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Bacteriological Contamination of Groundwater from Zango Local Government Area, Katsina State, Northwestern Nigeria

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Abstract Bacteriological contamination of drinking water is responsible for the occurrence of waterborne diseases such as typhoid fever, dysentry, cholera, meningitis and diarrhea. Little is known about the microbiology of well water in Nigeria as most analyses focuses on physical and chemical parameters. Faecal contamination of the wells comes from the presence of human and animal faeces. Groundwater has been recognized as playing a very important role in the development of our rural populace as most dwellers depend solely on water from hand dug wells and boreholes for their daily needs. In this study bacteriological quality of groundwater from hand dug wells were analysed in Zango Local Government Area of Katsina State with the aim of evaluating their suitability for domestic purposes. A total of 87 groundwater samples from the wells were collected for both dry and rainy season and analysed at National Research Institute for Chemical Technology Laboratory Zaria, Nigeria. The results indicate faecal contamination of the hand dug wells. The poor sanitary condition in the area and the closeness of some hand dug wells to pit-latrines, soakaways and dumpsites were identified as the factors responsible for the microbial contamination of the groundwater from the shallow aquifers. Boiling of water is recommended and subsequent hand dug wells should be cited far away from pit-toilet and soakaways to avoid contamination by leachates.

Keywords: *Bacteriological contamination, groundwater, Zango Local Government, Katsina State, Northwestern Nigeria*

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1. Introduction

The practice of physico-chemical analyses of water samples and the exclusion of microbial/bacteriological analysis is unacceptable in all ramification (Amadi, 2009). The bacteriological quality of most drinking water in many rural areas in Sub-Sahara Africa is worrisome. Interestingly, water borne illnesses like *typhoid fever, amoebic and bacillary dysentry, cholera, meningitis* and *diarrhea* as well as food and equipment damages are caused by bacterias (Cowan, 1974; Amadi *et al*., 2012). Lack of bacteriological analysis of drinking water may be attributed of prevailence of water borne diseases in rural area where basic amenities such as good road network, electricity, good pipe borne water and adequate health care are lacking. Studies have shown that the act of disposing faecal wastes and untreated effluents on rivers and streams are still common in rural areas in the country (Amadi *et al*., 2011; Amadi *et al.*, 2013).

According to Adetuye *et al*., (1997), poor sanitation and lack of save water makes communities vulnerable to diseases such as *shigellosis, amoebiosis, schistosomiasis, typhoid, leptospirosis, infectious hepatitis, giardaisis* and *parathyphoid*. This further confirms the fact that the supply of clean and treated water remains a challenge in developing countries especially in the rural areas.

In addition to air, water is essential for human beings, animals and plants. It is believed that man can survive without food for several weeks but in the absence of water death results in a few days. Besides the quantity of the water needed, the quality of water is of paramount importance. The increasing realization of the effect of pollutants of both organic and inorganic origin on soil and water supplies and the historical records from the hospitals, of the devastating nature of epidemics due to waterborne diseases has necessitated a careful and detailed analysis of water from the area for its hygienic value and for the development of ways and means to eliminate such pollution. This when achieved may enhance the chances of safety to the public health. The incidence of rusting and caving-in of corrugated iron roofing sheets, increasing risk of diseases, destruction of vegetation and agricultural land in the area was part of the reason for this research.

Many countries all over the world have their own regulations and quality standards for drinking water due to the fact that water quality is a matter of regional interest.

The primary prerequisite to good health is an adequate supply of safe that is of a good sanitary quality. Supply of clean and treated drinking water is one of the challenges faced by many developing countries. Due to increase in population and industrialization, provision of pipe borne water by government becomes inadequate and private individuals had to drill boreholes or dug wells to take care of their water needs. Well water became less expensive, dependable and most common. With the economic situation presently, the federal and state governments are finding it increasingly difficult to make pipe borne water available in urban centres due to increasing population.

Lack of enforcement on the regulations guiding the digging of wells and or drilling of boreholes in Nigeria by the relevant agencies constitute to this menace. Water wells are not properly planned before drilling and are often times located near unlined septic tanks or pit latrines with majority not properly covered. In the rural communities in Nigeria, hygiene is least considered when designing a well, since the primary objective is to supply water for drinking, washing, cooking and construction. Wells therefore stand the risk of microbial and faecal contamination. Water is usually tested for faecal contamination by isolating Escherichia coli or total coliform from any water sample. This point makes E. coli the indicator organism (Eden *et al*., 1977; Tacket *et al*, 1985; Amadi *et al*., 2010; Amadi *et al*., 2014b). This and other microbes are capable of infecting or transmitting disease to humans (Spores 1995). In view of the short comings surrounding the digging and use of wells, this study was undertaken to assess the bacteriological quality of well water in Zango Local Government Area of Katsina State.

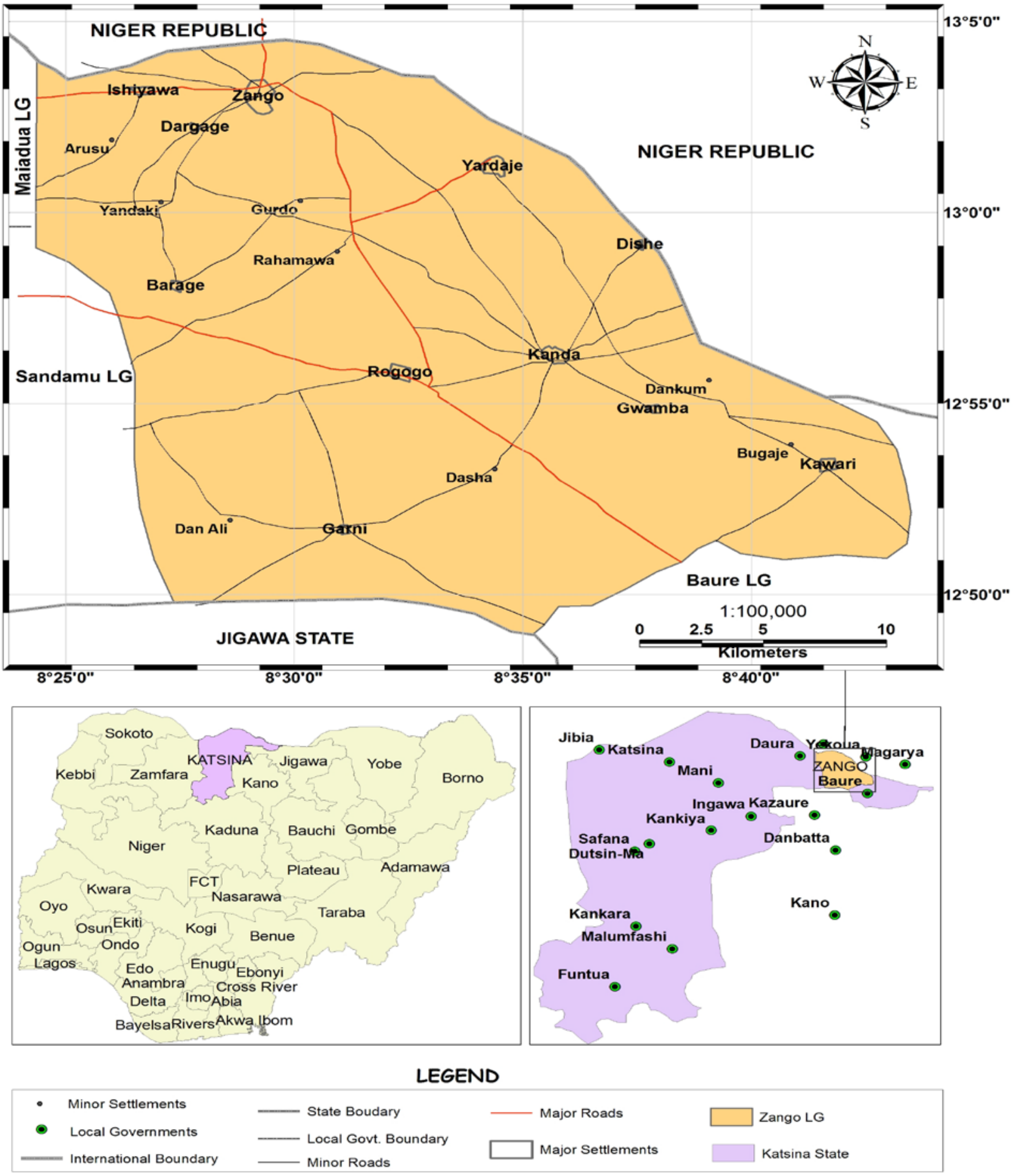

Figure 1. Map of Zango Local Government Area, Katsina State, Nigeria

1.1. Study Area Description

Zango Local Government Area (Figure 1) is located at the north-eastern part of Katsina State of North Western Nigeria approximately between latitudes 12°50`N and 13°00`N and between longitudes 8°26`E and 8°44`E. It is located about 100 Km east of Katsina town and is accessible through a network of both tarred and untarred roads. It has an area of 601 km² and a population of about 154,743 (Census, 2006). It is bounded in the north by Niger Republic, in the east by Baure Local Government Area, in the south by Jigawa State and in the west by Sandamu Local Government Area. Zango's uniqueness is extraordinary in the sense that it is the only local government area in Nigeria that is underlain by the following four different lithologies (Older Granites, Younger Granite/Rhyolites, Gundumi Formation and Chad Formation).

1.2. Climate and Vegetation of the Area

The climate of the area like other parts of northern Nigeria is characterized by the dry and rainy seasons. These seasons are usually punctured by the harmattan wind from the Sahara desert which is brings about cold usually in the months of December to February. The area consists of scattered trees with sparse shrubs and grasses. The trees here grow long tap roots and thick barks that make it possible for them to withstand the long dry season. The grass too has long durable roots which remain underground after stalks are burnt away or wilted in the dry season only to germinate with the first rains.

1.3. Geological Mapping of the Area

Reconnaissance survey was carried out on the study area in order to familiarize the area and identify the sampling points. This was followed by detailed geological investigation of the area in which four main rock types were identified. The lithologies includes: the Gundumi Formation emanating from the Sokoto Basin, the Chad Formation which is part of the Chad basin and the Older Granites from the Basement Complex Rocks as well as the Younger Granites/Rhyolites suites (Figure 2).

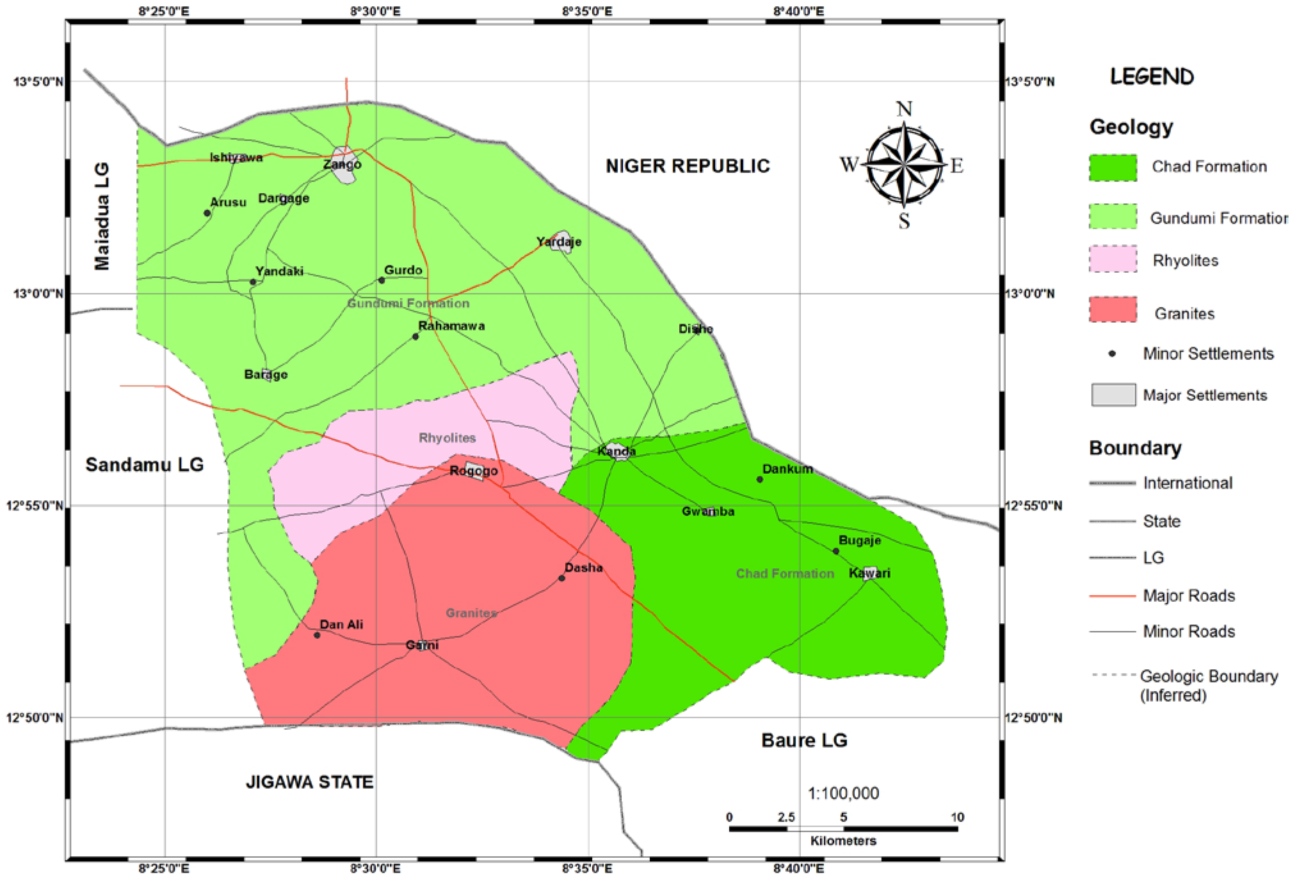

Figure 2. Geology Map of Map of Zango Local Government Area, Katsina State, Nigeria

1.4. Water Sampling

Water Samples were collected across the entire local government area. Boreholes, hand-dug wells and solar powered water schemes were the sources that were sampled for this study. The sampling covers the Gundumi Formation emanating from the Sokoto Basin, the Chad Formation which is part of the Chad basin and the older granite from Basement Complex rocks as well as the Younger Granites suites. A total of 87 water samples each were collected in the dry and rainy seasons. The measurement of the following physical parameter such as pH, temperature, conductivity and turbidity were carried out in-situ (on site) using their appropriate instruments in line with the specified standards (APHA, 1998). At each sampling point (Figure 3), the longitude, latitude and elevation were taken with the aid of a global positioning system. All the water analysis was carried out at National

Research Institute for Chemical Technology Laboratory Zaria, Nigeria. The determination of the physical parameters was carried out in the field using standard procedures while the analyses of chemical and bacteriological parameters were done in the laboratory. The physical parameters such as pH, electrical conductivity (EC) and temperature were taken in-situ. Anions such as SO_4, PO_4, NO_3, HCO_3, and Cl were determined using titration method while fluoride was determined using colorimetric method. The total and faecal Coliforms were determined using incubation method. Concentration maps were plotted using the ArcGis version 9.3.

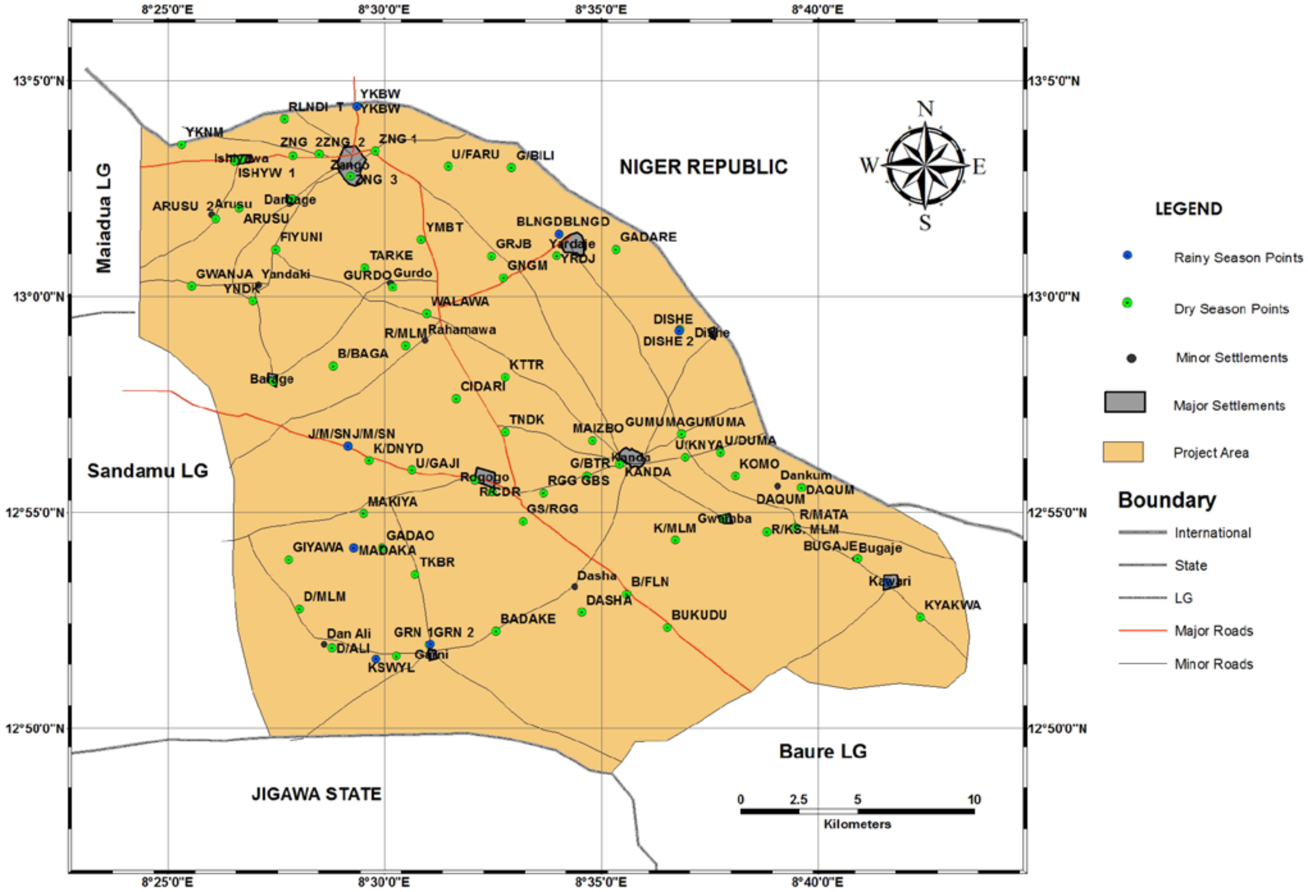

Figure 3. Map of Zango Local Government Area, Katsina State showing the sampling locations

1.5. Bacteriological Analysis

After the safe delivery of the samples to the laboratory, 15 No micro analytical bottles with one durham tube in each bottle were prepared. A MacConkey broth media was then prepared by dissolving 35.0 g of the media in 1000 ml of water. To each of the 15 bottles, 10 ml of media was added. The 15 bottles and all glass wires to be used were put in an autoclave and allowed to attain a temperature of 105°C for sterilization. After the bottles were brought out, they were allowed to attain back the room temperature. They were then grouped into 5-5-5 and labelled for addition of water sample in the order of 10 ml, 1 ml and 0.1 ml respectively. All the bottles were then put in an oven (Plate 1) set at 35°C and allowed an incubation period of 48 hours. At the end of the time, bacteriological growth was observed by trapping of air bubbles and de-colorization of the media. The de-colorized bottles were then compared with a standard chart. The analysis was extended to determine whether the bacteria detected above is E.coli or not. This was done by dissolving 38.0 g of MacConkey broth (purple in colour) in 1000 ml of water and using it as an indicator in the same procedure as above but with an incubation temperature and period of 40°C and 24 hours respectively. Further de-colorization of the media shows presence of the E.coli.

2. Results and Discussion

The results of the water quality analyses of Zango Local Government Area for dry and rainy seasons are contained in Tables 1 and 2 respectively. The conductivity of water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent (EPA 2001). The concentration of electrical conductivity (EC) ranged from 22.70-3050.00 µs/cm with a mean value of 305.04 µs/cm for the dry season (Table 1) and 32.80-3200.00 µs/cm with an average value of 980.85 µs/cm for the rainy season Table 2). The electrical conductivity is a valuable indicator of the amount of substances dissolved in water.

Table 1. Summary of the bacteriological and chemical parameters for dry season in Zango LGA

Parameter	Max.	Min.	Mean	Range	Variance	S.D	M.D	Skew	Kurt
EC (us/s)	3050	22.7	305.04	3027.3	22865	473.14	265.8	3.953	18.29
TCC/100ml	24.0	0.0	19.273	24.0	2735.096	52.298	27.705	3.546	11.94
FCC/100ml	94.0	0.0	6.87	94.0	319.43	17.873	10.083	3.593	13.73
Cl (mg/l)	21.62	0.0	7.208	21.62	25.599	5.06	4.073	0.557	-0.07
HCO_3 (mg/l)	126.0	6.0	23.786	120.0	389.117	19.726	13.592	2.717	12.06
Ca (mg/l)	127.82	0.06	5.815	127.76	240.026	15.493	6.712	6.721	51.85
Mg (mg/l)	3.19	0.0	1.714	3.19	1.44	1.2	1.11	0.229	1.613
Na (mg/l)	31.18	0.07	6.791	31.11	48.758	5.863	5.832	1.135	0.75
K (mg/l)	28.22	0.19	8.347	28.03	39.376	6.275	5.047	0.996	0.758
SO_4 (mg/l)	78.65	0.06	11.688	78.59	275.912	16.611	11.021	2.633	7.428
NO_3 (mg/l)	19.12	0.06	6.279	18.52	21.144	4.598	3.801	0.73	-0.23
PO_4 (mg/l)	9.4	0.01	1.744	9.39	4.021	2.005	1.564	1.688	2.96

TCC- total coliform count; FCC- faecal coliform count; Max- maximum; EC- electrical conductivity; Min- minimium; SD- standard deviation; MD- mean deviation; Kurt- kurtosis; Skew- skewnes

Table 2. Summary of the bacteriological and chemical parameters for rainy season in Zango LGA

Parameters	Max.	Min.	Mean	Range	Variance	S.D	M.D	Skew	Kurt
EC (us/s)	3200	32.8	980.85	3167.2	1161.669	1077.8	822.08	1.627	1.88
TCC/100ml	23.0	0.0	5.25	23.0	68.786	8.294	6.125	1.765	2.672
FCC/100ml	5.0	0.0	1.0	5.0	3.714	1.927	1.5	1.756	2.009
Cl (mg/l)	13.37	3.45	6.544	9.92	12.816	3.58	2.93	1.087	0.317
HCO_3(mg/l)	135.0	12.0	57.0	123.0	4599.0	50.974	35.76	2.03	4.211
Ca (mg/l)	10.95	0.03	4.149	10.92	10.355	3.218	2.116	1.297	3.005
Mg (mg/l)	14.9	0.32	11.82	14.47	25.716	5.071	3.633	-2.11	4.372
Na (mg/l)	25.39	3.7	13.108	21.69	57.698	7.596	6.283	0.464	-1.15
K (mg/l)	26.91	0.28	11.114	26.63	112.655	10.614	9.415	0.64	-1.83
SO_4 (mg/l)	110.0	1.0	27.75	109	1552.21	39.398	29.688	1.629	2.076
NO_3 (mg/l)	19.4	1.8	7.9	17.6	35.617	5.968	4.625	1.07	0.608

TCC- total coliform count; FCC- faecal coliform count; Max- maximum; EC- electrical conductivity; Min- minimium; SD- standard deviation; MD- mean deviation; Kurt- kurtosis; Skew- skewness

The conductivity values in some locations on both seasons exceeds the maximum permissible limit of 1000 μs/cm recommended by World Health Organization (WHO, 2006) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). A map showing the concentration of electrical conductivity is displayed in Figure 4. Areas of high conductivity coincide with the area of high total coliform count and faecal coliform count. The groundwater in the area is conductive due to the infiltration of leachate from the nearby dumpsites and soakaways.

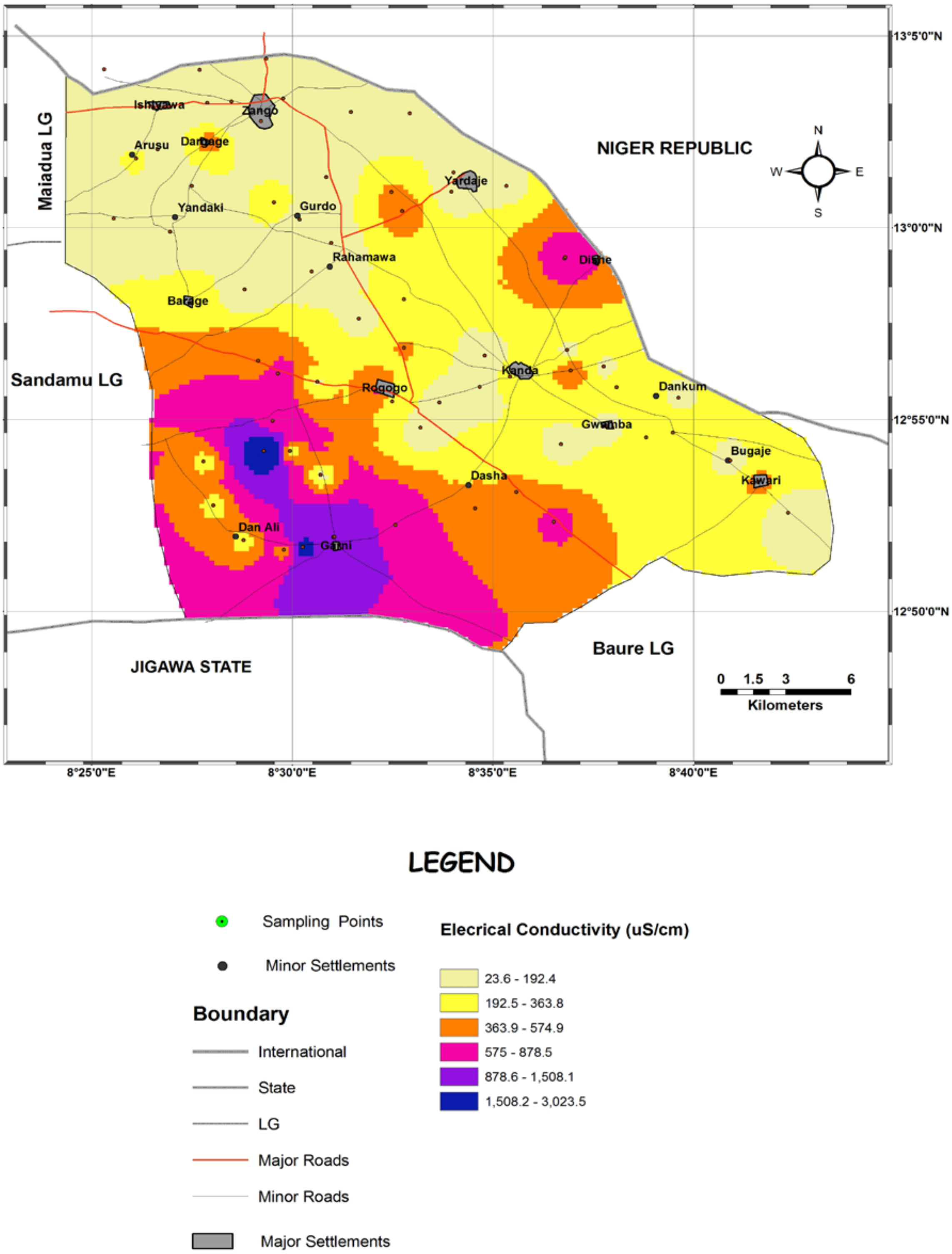

Figure 4. Concentration map of Electrical Conductivity (EC) in Zango Local Government Area of Katsina State, Nigeria

The concentration of total coliform count (TCC) for dry season ranged between 0.0 cfu/100 ml to 24.0 cfu/100 ml with a mean value of 19.27 cfu/100 ml (Table 1) and 0.0 cfu/100 ml to 23.00 cfu/100 ml with an average value of 5.25 cfu/100 ml (Table 2). Similarly, faecal coli count (FCC) for dry season varied from 0.0 cfu/100 ml to 94.0 cfu/ml with a mean value of 6.87 cfu/ml (Table 1) and between 0.0 cfu/100 ml to 5.0 cfu/ml with an average value of 1.0 cfu/ml for the rainy season (Table 2). The results of TCC and FCC were higher in the dry season than in the rainy season due to the dilution effect of rainfall during rainy season. The maximum allowable limit of 10.0 cfu/100 ml for TCC and 0.0 cfu/ml for (NSDWQ, 2007; WHO, 2006) were exceeded in the dry season at the following locations: Dishe, Dasha, Gidan Bili, Gingimi, Rahamawar Malamai, Garba Bature, Rogogo Cidari, Kwanar Danyada, Giyawa, Baba Daga, Yakubawa, Gwanja, Daqum, Kasuwayal, Bulungudu, Walawa, Arautaki and Zango 1, all of whose water samples are from open hand dug wells with the exception of Giyawa and Walawa whose water samples are from boreholes. The presence of TCC and FCC in water is a clear indication of groundwater contamination by human or animal faeces. Faecal contamination of groundwater is responsible for most water borne diseases such as cholera, typhoid, meningitis and diarrhoea (Amadi, 2009; Egharevba et al., 2010). Poor sanitary situation of an area such as close proximity of unlined soakaway/pit-latrine can introduce TCC and FCC into the shallow aquifer via infiltration. The concentration maps of the TCC and FCC are displayed in Figure 5 and Figure 6 respectively.

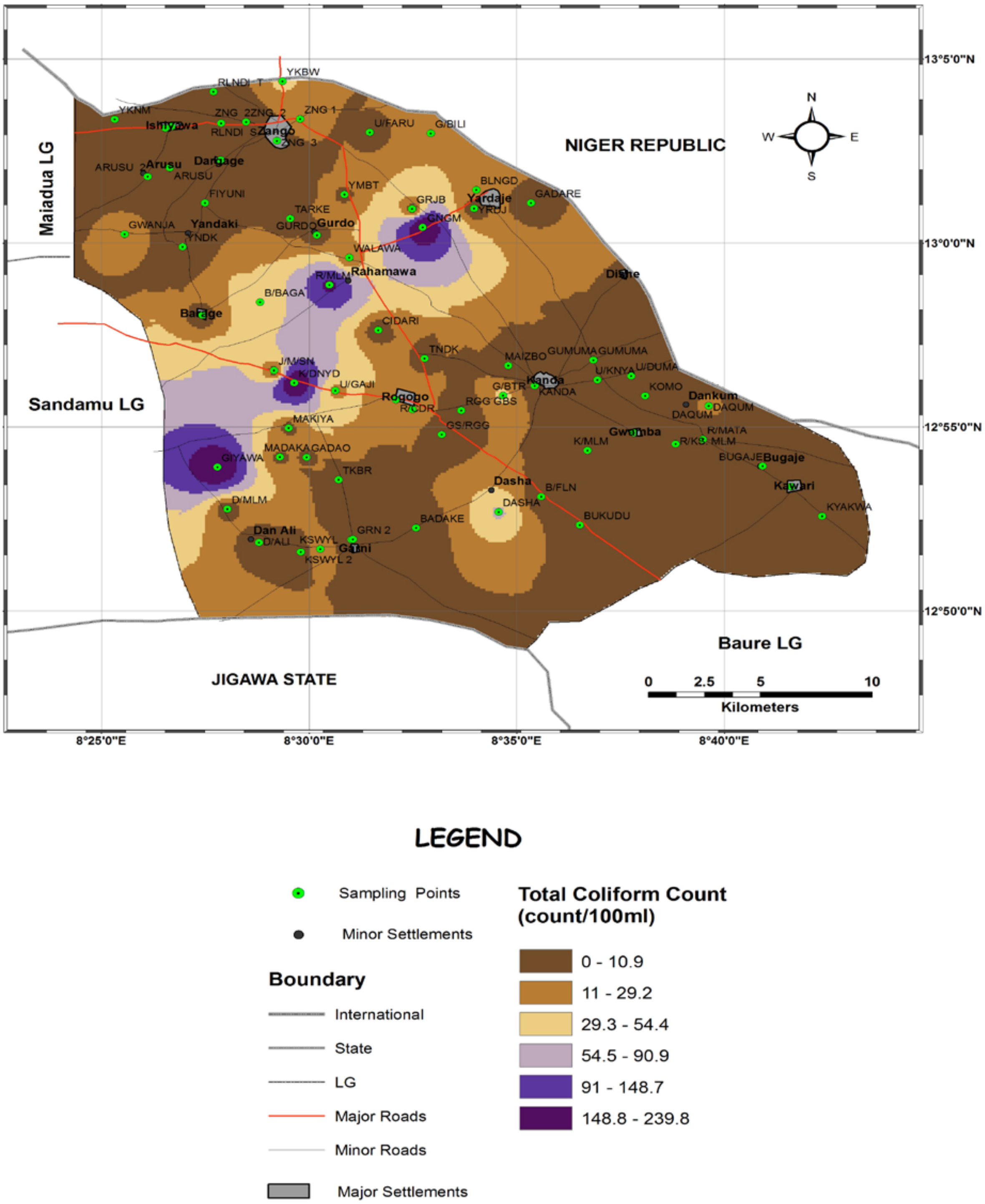

Figure 5. Concentration map of TCC in Zango Local Government Area of Katsina State, Nigeria

Apart from the electrical conductivity, total coliform and faecal coliform counts whose concentrations in most locations were above the recommended maximum permissible limits postulated by World Health Organization (2006) and Nigerian Standard for Drinking Water Quality (2007), other parameters analysed in both dry and rainy seasons (major cations and anions) have their respective concentration below the acceptable permissible limits (Table 1 and Table 2). This implies that the concentration of the cations (sodium, potassium, calcium and magnesium) as well as the anions (chloride, bicarbonate, sulphate, nitrate and phosphate) was found to be within the recommended permissible values though their presence in water does not constitute any health hazard (Amadi, et al, 2014). Their presence especially calcium and magnesium only causes hardness of water. Calcium is necessary for strong bone and teeth formation.

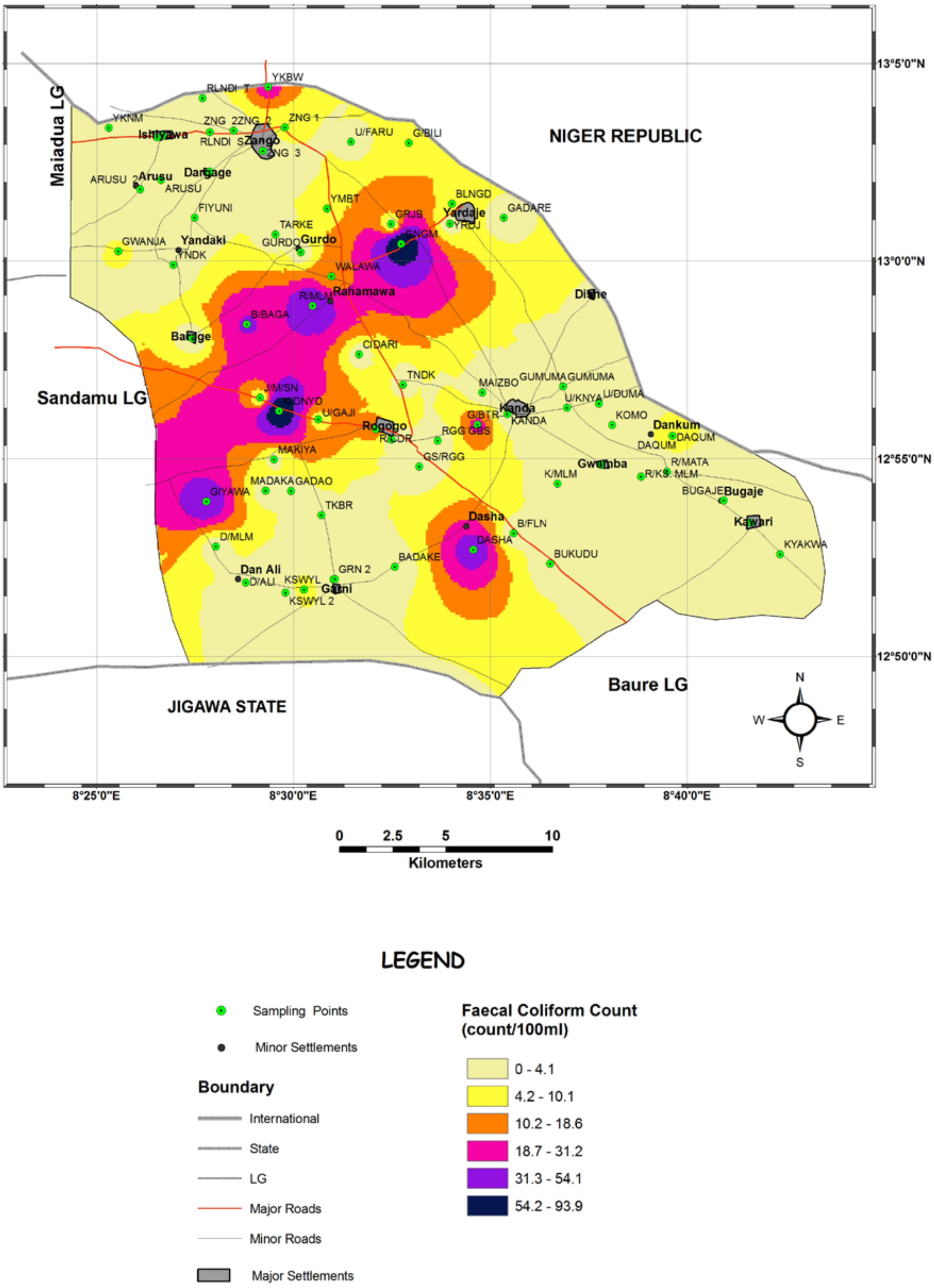

Figure 6. Concentration map of FCC in Zango Local Government Area of Katsina State, Nigeria

The presence of E coli and other coliforms in some of the samples indicate faecal contamination. This contamination may be due to several factors such as the sanitary habit of well owners and users. Uncovered wells also stand the risk of contamination in this way. In most cases, practices such as washing of cloths, household utensils, various materials and objects are done close to the wells. The washing of this items are unhygienic but when the washed dirt is poured on the ground, close to the well it becomes unsanitary. Shallow wells are susceptible to contamination by surface and soil microorganisms (Ijostem et al., 1997). Pollution of water from wells may also be attributed to the deliberate discharge of sewage effluents while some wells may have been contaminated from its inception by the uncleaniness of the diggers. Water purity may also be affected by buried corpses in the locality. High coliform number in wells in this study could be as a result of the presence of lizards, frogs which are usually found near the wells (Plate 2) as a coliforms have been isolated from their intestines (ijostem *et al*., 1997).

Most wells had cockroaches living inside the tunnels. Other factors affecting contamination of wells may be structural defects of the well which may allow seepage of pollutants from nearby sewage into wells (Ciravolo *et al*., 1979). Where wastewater can drain down through macropores such as root channels, rodent burrows and structural voids, the ground water may become significantly polluted with faecal coliforms and streptococci (Allen, 1979; Amadi *et al*., 2014a).

A more mechanized method of construction is necessary for a cleaner and tidy well as found for boreholes. In Nigeria majority of users are illiterates who may not be aware of the hazards or risks of unhygienic well environment. In many instances, household sewage is not properly disposed, some sewage pits close to the well contribute to pollution of well water if this effluent flow to wells. it is not uncommon to find wells close to septic tanks. Containers used to draw water from wells constitute another source of danger to health as this maybe dirty and improperly kept after use. The idea of using pumping machines to pump water from wells is cost expensive and outside the reach of the poor who actually are in the majority.

Plate 1. Bacteriological analysis oven

Plate 2. An open hand-dug well in Zango Local Government Area of Katsina State, Nigeria

Conclusion and Recommendation

The study has clearly revealed that the groundwater from shallow hand dug wells in parts of Zango Local Government Area, Katsina State, Nigeria was contaminated with both total coliform and faecal coliform counts. This is evidence that the groundwater from the hand dug wells may be in contact with human (animal) faeces. This is linked to the poor sanitary situation in the area and the proximity of the hand dug wells to the pit-latrines/soakaways and dumpsites in the area. Water treatment in wells is recommended for the water to be used for drinking. Construction of new hand dug wells should be deeper and far away from existing animal wastes, soakaways and pit-latrine.

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