PAPER 135 – A BRIEF REVIEW OF WATER PUMPS CATEGORY AND THEIR POWER SOURCES

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ABSTRACT
Water is the driving force of nature, without it, life will mean nothing. Ground water provides about half of the water requirements for human existence. This paper presents a review of different groundwater pump categories and their power sources available from literature. The review covers positive displacement pumps and centrifugal pumps. The power sources for the groundwater pumps reviewed includes manual, electric and fuel sources. The merits and de-merits of the different category of pumps reported by different authors was also highlighted. It was concluded that manually powered borehole water pumps are the cheapest and the most widely acceptable water pumps especially in rural communities of developing countries while the fuel powered pumps is the most expensive power source.

KEYWORDS: *Borehole, Ground water, Manual power, Pumps*

1. INTRODUCTION
Access to portable drinking water and sanitation has been recognised by the United Nations general assembly as a human right and as a necessity for the fulfilment of many other human rights (United Nations, 2010). Water is the lifeblood of all humans, it is the driving force of all nature; without water, life will mean nothing. Millions of people are dying in places where access to portable water supply is a challenge, and these places are especially in rural areas of underdeveloped and developing in nations (WHO, 2022; Cronin, *et al.*, 2008). According to estimates, groundwater provides about half of the world's drinking water, and 2.5 billion people rely primarily on this resource to meet their daily water needs (Gronwall and Danert, 2020). Nigeria has grown increasingly reliant on groundwater, which today is thought to supply drinking water to over 100 million people. The popularity of borehole water (a ground water) for drinking water has grown tremendously which were used by 32% of Nigerians in 2011 compared to 10% in 1999 (NBS, 2013). Ground water represents a large portion of water supplies used for different applications. To make quality ground water supply physically available, sufficient in terms of quantity and to guarantee its availability and affordability when required, water lifting devices were invented (Yannopoulos *et al.*, 2015).
Water lifting devices have been in existence since around 3000BC (Yannopoulos *et al.*, 2015). According to the Mateo-Sagasta *et al.* (2017), Animals muscles were employed to convert their efforts to the energy needed to move the wheels in early devices like water wheels and chutes. Up to the last century, various kinds of lifting devices like indigenous water lifts have been extensively utilised for irrigation and other water lifting purposes. However, Pumps were developed and is still in use today due to advancement in technology and its ease of operation. People in rural area frequently find it difficult to afford a typical water supply that is connected to the grid to meet their water demands, mostly because of the associated cost, lack of appropriate technology and trained technicians. Most times, even if they can afford the initial set up cost of the pump's energy costs keep increasing and, they are usually unable to match these operating costs hence this paper reviews ways to obtain ground water especially using borehole pump for people in these areas lagging behind. different types of pumps and their power sources were considered to address the problems of water shortage in rural areas, at the same time, improvements in the most prominent and conventional type of pump (manually powered borehole water pumps) in the rural areas was discussed to take advantage of appropriate technologies in the water and sanitation sector so as to guide researchers and stakeholders on technical alternatives to water pumping systems and its power sources to ensure the increase in reliable water supply to areas in need with less expenses and energy requirements.

2. PUMPS
A pump is a device that moves liquid from one place to another or from bottom to the top surface, typically by converting mechanical energy into fluid flow energy (Miao *et al.*, 2018). Pumps serve as a great blessing for these people who fervently need assistance in meeting their water needs for irrigation, village water supply and for livestock watering purposes (Bhatia, 2014). They are used in households in many locations to convey water and other liquid.

2.1 Types of pumps

According to Kassab (2017), pumps can be categorised based on the manner in which they add energy to the working fluid into two categories namely:

1. The centrifugal (rotodynamic) pumps
2. Positive displacement pumps (PDP).

While the positive displacement pumps were developed long before the centrifugal pumps, its capacity is not affected by pressure which it operates (Stewart, 2018). The centrifugal pumps was later developed and put into to address the problems of highly transferring viscous fluids which the PDP was faced with. The centrifugal pump is usually affected by pressure and other parameters. These two pump categories are discussed forthwith.

Centrifugal pump. Centrifugal pumps are used for moving liquids by increasing a specific volume flow to a specified pressure level (Gulich, 2014). The centrifugal pumps as shown in figure 2 also called rotodynamic pumps consists of one or more impellers which is completed by blades, which is installed on moving shafts and receives energy from pumps motor and is covered by a casing. They add kinetic energy to the fluid using a spinning impeller where the energized fluid enters the impeller axially and then fluid leaves the impeller with high relative speed and collected in volute or diffuser and then conversion of velocity head to pressure head occurs which is followed by decreasing velocity. These types of pumps can be divided into two namely: centrifugal pumps (axial, radial and mixed) and special effect pumps (jet and airlift pumps). The centrifugal pumps are used where low pressure is required. The benefit of centrifugal pumps is that they are simple to operate, they are long lasting and they are reliable. However, this category of pumps has the disadvantage of susceptibility to cavitation, internal recirculation and, seal or packing wear (Abelin, et al., 2006).

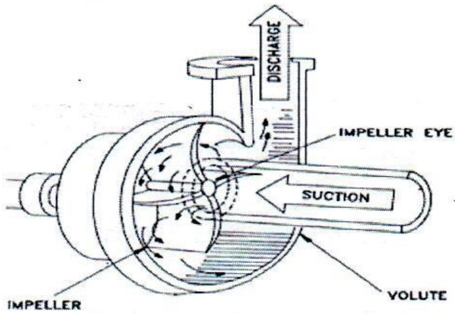

Fig 1: A Centrifugal Pump (United State Department of Energy, 2015)

Positive displacement pump (PDP). Positive displacement pumps add energy to a fluid by applying force to the liquid with a mechanical device such as piston or plunger (Stewart, 2019).The positive displacement pumps as shown in figure 3 pressurises the fluid with a collapsing volume action thereby squeezing and amount of the fluid equal to the displacement volume of the system with each piston stroke or shaft rotation (Abelin, et al., 2006). it uses energy periodically by application of force to one or more movable boundaries of any desired number of enclosed fluids containing volumes resulting in direct increase in pressure up to the value required to move the fluid through the valves or ports into the discharge line. Most manual pumps fall into this category of pumps (Savva and Frenken, 2001). according to (Abelin, et al., 2006)The positive displacement pumps are also divided into two: the reciprocating pumps and the rotary pumps. The reciprocating pumps are those in which linear motion of a piston or plunger in a cylinder causes the displacement, it is consisting of piston, plunger and, diaphragm. While the rotary pumps are those in which the circular motion causes the displacement, it consists of gear, lobe, screw and vane, a disadvantage of the positive displacement pump is that it can potentially over pressurise system piping and some components of the pump and, it requires more system safeguard such as relief valve. The cyclical nature of pumping action can cause fatigue in the components.

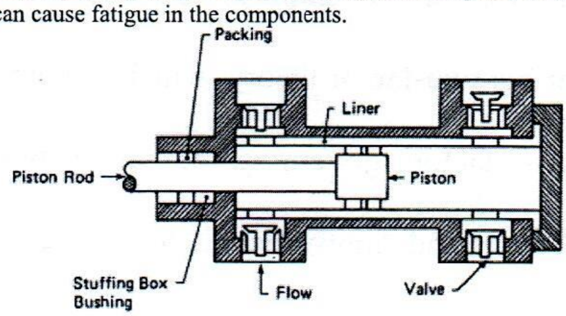

Fig 2: Positive displacement pump (Stewart, 2019).

2.2 Working principle of positive displacement pumps

According to Hussey (2007), positive displacement pumps work using two basic principles of operation, namely:

1. The direct lift principle, where a reciprocating rod, piston and valves lift water and,
2. The screwing principle where a rotating rod and rotor moves water through a screwing process.

In the direct lift principle as shown in figure 5, water is either raised through direct lift or suction. The direct lift pumps are either with pistons pumps or through direct action pumps. In direct lift pump (piston pumps), a piston is raised by a rod which sucks water into the cylinder through an inlet check valve or non-return valve on the upstroke which is opened by the vacuum created. On this stroke, water is discharged from pump head and on the downward stroke, the lower valve closes and water flows through the valve in the piston to the upper part of the cylinder for the process to be repeated. Pumps operating using this principle are generally used in rural communities on deep wells and boreholes where pistons can be installed below the residual water level. They are mostly more suitable than deep well pumps and easy to maintain.

Pumps operating on the suction principle use, a direct lift where the piston is situated above the water level. The pump here is primed to displace air from the pump cylinder, pump column or connecting pipes so that water is forced into the pump cylinder by atmospheric pressure. Suction pumps can either be with lift or force pumps or with diaphragm pumps. In the lift or force pumps, a suction pump with two valves, one-foot valve and one side valve where water does not pass through the piston is used. Water is drawn into the cylinder by a piston through a lower valve as the piston is raised. As the piston descends, it closes the lower valve and forces water out of the pump through a valve and delivery pipe. It is mostly suitable for direct connection to well points due to its similarity with other suction displacement pumps. The suction pump (diaphragm pump) on the other hand uses a flexible diaphragm to provide an alternative to a reciprocating piston to move water.an upward movement of the diaphragm increases the volume of a pump chamber. In the absence of air, water will flow into the chamber through an open valve. A downward movement of the diaphragm will reduce the volume of the pump chamber and consequently the valve closes and water will be expelled through another valve and a discharge pipe (Practical Action Group, 2008). Table 1 shows the merits and demerits of the different category of pumps.

Table 1: Merits and de-merits of different category of pump as reported by authors

Author	Category of Pump	Merits	Demerits
Savva and Frenken, (2001)	Centrifugal pump	Gentle and relatively quiet system.	No suction power
Mobley (2001)	Reciprocating Positive displacement pump	High pressure at outlet	High wear and tear
Islam *et al.* (2007)	Positive displacement pump	Easy to maintain	Stressful to operator
Nwoha (2016)	Centrifugal pump	Can be applied in many fields where high pressure is required.	Difficult to monitor
Bajpal (2018)	Dynamic pumps	Small in size	Cannot be used on highly viscous fluid
Koukouvinis and Gavaises, (2021)	Positive displacement pump	Can control flow rates hence, can be used as metering pumps	It is complex and difficult to maintain
Hellemans (2022)	Positive displacement pumps	Provides a constant flow of fluid at a given speed	Pump gets damaged If pressure relieving devices (PRD) isn't used.

2.3 Power Sources for Pumps

Water pumps are powered by a rotary or reciprocating mechanism that consumes energy while performing mechanical work of moving the fluid from one location to another. (Martin et al., 2011) opines that the optimal type of energy for pumps depends on the long-term relative price of one energy source compared to another. The energy sources required by water pumps thus include:

- Fuel engine power source
- Electrical power source
- Manual power source (Dey, 2022)

The most common source of power for water pumps is fuel and electricity. Diesel (fuel) powered pumps is a commonly used water pumping system in many areas where grid supply is difficult to reach (ISA, 2015). Resources used to generate energy, such as coal, gasoline and natural gas have become environmentally unfriendly, paving the way for alternative energies (Becenen and Eker, 2005). The shortcomings of the fuel source of energy for pumping systems include:

- Fuels sources produces fumes and noise which can cause environmental pollution
- Fuel engines need periodic maintenance to avoid breakdown and also require parts replacement occasionally.
- There is always need to transport fuel to the engines location which could waste time due to the state of roads especially in rural areas.
- Fuels could result in increased cost and spillage of these fuels could leads to land contamination (Eker, 2005).

However, the continuous use of fossil fuels and their negative impact on the environment has made researchers look out for clean sources like solar and manual power. Solar powered pumps are powered by the sun. A photovoltaic (PV) array, also known as solar modules or panels, converts solar energy directly into electricity to power a water pump in a solar-powered water pumping system. water pumps designed specifically designed for solar power and PV modules are available to meet a wide range of head discharge requirements (Wijetunge *et al.*, 2006). The advantages of solar powered pumps are that it is environmentally friendly as there is no pollution caused by them, and cost effective than internal combustion engine powered pumps and is easy to operate, while the disadvantage of solar water pumping systems is their relatively high initial cost when compared to other alternative energy sources. Table 2.0 shows the contribution of authors using different power sources for groundwater pumps. However, manual power is abundant almost everywhere, it is simple, cost effective and can be utilized without negative environmental effects: it is eco-friendly because no waste is produced which makes it a good source of power.

Table 2: contribution of authors using different power sources for groundwater pumps

Author	Power source	Contribution
Savva and Frenken (2001)	Multiple power source	Discussed different power sources for irrigation water pumps
Short and Oldach (2003)	Electrical Solar power	Addressed some issues associated with solar powered water pumping system.
Wijetunge *et al.* (2006)	Electrical Solar power	Evaluated the performance of solar water pumps
Islam *et al.* (2007)	Pedal pump (Manual)	Designed and developed a pedal pump for low lift irrigation purpose
Takacs (2014)	Electrical power	Developed and artificial liquid system using electrical submersible pumps (ESP)
Uche *et al.* (2014)	Dual power	Designed and fabricated a dual powered (manual pedal and DC motor) water pump
Waghmare *et al.* (2015)	Manual power	Designed a model for manually operated spiral tube water wheel pump
Nwoha (2016)	Manual power	Developed a manually operated centrifugal water pump to assist farmers and as a teaching aid for students.
Armanous *et al.* (2016)	Diesel fuel and Solar power	Used the life cycle of diesel fuel and solar pumps to assess the environmental impact of groundwater pumping system
Vartak (2017)	-	Applied the benefits of PD pumps in the chemical industry
Pawlick *et al.* (2018)	Hydraulic pump	Provided a manual that would serve as a guide for ram pump design and installation for use in developing countries.
Koukouvinis and Gavaises (2021)	Fuel(petrol)	Reported the factors that affect performance and cavitation formation in pumps

3. CONCLUSION

A variety of pumps and other water lifting devices are available for transferring water from one point to another, however, the main categories of pumps were considered in this review due to the available literature. From the papers reviewed, the centrifugal pumps appear to be applied in areas involving low viscous fluids while the positive displacement pumps appear to be utilized in areas where fluid flow rates need to be controlled by changing the speed of the pump. The manual power source if improved using the latest available technology is a viable (in terms of cost and ease of operation) power source for groundwater pumps to transfer water to areas not connected to the grid.

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