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Original article

Determination of water quality of selected public wells in Ekiti state, south-western Nigeria

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A B S T R A C T

Representative water samples taken from some Public Hand-Dug Wells in Ekiti State were analysed for physico-chemical and microbiolgical characteristics using standard analytical methods. Results showed significant spatial variation. The characteristics of the water from the Underground source revealed an acceptable quality for most measured parameters with low chemical pollutants burden when compared with drinking water standards.

1. Introduction

Natural water is never entirely 100% pure as it carries traces of other substances which bestow to it physical, chemical and bacteriological properties. The nature and amount of these substances called impurities vary with sources of the water including rainfall, glaciers, surface water, and groundwater (Tao and Wei 1997; Adefemi et al, 2004). Fresh water is a fundamental resource, integral to all environmental and societal processes. However, fresh water is only a small component of the total water resources. Lakes, rivers, reservoirs, and groundwater aquifers account for less than one-third of all fresh water, with the rest locked in glaciers and permanent snow covers (Raskin et al. 1995). Although most of the water on earth is not accessible, the surface water, which is accessible, represents only about 0.02% of the total. This slight fraction of the world water would be enough for man's needs if it were well distributed and kept clean. Since either of them is not done, water quality therefore becomes one of the primary concerns of man (Ademoroti, 1996a).

Furthermore, the dynamic balance in the aquatic ecosystem is upset by human activities, resulting in pollution which is manifested dramatically as fish killer, offensive taste, odour, colour and unchecked growth of aquatic weeds (Al Weher, 2008). The over production of higher tropic level biomass (aquatic weeds) and their subsequent decay in aquatic system could lead to oxygen depletion, resulting in the death of aquatic organisms and development of anaerobic zone where bacterial action produces foul odour and bad tastes (Wright and Welbourn, 2002).

Water is an inseparable aspect of life that determines the potential and possibilities of human activities in an environment. The importance of water quality to the existence of mankind cannot be over emphasized. In fact, human activities and settlement hinge on the availability of water, including both our physical and biological environment. In man, three quarters of the fluid in him is made of water; water forms the essential medium in which the chemical reactions of his cells proceed; it transports blood; it forms a pool for his digestion; it holds and helps transport the electrically charged ions that generate nerve signals and make the human brain possible (Ademoroti, 1996a).

As vapor, water absorbs radiation to influence heat balance/temperature of the environment and brings moisture to the continents. Also as liquid, water erodes and shapes the land, transports and concentrates minerals. Then as solid (ice), water gouges glacier valleys and lakes, pulverizes rocks by expanding when it freezes and thereby creating soil. Even as the most abundant liquid on earth, water runs steadily to sea along a vast network of rivers. It is a receptacle for sewage and can be used to rinse away toxic chemicals (Ademoroti, 1996a).

Most countries of the world now have water resources management policies aimed at achieving sustainable use of their water resources by protecting and enhancing their quality while maintaining economic and social development. Achieving this objective requires that the needs and wants of the community for each water resource are defined and that these resources are protected from degradation. This community needs generally called the *environmental values* (or *beneficial uses*) of the water body (Hart, 2004), include water for drinking, domestic use, agricultural food production, and/or ecosystem protection; the basis for which the Wells were conceived and constructed. However, the environmental values for which a particular water source could serve depend on the environmental quality parameters of the water. Environmental quality parameters are the natural and man-made chemical, biological and microbiological characteristics of rivers, lakes and ground-waters, the ways they are measured and the ways that they change. The values or concentrations attributed to such parameters can be used to describe the pollution status of an environment, its biotic status or to predict the likelihood or otherwise of a particular organisms being present. Monitoring of environmental quality parameters of a water body is a key activity in managing the environment (water body), restoring the environment if polluted and anticipating the effects of man-made changes on these Wells.

2. Materials and methods

2.1. Study area

The Public wells are located at Ise-Ekiti, Omuooke-Ekiti, Ilumoba-Ekiti and Ifaki-Ekiti, all in Ekiti State ,Nigeria. The inadequacy of good quality water for domestic, irrigation and other purposes has been associated with rural environment in Nigeria. However, the construction of these Wells at strategic locations in the State was facilitated by the urgent demand for water by the rural dwellers. Hence, the aim of the study is to check against the prevalence of water-borne diseases and to assess the quality of water from these underground sources.

2.2. Sampling and sample analysis

Water samples were collected from seven different Wells in each of the above named villages, covering June to October, 2011. Parameters such as temperature, pH and Conductivity were measured on- site with standard, calibrated portable meters and kit while other physicochemical and microbiological parameters were analysed in the laboratory using methods prescribed by APHA (APHA,AWWA,WPCF,1998). Heavy metals in the water samples were analysed using Atomic Absorption Spectrophotometer (AAS) after pre- concentration (Aiyesanmi et al, 2012). For every batch of samples for heavy metals analysis, spiked distilled – deionised water was treated in the same manner as the samples for accuracy study, with recovering ranging between 97.0% - 98.9%. Data generated from the monitoring programme were subjected to statistical analysis.

3. Results and discussion

3.1 Well water physico-chemical characteristics

The results of the physico-chemical parameters and results of statistical analyses of the Wells' Water from Omuooke, Ifaki, Ise and Ilumoba are presented in Tables 1- 4 respectively. While Tables 5-8 present the mean values for the Bacteriological characteristics of the water samples respectively.

The results revealed significant spatial variation as shown in the calculated values of coefficient of variation, implying that all the water samples were collected from various sources of distinct physico-chemical characteristics, which are mostly influenced by the geology of the area.

The Temperature values for Omuooke and Ifaki(27.00-29.50^{0}C and 28.40-29.90^{0}C) were higher than those obtained from Ise and Ilumoba (25.00-27.00^{0}C and25.00-25.30^{0}C) respectively. The relatively high temperature variation could be attributed to the differences in the depth of the Wells. This observation is in concordance with what Asaolu (1998) earlier reported for some groundwater in Ado-Ekiti, and for Deep Wells by Mather (1988), Najafpour et al, (2008), Pejman et al. (2009). Temperature controls the solubility of gases in water, the reaction rate of chemicals, and the toxicity of ammonia. Natural aquatic temperature regimes serve as an immediate indicator of the species that can be farmed in a particular area (DWAF, 1996).

Higher values of total suspended solids were recorded in the wells from Ifaki and Ise-Ekiti(0.80-2.00mg/L and 0.13-1.20mg/L) compared to results from wells at Omuooke and Ilumoba(0.02-0.40mg//L and 0.06-0.52mg/L) respectively. This trend could be attributed to the fact that the walls of the Wells with higher values are not protected with concreted rings and are not properly covered, unlike the Wells from Omuooke and Ilumoba.clay and silt remain suspended in water longest, because of their particle size and specific gravities (Adefemi et al, 2004; Aiyesanmi et al, 2006). This is corroborated by the higher total suspended solid recorded in the study. Suspended matter can contain toxins such as heavy metals and biocides and can also harbour microorganisms, protecting them from disinfection (WHO, 2008). Recent research has correlated turbidity levels with treated water supplies being contaminated with *Giardia* and *Cryptosporidium.* These microorganisms can cause outbreaks of illness. As such,suspended solid/turbidity may be used as a health parameter to indicate the safety of water.

Conductivity of the various water samples from Ifaki and Ise had higher values compared to others. Higher values of this parameter measured at Ifaki and Ise could be as a result of excessive evaporation of water since the Wells is uncovered, which consequently increases the concentration of dissolved salts. This is also observed from the TDS values. However, generally low values of conductivity and TDS measured in the water samples reflect freshness of the water, since fresh waters are characterized by low conductivity, TDS and salinity values (Oyakhilome et al, 2012). In fresh-water, the major ions that constitute TDS include carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium. However, in water that contains a high dissolved organic carbon content, TDS values will be much higher than those of conductivity and salinity (DWAF, 1996). Classification of potability based on electrical conductivity ascribes <325 μScm^{-1} for fresh and potable water (McKelvie, 2004**).** An aesthetic objective of 500 mg/L has been established for total dissolved solids (TDS) in drinking water (USEPA, 2002; Health Canada, 2003). At higher TDS levels, excessive hardness, unpalatability, mineral deposition and corrosion may occur.

The pH of the water samples were within the alkaline range except samples from Ifaki Wells that were in the acidic range. The lower values recorded in Ifaki might be due to careless deposition of some organic matter into water body feeding the Wells. Partial decomposition of this organic matter by bacteria and fungi has been recognized to produce various organic acids that are capable of lowering the pH of aqueous solution (Asaolu, 1998). Moreover, rain water of lower pH due to dissolved gases (CO_2, SO_2 and NO_2) contributes immensely to low pH values of the surface and groundwater (Aiyesanmi et al, 2006). Lower pH values for water samples were found to be consistent with the findings reported by Asaolu (1998) for some groundwater in Ado-Ekiti, and for Deep Wells by Mather (1988), Najafpour et al, (2008), Pejman et al. (2009). Many processes in natural waters are either dependent on or alternately are manifest by some change in the hydronium ion (H_3O^+_ or H^+_) concentration. For example, the surface charge of colloids in natural waters and hence their ability to coagulate or sorb ions will depend on the hydronium ion concentration, as will the solubility and speciation of dissolved ions, such as dissolved carbonates. The pH value of a natural water sample reflects the natural buffering by dissolved carbonates that originate either from the dissolution of atmospheric carbon dioxide or from the weathering of calcareous rocks in the stream catchment. In most natural waters the pH typically ranges between 6.5 and 7.5 whereas in marine waters the presence of borates may extend this range to approximately 8.3 (DWAF, 1996). Thus a measured pH change provides a very useful indication that some biogeochemical effect has caused the buffer capacity of a water body to be exceeded. Possible causes of a decrease in the measured pH include the intentional or accidental release of strongly acidic waste into a aquatic systems; the influence of acid rain, bacterial nitrification, or sulfate reduction; and the release of acid mine drainage water. Increases in pH may be caused by accelerated algal growth, such as that which may occur during an algal bloom (when pH can exceed 10) and denitrification. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Extremes of pH can affect the palatability of a water but the corrosive effect on distribution systems is a more urgent problem. No health-based guideline value has been proposed for pH (WHO, 2008), however, an acceptable range for drinking water pH is from 6.5 to 8.5 (USEPA,2002). Corrosion effects may become significant below pH 6.5, and the frequency of incrustation and scaling problems may be increased above pH 8.5. Turbidity, taste- and odour-producing compounds, micro-organisms and colour can be removed by a combination of coagulation, flocculation and filtration. The efficiencies of coagulation and flocculation processes are markedly dependent on pH, and it is standard practice in water treatment to adjust pH so that optimum floc formation is achieved. In certain instances, filtration efficiency is also sensitive to pH (AWWA, 1974). Of greater importance to the microbiological quality of water is the influence of pH on the effectiveness of chlorine disinfection. The germicidal efficiency of chlorine in water is lower at higher pH values; this has been attributed to the reduction in hypochlorous acid concentration with increasing pH (AWWARF, 1976). By keeping the pH below 8.5, the rate of chlorine disinfection is increased and the production of trihalomethanes is reduced. Nitrogen trichloride, which has an objectionable pungent odour tends to be formed in greater concentrations at low pH values (<pH 7) during the chlorination process (AWWARF, 1976).

In natural unpolluted waters, the acidity is mainly contributed by dissolved CO_2. In polluted waters, weak acids like CH_3COOH may contribute significantly to the total acidity. In some organic waters, organic acids also contribute to acidity (Iqbal, 2004). In present study, the elevated levels of acidity in Ifaki water samples as compared to others is reflected in the pH of the Well water. Since alkalinity is pH dependent, and a reversal of acidity, the higher values recorded at Omuooke, Ise and Ilumoba over Ifaki is expected.

Hardness in water comprises the determination of calcium and magnesium as the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally low in this context that they can be ignored. Thus, total hardness is taken to comprise the calcium and magnesium concentrations expressed as mg/l $CaCO_3$. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters. One of several arbitrary classifications of waters by hardness include: Soft up to 50 mg/l $CaCO_3$; Moderately Soft 51-100 mg/l $CaCO_3$; Slightly Hard 101 - 150 mg/l $CaCO_3$; Moderately Hard 151-250 mg/l $CaCO_3$; Hard 251-350 mg/l $CaCO_3$; Excessively Hard over 350 mg/l $CaCO_3$ (EPA, 2001). The values recorded for water samples from Omuooke, Ifaki, Ise, Ilumoba fall within the soft water, moderately soft, hard water and slightly hard water classification respectively. Although hardness may have significant aesthetic effects, a maximum acceptable level has not been established because public acceptance of hardness may vary considerably according to the local conditions. Water supplies with a hardness greater than 200 mg/L are considered poor but have been tolerated by consumers; those in excess of 500 mg/L are unacceptable for most domestic purposes (WHO, 2008). It has been suggested that a hardness level of 80 to 100 mg/L (as CaCO3) provides an acceptable balance between corrosion and incrustation.(Hudson, 1976; WHO, 2008). A number of ecological and analytical epidemiological investigations have suggested that there is an inverse statistical correlation between drinking water hardness and certain types of cardiovascular disease (Anderson et al, 1975; Tuthill, 1976; Hudson, 1976; Crawford et al, 1977; WHO, 2008), while other workers have reported that significant correlations cannot be demonstrated (Allwright et al, 1974; USEPA, 2002). There is some indication that very soft waters may have an adverse effect on mineral balance, but detailed studies were not available for evaluation (WHO, 2008).

There is no evidence of adverse health effects specifically attributable to calcium and magnesium in drinking water. Hence, guideline values for calcium and magnesium have therefore not been specified (WHO, 2008). Undesirable effects due to the presence of calcium in drinking water may result from its contribution to hardness. However, mention has been made of the possible contribution of drinking-water to total daily intake of calcium and magnesium and that drinking-water could provide important health benefits, including reducing cardiovascular disease mortality (magnesium) and reducing osteoporosis (calcium), at least for many people whose dietary intake is deficient in either of those nutrients (WHO, 2008).

Table 1
Mean* physico-chemical characteristics of Omuooke Well water.

Parameters	OM1	OM2	OM3	0M4	OM5	OM6	OM7	G.Mean	SD+_	CV%
Temp. (^{0}C)	29.00	28.00	27.50	29.00	28.00	29.50	27.00	28.29	1.13	3.99
Ph	7.50	7.80	8.00	7.90	7.40	8.60	8.30	7.93	0.62	7.82
T.Solid(mg/L)	0.70	0.60	1.00	1.00	1.20	0.70	1.10	0.90	0.45	50.00
TD.Solid(mg/L)	0.55	0.43	0.91	0.85	0.80	0.68	0.80	0.72	0.38	52.77
TS.Solid(mg/L)	0.15	0.17	0.09	0.15	0.40	0.22	0.30	0.18	0.35	194.44
Cond.(Us/cm)	2.00	1.80	2.04	2.40	2.60	1.95	2.50	2.18	0.16	99.08
Cl^-(mg/L)	5.90	4.60	8.50	5.10	4.60	4.50	6.20	5.63	3.87	68.74
Acidity(mg/l$CaCO_3$)	0.40	0.41	0.50	0.52	0.40	0.60	0.45	0.47	0.11	23.40
T.Alkal. (mg/l$CaCO_3$)	28.00	29.00	28.80	24.10	23.20	33.20	31.00	28.23	11.01	39.51
CO_2(mg/L)	20.00	21.15	24.50	30.40	29.10	33.80	25.90	26.20	9.61	36.67
T.Hard(mg/l$CaCO_3$)	47.90	34.20	38.60	42.30	46.50	49.70	50.20	44.20	11.59	25.21
Ca^{2+}(mg/L)	20.30	15.60	18.50	20.10	22.20	24.30	30.20	21.60	6.87	31.81
Mg^{2+}(mg/L)	27.60	18.60	20.10	22.20	24.30	25.40	28.00	23.69	29.98	126.55

G.Mean = grand mean, SD = standard deviation, CV = coefficient of variation, Mean = replicate of 3.

Table 2
Mean* physico-chemical characteristics of Ifaki Well water.

Parameters	IF1	IF2	IF3	IF4	IF5	IF6	IF7	G.Mean	SD+_	CV%
Temp. (^{0}C)	28.00	28.50	29.00	29.90	28.40	28.90	29.70	28.91	0.63	2.17
pH	6.84	7.27	5.19	4.84	4.95	6.83	5.20	5.87	0.94	16.01
T.Solid(mg/L)	62.10	58.00	53.00	55.10	63.05	60.20	55.80	58.10	42.33	72.85
TD.Solid(mg/L)	60.10	57.10	52.00	53.70	62.05	58.80	55.00	56.96	35.00	61.42
TS.Solid(mg/L)	2.00	0.90	1.00	1.40	1.00	1.40	0.80	1.21	0.23	22.44
Cond.(Us/cm)	100.00	105.00	103.00	101.00	112.00	100.00	100.00	103.00	5.60	5.30
Cl^-(mg/L)	14.40	16.00	16.00	15.00	14.80	15.20	12.90	14.90	6.52	43.76
Acidity(mg/l$CaCO_3$)	20.30	13.30	25.10	28.40	28.80	15.50	22.50	21.99	9.13	41.51
T.Alkal. (mg/l$CaCO_3$)	20.00	10.50	10.60	14.70	17.10	12.80	15.50	14.46	33.69	25.54
CO_2(mg/L)	60.30	53.30	72.00	63.30	66.70	57.60	59.60	61.83	9.08	15.23
T.Hard(mg/l$CaCO_3$)	56.00	196.10	98.00	80.00	164.00	50.00	85.00	104.16	48.23	46.30
Ca^{2+}(mg/L)	32.60	130.40	52.60	53.10	132.60	34.40	70.20	72.24	36.87	51.10
Mg^{2+}(mg/L)	23.40	65.70	45.40	26.90	31.60	15.60	14.80	31.91	11.59	36.32

G.Mean = grand mean, SD = standard deviation, CV = coefficient of variation, Mean = replicate of 3.

The generally low values of chloride recorded in this study may be attributed to the fact that the Well water is fresh water. Chloride is a ubiquitous aqueous anion in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl^-). Natural levels in rivers and underground waters are usually in the range 15-35 mg/L Cl^- , much below drinking water standards (EPA, 2001). In fresh waters the sources include soil and rock formations, sea spray and waste discharges (Aiyesanmi et al, 2006). An aesthetic objective of <250 mg/L has been established for chloride in drinking water (EU, 1998; EPA, 2001; USEPA, 2002; WHO, 2008). At concentrations above the aesthetic objective, chloride imparts undesirable tastes to water and to beverages prepared from water and may cause corrosion in the distribution system (EPA, 2001).

Table 3
Mean* physico-chemical characteristics of Ise Well water.

Parameters	IS1	IS2	IS3	IS4	IS5	IS6	IS7	G.Mean	SD+_	CV%
Temp. (^{0}C)	25.00	25.60	26.00	27.00	27.00	25.00	26.00	25.94	0.76	2.92
pH	7.72	7.80	7.72	8.34	8.00	8.17	8.17	7.99	0.29	36.86
T.Solid(mg/L)	52.13	50.40	61.10	50.00	56.13	55.20	49.92	53.55	0.42	0.78
TD.Solid(mg/L)	51.10	50.00	60.10	48.80	56.00	54.10	48.70	52.69	0.02	0.04
TS.Solid(mg/L)	1.03	0.40	1.00	1.20	0.13	1.10	1.22	0.86	0.30	34.88
Cond.(Us/cm)	104.03	100.20	122.10	98.10	131.00	130.87	101.02	112.46	1.68	1.49
Cl^-(mg/L)	20.40	30.20	22.10	16.02	32.30	19.50	28.20	24.10	13.13	38.04
Acidity(mg/l$CaCO_3$)	0.50	0.70	0.80	1,00	0.30	0.40	0.50	0.60	0.31	50.16
T.Alkal. (mg/l$CaCO_3$)	28.10	30.20	20.00	38.80	40.00	36.20	44.40	33.96	15.26	40.88
CO_2(mg/L)	21.02	24,15	34.65	26.15	24.22	23.04	30.25	26.21	7.98	30.44
T.Hard(mg/l$CaCO_3$)	196.20	146.00	309.20	222.00	210.00	255.00	198.00	219.47	42.90	19.57
Ca^{2+}(mg/L)	75.00	71.00	188.40	100.00	113.00	104.00	97.00	106.91	36.46	36.57
Mg^{2+}(mg/L)	121.20	75.00	121.20	122.00	97.00	151.00	101.00	96.91	19.30	20.12

G.Mean = grand mean, SD = standard deviation, CV = coefficient of variation, Mean = replicate of 3.

Table 4
Mean* physico-chemical characteristics of Ilumoba Well water.

Parameters	IL1	IL2	IL3	IL4	IL5	IL6	IL7	G.Mean	SD+_	CV%
Temp. (^{0}C)	25.10	25.00	25.30	25.00	25.10	25.00	25.20	25.10	0.13	0.52
Ph	7.94	7.72	7.82	7.77	7.56	7.67	7.79	7.75	0.13	1.67
T.Solid(mg/L)	1.07	0.90	0.86	0.50	1.10	1.05	0.75	0.89	0.23	25.84
TD.Solid(mg/L)	0.55	0.78	0.76	0.44	0.92	0.75	0.60	0.68	0.19	27.94
TS.Solid(mg/L)	0.52	0.12	0.10	0.06	0.18	0.30	0.15	0.20	0.17	85.00
Cond.(Us/cm)	1.80	2.10	1.60	1.10	1.70	2.20	1.80	1.76	0.38	21.59
Cl^-(mg/L)	30.30	23.10	24.50	24.40	31.10	17.80	26.50	25.39	9.42	37.10
Acidity(mg/l$CaCO_3$)	0.80	0.60	0.90	0.60	0.70	1.00	0.70	0.76	0.16	21.05
T.Alkal. (mg/l$CaCO_3$)	29.80	36.00	28.40	24.00	41.00	42.40	24.00	32.23	9.97	30.93
CO_2(mg/L)	32.40	21.60	25.00	16.70	35.20	23.40	33.60	26.84	8.94	33.31
T.Hard(mg/l$CaCO_3$)	67.40	47.00	96.00	96.00	75.00	120.00	88.00	84.20	23.05	27.37
Ca^{2+}(mg/L)	37.00	28.20	54.00	57.00	61.00	66.00	47.20	50.05	16.05	32.07
Mg^{2+}(mg/L)	30.40	18.80	42.00	39.00	14.00	54.00	40.80	34.14	12.01	35.17

G.Mean = grand mean, SD = standard deviation, CV = coefficient of variation, Mean = replicate of 3.

3.2. Well water microbial characteristics

The results of the microbiological examination of the Well water for total bacteria count and total coli form are presented in tables 5-8.

Table 5
Omuooke Well water microbiology.

Parameters	OM1	OM2	OM3	OM4	OM5	OM6	OM7
Total Bact.Count(Cfu/ml)	0.05	0.11	0.03	ND	0.15	ND	ND
Total Coliform(MPN/100ml)	ND	0.31	0.23	ND	ND	ND	ND

(TBC, TCF) X 10^2, ND = Not detected.

Table 6
Ifaki Well water microbiology.

Parameters	IF1	IF2	IF3	IF4	IF5	1F6	1F7
Total Bact.Count(Cfu/ml)	3.02	2.80	1.06	2.00	1.01	ND	2.13
Total Coliform(MPN/100ml)	2.25	1.90	1.00	3.00	2.00	ND	2.11

(TBC, TCF) X 10^2, ND = Not detected.

Table 7
Ise Well water microbiology.

Parameters	IS1	IS2	IS3	IS4	IS5	IS6	IS7
Total Bact.Count(Cfu/ml)	2.43	2.64	8.43	1.21	1.41	1.32	1.53
Total Coliform(MPN/100ml)	ND	1.31	6.32	4.82	3.00	ND	2.01

(TBC, TCF) X 10^2, ND = Not detected.

Table 8
Ilumoba Well water microbiology.

Parameters	IL1	IL2	IL3	IL4	IL5	IL6	IL7
Total Bact.Count(Cfu/ml)	1.76	2.15	2.35	1.32	2.44	1.05	0.53
Total Coliform(MPN/100ml)	0.13	0.34	0.78	1.30	1.02	0.41	2.12

(TBC, TCF) X 10^2, ND = Not detected.

Higher values of these parameters were recorded in the water samples from Ifaki and Ise. The higher values obtained could be attributed to influx through runoff of microorganisms originating from vegetation decay, municipal sewage, garbage, domestic and feacal waste into the water body supplying the Wells. Heterotrophic microorganisms include both members of the natural (typically nonhazardous) microbial flora of water environments and organisms present in a range of pollution sources. Enteropathogenic *E. coli* are enteric organisms, and humans are the major reservoir. Livestock, such as cattle and sheep and, to a lesser extent, goats, pigs and chickens, are a major source. They have also been associated with raw vegetables, such as bean sprouts and the pathogens have been detected in a variety of water environments (Health Canada, 2006a).

The microbial values recorded in the Well water represent high bacteria load compared to the recommended standards for drinking water (EU, 1998; EPA, 2001; Health Canada, 2006a; WHO, 2008). This condition constitutes a threat to end users as the water is unsafe for human consumption, thus suggesting adequate disinfection process before usage. The recovery of viable indicator bacteria from the Wells in intolerable numbers constitute a serious hazard to public health, as their presence is indicative of a possible presence of micro organism associated with water-borne diseases (Aiyesanmi, 2006).

3.3. Heavy metal concentration in the well water

Heavy metals concentrations in Well water from Omuooke, Ifaki and Ilumoba Ekiti are presented in Tables 9, 10 and 11 respectively. Also contained in the Tables are statistical analyses of the data. Coefficient of variation values for most metals examined revealed pronounced significant difference among sampling points. This could be attributed to the fact that the samples were collected from various wells of different physicochemical characteristics. It was observed in the studies that Cd,Pb and Ni were not detected in all the analyzed samples while Mn, Fe, Zn,Cu were detected except Cu that was not found in samples from Ifaki-Ekiti.

Comparison of mean concentrations of the metals in the Well water with guideline values for drinking water (EU, 1998; EPA, 2001; USEPA, 2002; WHO, 2008) showed compliance with all the investigated metals. The values of Iron ranged from ND - 3.89mg/kg. There is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. Therefore, a maximum acceptable concentration has not been set. At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and produce undesirable tastes in beverages. The precipitation of excessive iron impacts an objectionable reddish-brown colour to water.

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron (WHO, 2008). Manganese is generally present in natural surface waters as dissolved or suspended matter at concentrations below 0.05 mg/L (EPA, 2001). The aesthetic objective for manganese in drinking water is 0.05 mg/L (EU, 1998; EPA, 2001; USEPA, 2002). The presence of manganese in drinking water supplies may be objectionable for a number of reasons. At concentrations above 0.15 mg/L, manganese stains plumbing fixtures and laundry and produces undesirable tastes in beverages. As with iron, the presence of manganese in water may lead to the accumulation of microbial growths in the distribution system. Even at concentrations below 0.05 mg/L, manganese may form coatings on water distribution pipes that may slough off as black precipitates. Manganese at the recommended limit of 0.05 mg/L is not considered to represent a threat to health, and drinking water with much higher concentrations has been safely consumed (WHO, 2008). Manganese is among the elements least toxic to mammals; only exposure to extremely high concentrations from human-made sources has resulted in adverse human health effects (EPA, 2001; WHO, 2008).

The concentration of nickel in drinking-water is normally less than 0.02 mg/litre, although nickel released from taps and fittings may contribute up to 1 mg/litre. A provisional health-based guideline value of 0.02 mg/litre was published by WHO in 1993 (WHO, 2008).

4. Conclusion

The physicochemical characteristics of the Well water revealed a fresh water environment with low chemical pollutants burden. However, the microbial load of the Well water was high compared to the recommended standards for drinking water, thus constituting a serious hazard to public health, as their presence is indicative of a possible existence of microorganisms associated with water borne diseases, suggesting the need for adequate disinfection process before it could be consumed.

Table 9

Mean heavy metals concentrations (mg/l) in Omuooke Well water.

Sample code	Mn	Fe	Cu	Cd	Zn	Pb	Ni
OM1	0.17	0.30	0.14	ND	0.90	ND	ND
OM2	0.17	0.26	0.12	ND	1.90	ND	ND
OM3	0.02	0.34	0.02	ND	1.00	ND	ND
OM4	ND	0.21	0.04	ND	0.87	ND	ND
OM5	ND	0.21	0.02	ND	0.94	ND	ND
OM6	ND	3.89	0.02	ND	0.90	ND	ND
OM7	ND	0.09	0.51	ND	1.09	ND	ND
OM8	ND	ND	0.01	ND	0.88	ND	ND
OM9	ND	0.20	0.02	ND	1.21	ND	ND
Mean	0.04	0.61	0.05	_	0.98	_	_
S.D.	0.07	0.23	0.05	_	0.11	_	_
CV %	175	201.64	22.23	_	11.22	_	_

Table 10
Mean heavy metals concentrations (mg/l) in Ifaki Well water.

Sample code	Mn	Fe	Cu	Cd	Zn	Pb	Ni
IF1	0.11	ND	ND	ND	ND	ND	ND
IF2	0.03	0.02	ND	ND	ND	ND	ND
IF3	0.01	0.10	ND	ND	0.01	ND	ND
IF4	0.25	1.52	ND	ND	ND	ND	ND
IF5	0.03	ND	ND	ND	0.01	ND	ND
IF6	0.16	ND	ND	ND	0.03	ND	ND
IF7	0.03	ND	ND	ND	0.39	ND	ND
IF8	0.08	ND	ND	ND	0.07	ND	ND
IF9	0.52	0.75	ND	ND	0.01	ND	ND
Mean	0.12	0.24	_	_	0.04	_	_
S.D.	0.16	0.51	_	_	0.09	_	_
CV %	131.15	212.13	_	_	245.53	_	_

Table 11
Mean heavy metals concentrations (mg/l) in Ilumoba Well water.

Sample code	Mn	Fe	Cu	Cd	Zn	Pb	Ni
IL1	ND	ND	0.43	ND	0.88	ND	ND
IL2	0.17	0.34	0.12	ND	1.08	ND	ND
IL3	ND	0.33	0.09	ND	1.37	ND	ND
IL4	ND	0.96	0.05	ND	0.92	ND	ND
IL5	0.03	0.14	0.09	ND	1.37	ND	ND
IL6	ND	ND	0.06	ND	0.79	ND	ND
IL7	0.01	0.10	0.07	ND	0.76	ND	ND
IL8	ND	0.08	0.04	ND	0.77	ND	ND
IL9	0.03	1.64	0.03	ND	0.88	ND	ND
Mean	0.05	0.51	0.10	_	0.93	_	_
S.D.	0.07	0.58	0.12	_	0.21	_	_
CV %	110.70	114.07	122.45	_	23.80	_	_

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