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ENVIRONMENTAL CONDITIONS OF WELLS AND THEIR SUSTAINABILITY FOR DOMESTIC WATER CONSUMPTION IN GBAGYI VILLA, KADUNA STATE, NIGERIA

[1*]G.I. Danjuma, [1]B.R. Atiyong, [1]J. Birga, [2]I. Istifanus
[1]Department of Geography, Kaduna State University, Kaduna
[2]Shehu Idris College of Health Sciences and Technology, Makarfi
*Corresponding author: *babyglow6@yahoo.com*

Abstract
The study examined the environmental conditions of both open wells and boreholes water in Ghagyi village to determine the water suitability of these wells for domestic consumption. The objectives are to examine the environmental conditions and historical facts about the wells and to assess the strategies adopted by residents and the government towards improving the water quality of wells. A total of 342 respondents were purposively sampled for the study. Data were obtained through the use of a structured interview guide. Simple proportional percentages, pie charts and correlation coefficients were adopted in analysing the data. The result of the study on environmental conditions showed that 95% of the hand-dug wells sampled were covered with metal plates and lined with concrete rims. The result also shows that 73 % of the wells sampled were located near latrines, septic tanks and dirty surroundings. On the height of hand-dug wells above the ground level in meters, 84% of respondents raised their wells less than 0.4 meter height above ground level and treatment of wells is done by 58% of respondents against 42% not treating their well water. The result of strategies that can be employed to improve water quality shows that 53% of the respondents prefer to use a water filter, while 47% prefer using other forms of treatment for well water. Similarly, 43% of the respondents suggested the government should provide other alternative sources of water supply and equally subsidise water treatment materials to promote regular treatment of well water. The study concludes that the wells sampled were susceptible to contamination due to their location within close proximity to latrines, septic tanks, dirty surroundings, the low level of wells above ground level and no Government intervention measure toward improving water needs. The study recommends that the finishing of each well should include a watertight cover fixed with a suction pipe and hand/submersible bump to bring water to the surface through a tap. Hand-dug wells should not be sighted close to septic tanks, pit latrines, and dumpsites, among others.

Keywords: Groundwater, Water Quality, Environmental Conditions, Suitability, Potable water, Domestic

Introduction
The environment humans live in encompasses all the external abiotic and biotic components, conditions and influences that affect the life, development and survival of an organism or a community (Youmatter, 2020). In their publication, European Environment Agency (EEA, 2021) stressed that water is one of the most important, abundant components of the ecosystem and that it was in water life started on earth. This water has become a medium for many pollutants released into nature. Still, to continue enjoying the benefits of clean water, there is a need to fundamentally change the way water is being used and devise urgent measures for water treatment (EEA, 2021). Therefore, the quality of drinking water must be monitored, and its suitability ascertained at regular time intervals.

Although more than 70% of the earth's surface is water, potable water supply for domestic consumption has become a scarce commodity in many parts of the world and, more significantly, populated urban settlements in Nigeria (Habeeb & Solomon, 2021). The threat of a world portable or wholesome water crisis is becoming increasingly discernible in the face of increasing demand relatively to static supply and deteriorating quality to pollution (Adelana & Bale, 2004). The unavailability of this indispensable fluid of life and inadequate good quality delays development and inflicts enormous hardship on more than 1 billion members of the human family (Annan, 2003). The World Health Organization (WHO, 2012) and Kingsland (2021) reiterated that the consumption of water contaminated by disease-causing agents or toxic chemicals could cause health problems such as diarrhoea, cholera, typhoid, dysentery, cancer and skin diseases.

In the same way, Pimental *et al.* (1997) stated that about 90% of the diseases occurring in developing countries result from a lack of clean and safe water, leading to about 80% of the death of young children. Equally important is the prediction made by World Metrological Organization (WMO, 2002 and 2008) that by 2025, many African countries will experience water scarcity. Also, United Nations Environmental Programme (UNEP, 2006) reports that the degradation of groundwater is one of the most serious water resource problems in Africa; as such, its management is crucial. United Nations report of 2010 stressed that "Lack of access to safe, sufficient, and affordable water, sanitation, and hygiene facilities has a devastating effect on the health, dignity, and prosperity of billions of people and has significant consequences for the realisation of other human rights" (Kingsland, 2021). MacDonald (2005) posits that at least 1.1 billion people worldwide still do not have access to safe drinking water.

Groundwater appears to be subject to pollution due to man's daily activities, which tend to alter the water's physical, chemical and biological properties, restricting or preventing its use in various applications (Sasakova *et al*. 2018). The qualities of water from hand-dug wells and, to some extent, machine-drilled boreholes depend on the concentration of biological, chemical, and physical contaminants as well as human activities in such an area (Ajibade *et al.*, 2014). Faecal pollution of drinking water causes water-borne disease, which has led to the death of millions of people (Adefemi & Awokunmi, 2010). Natural water contains different types of impurities which are introduced into the aquatic system in different ways, such as weathering of rocks and leaching of the soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal-based materials (Adeyeye, 1994). In the majority of cases, the contaminants are introduced at the hand-dug well or machine-drilled borehole site probably during construction activities, the materials used for the construction, the level of wells above the ground, cover and uncovered wells, depth of the wells, distances of wells from sanitary conveniences, waste dumps among others.

A major way of groundwater abstraction for use is by hand-dug wells or machine-drilled boreholes. Hand-dug and machine-drilled borehole wells are vital sources of domestic water supply for most Nigerians. This hand-dug well water quality is rarely monitored or treated before use. Hand-dug wells are usually between 1 and 20-meter depth, depending on the geological character of the area and are lined with stones, bricks, and recently cemented rings. The depths of well water can adversely affect the quality of the water. Where there are no other sources of potable water, drinking water will be a severe problem for the inhabitants of a community. Hence there is a need to uphold the standard requirements for drilling and building wells and sustaining them for the purpose they are meant for.

Goal number six of the 2030 Agenda at the summit on sustainable development in 2015 aims to ensure the availability and sustainable management of water and sanitation for all (Ferasso *et al.*, 2021). Eziashi (2002) stressed that man does not and may never have any other home but the earth and the only planet that can support and sustain life; as such, man has no alternative but to protect and maintain the life support system in a healthy operating condition. Thus, failure to adopt environmentally friendly and sustainable ways of harnessing our land resources, more especially water resources, will lead to contamination or pollution of the water (Atiyong *et al.*, 2019). The processes of harnessing, drilling and building wells should adhere to by inhabitants for the sustainability of the well water quality. The inhabitant of Gbagyi Villa lacks the supply of pipe-borne water as evident compared to the Kaduna metropolis and environs. Due to the absence of pipe-borne water, as is the case, it will be expected that all the inhabitants would have to rely on their daily water needs from wells, either hand-dug wells or machine-drilled boreholes. A general says, or belief by notable scholars is that no water is physically, chemically, and biologically free from contaminants; this contaminant may probably emanate from the environmental conditions of the wells, well surroundings, inadequate maintenance of the wells, proximity to sanitary conveniences, coupled with natural and man-made factors. Therefore, the well water needs to be monitored at all times to create awareness among well users on the dangers posed by the conditions of wells to safeguard the purity, suitability and sustainability for human consumption.

Study Problem

Water no doubt portends a great danger to human health when the basic precautionary measures to safeguard the purity and portability of these wells are neglected. It is also worthy of note that the environmental conditions within the perimeters of most wells are not within the environmental health requirement of a sanitary well. Regular maintenance, monitoring of the wells and treatments of these wells' water is inadequate for most urban and rural communities with no access to pipe-borne water. Most ranging literature on the quality of well water and its suitability for domestic consumption has been widely carried out; little or no work on the environmental conditions that contributed to making the well water unwholesome for human consumption has been carried out. Most groundwater contained in aquifers is not naturally discharged; sinking wells can artificially discharge such water. Water wells are categorised into hand-dug wells and machine-drilled boreholes (Alemayehu, 2006).

Hand-dug wells, also known as shallow wells, are usually excavated by handwork using a pick shovel. The well is lined with wood, rock, concrete, brick or metal depending upon the cost and availability of materials. Water is obtained from them, usually by ropes tied to buckets and other devices that can fetch the water. The use of numerous fetchers by different individuals to fetch water in a well and the environmental condition within the proximity of the well can be a source of contamination of the well water. Due to the increased human population, industrialisation, use of fertilisers in agriculture and human activities in rural and urban communities, water is highly polluted with different harmful contaminants. This makes the availability of safe drinking water very scarce for human consumption in many parts of the world. Therefore, drinking water quality must be monitored, and its suitability ascertained at regular intervals.

Gbagyi Villa is a new Residential Area in Kaduna South Local Government Area. The residential area came into existence in 2011 and is currently facing many water challenges because it lacks multiple potable water sources. Thus, the area is compelled to rely on ground and rainwater only. Many machine-drilled boreholes and hand-dug wells have been located in the area to reduce the level of water scarcity due to the area's fast-growing population. These boreholes and hand-dug wells could be polluted either by natural means or by man's activities, as the case may be. In contrast, groundwater is the major source of water supply for the day-to-day life of people living in Gbagyi Villa; little or no research has been carried out on the environmental conditions of the area's well water.

Thus, there is a need to examine the environmental conditions and historical facts about the wells in the study area. It is also important to assess the strategies adopted by residents and the government towards improving the water quality of wells in this study area. This will not only create awareness of the residents' better ways of improving the quality of their water but also enhance the sustenance of the wells and reduce the consumption of contaminated water, which can be a health hazard to the inhabitants of Gbagyi Villa.

Study Area

Gbagyi Villa is located in South Western part of Kaduna Metropolis, between latitudes 10° 25'30" and 10°26' 00" North of the equator and longitudes 7° 25' 50" and 7° 26' 20" East of the Greenwich Meridian. Gbagyi Villa is a ward in Romi District in Chikun Local Government Area. It is also bounded to the North by Ungwan Yelwa and Television Village, the West by Ungwan Romi, the South by Ungwan Gimbiya and Ungwan Tanko to the East (Figure 1). Gbagyi Villa experiences Tropical Wet and Dry climatic condition (Nkhuwa, 2006), characterised by strong rainfall seasonality and relatively high temperatures.

Rainfall starts effectively in May and ends in October. The beginning of the rainy season is often marked by high-intensity thunderstorms produced by the Tropical Easterlies. Rainfall intensity decreases progressively as the rainy season becomes well established. It ranges from 25 mm/hour to 125 mm/hour (Johansson, 2004). The continentality of the climate is more pronounced during the dry season, especially in December and January. This dry season is quite prolonged, exceeding six months in some years. The Mean monthly temperature is about 27°C daily the maximum temperature can be as high as 35°C in April and May, and the daily minimum can be as low as I5°C in January. Mean annual rainfall is about 1100mm, with an intensity of 80mm/hour, and hazards are consequently high, with a recorded peak intensity of 285mm per hour (Ayoade, 1993). It is expected that the seasonality of rainfall would have its implication on the water level and consequently fluctuation on the availability and sustainability of the well water within the year.

The vegetation of the study area falls under the Guinea Savanna type of vegetation, and the trees here are deciduous (Nkhuwa, 2006). Because of adverse conditions, the vegetation developed adaptive features such as cuticles and young twigs to ensure survival during the annual bush burning common in the savanna regions. Bush burning devastates the soil structure and makes it vulnerable to raindrop impact and detachment, which may lead to surface erosion and can pollute well water for wells not raised above the ground level and uncovered wells.

In addition, the daily anthropogenic activities impacting the vegetation, such as logging, the felling of trees for firewood, and herding, among others. Gbagyi villa, located in the Savannah, is characterised by soft clay soil highly rich in nutrients and hygroscopic in nature, supporting the growth of rice, maise, cassava, and yam, among others (Odiba *et al.*, 2014). However, the implication of clay soft soil as the type of soil in the study area is that it dissolves easily and faster in water, which can lead to well water contamination. Wells may also collapse with time if not built with concrete linings or rings.

Materials and Methods

Gbagyi villa is a new residential area in Kaduna South Local Government Area, and it was originally used as farmland by the Gbagyi people until 2010, due to population increase and urbanisation, the people decided to use the place for residential layouts. The study area was purposively chosen because of its stability and uniqueness to the community's water needs. Johnson *et al.* (2004) argued that purposive sampling relies on the researcher's decision based on some well-known

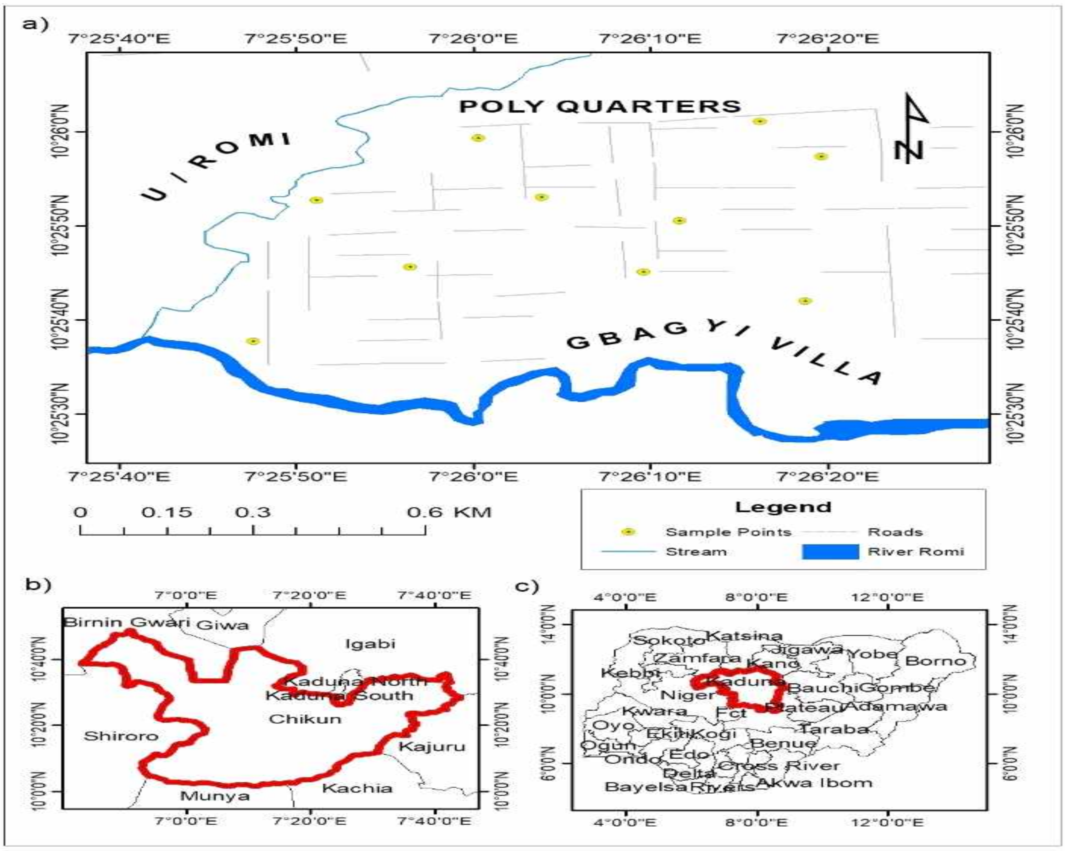

Figure 1a: Location of the Study Area with inset Map of Chikun LGA (b) and Nigeria (c)
Source: Adapted and Modified from Kaduna State Ministry of Land and Survey, (2017)

criteria, which in this case is the similarity in total dependence on groundwater as a major source of water supply for domestic consumption. An estimated total number of 4000 inhabitants of the study area was obtained from the village head as there were no Government official population figures of Gbagyi Villa being a new settlement and an up-shoot of Romi District. Using Cohen *et al.* (2011) table of sample size determination, 345 sample size was decided on at a 95% confidence level. Similarly, 345 inhabitants were purposively selected and interviewed. The primary sources of data were from direct field gathering of information through a structured interview guide administration, and the interview guide elicited information on; the bio-data of the inhabitants' environmental conditions of the wells, depths of the wells and the adopted measures to improve the quality of groundwater in the study area.

Percentages were used to present and summarise the data gathered on each category of response gotten on respondents' perceptions about the wells' environmental conditions and historical facts about the wells. The percentage was also used to present and summarise the height of hand-dug wells above the ground and the distance of wells from sanitary convenience/soak away. Similarly, percentages were used to present and summarise adopted strategies and suggested intervention measures to sustain and improve the quality of well water and government policy to improve water sources and quality. Correlation analysis was carried out using the Pearson Product Moment Correlation coefficient to show the relationship between the environmental conditions of the wells.

Results and Discussion

Environmental Conditions and Historical Facts about the Wells

The result of materials used and sanitary conditions of the wells are presented in Table 1. The results show that 95% of the hand-dug wells sampled were covered with metal plates and lined with concrete rims. The result also showed that 32% of the sampled wells were located within a distance of 25 meters from sanitary conveniences. While 68 % of the wells sampled were located within proximity to latrines and septic tanks, 5% of these wells found are within very dirty surroundings, full of litter and refuse, respectively. Similarly, on the height of hand-dug wells above the ground level in meters, the result presented in Table 1 shows that 84% of respondents raised their wells less than 0.4 meters height above ground level.

In comparison, only 16% raised their wells above 0.4 meters above ground level. The implication is that wells that are not covered tend to rain, splashing and surging into such wells, thereby contaminating the wells. As a very general guideline, it is recommended worldwide that the bottom of the pit latrine should be at least 2 meters above groundwater level and a minimum horizontal distance of 30 meters between a pit and a water source; this is to limit exposure to microbial contamination. The locations of most sampled wells in the study area negate the conditions for sanitary wells, and there should be enforced on the need for sanitary wells by environmental officers working within the Local Government.

The result of the household water treatment rate is presented in Table 1. The result shows that 58% of the respondents subject their wells to regular treatment; some of these wells are treated at 3 to 6 months intervals, and some, with tanks, are washed twice a year in addition to other means of treatment. In contrast, 42% of respondents do not subject their wells to any treatment. Multiple fetchers are also allowed into most of the sampled hand-dug wells; this may also contribute to water contamination. However, the result also shows that chlorine and aluminium sulphate are used as disinfectants and coagulating agents to purify well water for domestic consumption.

The implication is that the groundwater source's quality is enhanced by the treatment and made suitable for domestic consumption. This may have been the reason for the contamination-free well water from the result of the laboratory test of some wells carried out in a previous study by Atiyong *et al.* (2018) on the quality of well water in the study area. Hand-dug wells in the area could be developed in such a way that the finishing of each well should include a watertight cover fixed with a suction pipe and hand pump/submersible to bring water to the surface through a tap or into a portable storage tank. This will reduce the use of multiple fetchers.

Table 1: Environmental Conditions of Wells

S/No	Variables	Frequencies	Percentage (%)
Materials used and sanitary conditions of the wells			
	No concrete rims but covered with clean surroundings	37	16
	Metal cover/ clean surrounding	80	35
	Wooden cover/ clean surrounding	16	7
	Concrete rims/clean surrounding	62	27
	No cover	12	5
	Pump attached to the well/clean	23	10
Total		**230**	**100**
Distance of Wells to Sanitary Convenience/Soak Away			
	5-10	31	9.6
	11-15	68	20
	16-20	34	10
	21-25	101	29
	26-30	83	24
	Above 30	28	8
Total		**345**	**100**
Height of Hand-dug Wells above Ground Level(M)			
	0-0.2	10	10
	0.21-0.3	21	21
	0.31-0.4	53	53
	0.41 and above	16	16
Total		**100**	**100**
Household Water Treatment Rate			
	Treated	200	58
	Not treated	145	42
Total		**345**	**100**
Use of fetchers			
	Single	325	94%
	Multiple	20	6%
Total		**345**	**100**

Source: Field Survey, 2020 M^r- Multiple Response

Clarity of Water at Varying Distances of Wells from Sanitary Convenience/Soak Away

Practical experience from visual observation has shown that water from hand-dug wells and even boreholes often produce water that has colour in it right from the well or when it is allowed to stay for a short time in a container. Similarly, in practice, mixing the nature of pit latrines content, including rags and metal object, tend to accumulate and provide a constant source of contamination to groundwater. This is evident when the turbidity of water is cloudy and not too clear (Lapworth *et al.*, 2018). The use of visual perception of the clarity of the water is to complement the empirical study on turbidity done previously (Atiyong et al., 2018).

The result of the visual perception of the well water by the good owners surveyed is presented in Table 2. The result shows that 72.75% of respondents' well water is clear all the time within a location above 21 meters from sanitary conveniences/soak away. In comparison, 27.25% of the respondents revealed that their well water is also clear at a distance of 20 meters and below from sanitary convenience/soak away. The result corroborates the findings of Atiyong *et al.* (2018) study of the quality of well water for domestic consumption in the same Gbagy villa that revealed the turbidity of most of the well water was above the permissible limit of the World Health Organisation and that turbidity of the water sources was heterogeneous. This result implies that although there are many sources of pollution of underground water and the resultant change in the turbidity, wells located a distance away from sanitary conveniences may be free from contaminants from such a source.

However, it might not always be the case as the well water is prone to different sources of contamination depending on the permeability of the surface bedrock and the groundwater level. It is recommended that

Table 2: Clarity of Water for Domestic Consumption

Distance of wells to Sanitary Convenience/Soak Away (Meters)	Clarity of Water Clear all the time (Frequency)	Percentage
5-10	17	4.93
11-15	25	7.25
16-20	52	15.07
21-25	97	28.11
26-30	59	17.10
Above 30	95	27.54
Total	345	100

Source: Field Survey, 2020

Table 3: Relationship between Distance of the Wells from Sanitary Convenience/Soak away and Clarity of Well Water

Correlations			
		Clarity	**Distance of Well to Sanitary convenience**
Clarity	Pearson Correlation	1	
	Sig. (2-tailed)		
Distance of Well to Sanitary convenience	Pearson Correlation	0.850**	1
	Sig. (2-tailed)	0.000	

**Correlation is significant at the 0.01 level (2-tailed).

Table 4: Water Availability and Dates of Wells Construction

S/No	Variables	Number (M^r)	Percentage
Water availability			
	Perennial	344	99
	Seasonal	1	1
Total		**345**	**100**
Date Constructed			
	2011	31	9
	2012	47	13.6
	2013	48	13.9
	2014	33	9.6
	2015	29	8.4
	2016 to 2019	157	45.5
Total		**345**	**100**

Source: Field Survey, 2019 M^r: Multiple Responses

the bottom of the pit latrine should be at least 2 meters above groundwater level and a minimum horizontal distance of 30 meters between a pit and a water source (Tilley *et al.*, 2014: Mihelcic & Verbyla, 2018).

The relationship between the distance of the wells from sanitary convenience/soak away and clarity of well water in Table 3 revealed a strong positive relationship (0.850**) between clarity of water and distance of well to sanitary convenience/soak away. The closer the well to a sanitary convenience, the less clear the water will be, while the farther the well, the purer the water.

Water availability and Dates of Wells Construction

The result of water availability and dates of construction of wells are presented in Table 4. The results showed that all the sampled wells produced water throughout the year (perennial). This implies that water in the study area is available throughout the year, and residents do not have water scarcity issues for domestic consumption. The result of the wells' construction dates shows that 9% of the wells were constructed in 2011, when the settlement started springing up. Subsequently, 45% were constructed as the influx of people into the study area continued from 2012 to 2015 and 2016 to 2019, respectively. This result indicated that good drilling for the water needs of the inhabitant is the only source of domestic water supply.

Suggested Measures adopted by Residents towards Improving the Water Quality

The result of suggested strategies by residents towards improving the quality of water for domestic consumption is presented in Table 5. The result shows that 53% of the respondents preferred the use of a water filter, 21% preferred adopting the use of Alum, and 16% preferred the boiling of water, while 10% suggested the use of Chlorine as the effective method of improving the water quality. Water treatment removes contaminants and undesirable components and reduces their concentration so that water becomes fit for its desired end-use, which is crucial to human health. In one of the National Open University of Nigeria (NOUN, 2019) lecture series, they emphasised the need for water treatment as this helps to produce safe, palatable, clear, colourless and odourless water.

Table 5: Suggested Strategies for Water Treatment by Hand-dug Well owners

S/No	Variables	Frequency	Percentage
	Chlorine	10	10
	Alum	21	21
	Water Filter	53	53
	Boiling	16	16
	Total	**100**	**100**

Source: Field survey, 2020

The implication of these levels of treatment of well water by respondents of this study area is that there is an urgent need to make the source of drinking water wholesome and desirable for domestic consumption. Individual households should strictly observe wells' regular treatment, repair, and maintenance.

Suggested Intervention Measures by Government

The result of suggested intervention measures by the government to improve on their policy of providing water to residents of the study area is presented in Table 6. Twenty-five per cent of the respondents suggested that government should provide other alternative sources of water supply, 22% proposed that a central sewerage system should be provided to prevent indiscriminate digging of soak ways that will reduce groundwater contamination, and 18% said that government should provide and subsidise water treatment materials to promote regular treatment of well water. Furthermore, 11% opined that households should get approval before sinking any well as this will ensure proper sitting of wells, while 10% also suggested the government should impose a serious penalty on anybody caught practising open defecation and indiscriminate waste disposal. The remaining 14% recommended regular water quality monitoring while adhering to a standard method of good construction will help reduce groundwater contamination. It is expected that if the government implements all these suggested intervention measures, this will go a long way in the provision of more sources of water and better-quality water for human consumption in the study area.

Table 6: Suggested Intervention Measures by Government

S/No	Variables	Number (M^r)	Percentage
	Alternatives sources of water	215	25
	Provide central sewage system	187	22
	Approval before well construction	90	11
	Adhere to standard construction method	53	6
	Penalty for open defecation	86	10
	Regular monitoring of water	65	8
	Make available/subsidise water treatment materials	153	18
	Total	**840**	**100**

*Source: Field survey, 2019*M^r = Multiple responses

Conclusion

Almost all of the hand-dug wells sampled were covered with metal plates and lined with concrete rims. The wells sampled were susceptible to contamination due to their location near latrines, septic tanks and dirty surroundings. On the height of hand-dug wells above the ground level in meters, most respondents raised their wells slightly above ground level. Although most of the residents do not treat wells, a substantial number of wells had clear and less turbid water. The influx of residents led to the drilling of more wells. The use of water filters and Alum for boiling water and the use of Chlorine as the effective method of improving the water quality was the most accepted strategy for improving water quality. There has not been any Government intervention measure toward improving the water needs of the study area. Residents believe that the government should provide other alternative sources of water supply, among others.

Recommendations

Hand-dug wells in the area could be developed in such a way that the finishing of each well should include a watertight cover fixed with a suction pipe and hand pump/submersible to bring water to the surface through a tap or into a portable storage tank. Aside from making life easy for the household users, it will also adequately improve the water quality of shallow wells. However, some groundwater in the area is naturally suitable for most purposes without further treatment. Regular maintenance and repair of the water wells should also be a part of the main objectives of water development in the area. Before digging any water well, all the procedures for groundwater exploration should be employed, including a geophysical survey to determine the right point to sink water wells, and this is very important in other not to dig a water well close to septic tanks or toilets as it will help in preventing contamination of groundwater. Other water abstraction methods, such as rain harvesting and tank water collections, should be strongly adhered to. Equally important is that proper treatment and maintenance of the well water should be adhered to by the household users.

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