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Assessment of Borehole Infrastructure, Knowledge and Compliance with Drilling Regulations in Southwestern Nigeria

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Abstract

This study examined perceived effects of indiscriminating sinking of boreholes in Ife Central (Osun State) and Mushin (Lagos State) Local Government Areas (LGAs). The objectives are to characterize existing water sources and boreholes characteristics in the selected settlements as well as examined their knowledge and compliance with borehole drilling regulations. The study used 200 structured questionnaires which were purposively administered on owners and users of boreholes in each of the study LGAs. Results show that although sources of water differ significantly within the two settlements (Ile-Ife = $x^2(200)$ =78.52, p< 0.01); Mushin (x^2 (200) = 361.84, p< 0.01)), most (63%) respondents sourced potable water from borehole. Rating of public pipe borne water stood at a low 12% (Ife Central) and 3% (Mushin) thereby resulting in high percentage 85.5 (Mushin) and 68.5 (Ife Central) lacking access to water from the water works. With respect to borehole ownership, 62.5% and 30% (Ife Central and Mushin) respectively owned their own private boreholes while a joint value of 36% (Ife Central) and 69% (Mushin) use community/neighbourhood owned boreholes. Most of these boreholes (94.5% in Mushin and 88% in Ife Central) are located within 500m of each other. In terms of knowledge and compliance to borehole standards, a significant difference ($x^2(400)$) = 18.52, p< 0.01) between Ife Central and Mushin LGAs was recorded. Also, a few respondents (18% in Mushin and 28.5% in Ife Central LGAs) considered any associated risk before sinking their boreholes. The study concluded that while poor performance of stateowned waterworks may have prompted the sinking of boreholes in the study areas, the low level of awareness of the people on basic regulations and standards on borehole drilling as well associated risk may have contributed to the indiscriminate sinking of borehole in the areas of study.

Keywords: Borehole; Awareness of Associated Danger; Spatial distribution; Water supply.

Introduction

One of the important resources of earth, necessary for man's continuous sustenance, is water. The body of an average human adult is made up of about 60-65% water, with functions covering digestion, respiration, lubrication and movement of essential elements and nutrients in

the body (Forde et al., 2019; Forbes, 2012). In this regard, water becomes a vital factor in human life (Kaur and Sohpal, 2016; Menon, et al 2017). Aside from the direct consumption of water by humans, there are also indirect uses which covers domestic and daily needs as well as external uses including industrial/commercial

recreational/thermoelectric power as well as irrigation and agricultural uses among others (United States Environmental Protection Agency [US.EPA], 2018) These multidimensional uses of water have made it one of the most exploited resources in the world. However, as important as this resource of nature is, its availability and accessibility has become a global issue.

Although about 71% of the earth is covered with water, 96.5 percent of this, mostly saline, is held in large water bodies like oceans and seas, leaving 3.5% available as fresh water. By this fact, the amount of water for domestic and other uses is grossly limited. As human population increases and socio-economic activities are diversified, availability and access to water becomes dangerously intense. In the last few decades, the need for water has been on the increase globally (UN Water, 2018; UNESCO, 2019) and this has resulted in stiff competition both its availability and accessibility. Data on access to portable shows that about 1.1 billion people worldwide and another 2.4 billion lack access to potable water and water for sanitation respectively (European Public Health Alliance [EPHA] 2009).

Recent findings (e.g. du Plessis, 2019; McNabb, 2019; Tripathi et al., 2019; Mekonnen and Hoekstra, 2016) have suggested an increase in world human population facing water shortages, putting the value at about 4 billion people experiencing water shortages in at least 1 month of a year. Water shortages or scarcity has been generally divided into two namely; physical scarcity, that pertains to lack or limited availability of water in their physical storages like rivers and aguifers; and economic scarcity, resulting from institutional failure which makes it impossible to ensure regular supply of water to its users (United Nations, 2014). The increasing and unchecked urbanisation rate, particularly in Africa, has further worsened the gap in potable water supply demand and supply. An increasing number of developing countries in Africa are having running battle in filling this gap, with about 37.5% of African population living in water stressed areas (WHO/UNICEF (2010).

To underscore the magnitude of global water shortage, the World Economic Forum in 2019

listed it among global risks with possible severe impact in the coming decade (World Economic Forum, 2019). It is in this sense that the Sustainable Development Goals (SDGs) 6 captured water availability, its management and centrality to other SDGs as a global sustainable issue to be achieved before 2030.

While physical water shortage may be common to all parts of the world, economic water shortage is in most cases, dependent on the socioeconomic status of different countries of the In many developing institutional failure has made water shortages critical. In Nigeria for instance, water shortages are compounded by failure of the state to provide regular supply of water to the increasing population (Van Heerden et al, 2019; Raimi et al., 2018; Mapunda, 2018; Ameen and Mourshed, 2017; Bozorg-Haddad et al.. 2016). Consequently, alternative water sources methods like rainwater harvesting and hand dug well played prominent roles in providing water for Nigeria's rising population. In particular, the sinking of boreholes has rising to becoming the most reliable and predominant alternative source to public pipe borne water in the country (Healy et al 2020; Healy et al., 2018; Raimi et al., 2018; Balogun et al., 2017).

However, increasing use of boreholes has been linked to a number of environmental problems. Paramount among these, is the link between borehole drilling and seismic activities (Chi et al., 2019; Zhu et al., 2018; CNBC, 2015; BBC, 2012). While earthquakes were traditionally linked to seismically active regions of the world, recent happenings and findings have reported tremors and sometimes earthquakes in regions thought to be aseismic like Nigeria (Adepelumi, 2019; Oluwafemi et al., 2019; Akpan and Yakubu, 2010; Ajakaiye et al., 1987). The September 5 and 7 2018 tremors recorded in the Jabbi, Gwarinpa and Mpape districts of the Federal Capital Territory, Abuja, further lend credence to the fact that Nigeria is fast becoming an earthquake prone region. The report of the presidential panel on the Abuja tremor attributed it to excessive borehole drilling (Muanya and Onyenucheya, 2018).

So, in spite of its vast relevance as perfect alternative to public pipe-borne water supply system in many parts of the world, the use of boreholes for water supply is fast been reevaluated particularly in places like Nigeria, where there are limited official monitoring that gives room for indiscriminating sinking of boreholes at a rate with potentials for near-future tremors and earthquake. Although a number of studies have been carried out on boreholes in Nigeria, majority of these studies were focused on quality of water from the boreholes (Obioma et al., 2020; Duru et al., 2019; Akinlalu et al., 2018, Enyoh et al., 2018; Agbaire and Oyibo, 2009; Ibe and Okplenye, 2005) while a few more (Ugwuadu et al., 2019; Yaro et al., 2019; Etuk al., 2018; Akpabio and Udom (2018; Ifabiyi, 2011) looked at the spatial distribution of boreholes in Nigeria. Fewer number of the studies like Healy et al. (2020), Healy et al. (2018) and Capstick et al. (2017) have looked at the implications of the upsurge in borehole drilling in Nigeria. However, as the link between borehole drilling and seismic activities begins to generate global and local concerns, it becomes imperative to evaluate factors promoting the continuous, indiscriminate use and reliance on boreholes as a major source of water supply in a developing country like Nigeria. It is in this regard that this paper adopts a proactive attempt at raising awareness on issues surrounding impetuous sinking of boreholes in a country where reactionary disaster management is the norm. The paper therefore examines perceived effects of indiscriminating sinking of boreholes in Ife Central (Osun State) and Mushin (Lagos State) LGAs. The choice of the locations is based on their distinct characteristics as outlined later under the study area section of the paper. Specifically, the objectives of this study are to examine perceptions on water sources, specifically boreholes, as well as the compliance with borehole drilling regulations in the study areas.

Literature Review

Water and Water Sources

Water is one of the most essential needs of life required by plants, animals and humans for a variety of uses. This relevance has endowed it a significant position in the organization of sustainable needs of man has documented in the Millennium Development goals (MDGs) and the newly formulated Sustainable Development Goals (SDGs). Clean water and sanitation is listed as the 6th goal of the SDGs. In this context, Water has been inseparably connected to all form development (FAO, 2011; UNEP 2010) and has been majorly linked to achieving other goals in the SDGs (UNDESA, 2015). However, as central as water is to man's sustenance, its availability, especially the potable form, is grossly limited and its distribution skewed as clean water is highly variable geographically and seasonally (UNESCO, 2015). Globally and locally, this situation has made access to water a serious challenge.

Although water is ubiquitous, the availability of potable or safe drinking water is limited and this is influenced in most cases by environmental factors including rainfall and temperature, geological factors like rock type and gradient, as as infrastructural factors including technology and finance. Water sources generally can be divided into 2, namely surface and ground water. Surface water refers to water that are found on the ground like stream, river, lake, reservoir, or ocean and that is constantly replenished precipitation, and lost through through evaporation and seepage into ground water supplies (CDC, 2009). On the other hand, ground water refers to sources of water involving abstraction from aguifer located beneath the ground surface in pores and spaces in rocks and accessed majorly by drilling wells and boreholes.

While the global total water resources are put at 43,750 km³/year, Africa's portion of this amount stands at 9% (FAO, 1992). The implication of this is that 40% of sub-Saharan Africa's 783 million people have no access to an improved source of drinking water (The Last Well, 2019; Nutakor, 2015). Although Africa is dissected with large rivers basins and lakes, its distribution of improved water is largely clustered, leaving a large percentage of the continent in shortage of water. Access to water in Africa is both by surface and ground water. However, owing to its high climatic variability, particularly rainfall, a large percentage of the inhabitants of the continent rely heavily on groundwater as their

major source of serviceable water. Accessing ground water is either through shallow wells or boreholes, with the latter being the most used and most effective method.

A borehole is usually a narrow hole drilled to establish the nature of, sample, test, or monitor soil, bedrock or contained fluids and gases or for abstraction of water or minerals (Gaaloul et al., 2018). In this case, boreholes are sunk to abstract or obtain water from the aquifer of ground water and they consist essentially of a vertically drilled hole with strong lining to prevent collapse of the walls, a means of allowing clean water to enter the borehole space (screen), a surface protection as well as means of extracting water from the rich groundwater deposit whose depth is usually dependent on a number of geologic and environmental factors. Unlike wells and surface water which are often limited by seasonal changes and pollution, boreholes are less affected by drops in water level during drought, particularly, when drilled into deep water-bearing formations and are not easily contaminated (ICRC, 2010).

Water serving boreholes comes from a pool of reservoir located underground. underground water is found only in the cracks or spaces that break up solid rock or in the pore spaces in between grains of soils and like water flowing on the surface, groundwater also flows until it is trapped in available cracks and pores called aquifer. The depth of the aquifer varies downward and is depth of the aquifer varies downward and is determined by the prevailing geological constituent of the area where the aguifer is found (Akinlalu, 2018). Regardless of the depth at which it is located, groundwater is susceptible to contamination and misuse. Zektser and Everett (2004) clearly identified intensive human activities as the most probable factor that can lead to changes in groundwater resources, quantity as well as their quality. The most prominent human-induced activities essentially influencing groundwater resources, as identified Zektser and Everett (2004) includes groundwater exploitation by well fields for domestic-potable and industrial water supply; irrigation and pasture watering; mineral deposits mining, development of oil and gas fields; industrial and civil construction and engineering operation; rural development, including irrigation and drainage, and also forestry actions; hydraulic construction and construction with exploitation of other power stations, particularly nuclear power stations.

It is estimated that more than 75% of the African population uses groundwater as its main source of drinking water (UNECA, 2016). The reliance on ground water, particularly in Africa, has been attributed to failure of the States in providing necessary infrastructure for potable, pipe-borne water from its pool of surface water (Tatlock, 2006). Nigeria, like many parts of the continent, is not an exception.

Water Supply in Nigeria

Public water supply in Nigeria dates back to the 19th century, starting with the construction of public wells in selected parts of Lagos (NAI, CSO 1/1/8, Rowe to Kimberley, 17 April 1882). This metamorphosed into public water schemes in Lagos, Abeokuta, Ijebu-Ode, Calabar, Kano and Enugu (Akpor and Muchie, 2011). With the creation of states from the old regional political arrangement, State government took control of the water schemes. By this time, public water supply had been enshrined as developmental policies across the federation. However, with increasing urbanization and population expansion, the need for potable water rose substantially across the country (Macheve et al., 2015; Jideonwo, 2014) especially among the socio-economic nodes of towns and cities.

By 2015, an estimated 90million people were without access to safe and adequate water in making the 2015 Millennium Nigeria, Development Goal target on safe water a tall dream (UNICEF, 2015). As the urban centres continued to grow, demand for domestic use of water in particular doubled (Balogun et al. 2017). With increasing population, skewed infrastructural distribution and rising cost of maintenance amidst dwindling government revenue, regular supply of public water has become almost non-existent in many urban centres of the country (Okon and Njoku, 2017; World Bank, 2017; Macheve et al., 2015).

As a way out, alternative water supplies like rainwater harvesting, hand dug wells and boreholes have developed at all cost in response to the shortage of potable water supply in almost all Nigerian urban centres. For instance, in Lagos State, the large gap in demand and supply of pipeborne water has led to alternative supply, servicing almost 70% of the states' growing population (Krebs, 2010, Ince, et al., 2004). As with Lagos State, alternative water supply in Nigeria has risen appreciably and this has been attributed to system failure in public water supply, cost of subscribing to public water supply and most importantly, the safe and clean nature of underground water from the boreholes as well as favourable long term cost of sinking boreholes (Oyebode et al., 2015; Danert, 2014; Adekile and Olabode, 2009a).

With the realization of the potentials of groundwater as a perfect and viable alternate to public water supply in Nigeria, boreholes became the in-thing in the Nigerian safe water system. From the first borehole drilled around 1947 by the Public Works Department, to the first registered private drilling company in 1951 (Adekile and Olabode, 2009b), borehole drilling was on its way as a succour for the widening potable water supply gap in Nigeria (Mafuta et al., 2011). Started and empowered by many Federal Government initiatives, such as the National Borehole Programme (1981-1985), Department of Food, Roads and Rural Infrastructure (DFRRI) (1986-1992), Petroleum Trust Fund (PTF) Water Supply Project (1996-1999) and the Presidential Water Initiative (2003-2009) as well as the Millennium Development Goals Water and Sanitation Projects (till 2015), all of which are aimed at bridging the safe water gap in the country, borehole drilling has risen as most widespread, usable and most reliable source of potable water in Nigeria, particularly in the fast growing urban centres. For instance, as at 2010, Nigeria had recorded 57,600 boreholes for public water supply in Nigeria which pumped about 458m3 /day of groundwater (Federal Republic of Nigeria Federal Ministry of Water Resources [FMWR], 2014).

Methods

Study Area

The study area consists of Ife Central and Mushin local government areas of Osun and Lagos State respectively (Figure 1). The locations were carefully chosen to characterize boreholes in cities with traditional growth pattern and those which developed as offshoot of post Nigerian independent commercial expansion. While both Ife Central and Mushin local government areas are typical Yoruba settlements occupied by the Yoruba people of the south west Nigeria, they both differ conspicuously in terms of their economic functions and structural built. The two local government areas with distinct antecedent of development and socio-economic functions were used to contrast and compare access and compliance to sustainable sinking and use of boreholes in fast growing cities of Nigeria, as typical examples of developing countries of the world. Summary of the characteristics of the two sample locations are presented in Table 1.

Table 1: Study Areas Description

Socio-economic and Environmental Characteristics	Ife Central	Mushin
Geography (Latitude)	7° 33′ - 7° 24′ N	3° 30′ - 3° 32′
(Longitude)	4° 21′E - 4° 39′ E	1° 47′ - 1° 49′
Land cover	112.372 Km ²	17.576 Km ²
Mean annual rainfall	1000 - 1250 mm	1800mm
Mean annual temperature	27oC	27.20°C
Geology	western unit of the	sedimentary of tertiary
	Precambrian Ilesha Schist	and quaternary
	Belt	sediments.
Population (Projected from 2006 NPC value to 2020)	259,873 (2020)	982052 (2006)
Political Wards	11	10

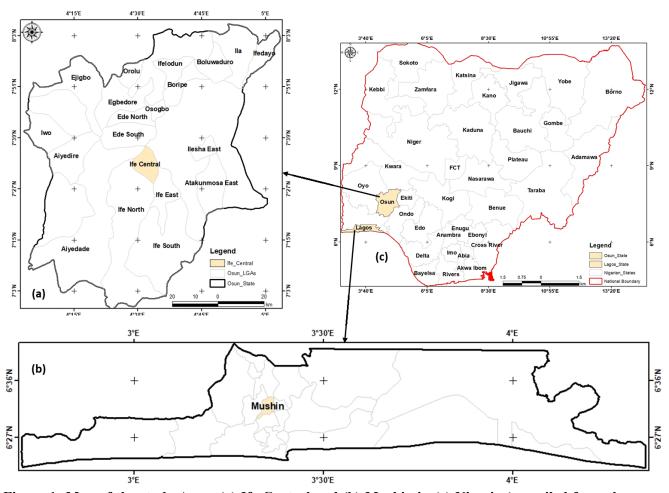


Figure 1: Map of the study Areas (a) Ife Central and (b) Mushin in (c) Nigeria (compiled from the Spatial Data Repository, 2018).

Data

This paper attempts to create the much-needed awareness on the associated dangers of proliferation of borehole as alternative means of water supply, by accessing level of compliance with sustainable borehole practices in Nigeria. Using basically primary data obtained through structured questionnaires administered on 200 respondents purposively selected in each of the two LGAs, on the basis of borehole ownership or use. This survey instrument consists of three sections. Section 1 is on respondents' profile. Section 2 elicited information relating to primary source of water supply, borehole ownership and associated characteristics as well as spatial distribution of boreholes and level of awareness of and compliance to borehole drilling technical specifications and legislations. Section 3 of the questionnaire sought information on borehole

construction characteristics. In all 400 questionnaires were administered.

Data Analysis

Descriptive statistics (frequencies and percentages) were used in the analysis of data collected.

Results and Discussion

Respondents' profile

The respondents' profile (see Table 2) shows that male respondents accounted for a larger proportion of the sample (60.5%) compared to female sample. Respondents between the ages of 18 and 40 comprised the highest proportion among the sample (64.8%). In terms of level of education accomplishment, 60.3% are graduates of tertiary educational institutions. Majority of

the respondents (47.3 %) are self-employed. The table (2) also revealed variation in respondent's profile between the two locations. In terms of distribution of household size among the sample, household size in the range of 6 to 10 people

accounted for the highest proportion among the sample: Ife Central (72.5%) and Mushin (57,7%). The distributions of household size in the two locations is shown in Figure 2.

Table 2 Respondents' Profile

Variable	Case	Ife Cer	Ife Central (n=200)		Mushin (n= 200)		Total (n= 400)	
variable	Cusc	Freq.	%	Freq.	%	Freq.	%	
Sex:	Male	127	63.5	115	57.5	242	60.5	
	Female	73	36.5	86	42.5	158	39.5	
Age Group	18 Years & Below	7	3.5	17	8.5	24	6.0	
	18 to 40 Years	145	72.5	114	57.7	259	64.8	
	41 to 65 Years	39	19.5	65	32.5	104	26.0	
	65 Years & Above	9	4.5	4	2.0	13	3.3	
Level of	No formal education	13	6.5	8	4.0	21	5.3	
Education	Full Primary education	17	8.5	17	8.5	34	8.5	
	Full Secondary education	49	24.5	53	26.5	102	25.5	
	Tertiary education	121	60.5	122	61.0	243	60.3	
Nature of	Government Employee	86	43.3	18	9.0	104	26.0	
Employment	Private Sector employee	27	13.5	47	23.5	74	18.5	
	Self employed	69	34.5	120	60.0	189	47.3	
	Pensioners	13	6.5	5	2.5	18	4.5	
	Employed	5	2.5	10	5.0	15	3.8	
Monthly Income	Below = $N = 50,000$	11	5.5	17	8.5	28	7.0	
	=N=10,001 to '=N=50,000	28	14	22	11.0	50	12.5	
	=N=50,001 to '=N=100,000	63	31.5	118	59.0	181	45.3	
	=N=100,001 to '=N=200,000	62	31	40	20.0	102	25.5	
	=N=200,001 to '=N=500,000	22	11	1	0.5	23	5.8	
	Above '=N=500,000	14	7	2	1	16	4	

Source: Author's field Survey, 2019

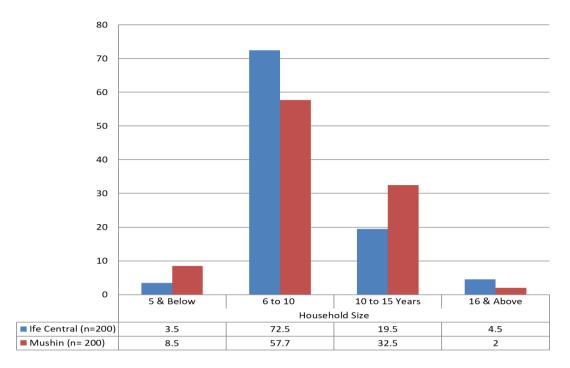


Figure 2: Distributions of household size

Sources of water supply

In this subsection, a number of issues relating to primary source of water supply was considered. In aggregate, majority (63.3%) of the respondents sourced their water from boreholes. Piped water from State owned waterworks and wells account for 23% and 13% respectively of the respondents' water sources (Table 3). The sources of water differ significantly within the two settlements: Ife Central($x^2(200) = 78.52$, p< 0.01); Mushin (x^2 (200) = 361.84, p< 0.01) and between them (x^2) (400) = 70.26, p< 0.01). Similar trend is reflected at sample location level. For instance, boreholes dominated the source of water among Mushin (82.5%) and Ife Central (44%) respondents. The high reliance on borehole as water source among Mushin respondents could be attributed to the higher economic function of the area which confers on it, the extension of socio-economic activities similar to that of the overcrowded Lagos city core. This on its own makes Mushin to be the base for a thick mix of residential and light industrial activities, most of which require regular supply of water that can only be matched through regular supply source like boreholes.

In terms of access to public water, a significant difference was revealed in each of the settlements: If Central $(x^2(200) = 27.38, p <$ 0.01); Mushin ($x^2(200) = 100.82$, p< 0.01). Table 3 shows that as high as 85.5% in Mushin and 68.5% in Ife Central lack access to piped water from government waterworks. The proportions of those with access to piped water are: Ife Central (31.5%) and Mushin (14.5%). This difference is also significant ($x^2(400) = 16.32$, p< 0.01). Table 3 also shows the rating of public water supply by respondents with access to the water source. The distribution of respondents that rated the supply of piped water as fair are Ife Central (12%) and Mushin (3%). Generally, the rating of piped water supply is not impressive among sampled respondents in both locations. This is consonance with studies by Healy et al., (2020); Balogun et al., (2017) and Okon and Njoku (2017) which affirms that one of the most important factors that significantly favoured the incursion of boreholes into the Nigerian water supply system is the poor performances of the country's public water works thereby explaining the search for and the increase in other sources of water supply.

Table 3: Source of water supply

Variable	Case	Ife Central (n=200)		Mushin (n= 200)		Total (n= 400)	
		Freq.	%	Freq.	%	Freq.	%
Sources of Household	Well	47	23.5	5	2.5	52	13.0
Water Supply	Borehole	88	44.0	165	82.5	253	63.3
	Stream	2	1.0	1	.5	3	0.8
	Public piped water	63	31.5	29	14.5	92	23.0
Access to Piped Water from Government	Yes	63	31.5	29	14.5	92	23.0
	No	137	68.5	171	85.5	308	77.0
Rating of Public Supply	Not Applicable	137	68.5	171	85.5	308	77.0
of Water	Very good	6	3.0	5	2.5	11	2.8
	Good	17	8.5	11	5.5	28	7.0
	Fair	24	12.0	6	3.0	30	7.5
	Poor	12	6.0	4	2.0	16	4.0
	Very poor	4	2.0	2	1.0	6	1.5
	Not sure	0	0.0	1	.5	1	.3

Source: Author's field Survey, 2019

Characteristics and distribution of boreholes Figure 3 shows ownership status of boreholes among the samples. As high as 62.5% and 30%% of respondents in Ife Central and Mushin respectively owned private borehole. The proportions of respondents that relied on either community borehole for their water sources are 19.5% in Ife Central and 23% in Mushin. Similarly, those that relied on neighbour-owned boreholes for water are 16.5% in Ife Central and

46% in Mushin. This finding on reliance on community of neighbours' boreholes as shown by respondent in Mushin is in consonance with the study by Capstick et al., (2017) which affirms the use of community or neighbours' boreholes, usually at no extra cost. It implies that if given the opportunity, respondents would prefer privately owned boreholes than those shared with other, thereby also increasing the rate of borehole sinking.

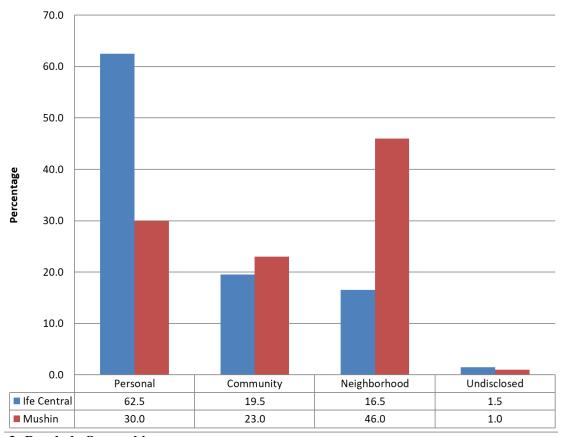


Figure 3: Borehole Ownership

One favourable condition that makes the sharing of boreholes possible is the short distance between the borehole water point and the various users they serve. As shown in Figure 4, some 35% in Mushin and 30% in Ife Central have boreholes within 50 metres of their residences while 16% in Mushin and 38% in Ife Central would not go between 51 to 100metres to meet their water needs. The proportions of those who relied on boreholes located between 101 to 500 metres of their residence are Mushin (43.5%) and Ife Central (19%). The spatial proximity of boreholes as discussed above is typical of towns and cities of many developing countries of the world (Capstick, 2017) and particularly in

Nigeria, where there is limited monitoring with regards to underground water abstraction. The spatial distances of boreholes in Mushin and Ife Central shows significant differences (x^2 (400) =18.80, p< 0.01). A large percentage (43% vs 55.5%) of the respondents seemed not to have information on the clustering of boreholes in their communities (Table 4). A combined value of 40% in Mushin and 33% of boreholes in Ife Central are found within 100metres of respondents' residence. Also, 14.5% and 2.5% in Mushin as well as 10% and 6% in Ile- Ife Central are within half a kilometre and a kilometre respectively.

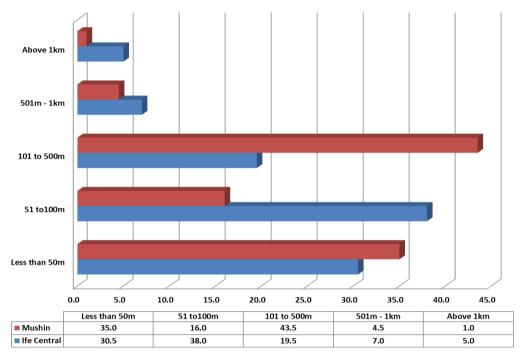


Figure 4: Spatial Distances to borehole water points

Table 4: Spatial proximity of boreholes in the study areas

Variable	Case	Ife Central (n=200)		Mushin (n= 200)	
		Freq.	%	Freq.	%
Spatial Distance (Meters)	Not Applicable	111	55.5	86	43
	less than 50m	42	21	20	10
	50m - 100m	25	12.5	60	30
	100m - 500m	20	10	29	14.5
	500m - 1km	12	6	5	2.5

Source: Author's field Survey, 2019

As positive a development as this may be, the proliferation and spatial proximity of boreholes, have started generating environmental and sustainability concerns, as they have been linked to seismic activities like earthquakes and sometimes tremors (Chi et al., 2019; The Nation, 2018; BBC, 2012). Although a very critical need of the communities may have been met, a long-term environmental compromise has been noted in the form of underground water pollution and near future occurrence of disaster, owing, particularly to the incursion of private contractors, who are grossly under monitored,

into borehole drilling. This gave room for every 'Tom, Dick and Harry' to acquire and operate borehole rigs with limited knowledge on geologic and environmental implications of drilling. The situation is further compounded by weak institutional policy on ground water management (Healy et al., 2020; Enyidi, 2017) and the 'it doesn't concern me' syndrome of the people whose only concern, in many cases, is access to water. With regards to the choice of contractors that installed sampled boreholes, it was discovered that private consulting (67% in Mushin and 55% in Ife Central were mostly used,

corroborating the findings from Capstick *et al*, (2017).

Knowledge of Borehole Standards and compliance with drilling regulations

The respondents were asked questions on general knowledge on borehole and on standards for installing boreholes (Table 5). In terms of knowledge of standard drilling requirements, a significant difference in the level of awareness of borehole standards was observed between Ife Central and Mushin respondents' $(x^2(400) =$ 18.52, p< 0.01). Majority (53%) of respondents in Ife Central lack such knowledge compared to 33.5% in Mushin. Awareness of such standard among the respondents is not impressive as 27.5% in Ife Central and 31% in Mushin have such knowledge. The low level of knowledge of drilling standards among the respondents indicate either sheer ignorance on the part of the people or weak institutional monitoring framework on underground water abstraction in the states and the country at large.

The questions on awareness of borehole standards dovetailed into specific issues relating

to technicalities on borehole installations like whether the drilling contractor carried out essential preliminary geologic investigation before sinking the boreholes. The result shows that majority (54% in Mushin and 50% in Ife Central) affirmed that their contractors did carry out such test on the sites. Also, awareness or knowledge of whether appropriate government permissions were sought before sinking the boreholes, shows that many (64% in Mushin and 73% in Ife Central) are not sure whether their boreholes were licensed or not. This same pattern is also observed on the awareness of policies or laws governing the abstraction of underground water. As high as 78% (Mushin) and 87% (Ife Central) signifies their lack of knowledge of such laws and regulations. These results support findings from Healy et al. (2018) and Jideonwo (2014), that one of the most fundamental factors that allowed the proliferation of boreholes into the Nigerian water supply system is the weak government intervention in the underground water abstraction business, thereby exposing the country's limited underground water reserve to pollution and the risk of future hazards.

Table 5. Knowledge of Borehole Standards and compliance with drilling regulations

Variable	Case	Ife Central (n=200)		Mushin (n= 200)		Total (n= 400)	
		Freq.	%	Freq.	%	Freq.	%
Knowledge of Standard	No	106	53	67	33.5	173	43.3
drilling requirements	Yes	55	27.5	62	31	117	29.3
	Not Sure	39	19.5	71	35.5	110	27.5
Preliminary geologic	No	51	25.5	14	7	65	16.3
investigation	Yes	100	50	109	54.5	209	52.3
	Not Sure	49	24.5	77	38.5	126	31.5
Permission from relevant	No	78	39	42	21	120	30.0
government agencies	Yes	49	24.5	30	15	79	19.8
	Not Sure	73	36.5	128	64	201	50.3
Knowledge of underground	No	68	34	12	6	80	20.0
water abstraction laws and regulations	Yes	45	22.5	32	16	77	19.3
	Not Sure	87	43.5	156	78	243	60.0

Source: Author's field Survey, 2019

Perceived Implications of borehole drilling With regards to implications or risks associated with borehole drilling, majority in both locations have no idea of any effect of drilling boreholes (Ife Central (38%) and Mushin (22.5%) or are not sure of the implications (Ife Central (26%) and Mushin (62%). The proportions of respondents with knowledge of the implications of drilling boreholes are 36% in Ife Central and 14% in Mushin. As shown in Table 6, a few percentages (18% in Mushin and 28.5% in Ife Central) considered any risk before installing their boreholes while a large percentage (82 in Mushin and 71.5 in Ife Central 1), including those who are

not aware, did not put anything into consideration. As obtained in Capstick et al., (2017) and Healy et al., (2018), the most perceived risk associated with borehole drilling among many people is underground water contamination. Beyond this, only a handful of respondents linked borehole drilling to seismic activities, suggesting the limited understanding of people of the nexus between earthquake and drilling activities. This was followed up by evaluating whether the people put into consideration technicalities about associated risks of borehole drilling.

Table 6: Issues relating to risks associated with boreholes drilling

Variable	Case	Ife Central (n=200)		Mushin (n= 200)	
		Freq.	%	Freq.	%
Implication of borehole drilling	No	76	38	45	22.5
	Yes	72	36	31	15.5
	Not Sure	52	26	124	62
Consideration for the implication of borehole drilling	No	67	33.5	18	9
	Yes	57	28.5	36	18
	Not Sure	76	38	146	73

Source: Author's field Survey, 2019

To drive home the risks associated with incessant drilling of boreholes within close proximity, the option of using centralized neighborhood boreholes, wherein a number of residences will be accessing the same borehole facility was raised. Figure 5 show that 80% (Mushin) and 57% (Ife Central) of the respondents would consider the option of using shared borehole facility. However, 33.5% of the respondents in Ife Central would not consider the option (Figure 5).

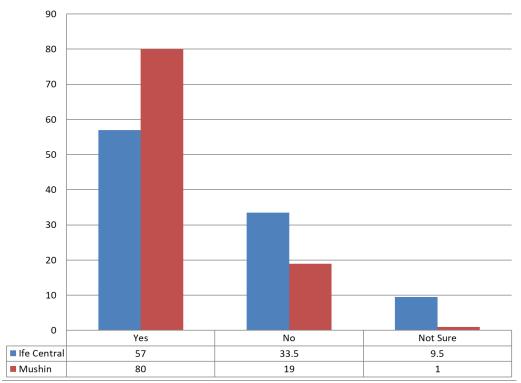


Figure 5. Consideration for joint boreholes

The reasons given by those in the categories of "No" and "Not Sure" with regards to using joint /community bore holes are as presented in Table 7. Most of the reasons giving relate to the need for personal space and safety. In terms of difference, the reasons giving by respondents in the two settlement are significantly difference $(x^2(400) = 33.87, p < 0.01)$. Similar differences were also established within each of the settlements: Ife Central $(x^2(200) = 365.04, p <$

0.01); Mushin (x^2 (200) = 835.12, p< 0.01). This implies that given the opportunity, many will prefer to sink their private boreholes, thereby increasing the risk of underground water pollution and initiating near future seismic activities. This confirms the principle of causality, as cited by Heine (1970), which holds that for every human action, there is a corresponding, and in some cases, more severe consequences.

Table 7: Reasons for preference for personal borehole

Reasons for not considering joint/community borehole	Ife Centr	ral (n=200)	(200) Mushin (n= 200)		Total (n= 400)	
	Freq.	%	Freq.	%	Freq.	%
Not Applicable	114	57.0	160	80.0	274	68.5
Avoidance of conflict	12	6.0	10	5.0	22	5.5
Problem of overutilization	8	4.0	9	4.5	17	4.3
Overcrowding and congestion	15	7.5	6	3.0	21	5.3
Inconveniency	11	5.5	4	2.0	15	3.8
Difficulty in accessibility	16	8.0	4	2.0	20	5.0
Poor maintenance	16	8.0	2	1.0	18	4.5
Self-preference	8	4.0	5	2.5	13	3.3

Source: Author's field Survey, 2019

Implication for Control

The results above brought to the fore a number of issues which cuts across the two study areas used in the study; Mushin and Ife Central local government areas, representing situation in cities with traditional growth pattern's antecedent and those which developed as offshoot of post Nigerian independence commercial expansion respectively. As shown in the results, the limited and irregular supply of piped borne water from state water works is responsible for the increase and continuous reliance on boreholes. Compared to other studies cited earlier, this pattern seems similar. However, the marked differences in each sample site may be attributed to the social and economic importance of each area. This implies that areas with higher economic functions like Mushin is likely to have more boreholes drilled for ground water abstraction. On the other hand, the higher count of artisan wells in Ife Central could attributed to its traditional growth, where before now, artisan wells were a major source of water supply. As shown in the results, the distribution and spatial proximity of boreholes in the study areas is concentrated within half a kilometre. Although, there exist significant differences in terms of spatial distances among the two study areas, the spatial density observed in two study areas is high and it is similar to what is obtainable in other Nigerian cities (Healy et al., 2020; Etuk, et al., 2018; Ezezue et al., 2017).

With respect to the knowledge on borehole standards and compliance level, the limited understanding of the respondents in both study areas is evident. Regardless of the fact that a larger percentage of the respondents have tertiary academic qualification, their awareness of salient issues on drilling of boreholes is low. Capstick et al., (2017) noted that information on basic borehole drilling standards among owners and users in Nigerian cities is very low. In the same vein, the respondents', as obtained in Healy et al. (2020), have very little knowledge on dangers associated with borehole drilling.

By implication, the limited knowledge of people's awareness on indiscriminate borehole drilling has been the driving behind the rise in number of boreholes sunk in the highly diversified urban settlements of Nigeria.

Although extensive studies have not been done on the link between borehole sinking and seismic activities as well as groundwater contamination, the few studies that have identified the link have suggested possible occurrences of seismic activities induced by excessive indiscriminate sinking of boreholes. Creating awareness on this potential danger, will go a long way in preventing any future disaster.

Conclusion

With boreholes taking lead role in potable water supply in Nigeria, the need to evaluate its relevance, in terms of people's understanding of requirements and technical surrounding the sinking of boreholes, becomes more pertinent now than ever before. As the link between borehole drilling and seismic activities begin to generate attention in empirical studies globally, the need to be proactive, by creating awareness on the potential dangers associated of borehole drilling, is the focus of this study. The study concluded that while poor performance of state-owned waterworks may have prompted the sinking of boreholes in the study areas, the low level of awareness of the people on basic regulations and standards on borehole drilling as well associated risk, may have contributed to the indiscriminate sinking of borehole in the areas of study. Based on this findings, it is recommended that there should be positive concerted efforts by government at all levels to enforce sustainable practices in groundwater use and management. Appropriate government apparatus should therefore be set up for monitoring compliance.

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