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Design and Fabrication of a Pumping Machine for Water Supply: Meeting the Challenges of Modern Water Infrastructure

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ABSTRACT

The ever-growing demands of modern water infrastructure have necessitated innovative approaches to water supply solutions. This study delves into the meticulous design and fabrication of a pumping machine tailored to meet the challenges posed by contemporary water supply needs. Incorporating cutting-edge technology, efficient material selection, and sustainable design principles, the pumping machine exemplifies a comprehensive response to the complex requirements of water distribution systems. It addresses issues of efficiency, reliability, environmental responsibility, and adaptability while retaining a focus on economic feasibility. The study underscores the critical role of technology in revolutionizing water supply systems, offering a glimpse into the future of sustainable and efficient water infrastructure.

KEYWORDS: *Water; Transportation; Efficiency; Pumping; Energy; Piston*

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1. INTRODUCTION

Water, the elixir of life, is a fundamental resource that underpins the very existence of civilization. Access to clean and reliable water supply is a cornerstone of public health, economic development, and environmental sustainability (Yannopoulos *et al.*, 2015; Mogaji, 2016). The provision of safe and adequate water for communities has been a longstanding challenge, particularly in regions facing water scarcity, inadequate infrastructure, or burgeoning urban populations. The critical role of water supply systems cannot be overstated, as they serve as lifelines for society, driving progress and well-being (Usman *et al.*, 2019).

In the quest to address the multifaceted demands of modern water infrastructure, the design and fabrication of efficient and sustainable pumping machines have emerged as a focal point of innovation and engineering excellence. These machines are the heart of water supply systems, enabling the extraction, transportation, and distribution of water from various sources to end-users. As the global population continues to grow and the impacts of climate change intensify, the need for reliable, energy-efficient, and environmentally responsible water supply solutions has become more pressing than ever (Okhaifoh *et* al., 2016).

This article embarks on a journey into the realm of the "Design and Fabrication of a Pumping Machine for Water Supply," a realm where technology, engineering, and environmental stewardship converge to provide practical and sustainable solutions to the challenges faced by communities worldwide. It explores the intricate blend of cutting-edge engineering, sustainability principles, and the real-world application of pumping machines in addressing water supply issues (Doro *et al.*, 2020).

Our discussion delves into the critical components of pumping machine design, emphasizing the need for innovation and customization to cater to diverse water supply requirements, such as municipal water distribution, agricultural irrigation, and industrial processes. We examine the vital role of efficiency in reducing energy consumption and operational costs, as well as the incorporation of smart technologies to enhance monitoring, maintenance, and optimization of pumping systems (Martin-Candilejo *et al*., 2020).

Furthermore, this article seeks to underscore the significance of environmental consciousness in the design and fabrication of pumping machines. Sustainable design practices, including the use of energy-efficient materials, renewable energy sources, and environmentally friendly manufacturing processes, are central to ensuring the long-term viability of water supply systems. As we traverse the landscape of "Design and Fabrication of a Pumping Machine for Water Supply," we will encounter both the challenges and the triumphs of engineers, researchers, and innovators dedicated to securing the future of water access. We will explore real-world case studies, breakthrough technologies, and collaborative efforts that are reshaping the way we approach water supply, and we will underscore the critical importance of sustainable design and fabrication in this mission (Karimi *et al*., 2023). In the face of mounting global water challenges, the need for practical, innovative, and environmentally conscious solutions has never been greater. The discussion within this article aimed to contribute to the ongoing dialogue surrounding water supply technology and inspire a deeper commitment to securing the world's most precious resource for generations to come. The specific objectives of this study is to develop an innovative and efficient pumping machine for water supply that addresses the specific challenges faced by modern water infrastructure, taking into account factors such as increased demand, water source variations, and energy efficiency.

2. Materials and Methods

During the initial phase of this research endeavor, meticulous attention was devoted to the design of the diverse components constituting the reciprocating pump. These essential components encompassed the structural frame, the intricately crafted pump chamber, the precision-engineered pump cylinder, the robust yet agile crankshaft, and the connecting rod. Subsequently, these components were adeptly assembled in accordance with the schematic illustration presented in Figure 1. This comprehensive approach to design and assembly formed the foundational basis upon which the subsequent stages of this research were constructed.

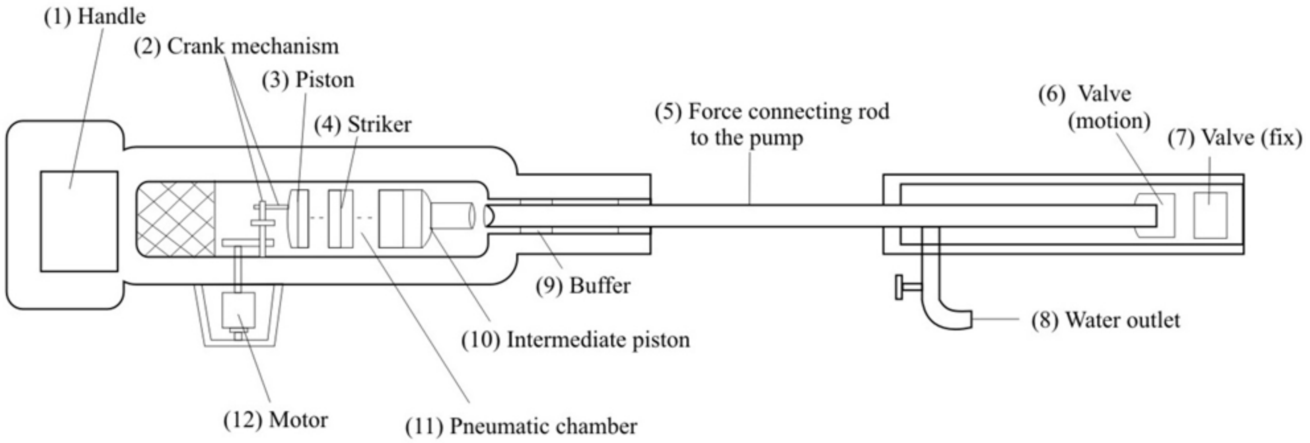

Figure 1: The schematic diagram of the assembled pneumatic pumping machine

The design of this pump exhibits a working mechanism reminiscent of the treadle pump, albeit with a distinctive characteristic - it is a hand-operated pump. This remarkable device can be aptly described as a hybrid, combining the efficiency of the treadle pump with the convenience of a hand pump, thus offering a versatile water pumping solution. The fundamental structure of the pump consists of two cylinders, thoughtfully positioned side by side. To establish a seamless connection with both the suction and discharge pipes, a junction box was thoughtfully integrated into the design. At the suction side of this junction box, a pair of check valves was strategically affixed, serving as a protective measure to prevent water from back flowing into the water source. A mirrored arrangement of check valves was mirrored on the discharge side of the junction box to ensure the smooth, one-directional flow of water. Table 1, enumerates the key design parameters of this pump. These parameters encompass the structural framework, the pump chamber, the pump cylinder, the intricately designed crankshaft, and the connecting rod, each bearing equal significance in the functional operation of the pump. Moreover, the table elucidates the belt arrangement employed in the design, underscoring the comprehensive nature of this water pumping solution.

Table 1: Design criteria for the hand pump.

POS NO	QUANTITY	DESCRIPTION	SPECIFICATION	MATERIALS	REMARKS
H-00	1	Steel cone assembly			
H-350	1	Steel cone		Q ST 52-3	Deep draw
H-351	2	Eye		ST 37	
H- 352	1	Flange plate		ST 37	
J- 00	X	Pump rod assembly and foot valve fitting			
J- 400	1	Foot valve connector		AISI-304/316	
J- 401	1	U-hook		AISI-304/316	
J- 402	1	Plunger connector		AISI-304/316	
J- 403	1	Plunger rod		AISI-304/316	
J- 404	X	Washer		ST 37 or AISI-304/316	
J- 405	X	Eye-hook	DIN 688	ST 37	
J- 406	X	Spacer		ST 37	
J- 407	X	Hook	DIN 688	ST 37	
J- 408	X	Rod	DIN 688	ST 37	

Design calculation

Pump pressure is a measure of resistance to flow. Without flow, there is no pressure.

- **Design for pressure**

The pressure of the pump is as expressed in Equation 1.

Pump pressure $p = \rho g h$ 1

Where,

ρ = density of water

g = acceleration due to gravity

h = height

Given $\rho = 1000$ kg/m^3, g = 9.81, height = 8m

Substituting the values into equation 1

Pump Pressure, P = 1000 x 9.81 x 8

= 78,480pa or N/m^2

Design of Force Rod

A Force Rod is used to transform various vanilla items and blocks into new Dart Craft items and blocks. For example, a Force Infuser is created by right-clicking a Enchanting Table with a charged Force Rod. In Beta 0.2. 18 you could craft an Enchanting Table with a Force Rod.

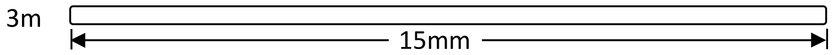

Figure 2: Force rod

Using $p = {}^{f}/_{A}$ 2

Where
P = pressure
F = Force
A = Area of the piston

Where $A = {}^{\pi d^2}/_{4}$

Where d = diameter of the piston = 60mm = 0.06m

P = 78480pa or N/M^2 (Equation 1)

Substituting the values into Equation 2

i.e.

$$p = \frac{\frac{F}{\pi d^2}}{4}$$

$$78480 = \frac{\frac{F}{\pi (0.06)^2}}{4}$$

F = 221.9N

Design of force rod diameter

Using Euler's formula for calculating critical load for a column where p = critical load, L = length, E = Elasticity, I = Inertia and n = 1 for Euler crippling load from pinned – pinned connection.

$$p = \frac{n\pi^2 EI}{L^2} \qquad 3$$

Where p = 221.9, n = 1, E = 200 Gpal, I = ?
L = 0.38

Substituting the values into Equation 3

$$221.9 = \frac{1 \times 3.142^2 \times 200 \times 10^9 \times I}{0.38^2}$$

$$I = 16 \times 10^9 N/m^2$$

Using

$$I = \frac{\pi d^4}{64}$$

$$d^4 = \frac{1024}{3.142} = 325.91$$

fr.d = 4.25mm say 9mm

But for safety reasons and market availability we used 9mm

Electric motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft.

Design for horse power (h.p) specification

$$h.p = \frac{TDH \times Q \times SG}{3960} \qquad 4$$

Where h.p = horse power
TDH = Total Dynamic Head
Q = flow-rate in gallon
SG = Standard Gravity

$$h.p = \frac{8 \times 4.73 \times 1}{3960}$$

$$h.p = 0.0095$$

= 7.087w

= 0.0071kw

But at the efficiency of 65% we have 0.01kw

Therefore, electric motor power =0.01kw

Revolution per minute rpm = 2400/1900

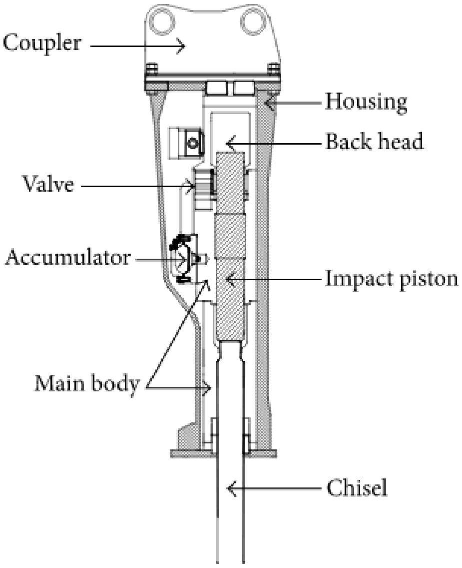

Figure 3: Electric motor

DESIGN SPECIFICATION

The design specification is the detailed document providing a list of points regarding the project which are listed in Table 2.

Table 2: Design specification

S/N	Parameters	Ratings
1	Pump pressure	78480 pa or N/m^2
2	Pump force	221.9 N
3	Force rod diameter	9 mm
4	Power	0.01kw
5	Frequency	50 – 60 Hz
6	Piston diameter	60 mm or 0.06 m
7	Length of force rod	38 cm

Materials selection

The process of selecting an appropriate material for a specific application is a multifaceted endeavour, demanding a comprehensive understanding of the material's performance in both its final form and during service. This necessitates a methodical approach, particularly when considering the economic feasibility, desired product shape, and the limited spectrum of materials available to professionals, such as engineers and designers.

Several crucial considerations play a pivotal role in the material selection process, ensuring that the chosen material aligns harmoniously with the intended application. These considerations encompass a range of factors, including:

Material Properties: The material must exhibit the requisite mechanical, electrical, thermal, and chemical properties to fulfill its designated function effectively.

Reliability: The material's reliability in the intended application is paramount, ensuring that it performs consistently and safely over its operational lifespan.

Environmental Impact: Assessing the potential adverse effects of the material on the environment, its resistance to corrosion, and susceptibility to various forms of deterioration is essential for sustainable and responsible material choices.

Economic Viability: Consideration of the cost-effectiveness of manufacturing products from the chosen material is integral to the decision-making process. Balancing performance with affordability is a crucial aspect of material selection.

Recyclability: The recyclability of the material is increasingly vital in today's environmentally conscious world. Evaluating whether the product can be recycled contributes to long-term sustainability. The complexity of material selection demands a willingness to embrace compromise and acknowledge that it extends beyond a simple assessment of cost and material properties. Other pertinent factors, such as:

Material Properties: Understanding the specific properties of materials is pivotal in determining their suitability for the intended application.

Material Cost: The cost of the material and its overall economic implications weigh heavily in the selection process.

Thermal Stability: The material's ability to maintain its structural integrity under varying temperature conditions is a critical consideration.

Corrosion and Degradation in Service: Assessing how the material withstands corrosion and degradation in real-world service conditions is essential for ensuring longevity.

Fabricability: The ease with which a material can be processed into the desired product shape influences its practicality for manufacturing.

Functional Requirements and Constraints: Understanding the specific functional requirements and limitations of the application is fundamental to selecting a material that will perform optimally. The selection of materials for engineering and design purposes is a multifaceted process that necessitates a holistic approach. By considering a broad spectrum of factors, including material properties, cost, environmental impact, and practicality, professionals can make informed decisions that result in materials best suited to the task at hand while ensuring the seamless alignment of material properties with the manufacturing process.

Components Construction Procedures

The components construction procedures are as follows:

1. Appropriate Specification
2. Build the foot valve assembly
3. Build the plunger assembly
4. Identify how much connecting pipe is needed.

- **Appropriate Specification:** The specification of the component parts are shown in Table 3.

Table: 3 Dimensions of the main components

Name	Description
Frame	Made of angle bar; Height (1250mm) × Length (600mm) × Width (385mm)
Junction box	Constructed from steel; Length (262mm) × Width (141mm) × Height (60mm)
Pump cylinder	Fabricated of cast iron; Diameter (96mm) × Height (217mm) × Thickness (10mm)
Crankshaft	Made of hollow pipe; Diameter (24mm) × Length (380mm)
Connecting rods	Fabricated of galvanized hollow pipe; Diameter (25mm) × total length (388mm)
Suction pipe	Made of 60 mm diameter PVC pipe
Pulley arrangement	Double pulley made of mild steel; Large pulley diameter (184mm) × small pulley diameter

- **Build foot valve assembly:** The purpose of the foot valve is to allow water into the cylinder without allowing it to fall back out. (The cylinder is the lower pipe section containing the foot valve and plunder assemblies.) It is composed of, from bottom to top:

a. 2in cap
b. 2in pipe screen with drilled holes (about 9in long)
c. 2in coupler
d. 2x3/4 reducer
e. 2x3/4 reducer with the lip filed out to allow the 3/4in pipe to slide all the way through.
f. 2in coupler
g. 3/4in pipe (about 4 in long)
h. 3/4in slip-male thread adapter
i. 3/4in brass check valve
j. 2in pipe about 36in long (not shown). It fits into coupler (f).

- **Build the plunger assembly.** The plunger serves two purposes. First, it provides a seal with the cylinder to generate suction. Second, it contains a second check valve to allow water in the upper cylinder.
  - 3/4in threaded pipe extender. Screws into bottom of check valve (d).
  - Spacers. The purpose of the spacers is to keep the gasket rigid. They should not contact the cylinder. You can use a 2in hole saw to score a ring in each side, then use a 1-1/8in Forstner bit to bore out the inner hole. The hole saw can be again used to finish the outer cut. These can be made from wood or plastic.
  - Leather gasket. Can also be made from rubber. Carefully cut this to fit snugly in the cylinder and on the pipe extender. When inserting the assembly in the cylinder to test the fit, first soften the leather with water. Otherwise, you will trim it too small and need to start over.
  - 3/4in brass check valve
  - 3/4in slip-male thread adapter
  - 3/4in pipe 6in long with drilled holes. This allows water to enter the upper cylinder after passing through the check valve.
  - 3/4x1/2in slip reducer
  - Rubber stopper. Held in place by the 1/2in pipe (i). Prevents water coming up the pipe (i).
  - 1/2in pipe
- **Identify how much connecting pipe is needed.** Pipe is needed to connect the cylinder to a pump head and the plunger to a handle at the surface. The amount of pipe depends on the depth of the static water level in the well. From the top of the cylinder, you can reduce the pipe down to a 1-1/4in diameter pipe to save on cost and weight. However, it does increase the force required to pull the water to the surface (hydraulic principles). Figure 4 illustrates the front view of the pump.

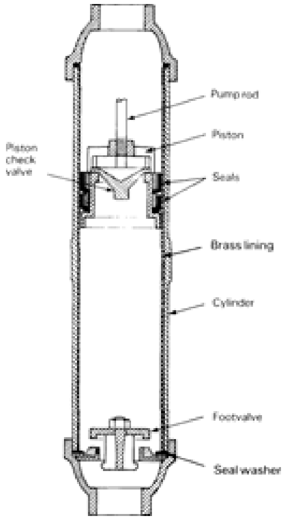

Figure 4: Front view of component part

3. Results and discussion

Table 4 depict the results from testing of the pump'

Table 4: Result and Findings

Height (m)	In 10 sec (cl) centilitre	In 60 sec. Centilitre	In 60 sec gallons
1	520	3120	8.25
2	430	2580	8.20
3	370	2220	5.87
4	320	1920	5.08
5	260	1560	4.12
6	200	1200	3.17
7	130	780	2.06
8	70	420	1.11

From the test analysis above, the pump can safely pump water to the average height of 4.5m under normal operating condition.

Pneumatic systems rely on a supply of compressed air, which must be readily available in sufficient quantity and at the appropriate pressure to accommodate the system's operational needs. When integrating a pneumatic system for the first time, one of the primary considerations revolves around establishing a reliable source of compressed air.

The cornerstone of any compressed air supply infrastructure is typically a reciprocating compressor. A pneumatic system comprises several key components, including a compressor plant, a network of pipelines, control valves, and the essential drive mechanisms. Within this framework, air undergoes compression within the confines of an air compressor, and subsequently, the compressed air flows through a meticulously designed pipeline system to reach pneumatic cylinders.

In the context of our discussion, this particular construction is underpinned by a pneumatic pumping machine. This device utilizes electrical current to compress air, generating the force required to transport water to a specific height. It's noteworthy that this pump boasts the capability to function effectively at varying water levels, accommodating depths as profound as 325 feet in static water level, while its motorized counterpart operates efficiently at depths down to 225 feet.

The core specifications of this pneumatic pumping machine are as follows: it features a 4" diameter and a 63mm cylinder, and it is tailored to fit boreholes ranging from a minimum of 100mm to a maximum of 150mm in diameter. With a design that incorporates two stages, it can generate a maximum pressure of 200 psi during its first stage, and it necessitates a maximum handle effort of 106 lbs. These specifications collectively underpin the reliable and efficient operation of this pneumatic pumping machine.

Operational procedure

This study introduces an innovative passive vibration protection system that integrates principles of vibration isolation and dynamic absorption, effectively applied to hand-held percussion machines. This system employs a vibration isolator positioned between the machine's handle and casing, primarily aimed at attenuating the high-frequency acceleration components experienced by the operator. Remarkably, this vibration attenuation system allows for the use of relatively rigid isolators without significantly increasing the overall tool mass, resulting in a considerable reduction in hand-transmitted vibrations. The empirical validation of our numerical simulations is presented in this paper, reaffirming the effectiveness of this approach.

Hand-held percussion machines are a ubiquitous presence across a multitude of industries, including construction, transportation, and various sectors of the industrial landscape. These machines are favored for their operational convenience, high efficiency, and adaptability to a diverse range of processes.

In this study, we concentrate our analysis on the electro-pneumatic percussion machine, a prominent example of piston-operated impact rippers with widespread utility in industrial and construction domains. The underlying mechanism involves an electric motor propelling the exciting piston through a crank and connecting rod arrangement. This reciprocating piston cyclically compresses and decompresses air within the pneumatic chamber, initiating motion in the striker. The striker subsequently impacts an intermediate piston, which, in turn, transfers energy to the pick, ultimately engaging with the material under treatment.

To ensure operational control and safety, the pick incorporates a collar preventing excessive penetration into the machinery after each rebound against the treatment object. Crucially, the machine necessitates the operator to exert a continuous force, referred to as the "feed force," by pressing the machine against the treatment object. The feed force provides a means for operators to regulate the machine's working process. Consequently, a nuanced understanding of the operator-machine interaction becomes imperative when investigating the dynamics of hand-held percussion machines.

Safety Precautions during Testing

1. Ensure that no loose wires are exposed, minimizing the risk of electrical shock, and verify that all connections are secure.
2. Prevent water from coming into contact with the mechanical output to avoid the potential for electrical shock or burn incidents.
3. Submerge the pump fully and securely in water, maintaining a safe testing environment.

Maintenance Guidelines

1. Regularly clean all components to ensure proper functionality and longevity.
2. Replace components when they show signs of wear or damage, prioritizing equipment integrity.
3. Apply lubrication to seals as necessary to maintain smooth operation and reduce friction.

4. Adjust the oil mist levels to meet operational requirements and maintain efficient performance.
5. Proactively identify and address any potential air leaks to uphold system integrity and safety.

4. Conclusion

In this study, we have successfully conducted a comprehensive analysis, design, fabrication, and testing of a pneumatic water pumping machine. The outcomes of our work not only demonstrate the viability of such endeavors but also hold promise for the design and fabrication of compact machinery and equipment. This, in turn, could catalyze technological advancement and foster development within our nation.

The integral components of this gear pump were meticulously crafted through machining techniques. However, it is worth noting that further exploration and research are warranted to investigate alternative processing methods that could enable mass production of external gear pumps in Nigeria, thus broadening the scope of indigenous manufacturing.

It is evident from our findings that this system presents a practical solution, particularly in regions with limited access to a stable electricity supply. This system effectively harnesses minimal electricity to draw water from the ground, offering a sustainable water supply solution. Furthermore, the versatility of this technology extends its applicability to the petroleum industry.

A noteworthy advantage of this pneumatic system is its resilience during power outages. Unlike electric motor-driven pumps that cease operation in such circumstances, this system can continue functioning by utilizing the reserved compressed air stored in the air cylinder. Notably, increasing the air pressure from the compressor can enhance the system's flow rate, adding to its adaptability and utility. The pneumatic water pumping system we've explored is not only practical but also exhibits remarkable versatility and resilience in the face of power supply challenges. It holds immense potential for addressing water supply needs in areas with intermittent electricity access and offers a promising avenue for technological advancement and industrial development in our country.

References

[1] Doro, K.O., Ehosioke, S., Aizebeokhai, A.P. (2020). Sustainable Soil and Water Resources Management in Nigeria: The Need for a Data-Driven Policy Approach. *Sustainability*, 12, 4204. https://doi.org/10.3390/su12104204.

[2] Karimi, H., Adibhesami, M.A., Bazazzadeh, H., Movafagh, S. (2023). Green Buildings: Human-Centered and Energy Efficiency Optimization Strategies. *Energies* 2023, 16, 3681. https://doi.org/10.3390/en16093681.

[3] Martin-Candilejo, A., Santillán, D., Garrote, L. (2020). Pump Efficiency Analysis for Proper Energy Assessment in Optimization of Water Supply Systems. *Water*, 12, 132. https://doi.org/10.3390/w12010132.

[4] Mogaji, P. B. (2016). Development of an Improved pedal powered water pump. *International Journal of Science & Engineering Research*, 7(2), 1115-1123.

[5] Okhaifoh, J.E., Igbinoba, C.K., Eriaganoma, K.O. (2016). Microcontroller based automatic control for water pumping machine with water level indicators using ultrasonic sensor. *Nigerian Journal of Technology (NIJOTECH)*, 35 (3); 579 – 583. 8821. http://dx.doi.org/10.4314/njt.v35i3.16.

[6] Usman, M.N., Mbajiorgu, C.C., Vinking, J.M. (2019). Design, Construction and Testing of a Hand Operated Water Pump for Small Scale Farmers in Nigeria. *International Journal of Advanced Research in Science, Engineering and Technology*, 6 (10); 11290-11298.

[7] Yannopoulos, S. I., Lyberatos, G., Theodossiou, N., Li, W., Valipour, M., Tamburrino, A., Angelakis, A. N. (2015). Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide. *Water,* 7, 5031–5060. https://doi.org/10.3390/w7095031.