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RESEARCH ARTICLE

Investigation of the use of photovoltaic solar water pump by occupants of residential buildings in Ile-Ife, Nigeria

Akeem Bolaji Wahab [1,*], Olamiposi Joy Oni [1]

[1] Department of Building, Obafemi Awolowo University, Ile-Ife, NIGERIA

ABSTRACT

The study examined the types of pumps used in supplying water to buildings, assessed the factors affecting the adoption and use of photovoltaic solar water pump and the perception of stakeholders on the use of the photovoltaic solar water pump in the study area. These were done to assess the effectiveness of the use of photovoltaic solar technology to improve the availability of water for the use of the building occupants. The study was carried out in Ile-Ife Region, Osun State, Nigeria. Stratified random sampling was used to categorize the selected residential buildings based on their distance limits to the locations of boreholes, 1-300m, 301-700m, and 711-100m respectively. Systematic sampling was further used in the selection of residential buildings and respondents in the study area. A total of 125 questionnaires were administered on the respondents and the data collected were analyzed using both descriptive and inferential statistical methods. The result shows that a very significant proportion of the respondents, 83.33% depended on wells and boreholes while 73.33% of the wells/boreholes used in the study area had pumping facility. A large proportion of the boreholes in the study area had photovoltaic facilities and were majorly (60%) donated by the government. The most significant factor that influenced the adoption and use of photovoltaic solar water pumps was the level of technical know-how (mean score of 4.1167) and the most ranked benefit had from the use of the facility was less time spent in collecting water (mean score of 4.3583). To foster the availability of quantitative and qualitative water for the use of the building occupants through the provision of photovoltaic water supply, efforts are direly needed to take advantage of the tropical environment of the study area, to ensure optimum performance and security of the facility to drastically reduce dependence on the national grid.

Keywords: Availability, buildings, energy, occupants, photovoltaic, pump, water supply

1. INTRODUCTION

According to [1-3], water occurs in various sources which are rainwater, spring water, groundwater, and surface water. Rainwater is described to be one of the reliable sources of water during rainy seasons in which water is collected and stored from the run-off from roofs after much rain has fallen and used for drinking purposes. Springwater, on the other hand, is derived from aquiver sources found underground and has travelled a short distance when it would come out to the surface for collection. Water gotten from spring is usually of good quality for drinking unless it is contaminated by either human or animal faces [4]. Groundwater is always found mainly in the sub-surface core spaces under the earth's surface, starting from the water table level and is appreciably difficult to extract through some measures put in place. Hence, adequate technology and energy are needed to bring the water from the ground to the surface for collection [5].

Water has always been documented for playing crucial roles in various aspects of people's activities, maintains the ecosystem that provides and gives valuable services to both the environment and human beings [6-7]. Since water is demanded in high proportion all over the world to meet the different needs of the ever-growing population, about 884 million people lack access to potable water supply [8]. The need for sustainable water supply for the use of the households and other occupants of buildings of different types have been increasing pressures on domestic, industrial, and agricultural activities. Many people in developing countries, especially rural areas, lack access to safe and clean drinking water. This may

Corresponding Author: wahabak2002@yahoo.com (Akeem Bolaji Wahab)
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further result in water-related diseases and various health implications which will further lead to either skin or eye diseases [9-11].

There is a need to ensure the availability of safe and hygienic water to meet the goals of the World Health Organisation (WHO) and Sustainable Development Goals (SDGs) [12]. Given this, energy is needed to drive the availability and supply of water to households and other occupants of buildings. It has been posited that there is dire need to take the issue of the source of energy that will make water available very seriously because it is one of the fundamental components needed in addressing physical water scarcity [13-14]. Different energy sources; fuel, electricity, and associated facilities are used to ensure water availability amidst physical difficulties like gradient, the height of buildings, and other operating factors. Due to this, manual pumping of water has become more difficult; while diesel and petrol are being used to power the generators, used to pump water into buildings or storage facilities, and energy efficiency of water supply system in buildings thus becomes a point of concern for sustainable development nowadays [15-16]. These fuels are used to pump water from deeper levels, but with innovations in technology globally, solar photovoltaic pumps are increasingly getting more popular because they are more environmentally friendly than other energy sources. Thus, the availability of safe and useable water in a suitable quantity has been a major problem in both urban and rural areas across the globe [17].

Water generation involves collecting water from the best available sources and thus subjecting it to processing, which will ensure availability of water of good physical quality, free from the unpleasant taste of odour and containing nothing which might be detrimental to health. Studies of [18-19] showed that potable water source in a community improves the overall well-being of residents in a particular place. Hence, there is a need to assess the effectiveness of the use of the photovoltaic solar method of pumping water into buildings. Also, photovoltaic solar energy has been documented as a renewable source that is generated from sunlight [20]. Various studies have indicated different advantages that solar energy has over other sources. Photovoltaic solar energy is provided as free, needs no fuel, and produces no waste or pollution [21]. Photovoltaic solar electricity has proved to be an alternative way of power to buildings where there is a poor supply of electricity. Its benefits of the use of solar energy to pump water and produce no waste or pollution in buildings and settlements informed this work.

The aim of the study is therefore to assess the effectiveness of the use of photovoltaic solar technology for pumping water to improve the availability of water to buildings. While the specific objectives of the study are to identify and examine the types of pumps used in the Ile-Ife region; assess the factors influencing the adoption and the use of photovoltaic solar water pump, and examine the perception of stakeholders on the use of photovoltaic solar water pump for domestic water consumption.

2. LITERATURE REVIEW

2.1. *Water availability and quality*

The world is striving to meet the requirement of the 'Sustainable Development Goals' (SDGs) target on how groundwater supplies, energy, and other necessary resources can be improved to provide a sufficient amount of water needed for the use of householders amidst scarcity of water [22]. The rapid expansion of housing development over time has made public water provision not to be adequate in meeting the current demands of water by building occupants [23]. Given the expected urban population growth rates; and because of some climate change issues, groundwater expansion is considered as one of the preferred responses in areas of Africa where suitable aquifers are present [24]. There is no single and common definition of water quality because it depends on the intended use. However, different methods are used for determining water quality, and each measures a definite variable of water with different accompanying processes [25-26]. In most countries the quality of drinking water is subject to extensive quality standards, regulating the maximum allowable levels of contaminants.

2.2. *Water distribution process*

Nowadays, the water distribution system consists of methods that collect, treat, store, and distribute water from its various sources to different buildings where it will be consumed [27]. This is needed to distribute and deliver water to consumers with certified pressure, quality, and quantity. This demands to have an effective distribution system that comprises the facilities, such as pump and its accessories meant to supply water from its source to the point of usage [16]. The water pump lifting devices that are used to lift water to a level or height allow users to have easy access to water and make it to flow at an increased pressure [10]. Water available from wells or boreholes lifted for direct distribution or re-distribution to buildings and storage units uses pump facilities [28]. Pumps generally require power to work and it can come from the steam engine; diesel engine, gasoline engine; or electric motor and this helps to distribute water into buildings [29]. Solar energy has also evolved to generate electricity to power the motorized pumps and helps to distribute water into buildings [30].

2.3. *Types of water pump*

There are a large number of pumps meant for different uses and in different areas. According to [31, 27, 29], two types of pumps commonly used for water pumping are surface and submersible type They can also be seen in the aspect of centrifugal and helical rotor pump. The centrifugal pump uses centrifugal force to increase the velocity of the water. When water enters the pump, it transmits through the impeller unit and thus makes the water to spin. This further makes the water pick up the speed which transforms the required pressure, makes the water leave the pump facility, and be distributed [32, 28-29]. The centrifugal surface water pump is the most popular choice used where the water source is shallow or found above the pump while the maximum suction lift is limited by the atmospheric pressure. The centrifugal submersible pump is installed completely underwater where the motor and the pump are connected as a one-single unit. The type used in wells and boreholes are often long, narrow cylinder-shaped and installed vertically. This type of pump's singular benefit of not relying on external air pressure, makes it a better option, particularly where the water source is below the suction limit and high heads conditions are needed. Its core demerit is that it has disadvantages of access to it for maintenance when faulty [28].

2.4. Processes of powering a water pump

There are various means in which a pump can be powered based on the various types comprising a hand pump, diesel-powered pump, electric driven pump, and solar-powered pumping system. According to [33-34], a hand pump comprises a pumping arm, a piston or plunger, valves, pump rods, and pump cylinder. The arm is pumped by hand and drives the piston and pump rods up and down within the pump cylinder causing different valves positioned above and below the piston to open and close, depending on whether water is being pulled in or pushed up. The diesel or petrol-powered pump employs fuel to drive the water pump operation. So, the total cost of the system includes the fuel cost, the diesel/petrol units, the cost of replacements, and mechanical operation. Pumps driven by diesel or gasoline engines are utilized when larger volumes of water are needed and/or significant depths are involved. The principles of operation and maintenance are similar regardless of the mode. According to [35], a solar-electric powered water pump makes use of electricity by a photovoltaic process. This makes a pump to lift water from wells, boreholes and is further pumped into buildings and any specially located storage facilities. Photovoltaic is preferable where there are sufficient solar resource, moderate demand, and no access to the electric grid and does not produce noise, carbon emissions, and has low operational and maintenance costs [36]. Stand-alone photovoltaic systems (as opposed to grid-connected systems) usually rely on a set of back-up batteries for night time and outages.

3. RESEARCH METHODOLOGY

The study was carried out in Ile-Ife Region of Osun State, Nigeria. The study area, Ile-Ife, is an ancient city of Yoruba which is in the South-Western part of Nigeria. The city is located in the present day of the State of Osun. Ile-Ife is about 218 kilometres (135 miles) Northeast of Lagos which has a population of 509,813 [37]. Ile-Ife is governed by Obas with Ooni of Ife as the title. The city had a substantial size between the 12th and 14th centuries with houses featuring potsherd pavements. The main city of Ife is divided into two Local Government Areas: Ife East, with its headquarters at Oke-Ogbo and Ife Central with its secretariat at the Ajebandele area of the city. Both local governments are composed of a total of 21 political wards and they both have an estimated population of 355,813 people [38].

It is located at the coordinates; latitudes 7°31′N and 7°34′N and longitudes 4°30′E and 4°34′E as shown in Figure 1; and is situated on an elevation ranging between 240 metres and 270 metres above the sea level [37]. Ile-Ife is a rural area with settlements where agriculture is the native occupation of the residents. The city has an undulating terrain under-laid by metamorphic rocks and characterized by two types of soils, deep clay soils on the upper slopes and sandy soils on the lower parts. It has an average rainfall of 1,000 –1,250 mm (39–49 in) usually from March to October and a mean relative humidity of 75% to 100%. Ife is east of the city of Ibadan and connected to it through the Ife-Ibadan highway (Department of Geography, OAU, Ile-Ife). Ile-Ife is also 40 km (25 mi) from Osogbo and has road networks to other cities such as Ede, Ondo, and Ilesha. There is an Opa river which is a perennial stream that flows within Ile-Ife and serves as water supply to the Obafemi Awolowo University, Ile-Ife [39].

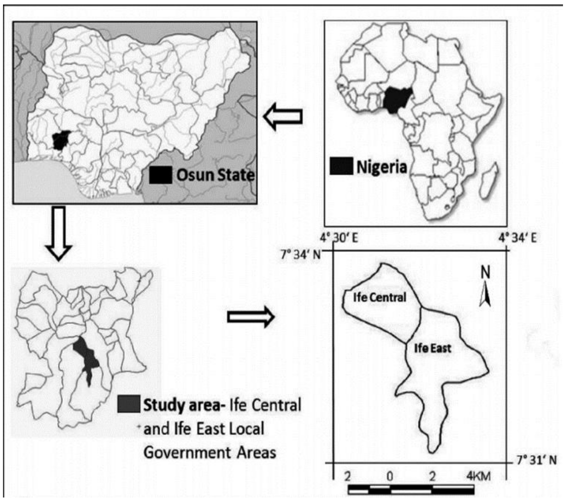

Fig. 1. Map showing Ife East and Ife Central Local Government Areas, Osun State of Ife, Nigeria [40].

Statistics usually provide the researcher with an array of methodologies to select the design of an efficient and cost-effective data collection scheme [41] and to provide answers to research problems, various research designs according to [42] are available. Hence, the survey research design was adopted by the use of the questionnaire to collect the data needed. The questionnaire was designed in a multiple-choice type on a 5-point Likert scale. Population study according to [43] is defined as the total number of persons, objects, or events whose behaviours are being studied. Thus, it defines the limit within which the research findings are applicable such that the result of the investigation is generalized into it. The study is designed to cover primarily, people living in Ife Central and Ife East Local Government Areas, Ile-Ife, and also part of the people living in the Area Office Council of Ife East, Modakeke. This is because; the two Local Governments form the blend of underdeveloped, developing, and developed residences. Therefore, the primary people of these areas are considered as the target population for this study.

The study area according to [44] is divided into 21 wards. The wards include Moore, Ilode I, Ilode II, Okerewe I, Okerewe II, Okerewe III, Yekemi, Modakeke I, Modakeke II, Modakeke III, Ilare I, Ilare II, Ilare III, Ilare IV, Iremo/Ajebandele, Iremo II (Eleyele), Iremo III, Iremo IV, Iremo V, Akarabata, Moore Ojaja. Purposive sampling method was used to select six areas in the study area where solar water pump facilities were installed. These areas are Ilare I, Iremo II (Eleyele), Moore Ojaja, Moore, Modakeke II, and Modakeke III respectively. Stratified random sampling was used to stratify the residential buildings in the selected areas into three, based on maximum proximity of 1000 metres to where the solar water pump was installed in the area. Therefore, buildings located within 300 metres to the point of installation of the solar water pump formed the first part of the stratum; those between 301-700m formed the second stratum while the third stratum formed consists of buildings within 701-1000m (Table 1). The choice of this stratification is based on the proximity of the residences to the solar water pump. The stratification enabled the study to determine the level at which the residents make use of the solar water pump as a means of getting water for domestic use. The systematic sampling method was further employed to select residential buildings from each stratum as one resident was chosen in a building for questionnaire administration. Twenty-five to Thirty houses as shown in Table 1 were selected in each ward for investigation and which informed the administration of 125 questionnaires on the respondents comprising 20, 15, 20, 30, 25, and 15 in Ilare I, Iremo II (Eleyele), Moore Ojaja, Moore, Modakeke II, Modakeke III respectively.

Table 1. Total number of selected buildings in the study area

Areas	0-300m	301-700m	701-1000m	Total No. of Sample
	Sample size			
Ilare I	5	7	8	20
IremoII (Eleyele)	3	5	7	15
Moore Ojaja	5	7	8	20
Moore	7	10	13	30
Modakeke I	5	7	13	25
Modakeke II	3	5	7	15
Total	28	41	56	125

3.1. Sources of data and analysis

The sources of data employed for this study were primary and secondary data respectively. The primary data was obtained through the use of a structured questionnaire that focused on issues relating to the quality of water supply, the type of distribution used, the type of pump used for lifting water, how reliable is the pump, the likely uses of the solar water pump, the factors that influenced the use of solar water and the perception of the stakeholders on the use of solar water pump. A face to face interview was also used to complement questionnaires that were administered on the respondents. The self-completion of the questionnaire method was adopted for this study where the respondents answered the questions by completing the questionnaire themselves and were interpreted if the respondent was illiterate with appreciable illustrations where necessary. The questionnaire was also framed in simple words that conveyed the exact meaning of all the words used. The secondary data was obtained from the review of related textbooks and any other publications on the effective use of the solar water pump. The data collected were analyzed with the use of both descriptive and inferential statistical methods.

4. RESULTS AND DISCUSSION

A total number of 125 questionnaires were administered, 120 were retrieved, and found useful for the analysis. The background information on the profile of the respondents shown in Table 2 indicates that the majority, (68.33%) of the respondents were females while males contributed to 31.67%. This is a fair representation of gender on the level by which water is collected for household use. About 35% of the respondents were between ages 20-29; 23.33% aged from 30-39 years, 12.5% were aged between 40-49 years, 17.5% were aged between 50-59 years, 5.83% were aged between 60-69, while 5.83% of the respondents were of age 70 and above. It was revealed that 45.83% of the respondents were married while 33.3% were single and 8.33% divorced or separated. This indicated that the use of water was mostly by the married individuals who are the majority living in buildings where the solar-powered borehole facilities were installed. It was also shown that 43.33% of the respondents had primary school leaving certificate, while 48% had a secondary school certificate, 16.67% had tertiary education while none of the respondents had no formal education. The indigene nature of the respondents indicated that 79.17% of the respondents were native of the study area while 20.83% are non-indigenes of the study area. This assisted majority of the respondents to have a deep understanding of the environment, the study area, while it was also obtained during the interview process that the non-indigenes have equally had a long period of stay in the area, which equally gave them the opportunity of the knowledge of events in the area. The Table also shows that 40% of the respondent lived in face-to-face (bungalow) building, 44.17% lived in face-face (storey building), 4.17% lived in flat (bungalow), 9.17% lived in flat (storey building) and a paltry 2.5% lived in duplex houses.

4.1. Preliminary assessment of the sources and availability of water consumed in the study area

Preliminary information on the nature, type, and uses of water available in the study area was carried out to determine the need to improve on the water to be supplied for the use of the building occupants. As depicted in Table 3, it was shown that tap water (83.33%), rainwater (83.33%), well water (79.17%) and sachet water are the common sources and types of water available for use in the study area. However, river water (12.50%) and stream water (8.33%) were less available, and this was justified as obtained during the interview process, on the ground that, there was no proximity of the respondents sampled to rivers and streams courses in the study area.

Table 2. Profile of respondents sampled in the study area

Gender Group of the Respondents in the Study Area		
Gender	Frequency	Percentage
Male	38	31.67
Female	82	68.33
Total	120	100.00
Age Group of the Respondents in the Study Area		
Gender	**Frequency**	**Percentage**
20-29	42	35.00
30-39	28	23.33
40-49	15	12.50
50-59	21	17.50
60-69	7	5.83
Above 70	7	5.83
Total	120	100.00
Marital Status of the Respondents in the Study Area		
Status	**Frequency**	**Percentage**
Married	55	45.83
Single	40	33.33
Widowed	15	12.50
Divorced/Separated	10	8.33
Total	120	100.00
Educational Qualifications of the Respondents		
Qualification	**Frequency**	**Percentage**
Primary	52	43.33
Secondary	48	40.00
Tertiary	20	16.67
No formal education	-	-
Total	120	100.00
Indigene Status of the Respondents		
Status	**Frequency**	**Percentage**
Yes	95	79.17
No	25	20.83
Total	120	100.00
Occupancy Status of the Respondents		
Status	**Frequency**	**Percentage**
Face to face (Bungalow)	48	40.00
Face to face (Storey Building)	53	44.17
Flat (Bungalow)	5	4.17
Flat (Storey Building)	11	9.17
Duplex	3	2.50
Total	120	100.00

The study sought to determine the overall satisfaction of the respondents with the general hub of sources of water available in the study area. As shown in Table 4, it was revealed that the majority (83.33%) of the respondents were satisfied with the quality of water gotten from the different sources of water in the study area while a paltry, 16.67% claimed that they were not satisfied. This helped to know if the quality of water sources in the study area is good enough and could pose a threat to the comfort and health of the building occupants. The differential level of satisfaction derived from the consumption of the different sources of water in the study area as shown through the ranking process in Table 5 revealed that borehole water had the highest level of satisfaction with a mean score of 4.20 followed by well water (4.12) while river water had the least level of satisfaction with a mean score of 2.0167. This was also attributed to its challenging proximity to the respondents sampled and the likelihood of having impurities in its raw form.

4.2. Assessment of the availability and use of water pumping facilities

From the fore-going on both bore-hole and well water as the most commonly available water sources that the building occupants in the study area depend on for consumption, it depicts the need to have facilities like the pump and its interrelated appurtenances to supply and distribute water in the buildings occupied by the respondents. It is shown in Table 6 that 73.33% (88) of the boreholes of the respondents used pumping facilities while 26.67% (32) did not have the pumping facilities system installed. It is indicated that a larger proportion of the respondents have the pumping facilities to facilitate water supply to buildings. It is shown in the Table that centrifugal submersible pump is the most commonly used type in the study area with 59.09% (52) response rate, while 40.91% (36) of the respondents used centrifugal surface pump and none used the helical rotor pump; as they claimed that they did not know of it. Furthermore, Table 7 indicated the performance level of the types of pumps used in the study area. It shows that the respondents were more satisfied with the performance of the centrifugal submersible pump with a mean score of 4.625 while the centrifugal surface pump had a lower mean score of 3.909.

In furtherance of the earlier results, Table 8 shows that either of the types of pumps used has been replaced, as 55% (66) of the respondents noted they replaced the pump every 10 years while 10% maintained that they replaced the pump every 5 years. However, 25% (30) indicated that they replaced the pump every two years while 7.5% maintained that their pump is replaced yearly. The remaining 2.5% (3) replaced the pump half a year to keep it in the optimal performance level. Generally, all these responses were found to be due to different performance levels of the installed pump facilities. The Table indicated the possible use of the photovoltaic facilities by the pumps installed in the study area. It is shown that about 93.33% (112) of the respondents claimed that their boreholes used photovoltaic facilities while a paltry figure, 6.67% noted that their water sources did not use photovoltaic facilities. It was also revealed in Table 8 that 60% of the solar water boreholes used in the study area were installed by the government at different tiers/levels, while 31.67% of the facilities were installed by individuals living in the study area, and 4.17% were installed by the Non-Governmental Organisations (NGOs). This implies that the tiers of government are the major organization that installed the solar water borehole for people in the study area.

Table 3. Sources of water available in the study area

Sources, Count (%)	Yes	No	Total
Tap source of water	100 (83.33)	20 (16.67)	120 (100.00)
Rain source of water	100 (83.33)	20 (16.67)	120 (100.00)
River water	15 (12.50)	105 (87.50)	120 (100.00)
Stream source of water	10 (8.33)	110 (91.67)	120 (100.00)
Well source of water	95 (79.17)	25 (20.83)	120 (100.00)
Borehole source of water	70 (58.33)	50 (41.67)	120 (100.00)
Sachet source of water	100 (83.33)	20 (16.67)	120 (100.00)

Table 4. Satisfaction on the sources of water available in the study area

Are you satisfied with the water gotten from the above?	Frequency	Percentage
Yes	100	83.33
No	20	16.67
Total	120	100

Table 5. Level of satisfaction derived from the available sources of water

Source of water	Mean	SD	Rank
Borehole water	4.2	1.1576	1
Well water	4.12	1.164	2
Sachet water	4.08	1.1121	3
Tap water	3.77	1.3886	4
Table water	3.517	1.2963	5
Rainwater	3.3917	1.3886	6
Stream water	2.35	1.3575	7
River water	2.0167	1.4684	8

Table 6. Availability and use of water pumping facilities

Does the Well/Borehole Used Have Pumping Facilities		
Description	Frequency	Percentage
Yes	88	73.33
No	32	26.67
Total	120	100.00
Type of Pumping Facilities Used		
Description	Frequency	Percentage
Centrifugal surface pump	36	40.91
Centrifugal submersible pump	52	59.09
Helical rotor pump	-	-
Total	120	100.00

Table 7. Level of performance of the pumping facilities used

Type of Pump	Mean	SD	Rank
Centrifugal submersible pump	4.625	0.4862	1
Centrifugal surface pump	3.909	1.3273	2

On the assessment of the type of solar-powered system used by the water pump in the study area, Table 8 shows that the respondents noted that that 47.5% of the borehole used 4-solar panels while 37.5% of the borehole used 5-solar panels. The other borehole used 3 and 2 solar panels which are 10% and 5% respectively. Equally, on the type of solar-powered system, it is shown in Table 8 that the battery coupled system with a 65% response rate is the major type of solar-powered system used, while 22.5% of respondents used the hybrid type solar-powered system and 12.5% used the direct-coupled system.

4.3. Factors affecting the adoption and use of photovoltaic solar water pump

The study also sought to determine the factors that might have affected the possible use of the photovoltaic solar water pump in the study area. The factors in the body of literature assessed were considered in assessing the indicators examined. The result shows that many of the respondents noted that consideration of technical know-how with a mean score of 4.1167 is the most significant factor why the photovoltaic solar water is being adopted and used as a measure to power the pump facility. It is because, often, its installation does not require extensive technicality and it also enjoins the availability of solar energy readily from the sun that is needed to power the panel. Other issues raised in the order of ranking were environmental factors (mean score of 3.9583) level of operations and maintenance (mean score of 3.7917) while the performance of the pump had the lowest mean score of 2.8583 and ranked the least (Table 9).

Table 8. Associated issues on the performance and use of the pumping facilities

How often is the Pump Replaced		
How Often	Frequency	Percentage
Half a year	12	10.00
Yearly	7	5.83
Every two years	10	8.33
Every five years	40	33.33
Every ten years	51	42.50
Never replaced it	-	-
Total	120	100.00
Does the Borehole/Pump Have Photovoltaic Facilities		
Does it have photovoltaic facilities	Frequency	Percentage
Yes	112	93.33
No	8	6.67
Total	120	100.00
Which Body Facilitated the Installation of the Photovoltaic Solar Water Pump		
Body	Frequency	Percentage
Government	72	60.00
Individual	38	31.67
NG.O	5	4.17
Community through donations	3	2.50
District assembly	2	1.67
Total	120	100.00
Number of Solar Panels Used by the Borehole		
Number	Frequency	Percentage
2	6	5.00
3	12	10.00
4	57	47.50
5	45	37.50
Total	120	100.00
Type of Solar Powered System of the Borehole		
Type	Frequency	Percentage
Direct-coupled system	15	12.50
Battery coupled system	78	65.00
Hybrid system	27	22.50
Others	-	-
Total	120	100.00

Table 9. Factors affecting the adoption and use of photovoltaic solar water pump

Factors	Mean	SD	Rank
Technical know-how	4.1167	1.124	1
Economic and environment factor	3.9583	1.148	2
Level of operations and maintenance	3.7917	1.377	3
Socio-cultural factor	3.5083	1.609	4
Performance of the pump	2.8583	1.1249	5

4.4. *Perception of stakeholders on issues associated with the use of photovoltaic solar water pump*

The study also assessed the likely perception of the respondents on the performance and use of the photovoltaic solar water pump in the study area because of different indicators extracted from the body of literature. As shown in Table 10, it was revealed that the most ranked benefit that the respondents obtained from their dependence on the photovoltaic solar water pump was the less time, spent in collecting water with a mean score value of 4.3583, cost of making the water available on the fuel or energy used with a mean score of 4.0667, while the reduction in the occurrence of water-borne diseases was rated least with a mean score of 3.4667.

Table 10. Perception of the respondents on the benefits derived from dependence on the use of photovoltaic solar water pump

Benefits	Mean	SD	Rank
Less time spent in collecting water	4.3583	0.9419	1
Lower cost of making the water available	4.0667	1.2816	2
Shorter distance from the water source	3.9333	1.2751	3
Enough water is available for domestic use	3.6833	1.2635	4
Reduction of water-borne diseases	3.4667	1.3530	5

Table 11. Complimentary issues associated with the use and performance of photovoltaic solar water pump

Issue of Theft and Vandalism		
Have you experienced theft/vandalism in the course of the use of solar water pump	Frequency	Percentage
Yes	58	48.33
No	62	51.67
Total	120	100.00
Measures Employed to Curb Theft and Vandalism		
Measures Employed	Frequency	Percentage
Employing the security guard	8	13.79
Construction of perimeter fence around the borehole	45	77.59
Community to stay at alert at night	5	8.62
Total	58	100.00
Problems Encountered During the Use of Solar Water Borehole		
Types of Problem	Frequency	Percentage
Failure of the pump	38	31.67
Bad weather	30	25.00
Theft	32	26.67
Vandalism	20	16.67
Inadequate water supply	-	-
Total	120	100.00

The other complimentary issues on the perception of the stakeholders on the availability and use of photovoltaic solar water pump comprising possibility of theft and vandalism cum any measures used to curb the menace and problems faced from the use of the facility were shown in this sub-section. Table 11 indicates that a lower proportion, 48.33% of the respondents had experienced cases of theft and vandalism of the facility and its complementary accessories at one time or the other; while a sparingly higher proportion, 51.67% had not had the experience. This indicates that a sizeable number of the solar water pumps used in the study area were fairly secured. The Table also reveals that 77.59% of respondents provided perimeter fence structure around the facility while 13.79% engaged services of the security guard. These were to ensure continuous supply and availability of water for different uses by the building occupants. Conclusively, Table 11 indicates that in ensuring the dependence of the respondents on the use of the solar-water pump, the greatest challenge faced was the failure of the pump (31.67%), theft (26.67%), bad weather (25.00%) and vandalism (16.67%) respectively.

5. CONCLUSION AND RECOMMENDATION

In the light of the myriad of challenges associated with the provision of tap water for the convenience and use of the building occupants in the study area by the government, various water sources such as wells and boreholes were significantly explored as alternatives for the quantitative and qualitative supply of water by the respondents. The wells and boreholes that were mostly used inevitably deserved the installation of pumping facilities to ensure the availability of water indoor for the use of the occupants. The study shows that the photovoltaic solar water pump is an effective facility that can be used to provide water for the occupants of buildings particularly in settlements where there is a poor supply of electricity and generally in areas, where there is an advantage of tropical environmental conditions with the abundance of sunlight. It shows that different operating factors such as technical know-how, economic and environmental factor amongst others influenced the use of the photovoltaic solar water pump; while the stakeholders also had varying levels of benefits derived from its adoption. The study also indicates that in the course of the use of the facility, various operational faults and challenges were faced and these were addressed with relevant strategies to ensure continuous use of the facility, supply, and distribution of water to be consumed by the building occupants. Based on the results of the study, there is a need to take good advantage of the tropical environment of the study area, so that any photovoltaic solar water pump to be installed must have a satisfactory number of solar panels that would have the required capacity to drive its efficient operation. This would help to drastically reduce, the likely impact of much dependence on the national grid to power facilities and appliances used in buildings. There is a need for the financiers or donors and the users, to jointly ensure its due use by ensuring that tight security provisions are made to safeguard the photovoltaic water pump facility from misuse and vandalism as may be applicable.

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