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HYDROCHEMISTRY AND SANITARY RISK ASSESSMENT OF DOMESTIC HAND-DUG WELLS IN ADO-EKITI, SOUTHWESTERN NIGERIA

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ABSTRACT: *This research focused on hydrochemistry and sanitary risk assessment of domestic hand-dug wells in Ado-Ekiti, southwestern Nigeria with a view to improve/ensure the safety of the drinking water supply in the study area. To carry out the sanitary risk assessment, all the hazards and hazardous events that can affect the safety of water supply from the shallow wells through treatment and distribution to the consumers' point of use were identified and evaluated. Subsequently, 30 water samples fairly spread over the catchment area were taken and analyzed for chemical constituents employing Atomic Absorption Spectrometer for the cations and ion chromatography for the anions. E-coli of another set of the 30 water samples were determined using standard method. Result of the sanitary survey revealed that 14 of the sampled wells were at high risk with 13 and 3 of them in intermediate and low risk respectively. The hydrochemistry of the groundwater revealed that most of the wells in the study area were at risk of contamination as indicated by the high chemical concentrations of* NO_3^- *(>50mg/L) and* Cl^-*(>250mg/L) in 43% and 70% of the sampled water respectively. All other chemical parameters have concentrations within approved WHO standard for drinking water. E-coli were present in 90% (27out of 30 samples) of the water samples and this clearly support the sanitary survey of which 27 of the sampled well water fell into high to intermediate risk category. The study indicated that 90% of the wells in the study area are at risk of contamination. High concentrations of* NO_3^- *and* Cl^- *from hydrochemical evaluation of the well water as well as presence of e-coli in 90% of the water indicated that the sources of pollution are from anthropogenic sources related to human and animal wastes at close proximity to wells. Safety of the water from the hand dug wells can be improved if health education is intensified in the area.*

KEYWORDS: Sanitary Risk Assessment, Hazards and Hazardous Events, E-Coli, Contamination, Chemical Parameters.

INTRODUCTION

Falconer (2003), described water as one of the world's most precious resource. He highlighted that the challenges of urbanization include how to ensure adequate water supply and a suitable water environment for future generation worldwide. Access to safe drinking water is a problem facing a large proportion of the inhabitants of the developing nations (UNICEF, 2005; Cosgrove and Rijsberman, 2000; Gomez and Nakat, 2002). In Nigeria despite considerable investments of government in water supply programme, over 52% of its population has no access to potable water (Oluwasanya, 2009). In Ado-Ekiti (study area), the various sources of water available to the inhabitants ranges from brooks, wells, springs, ponds, rivers, bore holes, rain water to pipe bore water. Sallow wells constitute main source of potable water supply due to their protective capacity and natural filtration characteristics. In addition, hand-dug wells also provide cheap and low technology solution to the challenges of rural and urban water

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supply. Well construction too affords an opportunity for community participation during all phases of the water supply process (Seamus, 2000).

The consumption of unhygenic water throws a lot of challenges on the health status of the inhabitants as some of them that drink directly from the wells, brooks, stream and ponds complained of typhoid, stomach pains and stooling (Bankole, 2010). In the study area, low access to safe water arisen from the enormous socio-economic development, poor planning, insufficient funding and haphazard location of buildings, to mention a few have increased the susceptibility of the environment to sanitary risk. Sanitary risk is considered to be the methods that encapsulate the necessary measures taken to protect society against risks linked with food and water safety, human and animal health and plant protection or to prevent or limit damage within the territory of a member from the entry, establishments and spread of pests. With increasing inadequacy of the maintenance of the microbial quality of groundwater in urban areas, more cities will find themselves facing problems of unacceptable water quality, with Ado-Ekiti not being an exception.

Ado-Ekiti had an area of 2.5 square kilometers in 1956, which increased to 6.9 square kilometers in 1996 and 36.7 square kilometers in 2006 (Oriye, 2013). The resultant expansion had resulted into rapid increase in population with the city having a population of 308,621 (2006, Census). Scarcity of water, pollution and occasional flooding constitute major water resources problem. In addition, the dreadful consequences of urbanization of which the problem of solid waste management with respect to environmental nuisance combined with the health hazards implications are issues of concern which the present research (sanitary risk evaluation) will address. The provision of water and sanitation facilities are important public health measures that contribute significantly to the reduction in the disease burden of populations. The study area is serviced by a medium dam of 4,930L/day, which is grossly inadequate for domestic activities of the community.

Hand-dug wells could be protected, un-protected or semi-protected. A protected well is one equipped with a dedicated pump (manual or motorised), concrete lining and platform (or apron), head wall, cover and drainage channel (Murcott, 2007; Oluwasanya et al., 2011). Un-protected well is without any of the features stated above and a semi-protected well may have one or more of the features found in a protected well (Oluwasanya *et al*., 2011). The wells are often more vulnerable to contamination than deeper boreholes. Whilst some shallow dug wells have mechanised pumping, the majority (particularly those in developing countries) have water abstraction through some form of hand pump, windlass or rope and bucket system (Collins, 2000). Shimizu *et al*., (1980) have shown that bacteria contaminate well water depending on location. Thus, it is suspected that water from wells in unhygienic areas could be contaminated according to their proximity to sources of pollution. Contaminants such as bacteria, viruses, heavy metals, nitrates and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-utilization of limited water resources (Adeyemi et al., 2007). Contamination of well water, which has led to health risks, is known in the study area (Talabi and Ogundana, 2014). In the study area, in the interest of public health many houses made provision for latrines to address the problem of open defecation. However Ado community is faced with infrastructural and developmental problems due to overcrowding in various localities and open defecation and haphazard surface dump of refuse are still very common. Sanitary inspection, which identifies actual and potential sources of contamination of groundwater abstraction points, was proposed by the World Health Organization as part of the comprehensive and complementary risk-based assessment of

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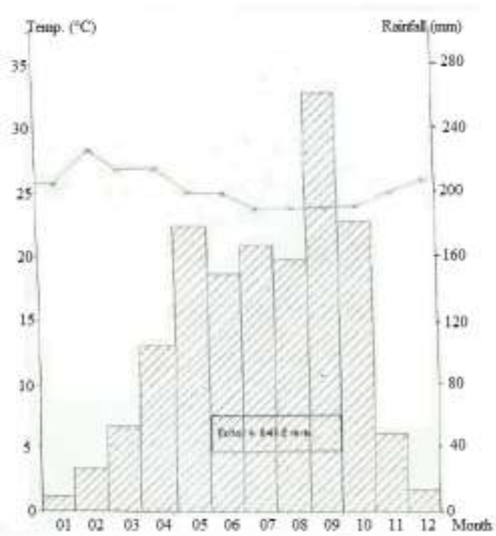
drinking water quality (WHO 2004; Luby et al. 2008). This research is therefore using the sanitary risk assessment to assess domestic hand dug wells in Ado-Ekiti with a view to identify the actual and potential sources of contamination of shallow hand dug wells, analyze the sanitary conditions of the wells and to support the operation and maintenance of such wells by providing clear guidance for remedial action to protect and improve water supply.

Location and Geology of the study Area

Ado Ekiti is a city in southwest Nigeria, the state capital of Ekiti State (Fig. 1). It is located on Latitude 7° 33′ and 7° 42′ N and longitude 5° 11′ and 5° 20′ E with an average elevation of 433 meters above sea level. The study area is in the tropics within Koppens A_W climate classification and consequently enjoys the sub equatorial climate characterized by double rainfall peaks which coincide with the passage of the 'equinoxes'. The annual rainfall totals in the region ranges from 1200mm and 1400mm while the highest mean monthly value varies between 105mm and 261mm. Eighty percent of the monthly rainfall occurs between May and October each year. September and October are usually the wettest months. The dry season spans November to March. However, the global warming phenomenon and the general global climatic fluctuations seem to have triggered alterations in the onset and cessation of rains in the area. Mean monthly temperature of the area is 27°C while the hottest months are in February and March (Adebayo and Arohunsoro, 2014)



Fi.2. Climate graph of Ado-Ekiti (Adebayo and Arohunsoro, 2014)

Rainfall is the dominant factor that determines the occurrence of groundwater in the study area, though seepage into the groundwater may arise from surface water (Rivers Elemi, Ajilosun, Ireje, Ero, Oge and Odo-Ayo). Groundwater occurence in a typical Basement Complex is restricted to the weathered overburden or in the joints and fractured systems of the crystalline rocks. The rocks are mechanically competent (granites more so than gneisses) and therefore respond to imposed strains by brittle fracture. Surface water percolates down through the fractures.

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Geologically, the study area is underlain by the Precambrian rocks of the Basement Complex of Southwestern Nigeria which covers about 50% of the land surface of Nigeria. The Basement Complex forms part of the mobile-belt east of the West African craton and Congo Cratons and South of the Touareg Shield (Black, 1980). The rocks are concealed in places by a variably thick overburden. The major lithological units are the migmatite-gneiss complex; quartzite; the older granites and the charnockitic rocks. The migmatite-gneiss complex (oldest rock) 2.0–3.0 Ga; (Dada & Briqueu, 1998) constitute highly denuded hills of essentially fine textures with closely spaced alternating bands of leucocratic and melanocratic minerals in the study area. Quartzite occurs as ridge of fine-medium grained rock characterized by the abundance of quartz rubbles majorly in the southwestern part of Ado-Ekiti. The Older Granites comprise of fine-medium grained to coarse porphyritic rocks, occur as intrusions within the migmatite-gneiss-quartzite complex (Omosanya et al., 2012 and Okonkwo & Folorunso, 2013). The Older granites occur as inselbergs and also as well-rounded boulders devoid of any preferred orientation of component minerals. The charnockitic rocks represent oval or semi-circular hills of between five and ten meters (10 m) high with a lot of boulders at some outcrops. They are dark-greenish in colour with medium to coarse grained texture. The charnockites occur in association mainly with the Older granites.

MATERIALS AND METHODS

This research attempts to address the question of the relevance of the WHO water safety plans framework to the actual supply systems (Yin, 2003; Yin, 2009). The research is composed of both quantitative and qualitative data acquisition. Water quality determination and sanitary survey of wells formed the bulk of the quantitative data. Interviews and direct observation of systems operations and handling represents the qualitative data gathering methods. Reconnaissance survey was carried out to decide on the number of wells to be sampled/surveyed. Thirty (30) wells selected randomly were earmarked for sampling. A standardized sanitary inspection format recommended by the World Health Organization (WHO, 1996) for Sanitary Risk Assessment in which series of questions with a yes and no options for designated risks were designed. The questions were designed so that the assessor can provide answers onsite using a mixture of visual observation and interviews. The WHO (1996) established format for sanitary inspection forms consisting of factors used to assess the sanitary risk of any groundwater source.

A score of one point was awarded for each “yes” answer (risk observed) and zero point for each “no” answer (no risk observed). By summing all “yes” scores, a final risk score was obtained which provide the overall assessment of the risk profile of each well. The total sanitary risk score was converted to a percentage. The aggregate risk score was graded as very high (90 to 100%), high (60 to 80%), intermediate (30 to 50%) and (0 to 30%) as low. This aggregate scoring is in line with WHO (2012) systematic approach of obtaining quantitative value from the standardized sanitary inspection.

Subsequently, a total of 30 water samples (Fig. 1) in triplicate were collected into polyethylene bottles that have been thoroughly washed with distilled water and rinsed with sample water at point of collection. All samples were labeled properly and according to the prerequisites for the sample analyses. Chemical analyses were in accordance to APHA (1998) standard methods. The analyses were carried out at the Federal Ministry of Water Resources, Akure Nigeria. HCO_3^- was determined by titration against standard HCl, Cl^- by titration against standard

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solution of $AgNO_3$, SO_4^{2-} by gravimetric method while NO_3^- was determined calorimetrically using spectrophotometric technique (APHA, 1998). Analyses of Ca^{2+} and Mg^{2+}, Na^+ and K^+ were by compleximetric titration against standard EDTA solution and flame photometry respectively.

E-coli were determined employing the Membrane filter technique. *E. coli* is a normal inhabitant of the intestinal tract and is not normally found in fresh water. Therefore, if it is detected in water, it can be assumed that there has been fecal contamination of the water. E. coli is the most common coliform among the intestinal flora of warm-blooded animals and its presence might be principally associated with fecal contamination. No E-coli are therefore allowed in drinking water (WHO, 1998). The Membrane filter technique consists of filtering a water sample on a sterile filter with a 0.45-mm pore size which retains bacteria, by incubating this filter on a selective medium and enumerating typical colonies on the filter, e-coli is obtained (APHA, 998).

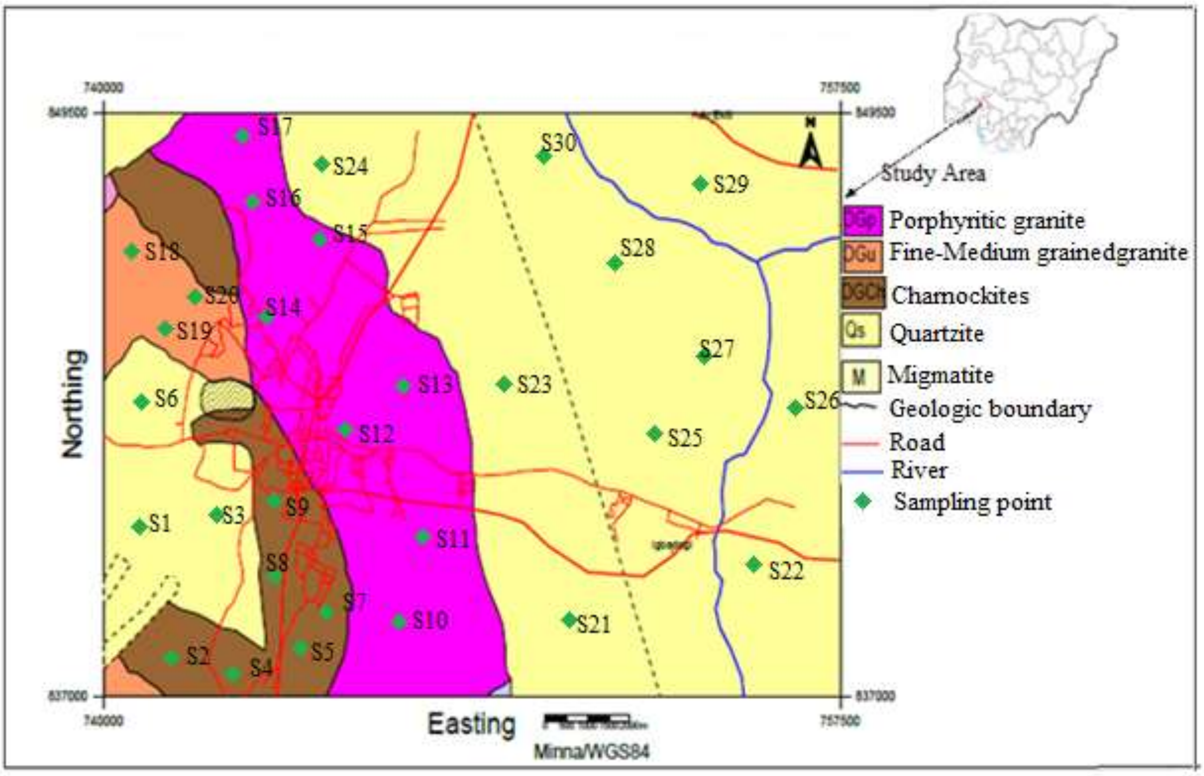

Fig. 1. Location/Geology of Study Area

RESULTS AND DISCUSSION

The results of the sanitary survey in this study are presented in Table1 while that for the chemical and e-coli are in Table 2. The results revealed that 27 out of 30 samples representing 90% fell in the category of high to intermediate risk while 3 of the samples were in the low risk class (Table 1). The common risks identified include distance to well less than 10 m, inadequate concrete apron height, well not lined, fetching rope exposed to the ground and fetching container placed improperly. Lack of basic hygiene knowledge constitutes the major problems

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of people in the study area and as such safety of the water from the hand dug wells can be improved if health education is intensified.

Results of chemical analysis (Table 2) revealed that all measured chemical parameters are within approved WHO (2004) approved standard of drinking water except for Cl^- and NO_3^- with concentrations above 250mg/L and 50mg/L respectively in 70% and 43% of the water samples from the hand dug wells. The order of the concentrations of major cations was $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ while that of the anions was $Cl^- > HCO_3^- > NO_3^- > SO_4^{2-}$. This order of concentrations was supported by the Schoeller diagram (Fig. 2). The Schoeller diagram clearly indicated that the well water was majorly rich in Na, Ca and Cl ions.

Furthermore, to categorize the well water, Piper diagram was employed (Fig. 3). The Piper diagram is a graphical representation of the chemistry of wells water samples in which the cations and anions are shown by separate ternary plots. The two ternary plots are then projected onto a diamond shaped quadilateral (Piper, 1953).

Table 1. Results of Sanitary Survey of the Wells in the Study Area.

Code	Distance to latrine <10m	Well Covered	Bucket and Rope	Animal breeding close to Well	Damage Apron	Well not lined	Contaminated rope /bucket	Marshy surrounding	NO_3 value >50mg /L	E-Coli present	Total Risk score (%)
S1	No	No	Yes	No	Yes	No	No	No	No	Yes	30
S2	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	60
S3	No	No	Yes	No	No	Yes	Yes	No	Yes	Yes	50
S4	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	40
S5	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	70
S6	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	60
S7	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	60
S8	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	70
S9	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	70
S10	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	80
S11	No	No	Yes	No	Yes	Yes	Yes	No	No	Yes	60
S12	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	60
S13	No	No	Yes	No	No	Yes	No	No	No	Yes	30
S14	No	No	Pump	No	No	No	No	Yes	No	No	10
S15	No	No	Pump	No	No	No	No	No	No	No	0
S16	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	50
S17	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	50
S18	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	50
S19	No	No	Pump	No	No	No	No	No	No	Yes	0
S20	No	No	Yes	No	No	Yes	Yes	No	Yes	Yes	50
S21	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	60
S22	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	60
S23	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	70
S24	No	Yes	Yes	No	No	Yes	No	Yes	No	Yes	50
S25	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	60
S26	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No	50
S27	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	50
S28	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	60
S29	No	No	Yes	No	No	Yes	Yes	No	No	Yes	40
S30	No	No	Yes	No	No	Yes	Yes	No	No	Yes	40

Contamination Risk Score: 90 – 100 = Very high; 60 – 80 = High; 30 – 50 = Intermediate; 0 – 20 = Low (WHO, 1996)

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Tble2: Results of chemical (mg/L) and E-coli (CFU/ml) Parameters in the study area.

Code	Ca	Mg	Na	K	Zn	HCO_3	Cl	SO_4	NO_3	E-coli
S1	94.23	24.56	80.11	160.54	0.01	12.2	727.2	35.78	21.54	$1.38X10^{9}$
S2	102.13	32.58	232.51	173.24	0.01	12.21	77.6	23.49	59.14	$1.16X10^{9}$
S3	24.36	4.76	32.25	12.58	0.02	12.26	3024.01	0.05	70.11	$1.55X10^{7}$
S4	21.05	4.65	40.51	14.56	0.01	12	3024.03	3.88	35.71	0.00
S5	46.58	26.13	168.24	29.87	0.03	12.08	2700.04	47.41	53.72	$1.07X10^{8}$
S6	90.48	38.56	255.59	72.19	0.02	12.03	676.8	23.92	59.78	$7.09X10^{7}$
S7	16.23	5.12	36.51	13.21	0.36	73.2	360	6.466	55.20	$3.26X10^{9}$
S8	17.45	6.1	47.56	20.14	0.15	85.4	532.8	4.095	50.20	$5.12X10^{6}$
S9	16.42	1.66	17.23	6.62	0.86	97.6	216	5.172	52.80	$2.87X10^{8}$
S10	71.52	32.51	85.23	132.54	0.19	341.6	1,598.40	12.5	22.20	$1.42X10^{7}$
S11	55.63	34.15	131.54	141.52	0.07	312.01	1,670.40	0.6	10.07	$7.90X10^{8}$
S12	81.02	29.34	150.53	48.46	0.36	219.63	662.41	4.96	33.33	$5.64X10^{7}$
S13	54.50	11.7	17.60	8.00	0.08	24.50	270.80	7.30	46.00	$2.57X10^{8}$
S14	19.60	12.10	36.40	16.40	0.14	102.60	560.90	16.10	34.30	0.00
S15	28.40	17.40	30.60	9.20	0.22	96.00	470.00	7.90	25.30	0.00
S16	64.10	10.80	18.20	10.30	0.46	68.40	280.80	22.10	15.50	$4.31X10^{5}$
S17	56.10	14.80	13.0	7.40	0.04	60.70	200.60	7.90	10.70	$7.19X10^{7}$
S18	32.20	11.40	23.60	8.70	0.01	56.40	320.40	18.30	11.21	$6.12X10^{6}$
S19	36.40	14.70	19.20	9.40	0.21	53.60	201.30	31.40	14.10	0.00
S20	32.20	11.70	39.10	8.50	0.08	97.10	520.60	12.30	51.59	$3.94X10^{7}$
S21	72.30	9.30	11.10	8.20	0.23	56.00	177.50	11.70	52.7	$2.67X10^{8}$
S22	18.60	19.50	47.20	12.30	0.06	38.80	286.80	24.10	11.6	$3.31X10^{7}$
S23	37.30	12.60	15.30	9.60	0.02	32.10	238.70	8.30	50.6	$7.42X10^{6}$
S24	38.50	10.40	67.40	8.70	0.10	50.60	156.70	17.50	13.5	$6.03X10^{8}$
S25	75.40	8.40	23.40	6.80	0.07	68.30	326.40	22.10	56.7	$3.43X10^{7}$
S26	19.20	30.50	63.40	10.30	0.31	160.90	537.80	17.20	54.2	$7.80X10^{7}$
S27	36.60	17.40	25.80	10.50	0.07	107.60	342.70	9.70	16.7	$6.13X10^{8}$
S28	21.40	25.30	23.10	8.40	0.23	78.70	341.70	15.30	51.4	$4.20X10^{6}$
S29	58.50	9.20	29.40	11.60	0.06	123.40	232.30	17.80	12.3	$5.14X10^{7}$
S30	43.40	13.70	49.80	10.30	0.13	116.60	343.70	21.30	15.6	$6.18X10^{8}$
Min	16.23	1.66	11.1	6.62	0.01	12	77.6	0.05	10.07	0.00
Max	102.13	38.56	255.59	173.24	0.86	341.6	3024.03	47.41	70.11	$3.26X10^{9}$
Mean	46.06	16.70	61.05	33.33	0.15	86.48	702.65	15.22	35.59	$3.28X10^{8}$
Stdev	25.66	10.19	63.75	49.57	0.18	81.05	833.45	10.76	19.53	$6.61X10^{8}$

The Piper diagram not only shows graphically the nature of a given water sample, but also dictates the relationship to other samples. The Piper diagram in this study revealed CaCl as the major water type with minor mixed CaMgCl water (Fig. 3).

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Few scatter plots were made as presented in Fig.4. The scatter plot of Na vs. Cl, barring few locations revealed that the two parameters are positively correlated with coefficient of correlation r = 0.77. This suggests same source of the ions and mostly geogenic. However, the plot of Ca + Mg vs. Cl revealed negative correlation. Cl ions are in excess of Na ions an

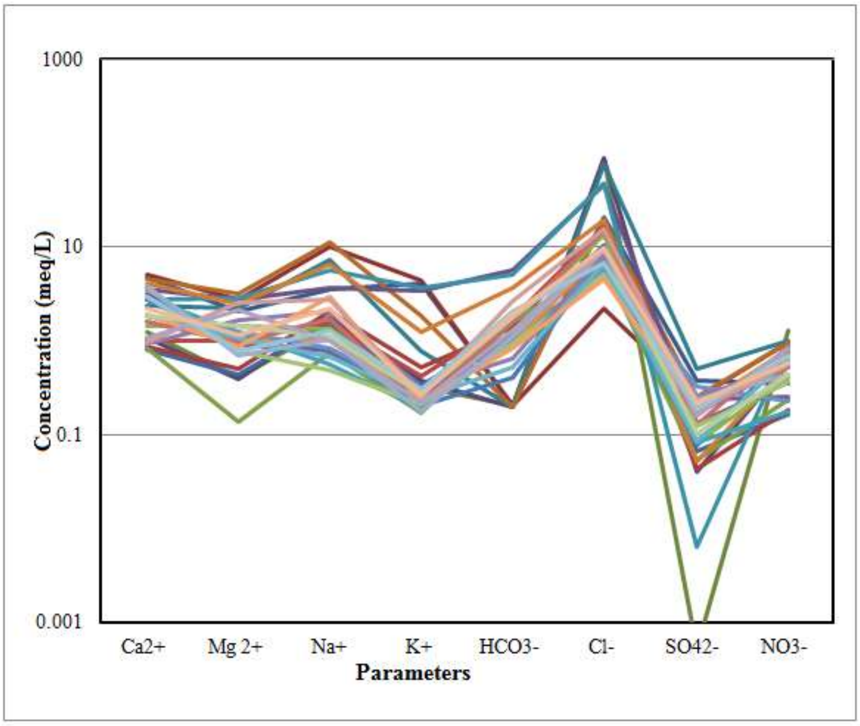

Fig. 2. Schoeller diagram of shallow hand dug wells water samples from the study area

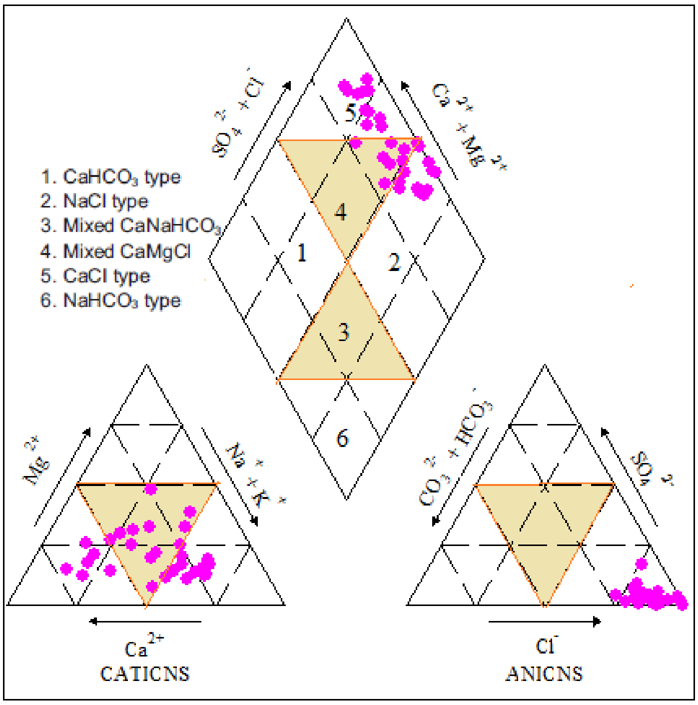

Fig. 3. Piper diagram of the hand dug wells water in the study area

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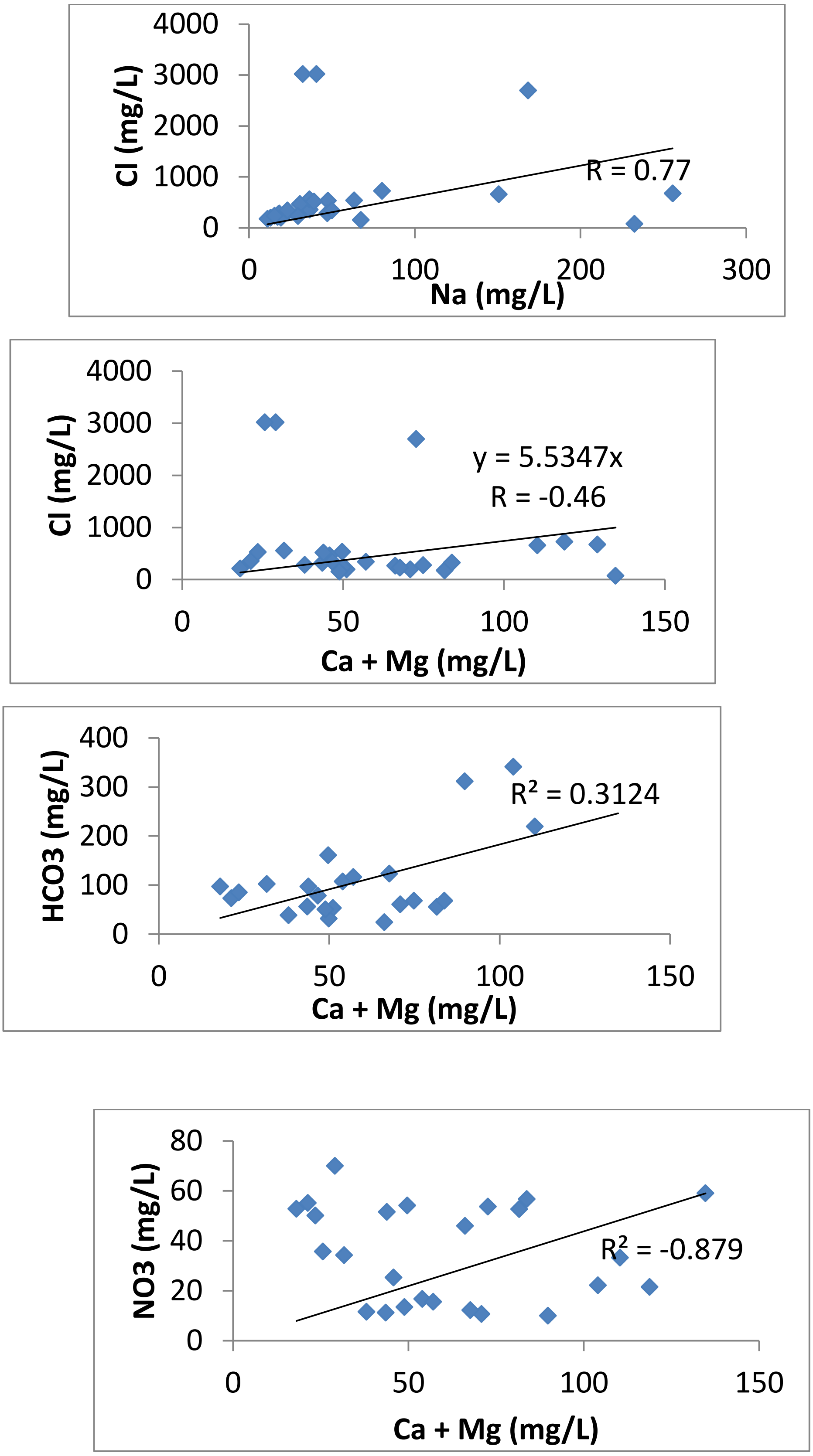

Fig. 4. Cross plots of few chemical parameters in the study area.

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indication that apart from the geogenic source, there is the likelihood of anthropogenic source. NO_3 ions are mainly as a result of anthropogenic source. This assertion was supported by the fact that a plot of Ca + Mg vs. NO_3 gave a strong negative correlation with correlation coefficient r of -0.879. The few scatter diagrams still buttress anthropogenic activities as sources of ions in the well water and by implications responsible for the high number of the wells in the high – intermediate risk category. This study has clearly revealed that the hand dug wells in the study area were exposed to high sanitary risk-factors due largely to ignorance on basic hygiene rules. Apart from the need of intensive hygiene education in the area, badly affected wells especially the ones in the high risk class can be abandoned while alternative sources of water supply is to be considered. In some other wells, the source of pollutants can be removed while treatment could be administered on others using chlorine tablets.

CONCLUSIONS

The study revealed that 90% of the hand-dug wells were at risk of contamination falling in the high – intermediate risk class. Identified sources of pollution were construction defaults including wells that are not lined, cracks in the concrete apron, lack of adequate apron around well head and close proximity to humans and animal wastes. Most of the Wells with high risk score were unprotected and used a bucket & rope method of abstracting water. The sampled wells with the low sanitary risk had pumps installed as a method of abstraction. All measured chemical parameters except NO_3^- and Cl^- were within approved standard of WHO (2004) for drinking water. Result of the chemical analysis in support of outcome of the sanitary risk assessment, indicated NO_3^- and Cl^- as pollutants of the well water arising from hazards and hazardous events that can affect the safety of water supply from the shallow wells. Intensive hygiene education should be embarked upon in the study area while complete abandonment of wells in the high risk category to seek for alternative source of water supply be encouraged.

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