Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Applied Science Research, 2011, 3 (3):94-108

(http://scholarsresearchlibrary.com/archive.html)

ISSN 0975-508X
CODEN (USA) AASRC9

Bacteriological, Physicochemical and Mineral Studies of Water Samples from Artesian bore-hole, Spring and Hand dug Well located at Oke-Osun, Ikere-Ekiti, Nigeria

***Odeyemi, A.T., [1]Akinjogunla, O.J and Ojo, M.A**

Department of Microbiology, University of Ado Ekiti, Ekiti State, Nigeria
[1]Department of Microbiology, Faculty of Science, University of Uyo, Uyo, Akwa Ibom State, Nigeria

---

ABSTRACT

Bacteriological and physicochemical values of water samples from Artesian bore hole, spring and nearby hand dug well located at Oke-Osun, Ikere-Ekiti were determined. Total viable and coliform counts were determined by using pour plate techniques. Antibiotic susceptibility were determined using disc diffusion method. The physicochemical and mineral content were analyzed using standard method. The mean total bacteria count of the water samples ranged as follow: A (113 x 10^2-67.1 x 10^3) CFU/ml, B (105.3 x 10^2-66 x 10^3) CFU/ml, C (76.9 x 10^2-61 x 10^3) CFU/ml and D (167 x 10^2-124.9 x 10^3). The mean total coliform count of the samples ranged as follow: A (25.4 x 10^2-16.7 x 10^3) CFU/ml, B (31.3 x 10^2-15.1 x 10^3) CFU/ml, C (63.3 x 10^2-39.3 x 10^3) CFU/ml and D (88.4 x 10^2-47.3 x 10^3) CFU/ml. The mean total enterococcus count of the water samples ranged as follow; A (4.7 x 10^2-2.1 x 10^3) CFU/ml, B (7.0 x 10^2-2.9 x 10^3) CFU/ml, C (3.0 x 10^2-1.4 x 10^3) CFU/ml and D (3.9 x 10^2-1.7 x 10^3) CFU/ml. The isolated organisms identified were Enterococcus spp, Escherichia spp , Pseudomonas aeruginosa, Salmonella spp, Klebsiella spp and Shigella spp. Some strains of the isolated bacteria were resistant to some antibiotics such as gentamycin, tetracycline and fusidic acid. The physicochemical values of the water samples ranged as follow: conductivity (2.40 x 10^{-2}-6.3 x 10^{-2}) μScm^{-1}, turbidity (ND-0.001) NTU, pH (5.15-7.33), chloride (5.33-30.2) mgL^{-1}, total suspended solid (17.4-26.2) mgL^{-1}, total hardness (24.0-152.0) mgL^{-1}, total alkalinity (18.0-128.0) mgL^{-1}, acidity as $CaCO_3$ (0.60-2.50) mgL^{-1}, total dissolved solids (11.5-19.3) mgL^{-1} and total solid (30.3-45.4) mgL^{-1}. The minerals analyzed in the water samples were have the following values; raw artesian water (13.3, 15.4, 16.6,14.4 and 0.25) mgL^{-1}, treated artesian water (10.5, 11.8, 9.25, 12.1 and 0.20) mgL^{-1}, spring water (11.7, 12.5, 8.54, 10.4 and ND) mgL^{-1} and hand dug well water (15.4, 18.6, 20.5, 13.4 and 0.12) mgL^{-1} respectively, while Pb, Mn, Cd and Co were not detected in all the water samples. The study however, discussed the likely sources of contamination of the artesian, spring and well water samples and some water borne hazards caused by consuming such untreated water.

Keywords: Antibiotic susceptibility, Enterococcus, Coliform, *Pseudomonas aeruginosa*, Contamination.

INTRODUCTION

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place, depending on the slope of the land, amount and intensity of rainfall, and type of land surface. Porous, or permeable, land containing lots of sand or gravel will allow as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable areas, as little as five percent may seep in. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater. As water seeps through permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table.

A well is human-made hole that is dug or drilled deep enough to intersect the water table. If the well is dug beneath the water table, water will fill the open space to the level of the water table, and can be drawn out by a bucket or by pumping. An artesian well is a deep drilled well through which water is forced upward under pressure. The geologic conditions necessary for an artesian well are an inclined aquifer sandwiched between impervious rock layers above and below that trap water in it. Water enters the exposed edge of the aquifer at a high elevation and percolates downward through interconnected pore spaces. The water held in these spaces is under pressure because of the weight of water in the portion of the aquifer above it. If a well is drilled from the land surface through the overlying impervious layer into the aquifer, this pressure will cause the water to rise in the well. In areas where the slope of the aquifer is great enough, pressure will drive the water above ground level in a spectacular, permanent fountain. Water from an artesian well or spring is usually cold and free of organic contaminants, making it desirable for drinking.

Groundwater is usually assumed to be a very good source of potable water due to purification property of soil [1]. However, underground water may be subjected to pollution and may not be as safe as is generally assumed.

Increasing amounts of discharged sewage, progressing urbanisation, the chemicalization of agriculture and industry, as well as anthropogenic activities all affect the quality of underground waters. The final effect of water degradation is the limits as to the use of drinking water reservoirs. Frequently this state is coupled with microbiological contamination, resulting in the penetration of potentially pathogenic bacteria or microorganisms detrimental to underground waters through the soil [2]. Hence, these bacteria may become the source of various diseases, the intensity of which would largely depend on microorganism pathogenecity and disease potential. Numbers of bacteria are also important, as well as their survival and possibilities to adapt and migrate deep into water-bearing underground reservoirs [3]. Some of the bacteria, such as *Pseudomonas* or *Aeromonas*, may be a threat to human health due to their ability to multiply in drinking waters [4].

Ikere-Ekiti Artesian bore-hole is a well which the water encountered at depth under sufficient (hydraulic) pressure to force the water up to the surface. This bore-hole intercepted the water saturated plane on 16th February, 1982 at the depth of 22metres (approximately 72 feet). The well was drilled to the depth of 35metres without any appreciable increase in water yield. The fact that water has been flowing continuously at the same rate since 1982 indicate that the aquifer is being constantly flushed with water from meteoric (rain) sources.

The objective of this study was to check the bacteriological and physicochemical parameters of the water samples from three major sources of underground water located at Oke-Osun, Ikere-

Ekiti, Nigeria and to find out the likely sources of contaminations and degree of pollution in them.

MATERIALS AND METHODS

Study site and collection of sample

The artesian bore-hole (A&B), spring (C) and the sampled well (D) (Figure 1, 2, 3, 4 respectively) are all situated at Oke-Osun, Ikere-Ekiti, Ekiti State, Nigeria (Fig 5and 6)

Using aseptic techniques, water samples were collected directly from the sampling points using 250 ml sterile sized-bottles. Samples were transported to the laboratory on ice and analyzed within 4 h after collection. Water samples collected for mineral analysis were chemically preserved by the addition of 5ml concentrated HNO_3 per litre of the sample.

Microbiological Analyses

Enumeration of bacterial population

Determination of bacterial load in water samples were done in triplicates. The total numbers of culturable heterotrophic bacteria were determined by serial dilution and plating on general purpose media. Serial dilutions of water samples (1 ml fresh volume) were made with one-fourth strength Ringers solution. Plate counts of culturally viable bacteria were made on Tryptone Soya Agar (TSA; Oxoid, Basingstone, Hampshire, England) amended with 0.1 g/l cyclohexamide. The plates were inoculated with 1ml of water inoculum and cultured at 37°C for 24 h.

Isolation and characterization of *Enterococcus* species

Isolation of *Enterococcus* species was carried out on Bile Esculin agar. The bacterial isolates were identified as described by [5]. Pure cultures of isolates were kept on nutrient agar slants at 12°C until used. The isolates were identified on the basis of cellular morphology following Gram stain, and results of biochemical testing, including catalase production, growth in 6.5% NaCl broth, haemolytic activity and motility [6].

Antibiotic susceptibility test

The antibiotics susceptibility of the isolates was determined by the disk diffusion method on Mueller-Hilton agar according to [7]. The bacterial isolates were tested against seven ABTEK disc antibiotics which comprised Fusidic acid, Kanamycin, Ampicillin, Cotrimoxazone, Streptomycin, Nalidixic, Colistin, Tetracycline, Penicillin, Erythromycin, Clindamycin, Trimethropim, Gentamycin and Sulfamethoxazole. The inoculum was standardized by adjusting its density to equal the turbidity of a barium sulphate (BaSO4) (0.5 McFarland turbidity standard), and incubated at 35^{o}C for 18 hours. The diameter of the zone of clearance (including the diameter of the disk) was measured to the nearest whole millimeter and interpreted on the basis of CLSI guideline [7].

Physicochemical and mineral analyses

The water sample temperature was taken at the site of collection using a simple thermometer calibrated in °C, electrical conductivity was measured with a CDM 83 conductivity meter (Radio Meter A/S Copenhagen, Denmark).Turbidity and pH were determined at site using Water Proof Scan 3+ Double Junction (Wagtech International, UK) and HI 98311-HI 98312 (Hanna) Water

Proof EC/TDS and Temperature Meters (Wagtech International, UK). The water samples were then stored in the deep freezer until analyzed. Other physicochemical characteristics determined were hardness determined by titrimetry; total dissolved solid and total suspended solid were determined by gravimetric method; acidity, alkalinity and sulphate were determined by titrimetry; both nitrate and phosphate were determined colorimetrically by Spectronic -20 (Gallenkamp, UK) as described by [8].

Zinc, iron, copper, cobalt, lead, cadmium, manganese, magnesium and calcium were analyzed in triplicate using an Atomic Absorption Spectrophotometer (PYE Unicam Sp 9, Cambridge, UK) [9]. Potassium and sodium were analyzed from the sample solutions by means of a Flame Photometer (BUCK 2010 VGP AAS).

RESULTS

The result of the viable bacterial count (Table 1&2) revealed that, the mean total bacteria count ranged as followed: A (113 x 10^2-67.1 x 10^3) CFU/ml, B (105.3 x 10^2-66 x 10^3) CFU/ml, C (76.9 x 10^2-61 x 10^3) CFU/ml and D (167 x 10^2-124.9 x 10^3) CFU/ml, while the mean total coliform count ranged as followed: A (25.4 x 10^2-16.7 x 10^3) CFU/ml, B (31.3 x 10^2-15.1 x 10^3) CFU/ml, C (63.3 x 10^2-39.3 x 10^3) CFU/ml and D (88.4 x 10^2-47.3 x 10^3) CFU/ml. The mean enterococcus count ranged; A (4.7 x 10^2-2.1 x 10^3) CFU/ml, B (7.0 x 10^2-2.9 x 10^3) CFU/ml, C (3.0 x 10^2-1.4 x 10^3) CFU/ml and D (3.9 x 10^2-1.7 x 10^3) CFU/ml. This indicated higher microflora in treated artesian and hand dug water samples than the raw artesian water samples. However, lower count was experienced from water samples from spring. Also the water samples from spring have the lowest enterococcus count while water samples from raw artesian bore-hole have the highest value.

The result of antibiotic resistance pattern of isolated coliform and enterococcus species were shown in Table 3 and 4. The levels of percentage resistance of coliforms to antibiotics are as follow: *Escherichia* spp (30%KAN, 25%AMP, 10%GEN, 40%COT, 50%TET, 40%STR, 50%NAL and 50%COL), *Salmonella* spp (30%KAN, 30%AMP, 10%GEN, 30%COT, 5%TET, 15%STR, 15%NAL and 15%COL), *Shigella* spp (15%KAN, 5%AMP, 10%GEN, 10%COT, 25%TET, 25%STR, 25%NAL and 25%COL) and *Klebsiella* spp (10%KAN, 10%AMP, 5%GEN, 5%COT, 10%TET, 5%STR, 10%NAL and 10%COL). Percentages of resistance of isolated enterococcus are as follow: fusidic (84%), Erythromycin (88%), trimethropin (92%), sulfamethroxazone (96%), tetracycline (88%), penicillin (100%), clindamycin (96%) and gentamycin (52%). This indicated that gentamycin is strongly active against both isolated coliforms and enterococcus organisms.

Physicochemical values of the water samples was shown in Table 6 and ranged as follow: conductivity (2.40 x 10^{-2}-6.3 x 10^{-2}) µScm^{-1}, turbidity (ND-0.001) NTU, pH (5.15-7.33), chloride (5.33-30.2)mgL^{-1}, total suspended solid (17.4-26.2)mg/l, total hardness (24.0-152.0)mg/l, total alkalinity (18.0-128.0)mg/l, acidity as $CaCO_3$ (0.60-2.50)mgL^{-1}, total dissolved solids (11.5-19.3)mgL^{-1} and total solid (30.3-45.4)mgL^{-1}. The minerals analyzed in the water samples were Na, K, Ca, Mg and Fe have the following values; raw artesian water (13.3, 15.4, 16.6,14.4 and 0.25)mgL^{-1}, treated artesian water (10.5, 11.8, 9.25, 12.1 and 0.20)mgL^{-1}, spring water (11.7, 12.5, 8.54, 10.4 and ND)mgL^{-1} and hand dug well water (15.4, 18.6, 20.5, 13.4 and 0.12)mgL^{-1} respectively, while Pb, Mn, Cd and Co were not detected in all the water samples.

DISCUSSION

Water that is free of pathogenic microbes and chemical substances deleterious to health is termed potable water. The lower bacterial count recorded of the artesian raw water samples were due to purification property of soil [1]. Whereas water samples from hand-dug well have the highest number of coliforms. This is as a result of unhygienic and poor sanitary condition such as washing dishes and cloths as well as defeacating near the well by the children, even animals were found around the well (fig.2). Even though the well water samples appeared clear and colourless, they may be heavily contaminated and has been observed to be a source of enteric pathogens in developing countries and hence it is a potential source of health hazards to users. The groundwater data are in agreement with two previous studies that examined groundwater wells situated near large-scale swine facilities [10] and [11]. [10] detected *E. coli* at a range of 0.5–32.7 CFU/100 mL in groundwater samples collected at two large-scale swine facilities in North Carolina. [11] detected fecal coliforms at a maximum concentration of 7 CFU/100 mL in shallow groundwater samples collected at a swine finishing facility in Illinois. In addition, [11] detected fecal streptococcus in more groundwater samples and at higher concentrations than fecal coliforms.

The higher coliform values recorded from the spring water samples may be as a result of human faeces and other wastes from anthropogenic activities (Figure 2) occasionally littered bushy locations close to the spring. Eventually they could be washed by rain water as run-off into the spring and thus contaminate it. This compromises the system as waste materials from humans and animals could find its way unchecked into the spring and other available water sources [12]. Enterococcus may be present in water samples as contaminant and may be of feacal origin, this is in agreement with [13] who reported that treated water may have a wide range of organisms which include indigenous species, saprophytic species as well as human pathogen such as *Enterococcus feacalis*, *E. facium*, *E. durans*, *E*. *avium* and other species of *Enterococcus*.

Some strains of enteric bacteria were resistant to gentamycin, tetracycline and fusidic acid. This is in support of the reports of [12] that, up to about 80% of the coliforms found in groundwater are antibiotic resistant. This is could be greatly attributed to drug abuse via indiscriminate drug usage among people. Most of the isolated Eterococcus spp are majorly resistant to fusidic acid, Erythromycin, trimethropin, sulfamethoxazole, tetracycline, penicillin, clindamycin and gentamycin. Based on the findings of the study, antimicrobial resistance demonstrated by encountered enterococcal isolates from water samples were remarkably high for all the tested antibiotics. The comparison of the percentage of resistant strains with previously published work is often complicated because previous researchers have used different numbers and kinds of antibiotics in their studies. However, the report of [14;15] corroborate writh the present work and suggested that the emergence of erythromycin resistance streptococcus might be as a result of prior exposure to drugs. [16] and [17] revealed through their work that virtually all enterococci tested were resistant to fusidic acid and the present work is line with this report. [18] observed higher minimal inhibitory concentrations for four antibiotics in enterococci isolated from down-gradient versus up-gradient surface water and groundwater. Elevated percentages of erythromycin- ($p = 0.02$) and tetracycline-resistant ($p = 0.06$) enterococci were detected in down-gradient surface waters, and higher percentages of tetracycline- ($p = 0.07$) and clindamycin-resistant ($p < 0.001$) enterococci were detected in down-gradient groundwater.

In contrast to high-level gentamicin resistance in enterococci, which appeared to be widely disseminated on different plasmids and in different strains by the time this phenotype was studied, penicillinase production in enterococci is still largely associated with a limited number of strains; moreover, in locations known to have more than one isolate, oligoclonal spread within each setting remains the rule.

Table 1.Bacteria count (CFU/ml) of water samples from Artesian bore-hole, Spring and Hand dug well

Water Samples	**Total Bacterial Count**		**Total Coliform Count**	
	10^2	10^3	10^2	10^3
A_1	47	40	23	15
A_2	39	28	20	10
A_3	50	45	34	22
A_4	180	93	30	17
A_5	160	49	26	18
A_6	191	102	25	21
A_7	124	113	20	14
Mean value	113	67.1	25.4	16.7
B_1	49	42	29	10
B_2	51	48	10	7
B_3	45	30	40	21
B_4	168	92	24	10
B_5	102	81	28	7
B_6	142	78	27	11
B_7	180	91	61	40
Mean value	105.3	66	31.3	15.1
C_1	51	44	30	17
C_2	30	28	36	15
C_3	24	16	120	103
C_4	96	73	39	19
C_5	128	99	70	23
C_6	106	96	45	20
C_7	103	71	103	78
Mean value	76.9	61	63.3	39.3
D_1	53	46	74	19
D_2	60	51	29	20
D_3	200	160	93	48
D_4	81	40	150	59
D_5	245	189	109	94
D_6	350	300	74	40
D_7	180	88	90	51
Mean value	167	124.9	88.4	47.3

A- Treated artesian well B- Raw artesian well C- Spring D- Hand dug well
1-7 – Period of sampling collection

In support of the present work on resistance of some of the isolated enterococci to tetracycline, [19] showed high levels of phenotypic and genotypic tetracycline resistance in Enterococcus isolates from broilers carrying the erm (B) gene, encouraging us to speculate that the frequent use of tetracyclines in poultry may co-select for resistance to MLS antibiotics, which may be important as alternative therapy for enterococcal infections in man.

Table 2. Enterococci count (CFU/ml) of water samples from Artesian bore-hole, Spring and Hand dug well

Water samples	Enterococci count (cfu/ml)	
	10^2	10^3
A1	6.0	4.0
A2	5.0	3.0
A3	2.0	1.0
A4	2.5	1.0
A5	4.0	1.5
A6	7.0	2.5
A7	6.5	2.0
Mean value	4.7	2.1
B1	8.0	4.0
B2	10.0	3.0
B3	6.5	2.5
B4	8.6	4.0
B5	10.0	5.0
B6	2.9	1.0
B7	3.0	1.0
Mean value	7.0	2.9
C1	2.5	1.5
C2	2.0	1.0
C3	2.0	1.0
C4	4.5	2.5
C5	1.5	0.5
C6	2.8	1.5
C7	6.0	1.5
Mean value	3.0	1.4
D1	4.0	3.0
D2	3.0	1.5
D3	6.5	2.5
D4	1.5	0.5
D5	4.5	1.5
D6	2.0	0.5
D7	6.0	2.5
Mean value	3.9	1.7

A- Treated artesian well B- Raw artesian well C- Spring D- Hand dug well
1-7 – Period of sampling collection

Resistance to clindamycin among the enterococcal isolates was also high (72%). Supporting this observation, [20] and [12] assert that like vancomycin use, the usage of clindamycin is equally or more often associated with infection with multiple drug resistant (MDR) enterococci.

Table 3. Antibiotic resistance pattern of isolated coliforms

Isolates	KAN			AMP			GEN			COT		
	R	S	I	R	S	I	R	S	I	R	S	I
Escherichia spp	6(30%)	2(10%)	2(10%)	5(25%)	3(15%)	2(10%)	2(10%)	4(20%)	4(20%)	8(40%)	1(5%)	1(5%)
Salmonella spp	2(30%)	-	1(5%)	2(30%)	1(5%)	-	2(10%)	1(5%)	-	2(30%)	-	1(5%)
Shigella spp	3(15%)	2(10%)	-	1(5%)	4(20%)	-	2(10%)	-	3(15%)	2(10%)	3(15%)	-
Klebsiella spp	2(10%)	-	-	2(10%)	-	-	1(5%)	-	1(5%)	1(5%)	1(5%)	-

Isolates	TET			STR			NAL			COL		
	R	S	I	R	S	I	R	S	I	R	S	I
Escherichia spp	10(50%)	-	-	8(40%)	1(5%)	1(5%)	10(50%)	-	-	10(50%)	-	-
Salmonella spp	1(5%)	-	2(10%)	3(15%)	-	-	3(15%)	-	-	3(15%)	-	-
Shigella spp	5(25%)	-	-	5(25%)	-	-	5(25%)	-	-	5(25%)	-	-
Klebsiella spp	2(10%)	-	-	1(5%)	1(5%)	-	2(10%)	-	-	2(10%)	-	-

Resistance = – Sensitivity = + Intermediate = I
KAN-Kanamycin GEN- Gentamicin AMP- Ampicillin COT- Cotrimoxazone
TET- Tetracycline NAL- Nalidixic COL- Colistin STR- Streptomycin

According to the report of [12] which stated Enterococci have a remarkable capacity of expressing resistance to several groups of antimicrobials thus posing a daunting challenge to the world of clinical practice as the number of therapeutic options for medical interventions are significantly reduced. The ubiquitous nature of the organism and its resistance to adverse environmental conditions is partly responsible for its ability to colonize different habitats and also its ability to spread easily through the food chain [21].

Table 4. Antibiotic resistance pattern of isolated *Enterococcus* species

Isolates	Antibiotic resistance pattern							
	FUS	ERY	TRM	SMX	TET	PEN	CLN	GEN
1	-	-	-	-	I	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	+
6	-	-	-	-	-	-	-	+
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	+
11	-	-	-	-	-	-	-	+
12	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-
14	-	-	+	-	-	-	-	I
15	-	-	-	-	-	-	-	-
16	+	I	-	-	-	-	-	+
17	+	-	-	-	-	-	-	+
18	+	I	-	-	I	-	-	+
19	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-
21	-	-	-	I	-	-	-	+
22	-	-	-	-	-	-	-	-
23	-	I	+	-	-	-	+	+
24	-	-	-	-	+	-	-	+
25	+	-	-	-	-	-	-	+
% of resistant isolates	84%	88%	92%	96%	88%	100%	96%	52%

Resistance = – Intermediate = I Sensitivity = +
FUS- Fusidic Acid ERY- Erythromycin TRM- Trimethropin SMX- Sulfamethroxazone
TET- Tetracycline PEN- Penicillin CLN- Clindamycin GEN- Gentamycin.

Table 5. Physicochemical parameters of water samples

Parameters	Water samples			
	Spring	Hand dug well	Treated artesian well	Raw artesian well
Colour	Colourless	Colourless	Colourless	Colourless
Odour	Odourless	Odourless	Odourless	Odourless
Turbidity	ND	0.001	ND	ND
Conductivity(µmhomscm^{-1})	2.40 x 10^2	6.0 x 10^2	6.2 x 10^2	6.3 x 10^2
pH	5.15	5.33	7.33	6.77
Chloride(mgL^{-1})	21.3	30.2	5.33	10.7
Total hardness(mgL^{-1})	24.0	40.0	116.0	152.0
Total alkalinity(mgL^{-1})	24.0	18.0	128.0	116.0
Acidity as $CaCO_3$(mgL^{-1})	2.50	1.80	0.70	0.60
Total solids(mgL^{-1})	33.6	45.5	34.5	30.3
TDS(mgL^{-1})	11.5	19.3	12.7	12.9
TSS(mgL^{-1})	22.0	26.2	21.9	17.4
Sulphate(mgL^{-1})	5.48	9.42	5.50	6.32
Nitrate(mgL^{-1})	3.50	6.75	3.45	4.21

ND- Not detected

Table 6. Mineral parameters of water samples (mgL^{-1})

Metals	**Water samples**			
	Spring	**Hand dug well**	**Treated artesian well**	**Raw artesian well**
Na	11.7	15.4	10.5	13.3
K	12.5	18.6	11.8	15.4
Ca	8.54	20.5	9.25	16.6
Mg	10.4	13.4	12.1	14.4
Cu	ND	ND	ND	ND
Fe	ND	0.12	0.20	0.25
Pb	ND	ND	ND	ND
Mn	ND	ND	ND	ND
Cd	ND	ND	ND	ND
Co	ND	ND	ND	ND

ND- Not detected

As presented by this study, the relevance of multiple resistances among environmental isolates of enterococci from sources that serve as drinking water to rural communities is thus a serious concern given the propensity to serve as reservoirs facilitating the spread of resistance traits to other non-resistant bacterial population.

The physicochemical parameters determined revealed values generally greater than values recommended by the [22].

Fig 1-Artesian borehole and the treatment measure (Sampling point B)

Fig 2-Point of collection of treated water (Sampling point A) under the influence of anthropogenic activities

Fig 3-Spring water (Sampling point C) under the influence of anthropogenic activities

Fig 4-Well water (Sampling point D)

Fig 5-The environment showing location of the Artesian borehole and the spring

Calcium concentration is within the 10-100 mgL^{-1} permissible in potable groundwater [23]. Calcium has no health effects on human. Magnesium concentrations in the sampled groundwater also fall within 1.0-40 mgL^{-1} normal range values in potable groundwater [24]. High magnesium concentration in water reduces its quality for domestic use, while a concentration above 500 mgL^{-1} gives an unpleasant taste and make it unfit for drinking purposes [25]. The value of Na is greater than that of K, which was in line with the observation that, concentration of K should normally be around one-tenth of sodium concentration and less than 10.0 mgL^{-1} for potable groundwater. The higher concentration of sodium limits the biological diversity due to osmotic stress. High sodium contents in the form of chloride and sulfates make the water salty and unfit for human consumption. Potassium plays the same role in water as sodium. It occurs in small amounts but is regarded as an important macronutrient in the metabolism of freshwater environments [25]. The iron values of all the water samples fall bellow WHO standard of 0.30 mg L^{-1} in potable water. High iron concentration in water could impart taste, discoloration, deposits and turbidity [26].

Groundwater contains major ions, trace metals and other toxic pollutants, in addition to bacteria [27]. The concentration of these substances in the aquifers is a function of the geological environment, composition of water, effect of storm water infiltration, water movement, its velocity, land use, rainfall and recharge mechanism. The increasing concentration of trace metals in ground water has generated a lot of concern in recent time. This has been attributed to human interference, proliferation of industries, and recent agricultural practice in urban areas where storm water flow recharges the aquifer. Effective retention of determinants depends upon soil types [28].

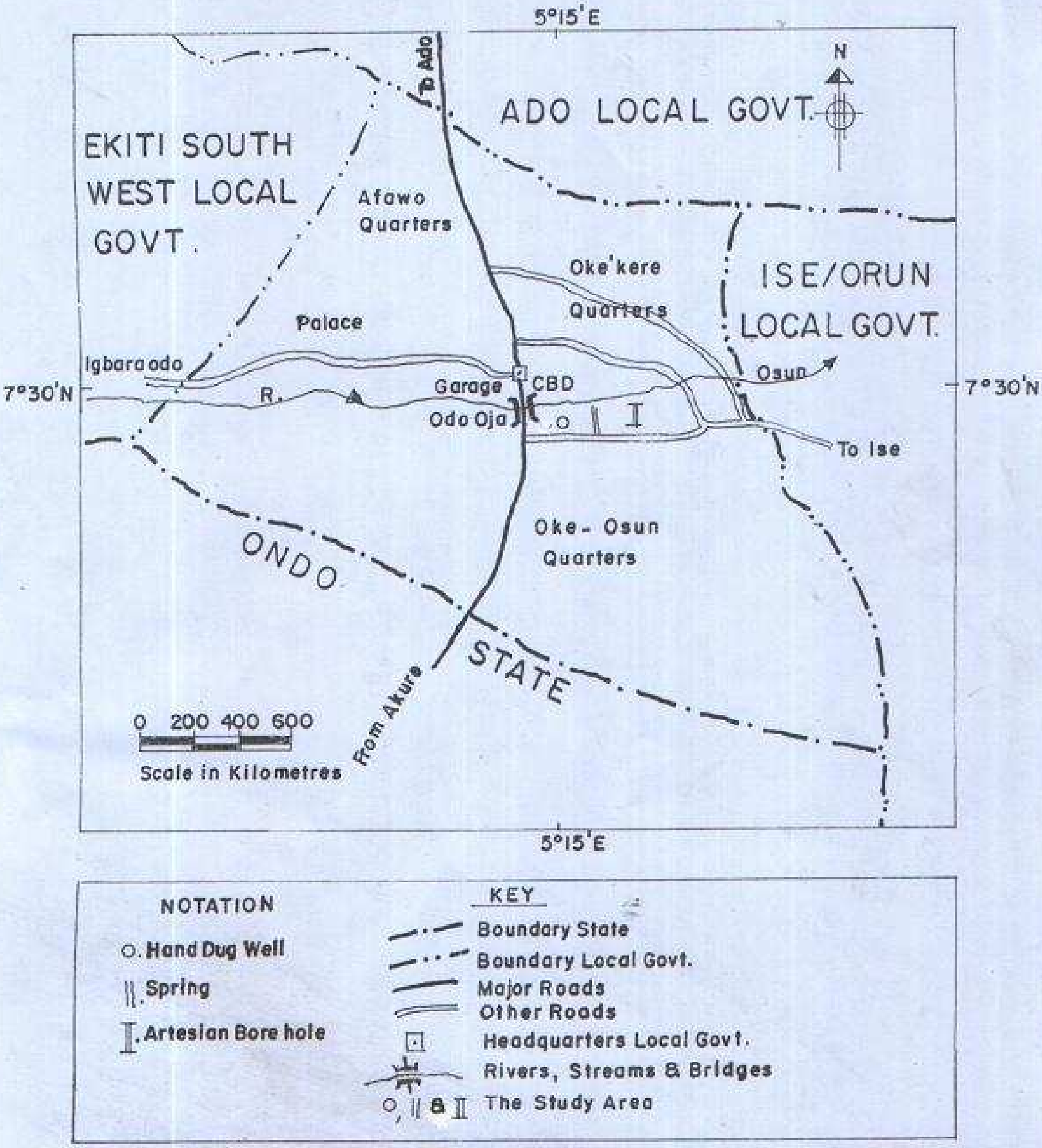

FIG. 6 : THE STUDY AREA WITHIN IKERE-EKITI, SHOWING THE ARTESIAN BORE HOLE, SPRING AND HAND DUG WELL.

SOURCE: Ikere Local Government Secretariat, Ikere-Ekiti / Dept. of Geography & Planning Science, Cartographic Unit, University of Ado-Ekiti, (UNAD).

Human activities have increased the concentration of metals in many of the natural water systems which have raised concerns regarding metal bioaccumulation and human health hazards [29]. The concentrations at which metals are considered important vary as some are essential at low concentration and toxic at higher levels. With increasing public concern regarding environmental contamination, there is a growing need to monitor, manage and remediate ecological damage [30;31].

CONCLUSION

The current research presented an analysis of the bacteriological and physicochemical studies conducted on Artesian borehole, the spring and an hand dug well, all situated at Oke-Osun, Ikere-Ekiti, Nigeria. The contamination of water samples from artesian borehole, spring and hand dug well with faecal coliforms suggest possibilities of contact with municipal waste or any other domestic effluents. The study also suggests a possible link between behavioral patterns of rural residents and the prevalence of antibiotic resistant enterococci in the water samples collected from underground water. It is therefore, important to educate inhabitants about the contamination of the underground water from the waste disposed in the neighbourhood, irrigation projects and industries that could lead to adverse health implication. The underground water need to be protected from outside contaminations.

REFERENCES

[1] M.K. Baptista., C.C.Sumesh and N. Gathu, *African Journal of Health Sciences*, **2004**, Vol.11.pp 61-66.
[2] R.E. Sjorgen, *Water, Air, and Soil Pollution*, **1995**, 81, 315.
[3] P. Payment., E. Coffin and G. Paquette, *Appl. Environ. Microbiol*, **1994**, 60, 1179.
[4] A.H. Havelaar, A. H., J. F. M. Versteegh and M. During, *Zentralbl. Hyg. Umweltmed.*, **1990**, 190, 236.
[5] G.I. Barrow and R.K.A. Feltham, *3rd edn. Cambridge: Cambridge University Press*, **1993**.
[6] L.A. Devriese., M.D. Collins, and R. Wirth, *The genus Enterococcus*, **1992**, 2nd edn, 2: 1465-1481.
[7] CLSI, *Clinical and Laboratory Standard Institute Wayne*, **2005**, vol.25, no.1.
[8] AOAC, *Association of Official Analytical Chemists, Wash. DC. , 15th edn*, **1990.**
[9] AOAC,*18th Ed Association of Official Analytical Chemist International, Gaithersburg, MD, USA, Official Method*, **2005**.
[10] M.E. Anderson and M.D. Sobsey, *Water Sci Tech*, **2006**, 54:211–218.
[11] I.G. Krapac., W.S. Dey, W.R. Roy, C.A. Smyth, E. Storment and S.L. Sargent, *Environ Pollution*, **2002**, 120:475–492.
[12] A.T. Odeyemi., A.C.Dada, O.R. Ogunbanjo and M.A.Ojo, *African Journal of Environmental Science and Technology*, **2010**, Vol. 4(6), pp. 319-327.
[13] P. Mathur., A. Kapil., R.Chandra., P.Sharma and B. Das, *Indian J Med Res*, **2003** 118:25-8
[14] M. Arvanitidou., V. Katsouyannopoulos and A. Tsakris, *J. Med.Microbiol*, **2001**, Vol 50, 1001-1005.
[15] G. Philips., D. Parratt, G.V. Orange, I. Harper, H. McEwan and N. Young, *J Antimicrob Chemother*, **1990**, 25:723-724.
[16] E.D. Toma., D. Barriault, C. Agbaba, and R. Morisset, **1989**, 164, p. 28.

[17] E. Toma and D. Barriault, *Journal of Clinical Microbiology*, **1995** 33(7) p. 1712–1715.
[18] R.S. Amy., C.C. Frank., E.G. Kristen and J.S. Kellogg, *Environ Health Perspect*, **2007**, 115:1040–1045.
[19] K. Cauwerts., A. Decostere., E.M. De Graef., F. Haesebrouck and F. Pasmans, *Avian Pathology*. **2007**, 36(5), 395-399.
[20] M.H. Mark., F.S. Daniel and S.G. Michael, *Emerging Infectious Diseases*, **1998**, 4: 2.
[21] P.F.S. Aparecida., E.M.D. Scheidegger., P.F. Santos., P.C. Leite and L.M. Teixeira, *Inst. Oswaldo Cruz*, **2007**, 102(7): 853-859.
[22] World Health Organization, *Guidelines for Drinking-Water Quality (Vol. 1). 2nd Edn.*, **1993**, pp: 36.
[23] W.H. Walker, *Groundwater*, **1973**, 11: 11-20.
[24] A. Adediji and L.T. Ajibade, *J. Hum. Ecol.*, **2005**, 17: 223-228.
[25] P.R. Trivedi and R. Gurdeep, *Akashdeep Publish.House, Delhi, India*. **1992**, pp. 141-152.
[26] World Health Organization, *Drinking Water Quality. 3rd Edn., Geneva*, **1971**, pp: 15-157.
[27] A. Zubair., M.A. Farooq and H.N. Abbasi, *The Pacific Journal of Science and Technology*, **2008**, 9 (1): 238-253.
[28] A. Zubair and M.A. Farooq, *A Paper Presented at the Ninth International Conference on Modelling, Monitoring and Management of Water Pollution*, **2008**.
[29] Y. Pan and R.B. Brugam, *J. Paleolimnology*, **1997**, 17:369-376.
[30] L. Jarup, *Braz. Med. Bull.* **2003**, 68:167-182.
[31] A.L.O.Silva., P.R.G. Barrocas., S.C. Jacob and J.C. Moreira, 2005. *Braz. J. Plant Physiol*. **2005**, 17:79-93.