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ABSTRACT: Hand-dug well facility is susceptible to pollution by natural and anthropogenic sources but pollution associated with human handling and management of hand-dug well facility and its accessories has been rarely discussed. A structured questionnaire was administered among 260 respondents cutting across the 5 quarters in Iwo, Osun State, Nigeria. The data collected was subjected to both descriptive and inferential analysis. Descriptive analysis showed that majority of the respondents were of female gender who relied largely on manual mode of fetching water in their respective hand-dug well facilities. Apart from this, different kinds of ropes of varying qualities were attached to their respective water fetchers, 72.69% of which are tyre-tube containers. Data factorability and its adequacy tests showed KMO value of 62.0% and its significance at $P < .05$, indicating that the data can be processed through Factor Analysis (FA). FA revealed that the pollution of well water attributed to human-handling of hand-dug well facility is associated with 8 variables with a total explanation of 75.55% namely; vicinity of the facility, the side wall quality of the hand-dug well, facility utilisation frequency, facility management authorities, maintenance of the associated facilities, quality of the lid, quality of water drawers and preference for the use of drawer at a time whether single or multiple. The findings suggest that stakeholders should make uptight effort to take the management of hand-dug well facility more conscientiously for sustainable human health. Further research is suggested to extend the frontiers of knowledge on pollutants associated with hand-dug water facility.

KEYWORDS: Hand-dug wells, water pollution sources, hand-dug well management, water quality, Factor Analysis (FA)

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Introduction

Sustainable and sound human health is partly and significantly dependent on unhindered accessibility and consumption of water with proven integrity.[1] Ogunbode and Akinola[2] and Ighalo et al[3] had both reiterated that water of good quality is an essential ingredient to human physiology. Today, one of the pursuits of the global community is the sustainability of good access to water for domestic utilisation towards good health enhancement. This target can be actualised with an uninterrupted monitoring of the status of water from various sources such as surface and subsurface.[4-7] It is a known fact that water quality influences human's access to it from any given source, either surface or subsurface.[5,8] For instance, a source of hard water is not likely to be accessed for washing and drinking purposes because it does not produce foam in washing.[4,9] Thus, people approach a given source of the resource for a specific home use by virtue of their experience on the quality of the water from the source. Various challenges associated with the consumption of water obtained from contaminated environment have been reported globally. For instance, Lin et al[10] reported that the most common disease from consuming polluted water is diarrhoea transmitted by enteroviruses, especially in an aquatic environment. One of the challenges being faced globally is increasing contamination of water sources mainly from both natural and anthropogenic activities.[2,11-15]

Safe Drinking Water Act, promulgated by the United States Congress in 1974 and amended in 1996, described contaminants as any physical, chemical, biological or radiological substance or mater in water. Thus, contaminants can be described in the light of this law as anything other than water molecules. Contaminants, otherwise called pollutants, could be introduced into water either by nature or man. Man's actions in various ways have been found to exacerbate degree of influence on the environment, the footprints of which are documented in literatures. Rakshit et al[16] found that Gangasagar Festival (AGF) acts as multiple trauma that induces instability to the natural roles of the ecosystem in the western part of India Sundabarn Megadelta. Considering the large number of people that visit the sites each time, they found the enormous impacts such pilgrimage caused to the chemical, biological and the physical quality and sustenance of the environment, water quality and plankton composition. According to anthropogenic means of polluting water include the location of groundwater tube especially around sewage or erosion channels, dumpsite areas, residues of fertiliser applied on farms, use of pesticides and manures in agricultural practices. Others are: mining activities, industrial smokes and effluents, domestic sewage, deforestation of woods, animal husbandry activities, inefficient irrigation and so on. Many publications are available on both natural and human-associated pollutants of groundwater. Virtually, all these either emphasised on the naturopogenic or anthropogenic sources of pollution to groundwater or considered both.[2,13]

To the best of knowledge, water quality distortion caused by human ways of handling groundwater facilities and its associated accessories has been well researched. It is evident that hand-dug wells are constructed in human environment, most often inhabited by man. Apart from this, several human actions in and around this habitation influence the state of hand-dug wells at any point in time. Man relates and makes use of the facility in different ways, the impact of which could introduce pollutants into the ground water source. For instance, the drawer facility used to fetch water from the well and other associated materials such as rope quality, container quality, the quality of the well wall, caretaking of the well in terms of protection using lids to cover, the number of people often permitted to fetch at a time, how the fetcher fetches (either by standing at the brink of the well or the staircase made by the well tube side. All these materials and their uses are potential avenues for the introduction of contaminants into the well water. Chowns[17] had noted that the management of most groundwater facilities and the associated accessories are often dependent on the owners, who could be private individuals and/or community or any other delegated authority. Even when the facility is provided by the government or any of its relevant agencies, Non-Governmental Organizations (NGOs), be it international or local, such facilities are often committed to the care of the immediate end-users for monitoring, maintenance and management (MMM), for its sustainable utilisation. This also corroborates the findings of Nespect and Khumalo[18] and Héctor et al,[19] where it was stressed that immediate beneficiaries of water facilities should be integrated in water projects so that the facility can be sustainably utilised.

It is germane to understand that deep borehole water facility, which forms another important outlet of groundwater extraction, enjoys better protection from human management-induced pollution for obvious reasons: firstly, in terms of the width, borehole has smaller diameter when compared with that of hand-dug well; two, water extraction from boreholes is usually by powered pumping machine, thus, its construction is restricted to those that have the financial requirement; and three, borehole water is often extracted by pipe networks from the source to the point of use or public tap. With these reasons, deep borehole could be seen as apparently free from pollution induced by human management of that facility.

The quality of water will deteriorate once there is any introduction of foreign substances into it in space and time. This makes the water unfit and non-potable for human consumption, otherwise, public health will be in jeopardy. It, thus, becomes imperative that to safeguard human health sustainably, stakeholders should hold significant, the protection of well tubes wholly. Efforts are albeit taken to ensure prevention of chemical, biological and physical contaminants in the water so that the water complies with the acceptable standard. In the same way, the hand-dug well facility, when provided, should be protected and maintained so that further distortion of the integrity of groundwater and the associated facilities are fortified from the way it is managed by the users. This research was initiated to assess how human-handling and management of hand-dug well contributes to the quality of well water. Specific objectives of the study are in two-folds: (i) to identify various ways man impacts the quality of hand-dug well facility; (ii) to quantify and rank the significant ways human handling of hand-dug well facility impacts the quality of the groundwater in the study area. The findings are expected to enhance the efficient management of hand-dug well facilities which forms the source of water for most of the inhabitants in the study area and other developing countries.

Method of Study

Study area

This research was carried out in Iwo Township in Osun State, Nigeria (Figure 1). Iwo occupies a land area of about 245 km^2 with a population of 191 348 according to 2006 population census. Iwo is located on the coordinate axis of 7°38′N and 4°11′E. Iwo is a tropical town with 2 distinct seasons in a year namely; humid and wet period (March-October) and dry and hazy period (November-February). Annual rainfall ranges between 1000 and 2000 mm with double maxima in July and September,[20] making agricultural practices predominantly rain-fed. However, the dry period is often dominated with poor water supply with most wells reaching their lowest yield. It is often cumbersome and stressful for the inhabitants to get water for their domestic uses during the dry period. Most surface sources are not fit for human consumption because of their susceptibility to heavy contamination.[14,21,22] Also, Aiba Water Works (AWW), which was purposely built to provide potable water for the inhabitants, has seriously become incapacitated for various reasons. These include the management's lackadaisical attitude to dam facilities and/or maintenance in favour of groundwater development. Thus, the dam could not perform its statutory roles effectively. Negligible number of people in the town, who are mostly living in the vicinity of the dam, have access to treated water from AWW. Consequent upon this is the reliability of the inhabitants on groundwater (hand-dug and deep boreholes) source for their day-to-day home uses.

Data collection

Primary data was generated for this study through the administration of structured questionnaire to 275 respondents in Iwo

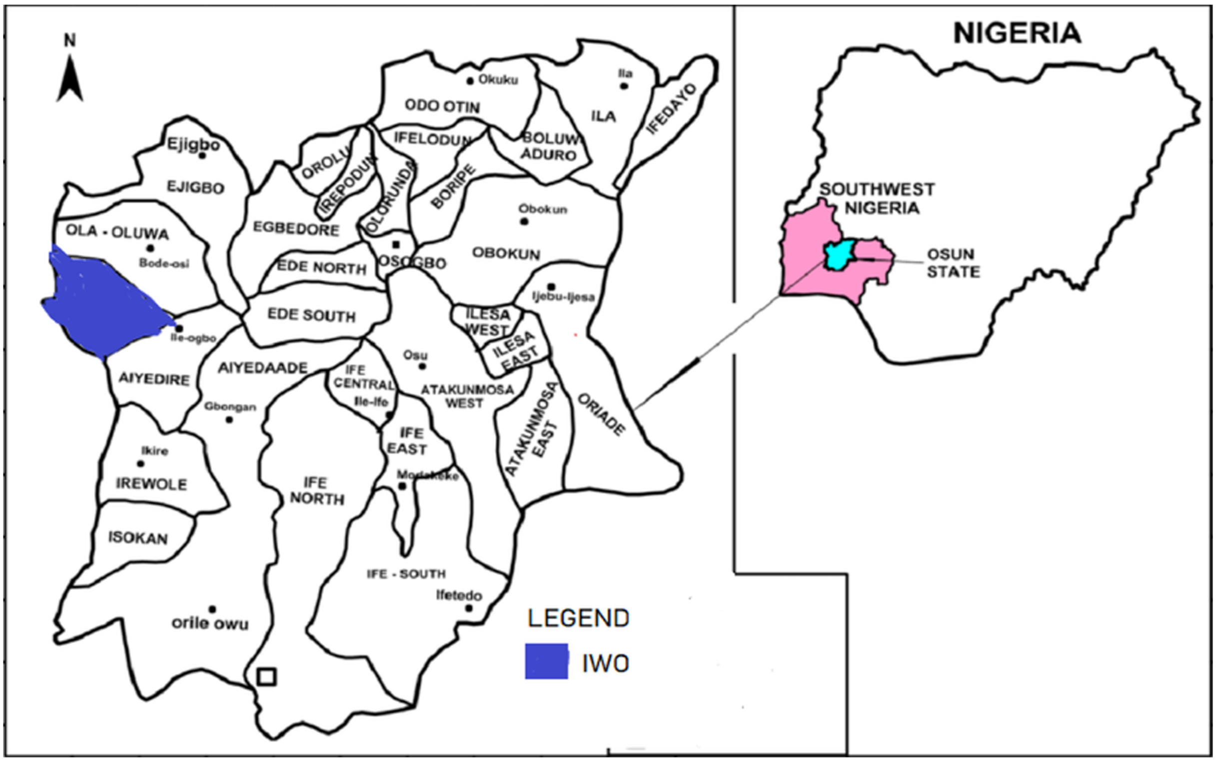

Figure 1. Map of Osun State showing the location of Iwo (Inset: Map of Nigeria showing the location of Osun State).

town. Multistage sampling technique was used to arrive at the samples used for the study. Out of 5 quarters into which Iwo is divided, namely Gidigbo, Molete, Isale-Oba, Oke-Adan and Oke-Oba, each has 3 wards within it.[23] The final samples of 55 households with hand-dug well facility were randomly selected from 2 wards within each of the quarters. Two hundred sixty copies of the questionnaire were completed and retrieved from the survey and were subsequently coded and entered for statistical analysis.

Data analysis

Descriptive and inferential statistics were used in the analysis of the data generated. Descriptive analysis includes tabulation of various characteristics of the respondents such as age categories, income level, respondents' various beliefs about water conservation, level of education, water use categories, religious affiliation categories, household size and gender distribution. Factor analysis was used to extract variables that significantly explain how human handling of hand-dug well facilities have contributed to the quality status of well water. Factor analysis was used for data reduction to determine the dominant use or uses of water. Jia et al[24] conjectured the effectiveness of factor analysis in extracting significant variables in an array of factors. Special Package for Social Scientists (SPSS) software was used for the analysis. The eigen value was set at minimum of 1.000, which implies that any factor with less than the maximum set is not considered as significant.

Results and Discussion

Respondent attributes

Basic attributes of the respondents that were involved in the survey are shown in Table 1.

Table 1 showed that most of the respondents of 64.62% comprised of those within the age range of 19 to 45 years while female gender dominated the population sampled, forming 82.31% of the respondents. The dominance of women in the survey was deliberate because of their high involvement in water issues at home and community levels in the study area. Ogunbode et al[25] had revealed that the responsibility of making water available in the house is the traditional role of women in most African homes. Thus, it is expected that water-related information are better sourced from women populace. However, the proportion of male gender that were involved in the survey were made so in a situation where the female is not available or indisposed for the survey. This is also supported by the work of Tong et al[26] where the role of men in alleviating the challenges of water supply was identified. The results further showed that manual fetching of water from hand-dug wells prevailed in the study area with 86.15% while 9.23% and 4.62% use powered and motorised modes respectively. In addition, the results showed that respondents engage the use of different kinds of water drawers of varying sizes to obtain water from their respective hand-dug wells with tyre tube containers dominating with 72.69%. Also, 11.92% uses aluminium containers while 10.39% use plastic buckets and 5.0% depends on the use

Table 1. Basic attributes of the respondents.

CATEGORISATION		DISTRIBUTION	
		SAMPLE SIZE	% OF TOTAL IN THE CATEGORY
A	Age range		
	19-45	168	64.62
	46-65	67	25.77
	>65	25	9.61
B.	Gender distribution		
	Male	46	17.69
	Female	214	82.31
C	Fetching method		
	Powered type	24	9.23
	Motorised type	12	4.62
	Manual	224	86.15
D	Types of drawers in use		
	Aluminium type	31	11.92
	Tyre-tube type	189	72.69
	Steel bucket type	13	5.0
	Plastic bucket	27	10.39
E	Type of rope in use		
	Locally-weaved rope	86	33.08
	Clothing/Textile material	35	13.46
	Factory-made type	101	38.85
	Twine and other types	38	14.61
F	Use of drawer searcher		
	Agreed	260	100%

Source: Authors' fieldwork, 2023.

of steel buckets. These variations could reflect the economic strength of the respondents. The influence of income level in household access to water and other social amenities was also noted by Grespan et al.[27] Apart from this, the rope accessory tied to the drawers also varies among the respondents. While 33.08% use locally-weaved rope, 38.35% use factory-made rope; 13.61% use clothing material and 14.61% use twine and wire materials (such ropes at times could be series of the types mentioned, tied together to form one single rope). Another accessory, drawer searcher, which is often used to scout for and remove drawers that fall into the well at any point in time, was in use by the entire respondents.

Hand-dug well management-induced pollution sources in Iwo

The data was found to be factorable and adequate for Factor Analysis (FA) with Kaisser Meyer Olkin (KMO) and Barttlets' Test of sphericity of 62.5% significant at $P < .005$. Eigen value was set at the maximum of 1.000. Thus, any variable with eigen value of less than 1.000 was not considered as significant to the explanation of the subject matter. Twenty-three variables that explained various ways pollutants are introduced into the groundwater by human management of the facility and its associated items were identified and subjected to FA. Out of the 23, 8 variables were extracted by FA as significant ones that explained various medium through which hand-dug well water is contaminated. The extracted variables offered 75.550% of the total explanation for the variance. The 8 variables and their respective properties/details are highlighted in Table 2.

The results, as presented in Table 2, showed that the vicinity of the hand-dug well in the study area was ranked first among other variables that explained ways pollutants may be introduced into the well water apart from the natural sources. It has RCM value of 78.5, eigen value of 2.265 and an explanation of 11.414% to the issue. The implication of this result is that the physical surroundings where hand-dug well is sited is very significant to the quality status of the water from it. Ogunbode et al,[13] Obeta and Mamah[28] and Sridhar et al,[29] among others, had expressed their concern on the proliferation of hand-dug wells in their respective study areas which contributed to the indiscriminate location of the facility without recourse to the implied effects on the quality of the water obtainable therefrom. For instance, Akinola and Ogunbode noted that the groundwater in their study area was not fit for human consumption in view of its poor quality caused by its closeness to septic tank area.

Also, second in the ranking was the modification of the side walls of the groundwater facility. This variable has RCM of 80.0, eigen value of 2.566 and also presented 11.155 proportion in the total explanation of human management-induced pollution in the hand-dug wells. Muhammad et al[30] had noted the benefits of concretising the side walls of well facility including the prevention of leaching into the well. However, when the sidewall of the tube is left unsealed, pollution through that medium is initiated. Poverty level in the study area may encourage such, as Akinola et al[14] lamented the impact of poverty on the respondents in their study area which made them incapacitated to concretise the side walls of their respective wells, which may enhance the growth of lichens and algae and other similar microbial which could be detrimental to the quality status of the well water.

The frequency of use of the facility was also found to be significant to the explanation of pollution of the hand-dug

Table 2. Eight extracted variables and their respective details.

VAR NO	VAR DESCRIPTION	RCM	EIGEN VALUE	% VARIANCE	CUMULATIVE %
VAR 1	Location of the hand-dug well facility	78.5	2.625	11.414	11.414
VAR 2.	Facility side walls modification	80.0	2.566	11.155	22.561
VAR 3.	Frequency of the facility use	73.8	2.496	10.854	33.423
VAR 4.	Facility management authorities	83.5	2.145	9.325	42.748
VAR 5.	Maintenance of the other associated facilities (eg, water drawers)	81.0	2.012	8.746	51.494
VAR 6.	The quality of the lid	81.8	1.889	8.211	59.706
VAR 7.	Degraded water drawers	85.9	1.829	7.953	67.659
VAR 8.	Preference for the use of drawers	72.7	1.815	7.891	75.550

Abbreviations: RCM, rotated component matrix; VAR, variable rank.
Source: Extracted from SPSS-generated Total Explained Table.

well. This variable was ranked third with RCM value of 73.8, eigen value of 2.496 and the variance percentage of 10.854. Omarova et al[31] had observed that the quality of well water could deteriorate if it remains underutilised over time. This may be valid because a stagnated hand-dug well without use has the potential of losing or diminishing quality over time. According to Omarova et al,[31] continuous utilisation of groundwater facility enhances its quality to a great extent while when it is not regularly utilised, sedimentation, bad odour and other organisms may be enhanced in the tube. As a matter of fact, it was of the opinion of the respondents that regular and consistent fetching from hand-dug wells promotes unhindered yield of such well facility.

Another variable that has significant contribution to the hand-dug well water quality, as shown in Table 2, is the management procedure. It is ranked fourth with eigen value of 2.145 and a contribution of 9.325% to the explanation of human-induced pollutants in the well water. This discovery was affirmed by the work of Ighalo and Adeniyi[5] where it was found that such water facility, when it is a common property, effective control of its use may prove difficult while when it is owned by a private individual, it is likely to be jealously protected and cared for. In another instance, a communally-owned water facility, when its control is in a designated hand of one or more people, may not be distorted in quality easily. Adeleye[32] had suggested that powered or motorised well facility may be of better quality than the facility with manual mode of fetching.

The handling of other hand-dug well accessories such as water drawers used for manual fetching was also extracted as a significant contributor to the quality of water. It has eigen value of 2.012 and a total explanation of 8.746%, thus, making the variable the fifth on the list. Since manual fetching from the tube involves the use of water drawer, it then requires that the quality of the water in the well is partly dependent on the quality of the drawer dropped into it. Powered and/or motorised wells had been suggested to keep the well water in a good condition and sustainable water quality.[32] These accessories need to be kept in good and hygienic condition when not in use and should be adjudged free of filth and clean enough to be used at a point in time.

Next to this variable is the type and quality of the lid with which hand-dug wells are covered or protected. With eigen value of 1.899 and a proportion of 8.21 in the total explanation of 75.550%, it ranked the sixth variable. Ogunbode[21] had noted different materials used in covering wells in the rural areas and its implied effect on the quality on the water. Materials found in use as lid to cover wells include wood, planks and steel materials. When the tube is covered with degradable material, decomposed parts are washed into the well water, thus, diminishing the quality of the water. Ayantobo et al,[33] in showing concern for the implied effect of bad materials in covering hand-dug well, had suggested that high quality steel that does not decompose easily should be used as lid to protect hand-dug wells for sustainable quality.

The quality of the drawers being used for manual fetching of water was also identified and extracted by FA as a significant medium through which man influences the quality of groundwater. It has an eigen value of 1.829 and contributed 7.953% to the subject matter. Different kinds of drawers being in use at different water points were noticed. These include aluminium type, plastic buckets, tyre-tube type, each of different age. Apart from this, the ropes attached to each of these drawers are of various types and qualities. While some are of poor quality, locally-made type that are susceptible to easy degradation and detachment when in contact with water, some are of textile/clothing material; while the others, but few in use, are those that are strong, durable factory-made. All these accessories have the potential of contributing to the quality status of well water if not well taken care of.[33]

Last in the list of factors identified and extracted by FA is fetchers' preferences for the drawers to be used for fetching at a point in time whether single or multiple usage. It has eigen value of 1.825 and a contribution of 7.891% to the explanation of well water quality induced by man's management procedure. In some instances, where a single and controlled water drawer is in use by the users, distortion of the quality is expected to be at barest minimum while the reverse could be the case where multiple drawers are engaged for fetching at same water points and time. Thus, Egboka et al[34] had suggested that the quality of water in motorised or powered facility is better than where water is manually fetched.

Further investigation on the extracted variables showed that 3 of the factors identified were closely related to the quality and use of drawer in manual fetching of water namely VAR 5, VAR 7 and VAR 8. The 3 variables together contributed than any of the other extracted variables with 24.59% (32.547% of the absolute value) out of the total explained. The implications of this is that pollutants in the hand-dug well are significantly dependent on the features of the drawers in use and its management by the users.

The findings have implication for environmental health in the study area and other similar environment. There is need to look beyond the physico-chemical constituents of ground water as the main sources of variations in the water quality. The quality of well water is also dependent on all other accessories used in getting water. All these accessories associated with the use of groundwater facilities such as drawers, ropes, lids and so on, are required to be of good quality, and should be adequately maintained and kept in good hygienic condition so that they do not introduce contaminants into the water- such action will partly enhance the environmental health. Ighalo and Adeniyi[5] and Ayejoto et al[35] had suggested that the government owes it a duty to curtail incessant pollution of water from various sources so that the health of the citizens is not in jeopardy, especially with global climate change scenario and its attendant impact on water resources quality.

Conclusion and Recommendation

The attributes of respondents showed that majority of the respondents were of female gender and relied mostly on the manual mode of fetching water in their respective hand-dug well points. Apart from this, different kinds of ropes ranging from weak locally-made to strong factory-made types are used for different kinds of water drawers, 72.69% of which are tyre-tube containers. Also, the result of factor analysis revealed that the quality of well water in the study area is dependent on 8 variables namely; (VAR 1) – the vicinity of the facility; (VAR 2) – the quality of the hand-dug well side walls; (VAR 3) – frequency of use of the facility; (VAR 4) – management of the facility; (VAR 5) – maintenance of other water accessories; (VAR 6) – the type and quality of the lid for tube cover; (VAR 7) – quality of the water drawer and the rope and (VAR 8) – preference for the use of drawers, whether single or multiple. The extracted variables explained 75.550% of the quality of well water induced by human handling of the facility. However, further analysis showed that 3 of the 8 variables namely: VAR 5, VAR 7 and VAR 8 were majorly about the quality of the accessories used in obtaining water from the well. The 3 alone offered 32.54% of the absolute value. This observation, notwithstanding all the extracted variables, need to be conscientiously taken care of, to keep the hand-dug well facilities in good shape, hygienic and sustainable condition.

Author Contributions

O.T.O, O.V.O. and A.O. contributed to the study design and conceived the analysis. O.V.O., A.O. and F.O.O. collected and curated the data. O.T.O and O.V.O. performed the analyses. O.T.O and O.I.R. supervised the study. O.T.O. and A.O. wrote the initial draft of the manuscript. O.T.O., O.V.O., A.O., F.O.O. and O.I.R contributed to reviewing and editing the manuscript.

Data Availability

All data used in this studies are available on request from the corresponding author.

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