and hospital acquired infections in humans [25,24]. *Klebsiella* species are natural habitants of many fresh water environments and they may multiply to high numbers in water rich in nutrients. These organisms are also excreted in the faeces of many healthy humans and animals, and they are readily detected in sewage polluted water. *Klebsiella* species isolated in drinking water sources are usually biofilms organisms and are unlikely to represent health risk [15]. However, *Klebsiella pneumonia* accounts for a significant proportion of hospital acquired urinary tract infections, pneumonia, septicemia and soft tissue infections [26,27]. *Citrobacter* is a commensal bacteria found in the intestine of humans and almost every other environments including water, wastewater and soil. The strain *Citrobacter freundii* is often implicated in opportunistic infections mostly associated with abdominal inflammatory changes in the intestinal tract. It can also affect the billary, urinary and respiratory tracts, and can enter the bloodstream of immune-

compromised patients. *Proteus mirabilis*, *S. liquefaciens* and *Acinetobacter* were isolated from the samples are naturally present in the environment and not regarded as pathogens, but can cause opportunistic infections when present in drinking water.

5. CONCLUSION

The presence of significant counts of coli form bacteria and *E. coli* in hand dug wells in some parts of Zaria communities is of great concern. This is indicative of improper well construction in terms of the topography and distance from septic system and/or breach in the sanitary integrity of the wells. The bacteria isolated from the various samples are mostly of enteric origin. These organisms acquire public health significance under certain conditions. Therefore their removal in drinking water should be given moderate priority. The wells in this study fail to meet the minimum standard for safe drinking water and are therefore not safe for domestic purposes especially for drinking purpose without adequate treatment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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