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Wellhead Protection and Quality of Well Water in Rural Communities of Udenu L.G.A of Enugu State, South Eastern Nigeria

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Abstract: ***Well water contamination is a major public health problem in rural Nigeria. To explore the impact of wellhead protection on well water quality and to identify possible well water contaminants, water samples were collected from twenty (ten protected and ten unprotected) wells in ten rural communities of Enugu state, southeastern Nigeria. Ten physico-chemical and bacteriological water quality parameters including Total coliform count, Escherichia coli, pH, Temperature, Ec, Turbidity, Nitrate, Chloride TDS, and Sulphate were analyzed. The values returned from the analysis of protected and unprotected well water samples were compared with each order and with WHO (2011) benchmark for drinking water. Results obtained indicated that studied wells exhibits high variations in the physico-chemical and bacteriological properties of the water samples. However, bacterial contamination in well water samples was more serious in the unprotected wells; as the Escherichia coli was detected in all samples from the unprotected wells. Contamination by physical and chemical parameters is not a serious problem in the study area. The result of the study has shown that capping is a major factor influencing bacterial contamination levels in well water of the study area. The paper, therefore, recommends that the state government should ensure that all wells in the area are properly capped to keep contaminants away from the community wells on which the people depend for their water needs.***

Keywords: Well water, Wellhead, Protected wells, Unprotected wells.

1. Introduction

A well is a direct, open channel from the surface to groundwater (Fielder et al, 1995). Any material entering the well moves directly to the groundwater without any impediment. Well is an important source of potable water in the world (Majuru et al, 2011). Many rural communities have traditionally relied on wells for their water supply. The well water accessed is used for various purposes, including washing of clothes, bathing, cooking, drinking, irrigation of crops, building, or construction, industrial activities, and other socio-economic activities such as car wash, laundry services (Murcott, 2007; Olushola et al., 2014; Okoro et al., 2014; Mamah, 2016).

Over much of Nigerian rural communities, well water is the only reliable water supply option for meeting the household water needs (Ayantobo et al. 2012). Piped water supplies are erratic, unreliable or non-existent. Commercial supplies are expensive; streams are difficult to collect and prone to contamination; rain water harvesting are seasonal and requires good rainfall throughout the year (FGN, 2007).

In contrast, well are relatively easy to develop and maintain in many Nigerian rural communities. In addition, Edungbola and Asaolu,(1984) and Ezemonye,(2009) added that wells in the Nigerian rural sector are generally:

1) Sited close to the point of demand:
2) Perennial and resistant to droughts,
3) Amenable to household operation and management communities
4) Yield water of acceptable quality.

Because of the above advantages, wells are routinely dug or drilled for household water supplies in Nigeria. In a recent survey Majuru et al. (2011), estimated that 86.5 million people or 71% of the Nigerian rural population access well water for domestic activities. Without these wells, the health and livelihood of many families can be severely affected (United Nations, 2000; MacDonald et al., 2005). Well water is however, susceptible to contamination (MacDonald et al., 2005).This is even worse in areas where well are poorly or totally un protected (Oluwasanya et al., 2011). Protecting well water is a key to sustaining safe drinking water supplies (UN, 2000; Olusiji, 2012).

In the study area, over 89% of the population receives their drinking water from either boreholes or wells, but because most of the boreholes are non-functional, almost all the households rely on large diameter private wells. Large diameter wells are ubiquitous in the study area. Well sinking is not new in the area. People have been sinking wells in the area for several decades. Two categories of wells exist in the area; these are the shallow and the deep wells. Shallow wells are simple, generally hand-dug, easy to develop and maintain. Deep wells are very expensive to develop, perennial and are mechanically drilled.

Some of these wells are protected while some are not protected (see Figs 1 - 4).There are six principals of well protection, which, according to Fielder (1995) include:(1) proper location (2) proper construction (3) keeping contaminants away from the well (4) preventing back flows (5) sealing abandoned wells (6) inspecting the well and testing well water. A well should be located on the highest ground available and as far away from possible sources of contamination as possible. Also a poorly constructed or sealed well creates a direct channel between the surface of the ground and the groundwater supply is therefore prone to contamination. Keeping potential sources of contamination away from the well in necessary to safe guard its quality. This also helps reduce chances of accidental spills around a well or contaminations of the soil near a well. Backflow that siphons pollutants into a well is a serious potential problem. Backflow typically happens when the pump shuts off unexpectedly because of a power failure, malfunction or other reason. Properly sealing abandoned wells is necessary to keep away migratory pollutants.

FIG.1: Protected well

FIG.2: Unprotected well

FIG.3: Unprotected well

FIG.4: Semi protected well

A fully protected well, according to Oluwasanya et *al*.(2011) and Ayantobo *et al (*2012) is one with the above features. An un-protected well is without any of the above features while a semi-protected well will not have all the features (Oluwasanya *et al*., 2011). This work is focused only on wellhead protection. Many wells are not capped or properly capped in our study area. When wells are not properly capped, then insects, small animals, refuse, sediments, and other forms of contaminants cannot be prevented from accessing the well water. This explains why (Ezemonye, 2009; Essien and Bassey, 2012) observed that unprotected and semi protected wells are prone to on-site contamination and threaten the quality of the well water.

The impact of wellhead protection on the physico-chemical and bacteriological quality of well water in the study area is currently unknown. Understanding the nature, extent and impact of wellhead protection on well water quality is necessary and will aid planning and well water management. Users simply assume that the well water is of good quality. No water quality test is carried out. The owner of a private well is responsible for the safety of the water from it. Routine testing to ensure that no contamination has occurred is not done. Management strategies in use are not informed by research findings.

Therefore, the objective of this study is to investigate the effects of wellhead protection on well water quality in rural communities of Udenu LGA of Enugu state of Nigeria.

2. Study Area

The study area is Udenu local Government Area of Enugu State, Nigeria. The study area lies approximately at latitudes 6° 48[1]N and 6° 58[1]N and Longitudes 7° 26[1]E and 7° 40[1]E. It covers an area of 248km^2. It is bounded to the northwest by Kogi State, Northeast by Benue State, to the West by Igbo-Eze North LGA, to the east by Isi-uzo LGA and to the South by Nsukka LGA (Fig.1). The study area is made up of 14 autonomous communities (see Fig 2) and underlain by the several geologic formations, with the Ajalli Sandstone and the Mamu Formation dominating. Only deep boreholes of up to 220-250m such as the one at Obollo-Afor encounter the Mamu. The lithology is made up of sandstone, shales, sandy shales and coal (De Swardt and Casey, 1963). The area is mainly drained by the Ebonyi river which flows through two(Obollo-Etiti and Obollo-Eke) communities. The rest of the area is drained by fast flowing springs Eze (2007). The climate of the area is a tropical wet and dry (Aw) climate type according to Koppen's classification system. According to the 2006 population census, Udenu LGA has a total population of 178,687 and an area of 248km^2 with 88,381 males and 90,306 females (NPC, 2010).

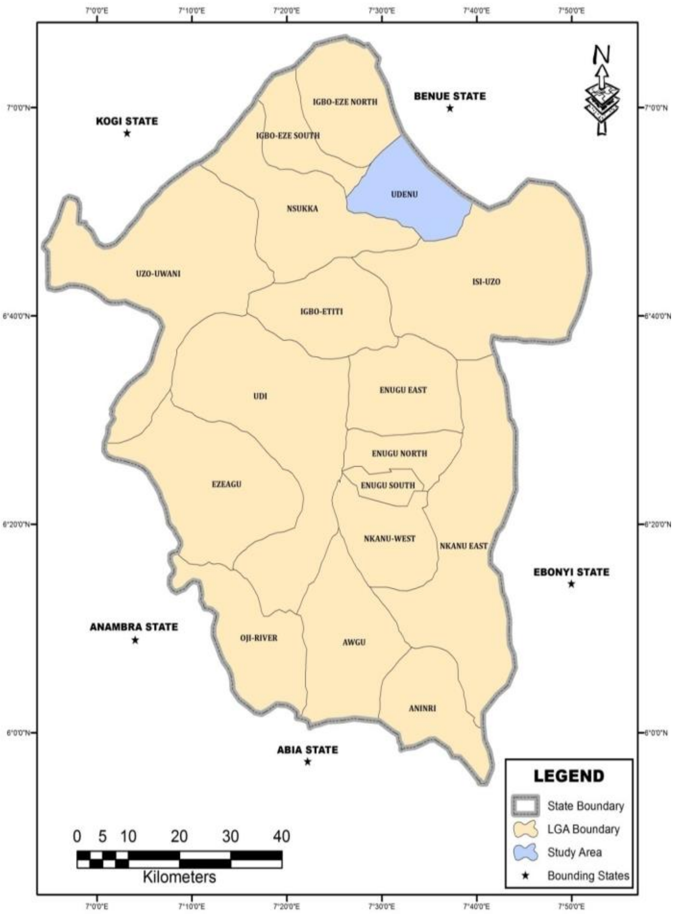


FIG.5: Enugu state showing Udenu LGA

Source: GIS Unit, Department of Geography, University of Nigeria, Nsukka

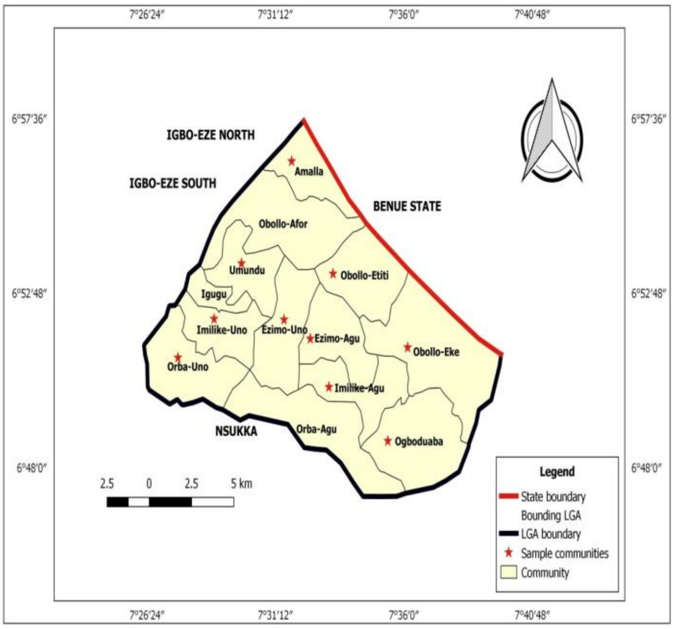


FIG.6 : Udenu LGA showing the autonomous communities
Source: GIS Unit Department of Geography, University of Nigeria, Nsukka

3. Materials and Methods

This study was conducted in 10 rural communities of Udenu LGA of Enugu state, Nigeria. A map of the sample sites is shown in Fig.6. Water samples were collected from twenty (20)

different locations in the sampled communities. Two (2) samples (one from protected and the other from the unprotected well) were collected from each of the sampled community (Table 1).

Table 1: Summary Characteristics of the Wells in the area

Location	Code	Method of construction	Depth of Well(m)	Mode of operation
Amalla	**DW1 +**	**Mechanical**	**188.6**	**Pump**
Amalla	**DW2 +**	**Mechanical**	**167.7**	**Pump**
Umundu	**DW3 +**	**Mechanical**	**182.8**	**Pump**
Umundu	**DW4 +**	**Mechanical**	**152.4**	**Pump**
Imilike-Uno	**DW5 +**	**Mechanical**	**132.8**	**Pump**
Imilike-Uno	**DW6 +**	**Mechanical**	**157**	**Pump**
Ezimo-Uno	**DW7 +**	**Mechanical**	**198**	**Pump**
Ezimo-Uno	**DW8 +**	**Mechanical**	**152.4**	**Pump**
Orba-Uno	**DW9 +**	**Mechanical**	**184.1**	**Pump**
Orba-Uno	**DW10 +**	**Mechanical**	**167**	**Pump**
Obollo-Eke	**HDW1 ++**	**Hand-dug**	**8.7**	**Bucket & Rope**
Obollo-Eke	**HDW2 ++**	**Hand-dug**	**11.3**	**Bucket & Rope**
Obollo-Etiti	**HDW3 ++**	**Mechanical**	**9.8**	**Bucket & Rope**
Obollo-Etiti	**HDW4 ++**	**Hand-dug**	**9.6**	**Bucket & Rope**
Ogboduaba	**HDW5 ++**	**Hand-dug**	**9.2**	**Bucket & Rope**
Ogboduaba	**HDW6 ++**	**Hand-dug**	**9.5**	**Bucket & Rope**
Imilike-Agu	**HDW7 ++**	**Hand-dug**	**7.9**	**Bucket & Rope**
Imilike-Agu	**HDW8 ++**	**Hand-dug**	**8.5**	**Bucket & Rope**
Ezimo-Agu	**HDW9 ++**	**Hand-dug**	**8.2**	**Bucket & Rope**
Ezimo-Agu	**HDW10 ++**	**Hand-dug**	**9.3**	**Bucket & Rope**

+ = Protected well; ++ =Unprotected well

Water samples were collected in the month of August 2015, when all the wells experienced rise in water table. All water samples were collected in sterilized rubber bottles following standard procedure. Sterilized bottles were labeled before sampling and all samples were taken immediately to the laboratory for analysis. Two different bottles were used for the collections from each of the location. One was for the physico-chemical analysis while the other was for bacteriological analysis. The samples for microbial analysis were preserved in Ice block in a cooler and sent immediately to the laboratory for analysis. The aim was to slow down the rate of any biochemical reaction. Samples were analyzed for pH, Temperature, Electrical conductivity, Turbidity, Sulphate, Chloride, Nitrate, Total dissolved solids, Total coliform, and Escherichia coli.

Microbial analysis of water was conducted to determine the total coliforms and *Escherichia coli*. The total coliforms in water were analyzed using the multiple tube most probable number (MPN) fermentation technique utilizing enzymes β-D-galactosidase and β-D-. Information on well depths, sanitary conditions of well sites, well owners, management strategies etc were gathered through measurement, interviews or personal observations.

4. Results and Discussions

Physico-chemical and Bacteriological Characteristics Well Water Samples

A summary of the laboratory analysis of the well water samples wells are shown in Table 2.

Table 2: Physico-Chemical and Bacteriological Characteristics of Water Sample from Protected and Unprotected Wells

	PROTECTED WELLS									
Code	**Ph**	**Temp**	**Ec**	**Turbidity**	**TDS**	**Chloride**	**Nitrate**	**Sulphate**	**Total Coliform**	**E.coli**
DW1	5.9*	26.5*	23	0.22	41	5.3	0.6	6.4	0.47	0
DW2	6.2*	25.5*	28	0.34	56	5.6	1.8	7.3	0.75	0
DW3	5.6*	27.5*	28.5	1.2	28	4.6	1.76	2.6	0.65	0
DW4	6.5	26.5*	38.5	1.3	38	3.7	0	3.7	0.01	0
DW5	6.4*	25.8*	16	2.6	63	3.2	2.3	6.2	0.91	0
DW6	6.3*	26.6*	23	2.3	52	20.1	3.1	8.6	2.87	0
DW7	6.6	28.6*	26	2.3	49.5	9.8	0.39	2.4	0.66	0
DW8	6.1*	25.4*	43	1.4	49.3	17.8	2.28	4.6	2.06	0
DW9	5.2*	28.4*	37	1	38	4.5	1.4	4.1	0.78	0
DW10	6.7	27.3*	33	1.2	40.1	8.5	3.4	5.6	0.68	0
Min	**5.2**	**25.4**	**16**	**0.22**	**28**	**3.2**	**0**	**2.6**	**0.01**	**0**
Max	**6.7**	**28.6**	**38.5**	**2.6**	**63**	**20.1**	**3.1**	**8.6**	**2.87**	**0**
Mean	**6.51**	**26.8**	**29.6**	**1.4**	**45.5**	**8.3**	**1.7**	**5.2**	**0.98**	**0**
WHO(2011)	**6.5-8.5**	**25**	**1000**	**5.0**	**500**	**-**	**10**	**250**	**10**	**0**
NSDWQ(2007)	**6.5-8.5**	**-**	**1000**	**5.0**	**500**	**250**	**50**	**100**	**10**	**0**
	UNPROTECTED WELLS									
HDW1	7.1	27*	64.3	3.5	120	3.5	2.7	10	6	1.3*
HDW2	6.8	25.5*	334	6.7*	140	7	3.7	8	4	0.9*
HDW3	6.5	27.4*	77.4	1.6	100	6	1.8	7	3	0.8*
HDW4	6.4*	26.2*	167	2.4	110	5.9	2.4	6	5	0.2*
HDW5	6.1*	27.6*	128.2	2.9	200	5.1	5.3	6.4	2	0.5*
HDW6	6.7	26.1*	220	3.2	180	8.4	9.4	7.4	5	0.8*
HDW7	6.2*	28*	262.4	5.0	170	11.5	5.8	5.8	4	1.8*
HDW8	7.2	24.4	123	2.6	150	9.3	11.2*	6.8	7	1.2*
HDW9	6.7	26.5*	77	4.5	140	8.5	2.8	ND	3	0.6*
HDW10	7.6	25.3*	147	3.5	170	10.1	6.5	8.6	6	1*
Min	**6.1**	**24.4**	**77**	**1.6**	**100**	**3.5**	**1.8**	**5.8**	**2**	**0.2**
Max	**7.6**	**27.6**	**334**	**6.7**	**200**	**11.5**	**11.2**	**10**	**7**	**1.8**
Mean	**6.73**	**26.4**	**160.03**	**3.59**	**148**	**7.53**	**5.16**	**7.3**	**4.5**	**0.91**
WHO(2011)	**6.5-8.5**	**25**	**1000**	**5.0**	**500**	**-**	**10**	**250**	**10**	**0**
NSDWQ(2007)	**6.5-8.5**	**-**	**1000**	**5.0**	**500**	**250**	**50**	**100**	**10**	**0**

* Values that exceed WHO (2011) Benchmark

**Values that exceed NSDWQ (2007) Benchmark

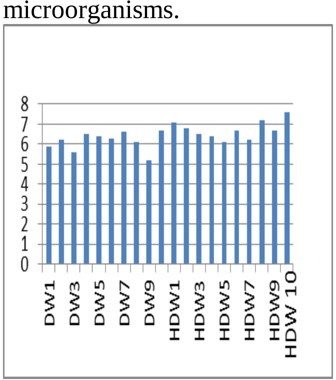
\- No Guideline Value

ND= Not detected

As shown in Table 2, low pH and high temperature values were returned for most of water samples. pH values ranged from 5.2 -7.6 with a mean values of 6.51 and 6.73 while temperature ranged from 24.4-28.6^{0}C with average values of 26.8^{0}C and 26.4^{0}C for protected and unprotected wells respectively. Ten of the pH values fall within the permissible limit of WHO (2011) and NSDWQ (2007) permissible limits for drinking water supplies. With the exception of HDW8, the recorded temperature values were all above the WHO recommended limits of (25^{0}C) for drinking water quality. Other parameters (Ec, Turbidity, TDs, Cl, Nitrate, Sulphate Total coliform and E-coli) returned values that were well within the WHO (2011) benchmark for drinking water. In contrast, all the water samples from unprotected well showed traces of microbial contamination. From the analysis, all the sampled stations recorded values of chloride that are all within the WHO and NSDWQ permissible limit for human use. The returned values for nitrate ranged from 0-11.2 mg/. The highest nitrate value (11.2mg/l) was recorded in the unprotected well (HDW8) which is not within the permissible limit of WHO (10 mg/l) for human use, although, it was within the NSDWQ permissible limit (50 mg/l). The returned values for sulphate indicate that all stations recorded values that are all within the permissible limit of WHO and NSDWQ. Values of Total coliform counts for the sampled stations are shown in column 10 of table 2. The returned values ranged from 0.01-7cfu/100ml. The highest returned value of 7cfu/100ml was recorded in HDW8 (Imilike-Agu). The values of Total coliform count are within the permissible limit (10cfu/100ml) of WHO and NSDWQ. The presence of E coli in the water samples from the unprotected wells is an indication of faecal contamination. The returned values ranged from 0-1.8cfu/100ml. Values from the unprotected wells are above the WHO and NSDWQ permissible limit of 0cfu/100ml. The wells are unfit for human use.

Variations in Values of Returned Water Quality Parameters from Protected Wells and the unprotected wells in the Study Area

Figures 7 to 16 present a summary of the variations in the returned values of the analyzed water quality parameters from the protected and unprotected wells. As shown in figure 7, Ph values from the unprotected wells (HDW1 to HDW10) were generally higher than the values returned from the protected wells (DW1 to DW10). The low values returned at some of the sampling sites such as in HDW4, HDW5, and HDW7 show that the well water at these sites are acidic and below allowable limits of the WHO (2011) benchmark. Elevated value of nitrate was returned in one unprotected well samples tested; this may be an evidence of direct intrusion of nitrate from agricultural land into the unprotected wells. Nitrate is common in groundwater as a result of agricultural activities and wastes. E-coli were not detected in any of the protected wells; however, all the unprotected wells had traces of E-coli (see Fig. 16). Interviewees attributed the presence of E-coli in the unprotected wells to the unhygienic conditions around the wells which make the well environment conducive for the growth of microorganisms.



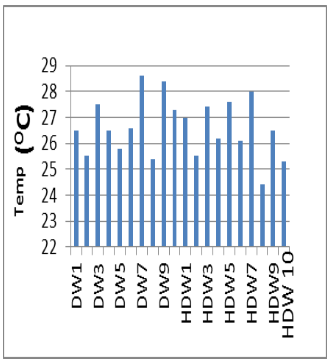
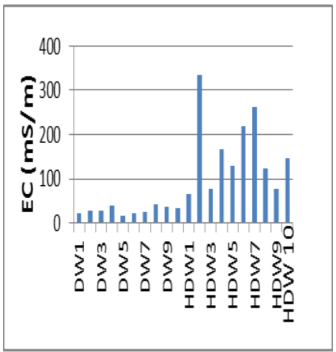


FiG.7: Variations in pH

FIG.8: Variations in Temperature



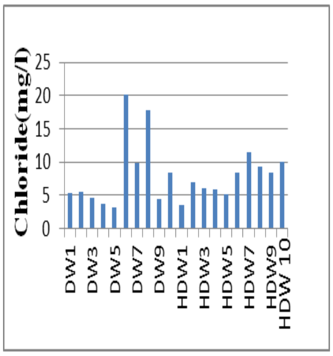
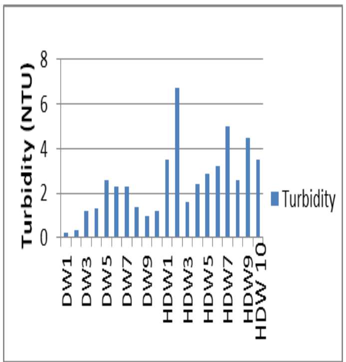


FIG. 9: Variations in Electrical conductivity

FIG. 10: Variations in Chloride



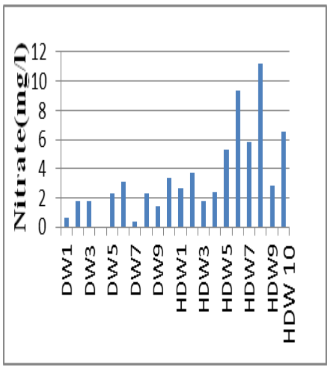
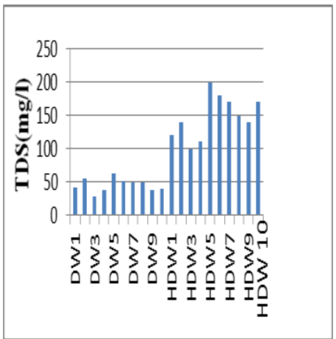


FIG. 11: Variations in turbidity

FIG. 12: Variation in Nitrate



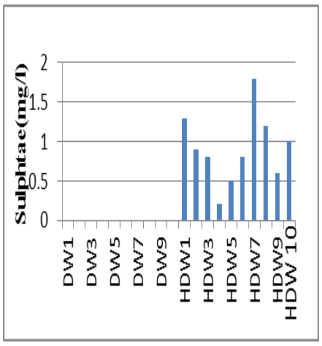
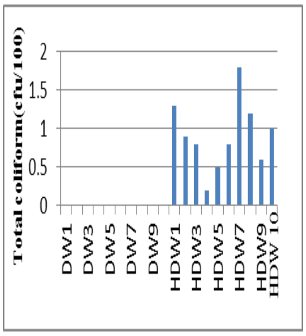


FIG.13 Variation in total dissolved solid

FIG. 14: Variations in Sulphate



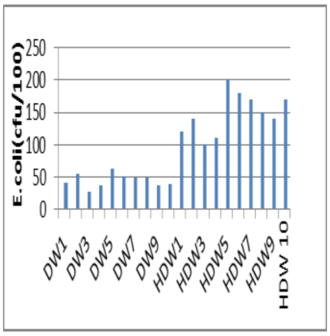


FIG. 15: Variations in total coliform

FIG. 16: Variations in E.coli

Taken together, all the shallow hand-dug (unprotected) wells returned higher elevated values of analyzed parameters than those of the deeper drilled (protected) wells.

5. Discussion

Over 55% of the sampled households in the communities draw water from shallow wells which, as shown by the findings of this research, are unfit for human use. Only 34% of the sampled households depended mostly on water from deep wells and/or on vendors or other mixed sources. Generally, water users in the study area have traditionally relied on hand–dug wells for decades. During field survey, observation shows that there are many hand dug wells in the study area and that they are either poorly or not capped (see figures 2 & 3) The average depth of hand-dug wells in the area was found to be 9.2 meters while the deeper wells have average depth of 168.3m.Only few were capped with an engineered well cap or seal. Wells with such conditions are vulnerable to pollution as pollutants such as: insects, small animals, refuse, sediments, and other forms of contaminants cannot be prevented from accessing the well water. Also, the method of abstraction of water from these hand dug well could introduce pollutants into these wells. Field survey revealed that all sampled hand dug wells in the area are abstracted by bucket and rope of different types and different sources. These buckets and rope are most often dirty and kept in open spaces where contaminants access them. Thus, users of these well are exposed to high level of contamination which pose threats to their health and livelihoods.

6. Conclusion

This research work examined the quality of water from protected and unprotected wells in ten rural communities in Enugu State of Nigeria. Result shows that the unprotected wells in the study area have more pollutants than the protected wells. These pollutants intrusion are attributable to unhygienic condition around well environments. The findings of this work underscore the importance of wellhead protection. Wellheads are needed to protect well water, keep pollutants away and ensure the supply of quality water. Therefore, we recommend that the state government should ensure that wells be properly protected for quality to be guaranteed; this can be achieved through a legislation to protect community wells.

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