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Energy Consumption Scenario of Submersible Pumps Using in the Barind Area of Bangladesh

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Abstract

In this work the ground water level and water pumping for irrigation and drinking purposes in Northern part of Bangladesh have been studied. The Barind Multipurpose Development Authority (BMDA) and Rajshahi WASA are the major water supplying authority in the Northern Part of Bangladesh by using 14386 and 87 nos of submersible pumps, respectively. The depth of ground water level remains under 30ft throughout the year that enforcing the use of submersible pumps in most parts of Barind zone. An investigation for the values of lifecycle cycle cost elements of submersible pumps has also been carried out. Energy consumption cost is dominating the life cycle cost of the pumps using in this region and improper matching of pump performance and operation/system requirements are the main causes of energy loss. It is found that 10% to 30% of the energy consumed by submersible water pumps could be saved through the change of way of operation and control system.

Keywords: Barind area, Submersible pump, Energy consumption, Ground water level.

1. Introduction

Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations [1]. Pumping systems are widespread; they provide domestic services, commercial and agricultural services, municipal water/wastewater services, and industrial services for food processing, chemical, petrochemical, pharmaceutical, and mechanical industries. The energy and materials used by a pump depend on the design of the pump, the design of the installation, and the way the system is operated. These factors are interdependent [1-3].

The demand for submersible pumps has been rising recently. World leading pump companies are continually building up the share of submersible pumps in their production volumes. While 50 years ago submersible pumps with air-filled electric motors were produced by only one company, by the 1990s all of the ten leading manufacturers of pumps produced submersibles. These companies, which together account for a third of the world market, dictate their policy to the remaining 10000 pump manufacturers [2-3].

During the draught season, the ground water goes down at lower level. It is generally caused when the groundwater heads in an aquifer fall below a critical level over a certain period of time due to natural or human induced causes and inventions. In the recent past, there was increased frequency of draughts in Bangladesh. Particularly, the Northern region of the country was severely affected by the occurrence of draughts and high variability in rainfall. At that time, farmers had to face tough situation due to scarcity of water and they had to dependent on ground water for irrigation. As the ground water level is declining day by day, it is almost impossible to lift water by low lift pump like centrifugal pump for irrigation, drinking and industrial purposes today. It has become urgent to lift water by high lift pump like submersible pump for irrigation and other purposes. Barind Multipurpose Development Authority (BMDA) takes initiatives for irrigation using ground water by installing deep well and supply drinking water in barind area where the depth of ground water level is high.

There are variety brands of submersible pumps available in the market place. Some of them are cheap but shorter lifespans and high maintenance and energy consumption costs. These cheapest brands pump draw primary interest of the most customers. Some other brands have comparatively longer lifespan with low maintenance and energy costs. The customers do not feel interest for high price of these pumps that is very smaller than the energy consumption cost during its life. Under these circumstances it is crucial to obtain an optimum solution for selecting a good pump and also operation of submersible pumps. However, the main objectives of the present study: (i) to investigate the causes of energy loss in operation of submersible pumps in Bangladesh.(ii) to study the ground water level in Rajshahi divisions for different seasons.(iii) to study the life cycle cost (LCC) for submersible pumps using in Northern part of Bangladesh.

2. Elements of Life Cycle Costs

The life cycle cost (LCC) of any pump is the total lifetime cost include initial costs, installation and commissioning costs, energy costs, operational costs, maintenance and repair costs, down time costs, environmental costs, and decommissioning and disposal cost [1].

However, LCC may be expressed mathematically by Eq^n. (1)

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d \tag{1}$$

Where,

C_{ic} is the initial cost of the pump: The initial costs usually includes: engineering (e.g. design and drawings, regulatory issues); the bid process; purchase order administration; testing and inspection; inventory of spare parts; training; auxiliary equipment for cooling and sealing water.

C_{in} is the installation cost that includes: Foundations—design, preparation, concrete and reinforcing and installation of deep well; setting and grouting of equipment on foundation; connection of process piping; connection of electrical wiring and instrumentation; connection of auxiliary systems and other utilities; provisions for flushing or 'water runs'; performance evaluation at start-up.

C_e is the energy costs: Energy consumption is often one of the larger cost elements and may dominate the LCC, especially if pumps run more than 2000 hours per year [1]. Energy consumption is calculated by gathering data on the pattern of the system output. If output is steady, or essentially so, the calculation is simple. If output varies over time, then a time-based usage pattern needs to be established. The input power calculation formula is:

$$P = \frac{Q \times H \times S}{366 \times \eta_p \times \eta_m} [\text{kW}] \tag{2}$$

Where, P = power**,** H = head (m), Q = rate of flow (m^3/hr.)**,** η_p = pump efficiency**,** η_m = motor efficiency and S = specific gravity (for water S = 1)

C_o is the operational costs: Operation costs are labor costs related to the operation of a pumping system. These vary widely depending on the complexity and duty of the system. For example, a hazardous duty pump may require daily checks for hazardous emissions, operational reliability, and performance within accepted parameters. On the other hand, a fully automated non-hazardous system may require very limited supervision. Regular observation of how a pumping system is functioning can alert operators to potential losses in system performance. Performance indicators include changes in vibration, shock pulse signature, temperature, noise, power consumption, flow rates, and pressure.

C_m is the maintenance and repair cost: Obtaining optimum working life from a pump requires regular and efficient servicing. The manufacturer will advise the user about the frequency and the extent of this routine maintenance. Its cost depends on the time and frequency of service and the cost of materials. The design can influence these costs through the materials of construction, components chosen, and the ease of access to the parts to be serviced. The maintenance program can be comprised of less frequent but more major attention as well as the more frequent but simpler servicing. The major activities often require removing the pump to a workshop. During the time the unit is unavailable to the process plant, there can be loss of product or a cost from a temporary replacement. These costs can be minimized by programming major maintenance during annual shut-down or process change-over. Major Service can be described as "pump unit not reparable on site," while the routine work is described as "pump unit reparable on site." The total cost of routine maintenance is found by multiplying the costs per event by the number of events expected during the life cycle of the pump. Although unexpected failures cannot be predicted precisely, they can be estimated statistically by calculating mean time between failures (MTBF). MTBF can be estimated for components and then combined to give a value for the complete machine**.**

C_s is the downtime cost: The cost of unexpected downtime and lost production is a very significant item in the total LCC and can rival the energy costs and replacement parts costs in its impact. Despite the design or target life of a pump and its components, there will be occasions when an unexpected failure occurs. In those cases where the cost of lost production is unacceptably high, a spare pump may be installed in parallel to reduce the risk. If a spare pump is used, the initial cost will be greater but the cost of unscheduled maintenance will include only the cost of the repair. The cost of lost production is dependent on downtime and differs from case to case.

C_{env} is the environmental cost: The cost of contaminant disposal during the lifetime of the pumping system varies significantly depending on the nature of the pumped product. Certain choices can significantly reduce the amount of contamination, but usually at an increased investment cost. Examples of environmental contamination can include: cooling water and packing box leakage disposal; hazardous pumped product flare-off; used lubricant disposal; and contaminated used parts, such as seals. Costs for environmental inspection should also be included.

C_d is the decommissioning cost: In the vast majority of cases, the cost of disposing of a pumping system will vary little with different designs. This is certainly true for non-hazardous liquids and, in most cases, for hazardous liquids also. Toxic, radioactive, or other hazardous liquids will have legally imposed protection requirements, which will be largely the same for all system designs. A difference may occur when one system has the disposal arrangements as part of its operating arrangements (for example, a hygienic pump designed for cleaning in place) while another does not (for example, a hygienic pump designed for removal before cleaning). Similar arguments can be applied to the costs of restoring the local environment. When disposal is very expensive, the LCC becomes much more sensitive to the useful life of the equipment.

3. Water Pumping by BMDA and Rajshahi WASA in Northern Part of Bangladesh

Barind Multipurpose Development Authority (BMDA), Rajshahi is supplying water by using deep well pumps mainly for irrigation in sixteen districts of Northern part of Bangladesh. In some cases the BMDA supplies drinking water in Barind areas. There are total of 14999 Nos. deep well pumps under BMDA among which 14386 Nos. pumps are submersible and 613 Nos. are turbine pumps up to June 2015 [6]. Rajshahi Water Supply and Swerage Authority (Rajshahi WASA), Bangladesh is using 87 Nos. submersible pumps for supply of drinking water and household affairs in Rajshahi City Corporation (RCC) [7]. Besides, a big number pumps of smaller capacity are running for the supply of water for irrigation and drinking purposes by other organizations/private sectors in agricultural fields and towns of the Northern part of Bangladesh. Table 1 shows distribution of zone wise deep well pumps used by BMDA and Rajshahi WASA up to June 2015.

Table 1. Distribution of zone wise deep well pumps used by BMDA and Rajshahi WASA

Sl. No.	Name of water supply authority	Name of zone	Nos of deep well pumps
1	BMDA	Rajshahi	2883
2		Chapai Nawabgonj	1641
3		Naogaon – 1	2149
4		Naogaon – 2	1951
5		Joypurhat	319
6		Bogura	236
7		Pabna	328
8		Sirajgonj	160
9		Natore	300
10		Taqurgaon	1340
11		Dinajpur	1469
12		Ponchogor	357
13		Gaibandha	374
14		Rongpur	572
15		Nilphamari	229
16		Kurigram	408
17		Lalmonirhat	283
18	Rajshahi WASA	Rajshahi City Corporation (RCC)	87
		Total Nos. of pump	15086

A survey work has been completed for the assessment of life cycle cost of submersible pumps that are using by BMDA and Rajshahi WASA. The reasonable values of the life cycle cost elements obtained from field data and practical experiences of the Engineers, Technicians and Operators engaged in the field level. The field data obtained from the survey work for determining the values of life cycle cost components for submersible pumps of capacity 1 cusec are summerised in Table 2.

The operation of a submersible pump of capacity 1 cusec that is supplying water for both irrigation and drinking purposes at the site Shantoshpur, Paba near Rajshahi City Corporation area has been investigated. The layout of the submersible pump under study is presented in Fig. 1. Figure shows that the depth of well from the earth surface is 186 feet and submersible pump is hanged at 80 feet depth submersed in ground water. A drinking water overhead tank is placed at 30 feet above the ground level. Stainless steel strainer is used to separate water from gravel packing. A screen is used for filtering water at the intake of the pump. The fluctuation of the ground water level over the year at site is shown in Fig. 2. (a).

Table 2. Field data for submersible pumps of 1 cusec capacity used by BMDA and Rajshahi WASA [6, 7]

Sl. No.	Item description	BMDA	Rajshahi WASA
1	Total number of pumps (Nos)	14999	87
2	Pump types	Submersible and only 613 nos are Turbine	Submersible
3	Pump brand	KSB, SABAR, KALAMA	KSB
4	Capacity of the pump (Cusec)	0.75 – 2.00	1.00
5	Purpose of the pump	Irrigation and drinking water supply	drinking water supply
6	Price of the pump/ initial cost (TK)	1,50,000.00/pump	5,50,000.00/pump
7	Installation cost (TK)	15,00,000.00/pump	22,50,000.00/pump
8	Annual operational cost (TK)	52,000.00/pump	2,16,000.00/pump
9	Annual energy consumption (kWhr)	34,000/pump	66,000/pump
10	Energy rate (TK/kWhr)	9.00	10.00
11	Annual pump maintenance cost (TK)	11,500.00/pump	1,00,000.00/pump
12	Average life of pump (years)	10 – 15	15 – 18
13	Water supply system	Burried	Burried

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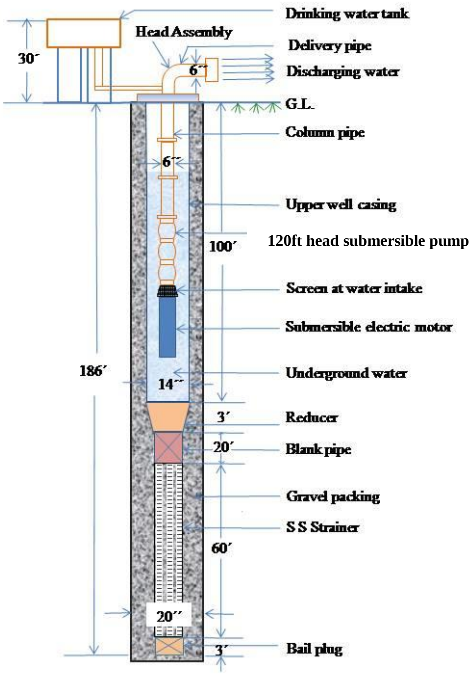
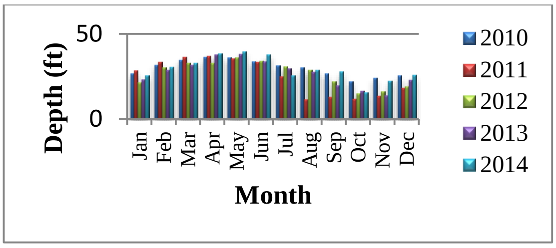


Fig. 1. Layout of 1 cusec capacity submersible pump at Shantoshpur, Paba, Rajshahi.

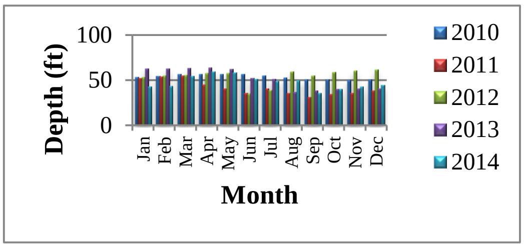
4. Water Level in Northern Part of Bangladesh

The survey work has been completed for detail study of ground water level in 25 Thana of Northern part of Bangladesh for five years. The ground water level for four sites is presented in Figs. 2(a)-(d). It is seen from these Figs. 2 (a)-(d) that the depth of ground water level is high during January-June and low during July-December. It is also seen from these figures that ground water level fluctuates yearly and on the basis of region. Fig. 2(a) and (b) shows that depth of ground water level is almost 40 feet at Shantospur, Paba, Rajshahi site and

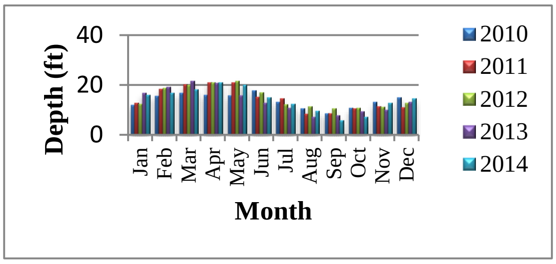
60 feet at Atahar, Nawabgonj, Chapai Nawabgonj respectively due to dryness of the river Padma. Thus it is essential to use submersible pumps in Rajshahi and Chapai Nawabgonj regions. For this reason Table 1 shows more numbers of submersible pumps are using in these regions. Fig. 2 (c) and (d) shows that during the last five years maximum depth of ground water level is 22 feet at Chakmarojpur, Gaibandha and 25 feet at Chakai, Birganj, Dinajpur respectively. As the rivers Jamuna and Tista flows beside these regions, depth of ground water level remains low almost throughout the year. This is why less numbers of submersible pumps are using in these regions shown in Table 1.



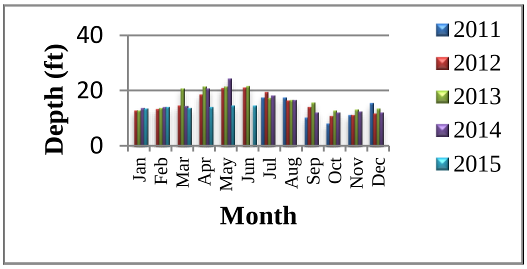
(a) Shantoshpur, Paba, Rajshahi site



(b) Atahar, Nawabgonj, Chapai Nawabgonj site



(c) Chakmarojpur, Gaibandha site



(d) Chakai, Birganj, Dinajpur site

Fig. 2. Yearly fluctuation of ground water level in different sites of Northern part of Bangladesh [6].

5. Results and Discussion

The performance of KSB brand submersible pump have been studied in Bangladesh University of Engineering and Technology (BUET) and its characteristics is presented in Fig. 3. From this figure it is seen that the pump shows best efficiency when the discharge of the pump is 1 cusec under a head of 120ft. If the pump operates in either sides of the best efficiency point, combined efficiency decreases and ultimately more energy is consumed to get specified amount of water by the pump. The energy loss of a submersible pump occurs due to various causes. The main causes of energy loss includes: operation with over calculated head; operation with high flows; running far from their best efficiency point (BEP); change in surface roughness of impeller and diffuser; change in flow path size in the pump; variable speed drive of the pump; improper matching of pump performance and system requirements [4-5].

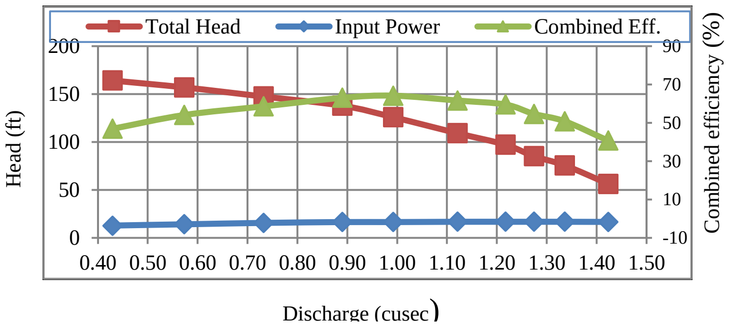
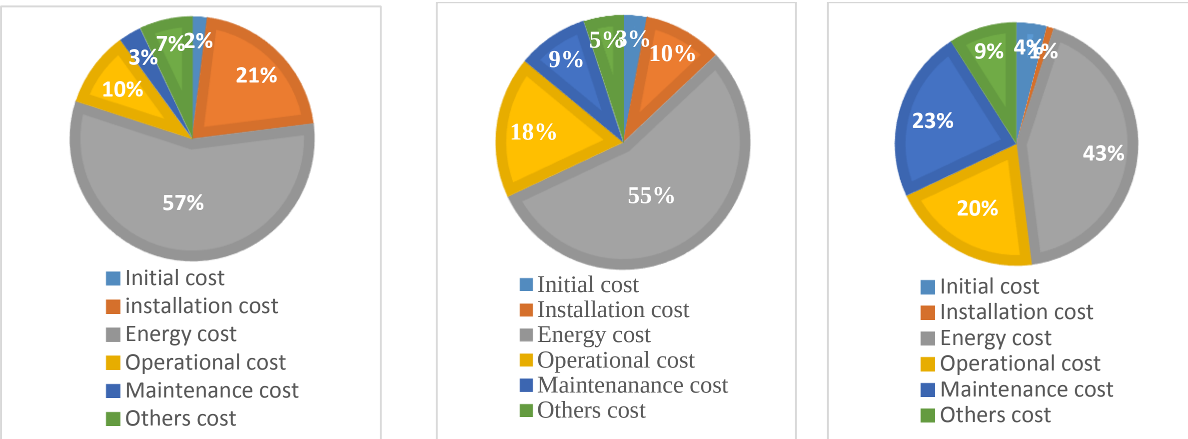


Fig. 3. Characteristics of KSB brand submersible pump of capacity 1 cusec under head of 120 ft using by BMDA

The life cycle cost of a submersible pump using by BMDA and Rajshahi WASA have been determined with the help of Eqt^{n} – (1) and field data from Table 2. The calculated life cycle cost components are presented in Fig. 4 (a)-(b) and also compared with those of a waste water pump of Fig.(c). From these figures it can be seen that energy and installation costs of submersible pump using by BMDA and Rajshahi WASA are higher but maintenance and operation costs are lower than that of waste water pump. It is also seen from these figures that operational cost of Rajshahi WASA is higher than that of BMDA because of the pumps of WASA runs throughout the year while the pumps of BMDA runs mostly during irrigation period. The energy cost of BMDA and WASA pumps is higher than that of waste water pump. Other cost components are almost similar. The life cycle analysis for the pump ensures that the energy cost component is the major element. From Fig. 3 it can also be seen that if the pump delivers water under head of 100ft, then its combined efficiency will reduced to 60% and consequently energy loss up to 10%. On the other hand if the pump operates under a head of 150ft and energy loss becomes up to 30%. These loss can be reduced by repositioning (lowering)/uppering) the pumps twice a year, one in the month January and other repositioning in July following ground water level history in respective sites. Drinking water supply using the same pump of irrigation site add extra head on the pump. This additional head reduces the efficiency of the pump.



(a) Pump of the BMDA, Rajshahi (b)Pump of the Rajshahi WASA, (c) Waste water pump U.S.A

Fig 4. Life cycle cost for a 1 cusec, 120 ft head submersible pump using by BMDA, Rajshahi WASA and Waste water pump

6. Conclusions

The initial purchase price is a small part of the life cycle cost for high usage pumps. Operating requirements may sometimes override energy consumption considerations, an optimum solution is still possible. A greater understanding of all the components that make up the total cost of ownership will provide an opportunity to dramatically reduce energy consumption, operational, and maintenance costs.

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