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Development and Performance Evaluation of a Vacuum Drum Based Water Pumping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A vacuum drum based water pumping system (VDBWPS) is a cost effective system for lifting and carrying water from a nearby flowing canal/*nallah* as well as from standing water of farm pond/open well. The main component of the developed system includes of a mild steel (MS) drum, polyvinyl chloride (PVC) pipe, jointer, elbow joint, T-joint, L-joint, regulator valve, and foot valve. In this system water can be filled manually or via other devices, such as a solar pump or a treadle pump. The drum's capacity is nearly 80% filled, and the remaining 20% is kept empty. A continuous supply is created by closing both air release valves and opening the discharge valve. More is the vacuum, better will be the pumping. The testing of vacuum drum based water pumping system was evaluated at different suction lift and carrying horizontal distances, both affecting the discharge. The result show that the water pumping system gave a discharge 2.22 to 2.40 litre per minute (lpm) at a constant suction lift of 0.92 meter (m) and varying distances 0 to 12 m. it was also found that the discharge increase with the distance having peak discharge at 6 m i.e. 3.75 lpm and afterwards it

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decreases gradually as the carrying length increases. The vacuum drum based water pumping system can give a discharge of 5400 litre per day (lpd) at 0.92 m of suction lift and carrying horizontal distance of 6 m. The cost of operation of vacuum drum based water pumping system was 352.41 ₹/day. It has always been a demand that the "technology should be technically feasible, economically viable and socially acceptable".

Keywords: Vacuum, discharge; suction lift; distance; economic cost; vacuum drum based water pumping system pumping system (VDBWPS).

1. INTRODUCTION

India is an agrarian country with nearly 75% of the people directly or indirectly depending upon agriculture [1]. Water is the prime input in agriculture and there are different means available for water lifting including a wide range of pumps. Water resources are becoming crucial for meeting the needs of our society [2]. Most of these irrigation pump sets are mainly operated either using electricity or diesel power, having a significant carbon footprint especially, when the electricity is being generated in thermal power plants.

Lifting and carrying water are great importance in agriculture for irrigation purpose. Traditionally, various types of animal powered and manual pump have been available for water pumping, some superior to others for various purposes. There is always much scope for improvement of non-conventional water pumping system than evolving the new water pumping techniques.

Securing water availability in regions of high altitude required the expenditure of energy. As electrical energy and energy from fossil fuels were unknown, manually operated mechanical devices, or devices driven by natural forces, such as wind, had to be invented. Such water lifting devices originate in the prehistoric times [3,4].

A vacuum drum based water pumping system is a non-conventional water pumping system that operates as a positive displacement pump and uses vacuum as the pumping medium. Under normal environmental conditions, creation of vacuum requires a removal of gases, contained in atmospheric air, from a given vessel or a chamber. A vacuum is a condition in which the pressure is below atmospheric pressure [5]. Similarly reported by Berman, a vacuum is a gaseous environment with lower pressure or density than the standard atmosphere, typically achieved by pumping gas from an airtight vessel [6].

The system does not require conventional fuel sources for its operation and is self-sustaining for pumping water in standing and flowing water, given suitable site conditions. Basic construction of a vacuum drum based water pumping system is very simple and can be created using materials that are readily available in the local market. The system allows a column to be formed by closing both control valves and opening the discharge valve with vacuum pressure during operation and continuous water syphoning. The air chamber is a standing pipe that equips with the outlet pipeline for increasing the pressure of the discharge [7]. The operation of pumping process takes longer time in the low pressure stage. The pumping time is more sensitive to the variation of the pumping speed in the low pressure stage [8]. A vacuum based water pumping system there has no moving parts, that's eliminating wear and particulate creation of vacuum inside the closed chamber and increasing reliability, also the power required is low as there has no valve are required, and the pumping system is silent, without noise being generated [9,10]. Vacuum drum based water pumping system; it also avoids the manpower; provided running water is available under site-specific conditions.

2. MATERIALS AND METHODS

The present research work has been carried out in the field of laboratory, Department of Soil and Water Engineering, SVCAET & RS, FAE, IGKV and Centre of Excellence on Protected Cultivation and Precision Farming, IGKV, (C.G.), situated in the central part of Chhattisgarh at 21º14'9'' N latitude and 81º42'10'' E longitude and at an altitude of 302 meters above from the mean sea level.

A vacuum drum based water pumping system, uses vacuum as a means of pumping for lifting

and carrying water. The Auto-CAD software was used to create a drawing of vacuum drum based water pumping system. The dimension of the VDBWPS is 3000 mm in length, 1828 mm in width and 1371 mm in height, as shown in Fig. 1.

2.1 Major Components of Vacuum Drum Based Water Pumping System

MS Drum: A 200 litre mild steel (MS) iron drum, weighing 22 kg, is supported on stand at the ground surface in the source of water. Its dimensions are 580 mm in diameter and 880 mm in length.

Main stand: It was made of mild steel having overall dimension of 762 millimetre (mm) in length and width of 609 mm. It is the most essential part of vacuum drum based water pumping system, and provides strength and also has stability of the overall system body. The frame holds weight of the entire systems.

PVC pipes: A 25 mm diameter plastic pipe is used in a water pumping system for plumbing and other purposes of water pumping system and strength, durability, installation, has to high as compare to the mild steel pipe, with a 5 m length has been used in the system.

T-joints and L-joints: In general the most widely used joints are T and L. These joints are made of PVC material, and has diameter of 25 mm for both. These joints have been used for interconnecting PVC pipe in the system.

Regulator valve: Three regulator valve of diameter 25 mm has been installed in the system. Out of the 3, one control the outlet of water and the two regulate the pressure within the system.

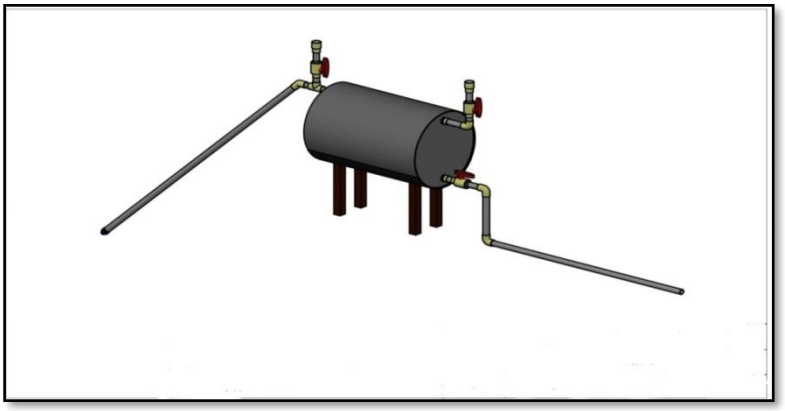

Fig. 1. 3D and Isometric view of vacuum drum based water pumping system

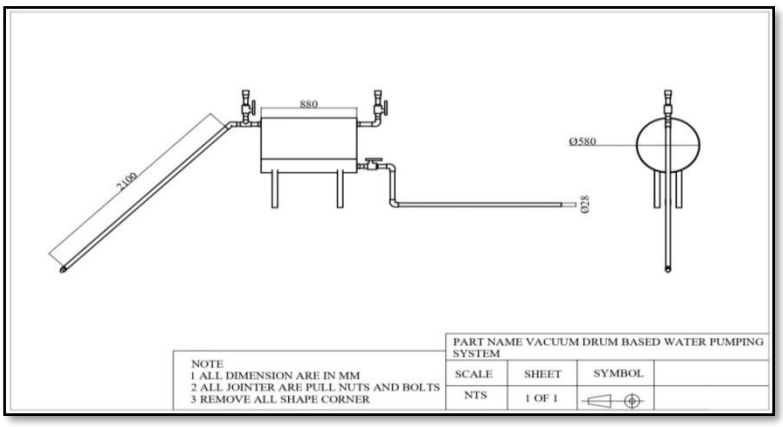

Fig. 2. Isometric view of vacuum drum based water pumping system

Solvent cement: Solvent cement is used for proper sealing of all parts of the system. It is in liquid form that has to be applied on the mouth of two interconnecting pipe and then joined. Solvent cement is strong adhesive and dries within few second.

Jointer and Socket: These are used to joint two interconnecting pipe. Special attention has to be given while joining so as to avoid leakage in the system.

Foot valve: Foot valve is also known as one way valve or check valve that only allow the inlet of water and omit the back water flow and fixed at the bottom end of the suction pipe. It also maintains the water in the suction pipe during functioning of the system. The dimension of foot valve is 28 mm diameter.

2.2 Working of Vacuum Drum Based Water Pumping System

A water pumping system is a very effective system for lifting and carrying water to farm pond/open well from a nearby canal/*nallah*. It consists of MS drum, PVC pipe, elbow joint, T-joint, L-joint, jointer, regulator valve and foot valve. A drum with 200 litre capacity is fixed on a foundation of suitable height. Two holes of 1" diameter is attached with air release valve at 90 degree angle and third hole of 1" is given for discharge cell. One of regulators is attached with suction pipe whose one of the ends is connected with foot valve which has to be submerged in water body. For operation, drum has to fill-up with water via air release valve. Water can be filled manually or through other means like solar pump, gym cycle pumps etc. Only 80% of the drum capacity is filled with water while the rest 20% space is left out. As the system is purely based on vacuum to be created inside the drum, 80% filled up conditions was adopted for further experiment. It is to be noted that the water column (Head) inside the drum along with the vacuum is the driving force. Only 80% of the drum capacity is filled with water while the rest 20% space is left out and the space facilitates both water flow and the creation of a vacuum inside the drum. Both air release valve are now closed and discharge valve is opened creating a continue supply of water. However, in all the real situations, the pressure will not remain constant and increased due to the presence of leaks. More is the vacuum more discharge may come. A site with quick and shallow surface flows, such a canal, *nallah*, or river, is ideal for the operation of the developed vacuum drum-based water pumping system.

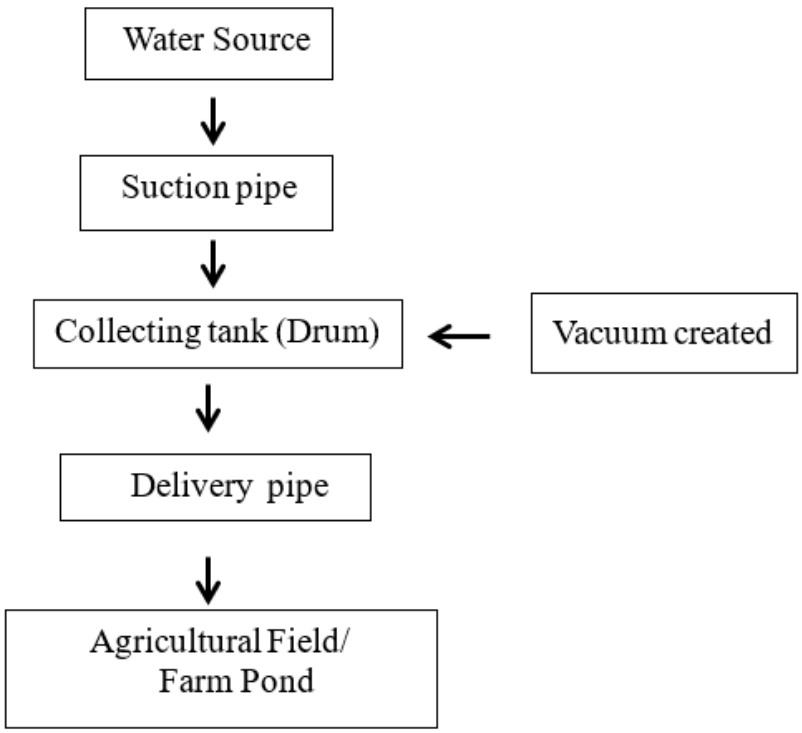

Chart 1. Flow chart of vacuum drum based water pumping system

2.3 Testing Procedure of Developed Vacuum Drum Based Water Pumping System

Measurement of suction lift: The suction lift is the vertical distance between the water level in the pond, canal or river and water level in the drum where the water stored. It is measured by the difference of lifted level of the two concerned points. The suction lift was adjusted by fixing the carrying distance at different points in the slope of field.

Measurement of discharge by the pumping system: The pumping discharge was measured using the volumetric method, calculating the time taken to fill a bucket of known volume. The pump discharge in litres per minute was calculated by dividing the amount of water discharged by the measured time. The time required to fill the bucket was counted with a stopwatch.

3. RESULTS AND DISCUSSION

The result of the experimentation have been shown in the form of graph and each point on a graph represent an average of three discharge rate. The performance and economic evolution for lifting and carrying horizontal distance was carried out in terms of associated discharge and distance.

3.1 Performance Evolution of Developed Vacuum Drum Based Water Pumping System

The developed water pumping system has been tested independently at different sites for assessing its performance. Now, the system was fixed and observations were taken on discharge with varying horizontal distance. When the suction lift is constant at 1.22 m and distance is varying from 0 to 12 m, it was observed that the discharge of water varying from 2 to 2.07 lpm, respectively (Table 1). It was also found that the discharge increases with the distance having peak discharge at 6 m i.e. 3.16 lpm and afterwards it decreases gradually as the carrying length increases, as presented in Fig. 2. This may be due to the fact that directly at the discharge near the drum, there is possibility of entry of air into the drum. With increase in carrying pipe length the opportunity of entry of air reduces while after some length the friction losses escalates and reduces the discharge. Similarly, When the suction lift is constant at 1.08 m and distance is varying from 0 to 12 m, it was observed that the discharge of water varying from 2.22 to 2.40 lpm, respectively (Table 2). It was also found that the discharge increases with the 91 distance having peak discharge at 5 m i.e. 3.53 lpm and afterwards it decreases gradually as increasing the distance, as shown in Fig. 3. When the suction lift is constant at 0.92 m and distance is varying from 0 to 14 m, it was observed that the discharge of water varying from 2.31 to 2.14 m, (Table 3). It was found that the discharge increases with the distance having peak discharge at 6 m i.e. 3.75 lpm and afterwards it decreases gradually as increasing the distance, as shown in Fig. 4.

The test was conducted at three different suction lifts via; 1.22 m, 1.08 m and 0.92 m. The highest discharge was found at suction lifts of 0.92 m at a distance of 6 m with the peak discharge of 3.75 lpm.

Table 1. Testing of vacuum drum based water pumping system at constant suction lift of (1.22 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, (sec)	Discharge, (lps)	(lpm)	(lph)	(lpd)	Distance, (m)
1	1	30	0.033	2.00	120	2880	0
2	1	27	0.037	2.22	133.3	3200	2
3	1	23	0.043	2.61	156.5	3756.5	4
4	1	19	0.053	3.16	189.5	4547.3	6
5	1	24	0.042	2.50	150.0	3600	8
6	1	27	0.037	2.22	133.3	3200	10
7	1	29	0.034	2.07	124.1	2979.3	12

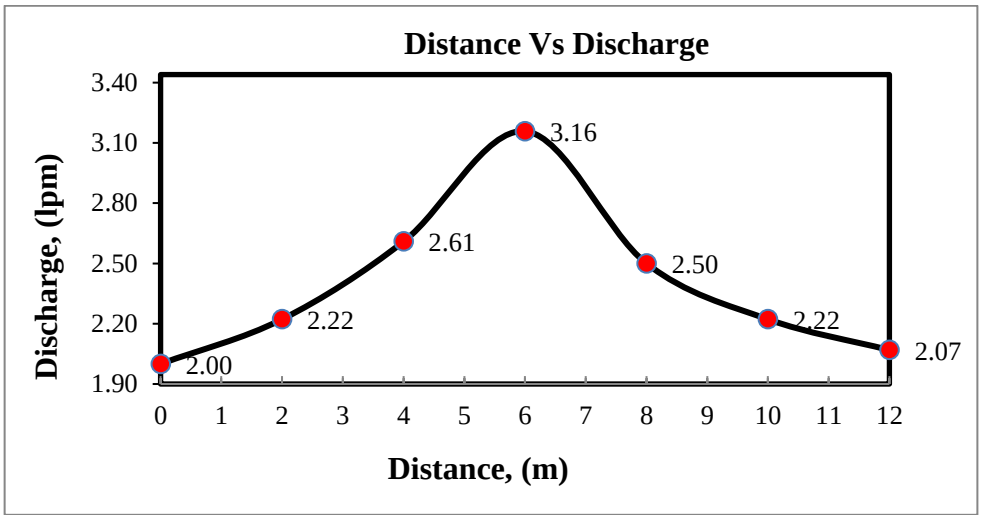

Fig. 3. Relationship between discharge and varying horizontal carrying distance at constant suction lift (1.22m)

Table 2. Testing of vacuum drum based water pumping system at constant suction lift of (1.08 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, (sec)	Discharge, (lps)	(lpm)	(lph)	(lpd)	Distance, (m)
1	1	27	0.037	2.22	133.3	3200	0
2	1	24	0.041	2.50	150	3600	1
3	1	20	0.050	3.00	180	4320	3
4	1	17	0.058	3.53	211.7	5082.3	5
5	1	21	0.047	2.86	171.4	4114.2	7
6	1	23	0.043	2.61	156.5	3756.5	10
7	1	25	0.040	2.40	144	3456	12

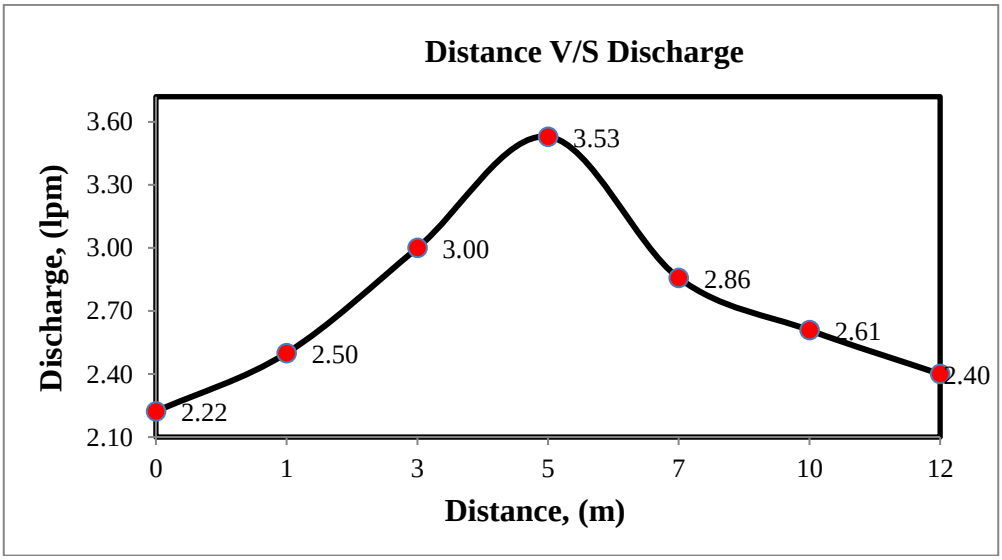

Fig. 4. Relationship between discharge and varying horizontal carrying distance at constant suction lift (1.08 m)

Table 3. Testing of vacuum drum based water pumping system at constant suction lift of (0.92 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, (sec)	Discharge, (lps)	(lpm)	(lph)	(lpd)	Distance, m
1	1	26	0.038	2.31	138.4	3323.0	0
2	1	23	0.043	2.61	156.5	3756.5	2
3	1	19	0.052	3.16	189.4	4547.3	4
4	1	16	0.062	3.75	225	5400	6
5	1	20	0.050	3.00	180	4320	8
6	1	23	0.043	2.61	156.5	3756.5	12
7	1	28	0.035	2.14	128.5	3085.7	14

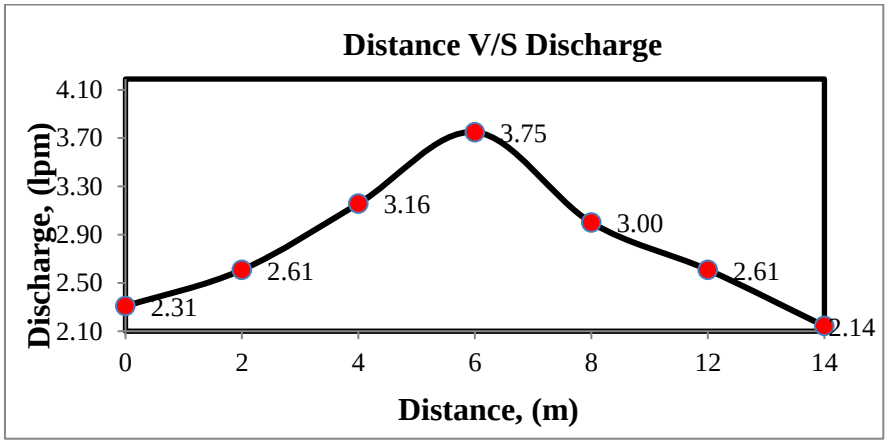

Fig. 5. Relationship between discharge and varying horizontal carrying distance at constant suction lift (0.92m)

3.1 Economic Analysis of Vacuum Drum Based Water Pumping System

Economic evaluation is a comparative analysis of inputs and outputs of two or more than two alternative activities. The economical cost evaluation of vacuum drum based water pumping system is to evaluate the optimum course of action. During the performance evaluation of vacuum drum based water pumping system at varying suction lift and distance, it was found that the average discharge of vacuum drum based water pumping is 5400 lpd at 0.92 m of suction lift. It has always been a demand that the "technology should be technically feasible, economically viable and socially acceptable". The developed technology under this study seems acceptable as a technology provided site specific and technically required conditions are met with. The discharge of Vacuum drum based pumping system seems quite less; however, it is suitable under different specific situation including standing water. The performance of the vacuum drum based water pumping system has also been compared with the conventional system of using electric AC motor (12 Volts). Further deep into comparison reveals that the diesel pumping system is more expensive as compare to vacuum drum based water pumping system.

4. CONCLUSIONS

It is appropriate to use vacuum, there are no fuel consumptions for water pumping and also it is sustainable and eco-friendly. It can wok continuously without any external sources of energy. The vacuum drum based water pumping system can give a discharge of 5400 lpd at suction lift of 0.92 m at a distance of 6 m with the peak discharge of 3.75 lpm. The cost of operation of vacuum drum based water pumping system was 352.41₹/day as compare to traditional water pumping system are much lesser then other one. Utilizing the developed system can fulfill the site specific water pumping requirement for *Badi* irrigation located apart to *nallah*, pumping water from nearby *nallah* to the nearby pond, without utilizing

electric and diesel pump. Under the favourable conditions, the developed water pumping system is definitely a much better choice as it is accomplished with several intangible benefits also.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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