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Evaluation of Trace Element Levels and Microbiological Quality of Borehole and Well Water from Different Sources in Wukari, Taraba State

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Abstract

This study assessed the levels of trace elements and microbiological quality of groundwater sources from boreholes and wells in Wukari. Sampling was conducted at five locations, with five samples each collected from boreholes and wells and analyzed using standard procedures. For borehole samples, trace element concentrations ranged from iron (Fe: 0.0127–0.0145 ppm), chromium (Cr: 0.0014–0.0110 ppm), manganese (Mn: 0.0019–0.0183 ppm), and copper (Cu: 0.0013–0.0155 ppm). Well water samples showed higher variability, with Fe (0.0216–0.6216 ppm), Cr (0.0190–0.1786 ppm), Mn (0.0109–0.0291 ppm), and Cu (0.0101–0.0425 ppm). All samples were within World Health Organization (WHO) permissible limits, except for elevated Fe in sample EPW (0.6216 ppm) and high Cr in samples OMW and EPW (0.1190 ppm and 0.1786 ppm, respectively). Zinc was not detected in any sample. Microbiological analysis revealed aerobic plate counts ranging from 3.1×10^7 to 8.0×10^7 cfu/ml, with no coliform or fungal growth detected. Bacterial isolates included *Escherichia coli*, *Pseudomonas* spp., *Klebsiella* spp., *Bacillus* spp., *Staphylococcus aureus*, and *Staphylococcus epidermidis*, with *Klebsiella* spp. and *E. coli* being predominant. While trace element levels suggest that groundwater sources are largely safe for drinking, the presence of potentially pathogenic bacteria highlights the need for appropriate treatment before consumption or use in food processing. These findings underscore the importance of continuous monitoring to safeguard public health and prevent waterborne diseases.

Keywords: Trace Elements; Microbiological Quality; Borehole Water; Well Water; Wukari; Public Health

INTRODUCTION

Water is one of the natural resources that support the existence of human beings and other living organisms on earth. Water occurs in different areas or zones in the earth, there exists surface water occurrence popularly known as "surface water bodies" and "Groundwater bodies" the surface water bodies includes streams, lakes, seas and oceans, whereas, Groundwater bodies refers to water formed beneath the earth sub surface i.e water saturated zone within the different layers or zones of the earth 's crust. Groundwater is an important source of drinking water for humans, it contains larger percentage of the available fresh water resources and it is an important reserve of good quality water. Groundwater is extensively being exploited through the construction of boreholes and hand dug wells in urban and semi urban areas for domestic, agricultural, and industrial usage. Rapid population growth and urbanization leads to an increase in demand and exploration for potable water. Groundwater pollution is a gradual degradation in water quality through the addition of chemicals, heat or bacteria to a level that constitutes public health hazards, and affects it adversely in terms of domestic, agricultural, and industrial utilization (Akhilesh *et al.,*2009; Musa *et al.*, 2013).The water pollution by trace elements has become a question of considerable public and scientific concern in the light of the evidence of their toxicity to human and biological system (Anazwa *et al.*,2004). Trace elements particularly are of great concern, due to their toxicity even at low concentrations (Marcovecchio, *et al.*, 2007). These metals include: lead(Pb), cadmium(Cd), zinc(Zn), mercury(Hg) arsenic(As), silver(Ag), chromium(Cr), copper(Cu),iron(Fe), platinum(Pt) and manganese (Mn). Although some trace elements at low concentrations are essential to life, at high concentrations, they tend to be harmful. The high level of trace elements in natural water bodies can be attributed to some anthropogenic activities such as mining, fuels, farming and improper municipal waste disposal. Standards and guidelines in water quality stem from the need to protect human health. Therefore, the aim of water quality management is usually to minimize the health risks associated with either direct or indirect use of water of water (Udom *et al.*, 2012). This is important since world population cannot be sustained without access to safe water.

The microbiological quality of drinking water has attracted great attention worldwide because of implied public health impacts Microbiological health risks are associated with many aspects of water use, including drinking water in developing countries, irrigation, reuse of treated wastewater and recreational water use (Grabow,2000). It has been reported that drinking water supplies have a long history of association with a wide spectrum of microbial infections. Some microorganisms are native or adapted to saturated sediment and rock and are present in significant numbers in most water supply aquifers and even deep geoclinal formations. Biofilm formation sometimes encourages the growth of bacteria in wells and groundwater. Events which occur between and within bacteria and plankton populations also affect water quality, (Nishiguchi, 2000).A lot of bacterial, viral and protozoan pathogens are causing a waterborne infections. Some are primarily the enteric bacterial pathogens such as *Vibrio cholera, Salmonella spp*, *Shigella spp* and recognized pathogens from faecal sources such as *E. coli,* (Szewzyk, *et al.*,2002). Several new bacterial pathogens such as *legionella spp*, *Pseudomonas aeruginosa* and *Mycobacterium spp* are found in drinking water usually in low numbers and grow within the distribution system biofilms.The evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water. High coliform counts indicate a contaminated source, inadequate treatment or post treatment deficiencies. The occurrence of coliform in the potable water sources could be due to the presence of human and animals excreta in such water, (Egbe, *et al.*, 2013; Aboh, *et al.,*2015). The excreta could provide appropriate nutrients require for growth and proliferation. Generally, *E. coli* and *Enterobacter aerogenes* in potable water indicates presence of recent faecal matters (Onilude *et al.*, 2013).

Isikwue and Chikezie (2014) stated that feacal coliform in water is influenced by presence of wastewater and septic system effluent, animal waste, sediment load, temperature and nutrients levels. International standards for water quality aimed at preventing pathogenic microbes in potable water, which is due to the fact that pathogen that contaminates water could transmit infectious diseases (Bukar, *et al.*, 2015). Fecal contamination of drinking water is a major problem in rural communities where groundwater sources like boreholes and wells, likewise sachet water are used for drinking. The major source of drinking water for the inhabitants of Wukari in recent time is the untreated groundwater obtained from boreholes and wells. Most of these underground waters were constructed long time ago while some are newly constructed and there is no existing information on their water quality. Meanwhile, the area is known for its intensive domestic and agricultural activities and therefore the underground water could be contaminated. It is on this background that the water quality assessment of these underground waters (borehole and well) became necessary so as to determine its suitability for drinking purposes.

MATERIALS AND METHODS

Materials

Samples of well and bore hole water were collected randomly at five different locations in Wukari, Taraba state, Nigeria. The areas included: Federal University Wukari, Ladan (New market), East Primary School, Old market and Wapan Nghaku (Fig 1.1).

Sample collection

Water samples were collected according to the WHO Guidelines for drinking water quality assessment (WHO, 2003).Water samples for analysis were collected in sterile containers. Twenty samples were collected, two samples each from well and borehole from the five distinct locations. All samples were transported to the Food science and technology laboratory in ice-bag and in a cooler and were stored at room temperature for analysis.

The samples were majorly analyzed for trace elements and microbiological analysis.

Trace Elements Analysis

Determination of Iron, Copper, Lead, Chromium, Zinc and Manganese

Determination of iron, copper, lead, chromium, zinc and manganese were determined as described by (Yusuf, *et al.*, 2018). Five millimeters (5ml) of the water sample were dispensed and poured into Teflon tube; and place into the digestion tube block in a fume cupboard. 20ml of Nitric acid (Conc. HN03) + 20ml of Hcl (Conc. Hcl) were added to each tube. It was then left for some time and the digestion tube block containing samples were heated to dryness, it was then brought out and distilled water was added to wash the tube using 100ml volumetric flask until it was up to 100ml in volume. Reading for various elements using atomic absorption spectrophotometer (BUCK 200 model) was taken.

Microbiological Analysis

Preparation of culture media

All media were prepared according to the manufacturer 's instructions. 2.8g of Nutrient agar, MacConkey agar 5.5g and Potato dextrose agar 3.9g/100ml respectively were weighed and dissolved in distilled water in a conical flask and sterilized by autoclaving at 121°C at 15 pounds per square inch (PSI) for 15 minutes and cooled to 45-50°C.

Isolation and Enumeration of Microorganisms

Total bacterial count was determined using the method of (Edem and Elijah, 2016). The stock solution was made by taking 1.0 ml of the sample of water into 9.0 ml sterile peptone water and shake vigorously. Serial dilution (10 fold) was then carried out (1:10, 1:100, 1:1000, and 1:10000). Aliquots (1.0ml) of dilution 10^{-6} was plated on Nutrient agar and dilution 10^{-8} on MacConkey agar plate using pour plate method and incubated at 37^{o}C for 24–48 hours for total bacterial and coliform count respectively. For yeast and mould count 1.0ml amount of appropriate dilutions was also poured on plates of PDA. Enumeration of yeast and mould were done after three to four days. All enumerations were expressed as colony forming units per milliliter (cfu/ml) of plated samples.

Purification and maintenance of microbial isolates

Bacterial isolates were transferred onto fresh agar medium of isolation and incubated at 37^{O}C for 24hours. Pure colonies of Bacteria were maintained on slant and stored at 4 ^{O}C until needed.

Characterization and Identification of Isolates

Bacteria and fungal isolates were characterized and identified based on their microscopic appearance, colonial morphology, surface, spore, gram staining and biochemical tests. The isolates were identified using standard methods, by comparing their characteristics with those of known taxonomy, as described by Bergey 's Manual of Systematic Bacteriology (John *et.al.,* 2005; Cheesbrough, 2006 and Obasi et.al; 2019). The morphological identification and biochemical tests procedures included: motility test, color

/pigmentation on culture plates, Oxidase, Catalase,Coagulase, Indole, Citrate Utilization Test and triple sugar ion fermentation (TSI) respectively.

1.6 Statistical methods

Analysis of Variance (ANOVA) were used to test levels of significant values ($p \leq 0.05$). Mean values were separated using Duncan multiple range test.

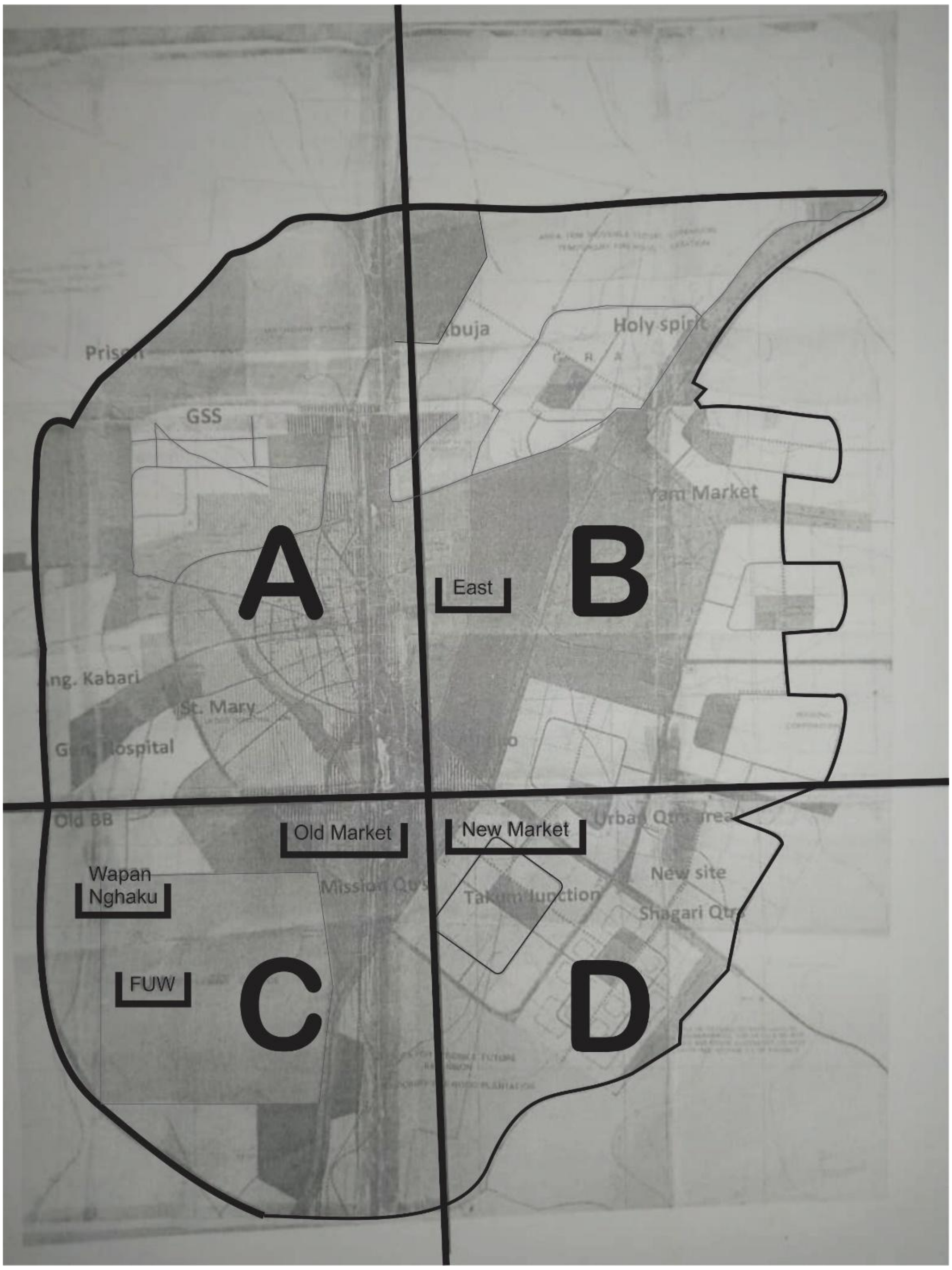

FIG 1.: Map of Wukari showing samples collection locations.

Key

B= East

C= Wapan Nghaku, Old Market and FUW

D= New Market

RESULTS AND DISCUSSION

Trace elements level in well and borehole water.

The result in table 1 showed the concentrations of trace elements levels in well water samples in Wukari which ranged from 0.0217–0.6216 (Iron), 0.0190–0,1786 (Chromium), 0.0109–0.0291 (Manganese), 0.0101–0.0425 (Copper). Iron showed the highest value in EPW (0.6216) than all other samples, this excess concentration of iron may be attributed to rocks and soil containing iron, which can dissolve into the water source. The high concentration of iron which was above recommended standards could also be linked to waste dump sites, agricultural activities and sewage that are common in the study area. Even though iron poses no danger to health at levels found in drinking water, it may affect acceptability of drinking water by altering its appearance, taste, odour, stain clothing and appliances and promote the growth of iron bacteria in the water system (WHO, 2011). High level of iron in one of the water sample (EPW) was in agreement with the research carried out by Winifred, *et al.,* (2014), Shalom, *et al*., (2011) and Akoto and Adiyiah, (2007) who reported high iron concentration in well water, ground and drinking water respectively. Also correlated with the result reported by Odukoya, (2015) who analyzed well and borehole water at Ijebu Igbo. Concentration of copper and chromium were within the standard except for high chromium level in sample OMW and EPW. This was as a result of anthropogenic sources like mining, leaching of refuse materials, agricultural activities and suckaways. High chromium level in one of the well water is similar to the result gotten by Yusuf, *et al.,* (2018) who analyzed well and borehole water in Kashere. High chromium level causes lung cancer in man, liver and kidney damage in animals and skin irritation (Valkovic, 1983).The concentration of manganese was within the permissible limit which was in accordance with the work carried out by Winifred, *et al*., (2014) in Ota, Nigeria.

Table 1: Trace elements concentration levels in well water from different sources in Wukari in parts per million(ppm)

Samples	Fe(ppm)	Cr(ppm)	Zn(ppm)	Mn(ppm)	Cu(ppm)
Ladan (LAW)	$0.0217^{d}\pm0.00$	N.D	N.D	$0.0109^{d}\pm0.00$	$0.0425^{a}\pm0.00$
Old market (OMW)	$0.0270^{c}\pm0.00$	$0.1190^{b}\pm0.00$	N.D	$0.0174^{c}\pm0.00$	$0.0101^{f}\pm0.00$
East primary (EPW)	$0.6216^{a}\pm0.00$	$0.1786^{a}\pm0.00$	N.D	$0.0291^{a}\pm0.00$	$0.0152^{c}\pm0.00$
Fed. University (FUW)	$0.0216^{d}\pm0.00$	$0.0190^{c}\pm0.00$	N.D	$0.0174^{c}\pm0.00$	$0.0124^{e}\pm0.00$
Wakan Nghaku (WNW)	$0.0315^{b}\pm0.00$	$0.0146^{d}\pm0.00$	N.D	$0.0182^{b}\pm0.00$	$0.0135^{d}\pm0.0$

Mean within a column with different superscripts were significantly different ($p < 0.05$).

Key: N.D= Not detected

Table 2 showed the concentration of trace elements levels in borehole water samples in Wukari and were found to range from 0.0127–0.0145 (Iron), 0.0014–0.0110 (Chromium), 0.0019–0.0183 (Manganese), 0.0013–0.0100 (Copper). Possible sources of trace elements in the analyzed water are natural originating from the rock and soil in the area with which the water was in contact and anthropogenic human activities which comprises of disposals of waste, agricultural application of chemicals, sewages from homes and others. All borehole samples were within the standard according to world health organization(WHO, 2014) and Nigerian industrial standards (NIS, 2007) which agreed with the work by Oluyemi, *et al*., (2010) and Njar, *et al*., (2012) who analyzed boreholes in Osun state and cross river respectively. All samples of borehole analyzed were within the permissible limit which correlated with the results as reported by Odoh, *et al*., (2018) and Yusuf, et al., (2018) who examined borehole water in Otukpo and Kashere respectively. In all the water samples analyzed, zinc was not detected, this implies that the boreholes do not have caustic taste, hence ideal for consumption and other domestic uses which was in agreement to the study carried out by Shalom, *et al*., (2011) and Emeka and Weltime, (2008) who analyzed groundwater. However, zinc deficiency can lead to reduction of normal growth and impaired bone development (Buzadzic, *et al*., 2002). At lower concentration some of these trace elements are required in the body as micronutrient; zinc, manganese, copper and iron are utilized in the body in metabolic activities. Iron specifically assists in the formation of protein haemoglobin, low iron in the body can affect immune system, in young children this can affect mental development which can lead to irritability and concentration disorder. But abnormal higher concentration of trace elements in the body is toxic in human which can lead to malfunctioning of organs and illness.

Table 2: Trace elements concentration levels in borehole water from different sources in Wukari in parts per million(ppm)

Samples	Fe(ppm)	Cr(ppm)	Zn(ppm)	Mn(ppm)	Cu(ppm)
Ladan (LAB)	$0.0135^{f}\pm0.00$	N.D	N.D	$0.0058^{f}\pm0.00$	N.D
Old market (OMB)	$0.0134^{f}\pm0.00$	N.D	N.D	$0.0034^{g}\pm0.00$	$0.0100^{f}\pm0.00$
East primary (EPB)	$0.0127^{g}\pm0.00$	$0.0014^{f}\pm0.00$	N.D	$0.0183^{b}\pm0.00$	$0.0013^{g}\pm0.00$
Fed. University (FUB)	$0.0145^{e}\pm0.00$	N.D	N.D	$0.0019^{h}\pm0.00$	N.D
Wakan Nghaku (WNB)	$0.0135^{f}\pm0.00$	$0.0110^{e}\pm0.00$	N.D	$0.0105^{e}\pm0.00$	$0.0155^{b}\pm0.00$

Mean within a column with different superscripts were significantly different ($p< 0.05$).

Key: N.D= Not detected

These results were further group into bore holes and hand wells and their mean computed and compared with the (WHO, 2014) and (NIS,2007) maximum permissible limits in Table 3. The concentration of trace elements level in well and borehole were all within the maximum permissible limit. In the mean computed, it was found that the concentration levels of well water is more than borehole water

Many trace elements are necessary in small amounts for the normal development of the biological cycles. These same elements, at higher concentrations can cause adverse health effects or illness (Valavanidis and Vlachogianni, 2010). Iron has been associated with genetic and metabolic diseases and, repeated blood transfusions (Fraga and Oteiza, 2002)**.**The low concentration of Fe means water from these boreholes does not have the potentials of staining laundering as well as disrupt the human system. Manganese may hamper the intellectual development of the child (Buschmann, *et al.*, 2008). The low concentration of Mn implies that water from the sampled boreholes has good taste and would not promote the growth of algae in reservoirs or collection tanks (Nwankwoala, *et al.*, 2011). Zinc is an important trace element that plays a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to organisms (Ferner, 2001). Excess amount of zinc can cause system dysfunctions that result in impairment of growth and reproduction. Zinc toxicity leads to diarrhea (Osibanjo and Majolagbe, 2012). The clinical signs of zinc have been reported to include vomiting, diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anemia (Duruibe, *et al*., 2007). Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. Copper toxicity is related to several health concerns, including stomach cramps, nausea, vomiting, diarrhea, cancer, liver damage and kidney disease (EPA, 2013).

Table 3. Mean value of trace elements contained in well and borehole water analyzed compared with standards.

Parameter	Borehole water	Well water	WHO	NIS
Iron	0.014	0.698	0.3	0.3
Chromium	0.006	0.083	0.05	0.05
Zinc	ND	ND	15	3.0
Manganese	0.008	0.019	0.4	0.2
Copper	0.009	0.019	2.0	1.0

Microbial load of bacterial cells obtained from well and borehole water

The total aerobic plate count of the bacterial cells shown in table 3.4 ranged from 3.1×10^7–8.0×10^7 respectively from different samples of water analyzed (well and borehole). The microbial load in this study was found to be high which exceed the standard of 1.0×10^2cfu/ml set by World Health Organization/Food and Agricultural Organization as allowable limit for potable water. The reason for the gross contamination of well waters as observed in this study may be due to openness and shallowness of the wells which allows easy entrance of particles from the surroundings. It may also be due to poor sanitary condition around the areas where such wells and boreholes are located or drawing water from the wells with contaminated containers, a practice that is common among the users since individuals bring along their own water containers. Pollution of groundwater could also arise from poor hygienic level, closeness of borehole to the septic tank and waste pit. The microbial diversity and density in the potable water sources is a reflection of the contamination level. The result of this study corroborated with Idowu, *et al*., (2011) and Ali, *et al.*, (2012), who recorded high microbial load in well water analyzed in Sagamu, Ogun state and Kaduna respectively. Sylvester and Ebinyo, (2015), who analyzed well and borehole water in Nigeria and Azuonwu, *et al.*, (2017) reported high microbial load in well and borehole water analyzed in River state. This study also agreed with earlier studies in Lagos and Ibadan where it was discovered that well water used as source of water for drinking and cleaning purposes were grossly contaminated with high microbial load (Adeyemo, *et al.,* 2002; Akinyemi, *et al.*, 2006). Angaye, *et al.*, (2015) also reported total heterotrophic bacteria in the range of 8.23–10.79 x 10^8 cfu/ml. No coli form and fungi counts in the water analyzed, this showed that there was no faecal contamination. According to World Health Organization guideline (WHO, 2003), coliform counts must not be detected in any 100 ml of drinking water samples. Therefore, results of coliforms obtained in the present study showed that all examined samples from wells and boreholes conformed to the standard. Also, this was similar to Onuorah, *et al.*, (2018), Abdullahi, *et al.*, (2013), Olajuba and Ogunika, (2014) and Nkamare, *et al.*, (2012) who reported the absence of coliforms in the borehole water samples they examined in Onueke, Ebonyi State; the Science Department and Staff school of Nigeria State Polytechnic Zungeru Campus; Akungba Akoko, Ondo State and Okutukutu, Bayelsa State respectively, all in Nigeria.

Table 4. Total aerobic plate count of bacterial cells (cfu/ml) of well and borehole water

Samples	Total aerobic plate count (cfu/ml)
Wapan nghaku borehole (WNB)	8.0 x 10^7
Wapan nghaku well (WNW)	5.8 x 10^7
Old market borehole (OMB)	3.1 x 10^7
Old market well (OMW)	7.2 x 10^7
Federal University borehole (FUB)	4.1 x 10^7
Federal University well (FUW)	4.8 x 10^7
Ladan borehole (LAB)	3.1 x 10^7
Ladan well (LAW)	7.5 x 10^7
East primary school borehole (EPB)	-
East primary school well (EPW)	5.2 x 10^7
Water samples control (WSC)	-

Identification and characterization of microorganisms that is isolated from well and borehole water.

The prevalence of Organisms Isolated from well and borehole water samples shown in Fig 3.1 revealed the identity of the following microbial flora from the various water samples, these included: *Escherichia coli* (97.5%), *Staphylococcus epidermidis* (7.5%), *Klebsiella spp.*(100%), *Pseudomonas spp.*(35%), *Bacillus spp.* (62.5%) and *Staphylococcus aureus* (30%), and the least prevalent were *Staphylococcus epidermis* and *Pseudomonas spp.* The contamination of these water sources is probably due to poor protections and exposure to contamination by human and domestic wastes. The behavioral and hygienic practices of the community might also be contributing to this high load of indicator organisms. *Escherichia coli* was not isolated from one of the borehole analyzed (EPB), this was in agreement with the result reported by Tukura, *et al.*, (2017), Addo, *et al.*, (2016) and Maureen, *et al.,* (2012) which was an indication of absence of fecal contamination. This agrees with Howard that boreholes as low cost technology option for developing countries are generally considered as safe sources of drinking water when properly constructed and maintained, they provide consistent supplies of safe and wholesome water with low microbial load and little need for treatment of the drinking water (Deutsch, 2003). *Escherichia coli* and *Klebsiella spp* were the predominant organisms. Isikwue and Chikezie, (2014) stated that feacal coliform in water is influenced by presence of wastewater and septic system effluent, animal waste, sediment load, temperature and nutrients levels. This result is in agreement with the report of Okunye and Odeleye, (2015) who studied bacteriological investigation of well water samples from selected market locations in Ibadan Nigeria, Negera, *et al.*, (2017) and Idowu, *et al.,* (2011) in Sagamu, they all isolated *Escherichia coli* and *Klebsiella spp* as the predominant in well water. Onuorah, *et al.,(*2018) isolated *Klebsiella spp.and Pseudomonas aeruginosa* from the borehole water they examined in Onueke, Ebonyi State, Nigeria while Abdullahi, *et al.*, (2013) isolated *Escherichia coli,* and *Klebsiella spp.* from the Staff school, Science Department and female hostel boreholes in Niger State Polytechnic. Ngele, *et al.*, (2014) also isolated *Escherichia coli,* and *Pseudomonas aeruginosa* in selected borehole samples in Amike-Aba, Abakaliki while Olajuba and Ogunika, (2014) isolated *Pseudomonas aeruginosa, Klebsiella pneumonia and Staphylococcus aureus*, from borehole samples from Akungba-Akoko, Ondo State, Nigeria. In addition, Josiah, *et al.*, (2014) isolated *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa* from drinking water and water used for domestic purposes in Okada Town, Edo State, Nigeria. Ibe and

Okpalenye, (2005) detected *Escherichia coli, Klebsiella spp, Pseudomonas spp* and *Staphylococcus aureus* in the borehole water they analyzed in Uli, Anambra State, Nigeria while Uhuo, *et al*., (2014) isolated *Escherichia coli* and *Klebsiella aerogenes* from the borehole water in Peri-Urban areas of Abakaliki, Ebonyi State, Nigeria. Ukpong and Okon, (2013) also analyzed public and private borehole water supply sources in Uruan Local Government Area of Akwa Ibom State and isolated *Escherichia coli, Klebsiella aerogenes* and *Staphylococcus aureus* in the samples. *Escherichia coli,* which was isolated from the samples in this study and whose presence indicates the possible presence of other intestinal pathogens. *Staphylococcus aureus, Pseudomonas spp,* and *Bacillus spp* which were isolated and identified from the samples are other pathogens of importance that have been linked to gastrointestinal disorders (Nwidu, *et al*., 2008). *Escherichia coli* and *Pseudomonas spp* belong to the group referred to as Enterobacteriaceae. They can cause illness such as watery and bloody diarrhea, dysentery, urinary tract infection and when introduced into the bloodstream, they can lead to bacteremia. In addition some strains of *Escherichia coli* are able to produce enterotoxins in the small intestine which can also cause diarrhea if not managed in good time. One risk of infection by *Staphylococcus aureus* is the issue of its resistance to beta-lactamase antibiotics including penicillin and methicillin-a derivative of penicillin. The presence of this species in water thus calls for public health concern.

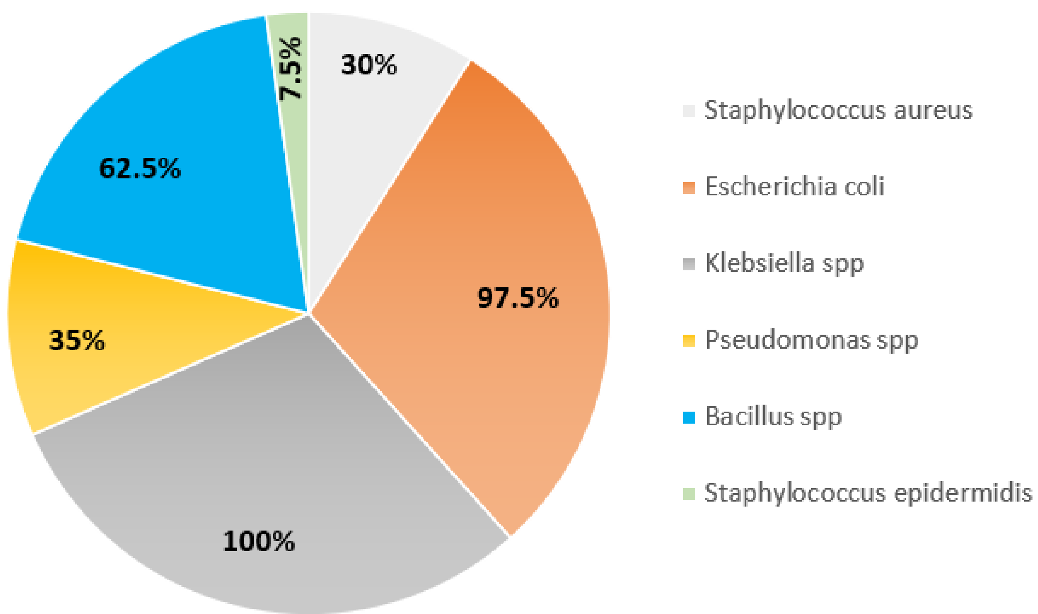

Fig. 2 Prevalence of Organisms Isolated from borehole and well water samples from various location in Wukari, Taraba State.

CONCLUSION

The result obtained from the study showed the concentration of the trace elements detected in all water samples analyzed to be in the sequence of Fe>Cr>Cu>Mn>Zn which were within the acceptable limit set by World Health Organization(WHO) which showed the water analyzed is safe for human consumption and can be use for food processing. The presences of coliform in the water samples were insignificant due to their low count which indicates its suitability. However, due to some of the bacteria flora isolated, water sources should be properly treated prior to consumption using appropriate methods, such as boiling and reverse osmosis, so as to avoid the occurrence of waterborne disease and prevent public health issues in the community.

Recommendation

• Closeness of borehole to the septic tank and waste pit should be avoided.

• The national environmental standards and regulation enforcement agency, the Nigerian industrial standards organization and other regulatory bodies responsible for borehole construction and water quality must take necessary steps to ensure proper siting, construction, and to minimize contamination.

• Good, proper environmental and personal hygiene should be practiced by covering of the wells especially by the users of those wells to prevent their contamination with bacterial pathogens.

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