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STUDY ON AIRLIFT PUMP AS A PUMPING AND AERATION SYSTEM IN AQUACULTURE

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ABSTRACT

This paper aims to study the performance of using the airlift pump as a pumping and aeration system in the aquacultural systems. Water flow rates, dissolved oxygen and temperature were measured, and standard aeration efficiencies (SAE) were determined in airlift pumps 5.0, 7.5 and 10.0cm in diameter, 0.5, 1.0 and 1.5m in length and submergence of airlifts were 70, 80 and 90% from pipe length to develop performance data that might be useful to aquaculturists. Air was injected through leaky pipes (ϕ 13mm).

The results indicated that, the water flow rate and standard aeration efficiency (SAE) increased with increasing of both length and diameter of airlift pumps and submergence ratio. The water flow rate increased with air injection until it reaches to the peak then it decreased. The standard aeration efficiency (SAE) increased in narrow range with increasing the air flow rate, after this range it decreased with increasing the air flow rate.

Keywords: Airlift – Pump – Aeration – Aquaculture - SAE

1. INTRODUCTION

Next to centrifugal pumps, air lift pumps are probably the most common type of the pump used in the aquaculture industry (Lawson, 1995).

Air lift pumps are described by Wheaton (1992) and Spotte (1979). An air lift pump uses a rising column of air to generate flow in a liquid system. The most common type air lift consists of an open-ended tupe or pipe that is partially submerged in fluid into which air is injected. Air lift

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pumps operate due to the difference in specific gravity between the fluid on the outside and the air fluid-mixture on the inside of the tube. Air injection into the tube causes the specific gravity of the fluid mixture in the tube to be lowered.

Airlift pumps have been used to move liquids since at least 1797 (Ivens 1914). Small water reuse systems such as aquaria for hobby fish use airlift pumps to move water through the filter system. The simplicity of airlift pumps makes them a first choice for use in aquaria (Castro et al., 1975, Spotte 1979). However, maintaining an even flow of air and water from multiple pumps connected to a common air source has been a problem. The water flow is usually adjusted with a series of small valves which control air delivery to individual pumps. In larger systems it is difficult to properly balance air flow with a series of valves, but, systems properly designed with fixed orifices to regulate airflow will work reliably.

Water circulation and aeration in aquaculture ponds have increased primary productivity, reduced stratification, increased nutrient solubility, reduced organic accumulation on the bottom, and increased fish production. Pond aeration techniques have been investigated to increase the growth, survival, and production of both fish (Ito et al., 1974; Sarig and Marek, 1974; Parker, 1979, 1983; Parker et al., 1984) and crustaceans (Morrissy, 1979; Apud and Camacho, 1980). Airlift pumps of various sizes and configurations have been used to circulate and aerate pond water, but due to fluctuating water level in ponds, not all systems have worked reliably and efficiently. The design and flow predictions for airlift pumps have typically been based on data derived from small systems suitable for aquaria and tanks, or from performance charts showing the vertical lift capacity of airlifts that are 40-90% submerged (Spotte, 1970; Castro et al., 1975; Murray et al., 1981).

Several investigators have reported the flow rates of small-diameter airlift pumps used to lift water vertically. Spotte (1970) presented data on the vertical lift capacity of airlift "pumps 2.5-15 cm in diameter and 40-70% submerged. Castro et al. (1975) reported on the pumping rate of airlift pumps 1.27-7.62 cm in diameter, 0.3 to 3.7 m long, and 40-70% submerged.

Airlift pumps used to circulate water in ponds operate almost totally submerged and need to move water only from the bottom of the pond to the surface. The theory of operation and equations describing performance for airlift pumps operated in this mode has previously been reported by Nicklin (1963). Murray et al. (1981) defined the nomenclature used to describe airlift pumps, discussed theory of operation, and presented performance data on pumps of 1.78-3.65 cm in diameter operated at 50-80% submergence.

One of the main factors affecting the efficiency of an air lift is the submergence of the lift tube. Submergence is the percentage of the overall length of the lift tube beneath the surface of the liquid, expressed as a decimal value. As the submergence increases, the efficiency increases. The submergence ratio is the ratio of the length of the tube beneath the surface to the total tube length. The minimum acceptable value for submergence ratio for the operation of aquaculture air lifts is 80%.

The objective of this study was to determine the influence of four variables: pipe length, pipe diameter, submergence ratio and volume of air injected on the water flow rate and standard aeration efficiency (SAE) of airlift pumps suitable for use in aquaculture ponds.

2. EXPERIMENTAL PROCEDURE

The present study aimed to study the performance of air lift pump as a pumping and aeration systems in the aquacultural systems. The study was carried out at a private farm, near Cairo, Egypt. The effect of airflow rate, pipe length, pipe diameter and submergence of stand pipe on airlift pump discharge and standard aeration efficiency (SAE) in the aeration tank was studied.

2.1. System description:

This system consists of a pressure air blower, PVC pipes (50mm in diameter), leaky pipes (13mm in diameter), and PVC couples (elbow and T-shape). The pressure air blower (3 Phase) works on Maximum Duty 2.0m H_2O at free air. A PVC pipe (50mm in diameter) was fitted on the blower, as shown in Figure (1). This pipe was ended by a T-shape PVC couple, which was branched into two directions (0.5 meter each). The leaky pipes were mounted on these branches. Aeration tank was built of concrete and its dimensions were 1.0×1.0×1.5m for width, length and depth, respectively. Airflow was regulated using 2” ball valve.

Airlift pumps with nominal diameters of 5.0, 7.5 and 1.0cm were constructed from polyvinyl chloride (PVC) pipe. Each pump consisted of a vertical section of pipe with lengths of 0.5, 1.0 and 1.5m, fitted with a 90° elbow at the upper end (Figure 1). Air was injected through a leaky pipe ϕ 13mm placed at the center of stand pipe.

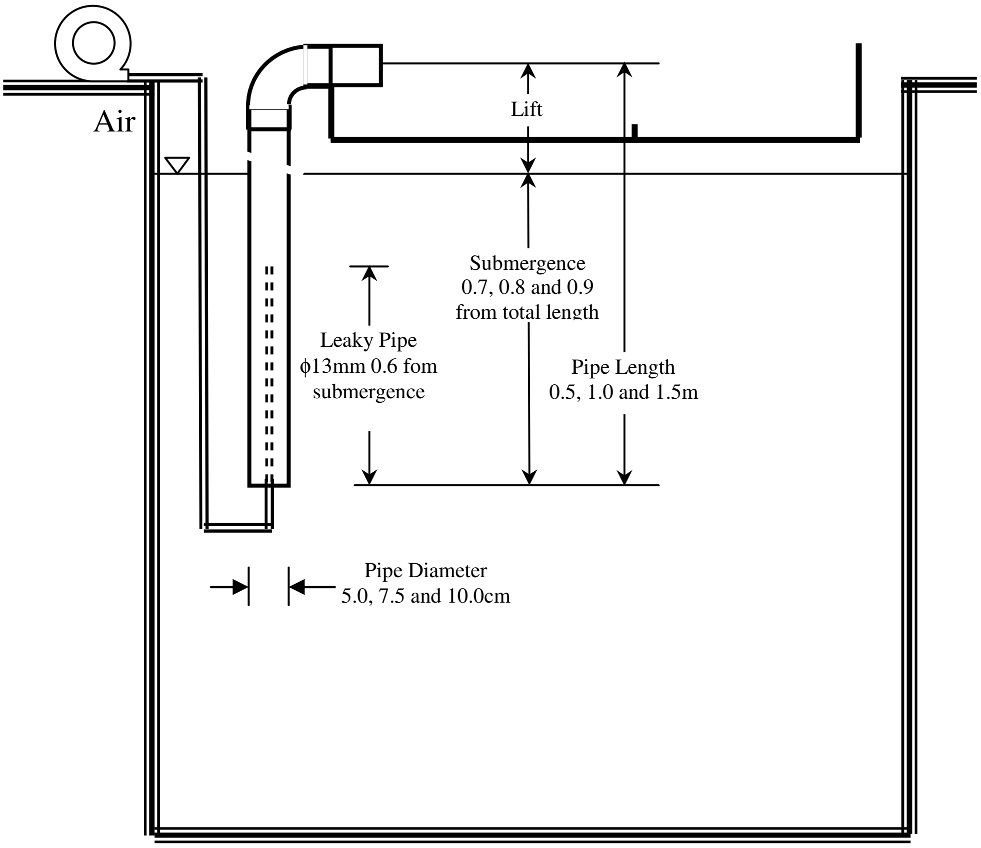

Figure (1): Layout of the experimental procedure.

Air volume was regulated with a ball valve type. Measurements were made when water and air temperature was about 20-25°C. All measurements of water and air represent the mean of three independent measurements made at approximately 5-min intervals after flows were stabilized. The standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) in the aeration tank at different treatments were determined.

2.2. Measurements:

Airflow rate was measured and controlled by measuring the air velocity in the pipe. It was measured using a “hot wire anemometer” (Service: Testo, GmbH &Co., Germany). The air pressure was measured with a manometer, which was inserted in the air stream before and after the air blower through a small opening on the PVC pipe. The dissolved oxygen concentration and temperature in aeration tank were measured by a dissolved oxygen meter (Cole-Parmer Instrument Co., Model #53012-Series). Water flow coming out of the airlift pump is collected in a wooden box with a rectangular weir. The dimensions of the box are 0.7×0.13×0.3m. Water pumped out by the airlift flows into the weir box from the bottom, goes over the weir head and then discharges back into tank.

2.3. The standard aeration efficiency (SAE) determination:

To determine the standard aeration efficiency (SAE) in the aeration tank, the current dissolved oxygen concentration was measured, and the water in the tank was deoxygenated with 0.1-mg/L cobalt chloride ($CoCl_2.6H_2O$) and 10.0-12.0 mg/L sodium sulfite ($Na_2 SO_3$) for each mg/L of dissolved oxygen (Boyd, 1986). The cobalt chloride and sodium sulfite were dissolved in a pail of water from the tank and splashed over the water surface in the tank. The dissolved oxygen meter probe was immersed in the middle of the water tank. The dissolved oxygen concentrations (DO) were measured at one-minute intervals until the dissolved oxygen reached 85% of saturation.

The dissolved oxygen deficits (OD) were obtained by subtracting dissolved oxygen concentrations in the tank from dissolved oxygen concentrations at saturation (Ce), which estimated, using the following equation (Soderberg, 1995):

$$Ce = 125.9 / (32 + 1.8\ T)^{0.625} \quad \textbf{(1)}$$

where:

Ce = the equilibrium concentration of oxygen, mg/L at atmospheric pressure;

T = the water temperature, °C.

The oxygen transfer coefficient was computed by using the points representing 10% and 70% oxygen saturation (Boyd and Watten, 1989) and using the following equation:

$$(K_La)_T = [LN\ (OD_1) – LN\ (OD_2)] / [(t_2 - t_1)/60] \quad \textbf{(2)}$$

where:

$(K_La)_T$ = overall oxygen transfer coefficient at temperature of test water, h^{-1};

OD_1 = oxygen deficit at point 1, mg/L;

OD_2 = oxygen deficit at point 2, mg/L;

t_1 = time at point 1, min;

t_2 = time at point 2, min.

Water temperature influences oxygen transfer. The oxygen transfer coefficient was adjusted at 20 °C using the following equation:

$$(K_La)_{20} = (K_La)_T \div \theta^{T-20} \quad \textbf{(3)}$$

where:

$(K_la)_{20}$ = oxygen transfer coefficient at 20 °C, h^{-1};

θ = it ranges from 1.016-1.047, 1.024 is recommended. (Lawson, 1995).

The overall oxygen coefficient was used to estimate the standard oxygen transfer rate in the aeration tank. The oxygen transfer rate was calculated at standard conditions (0 mg/L-dissolved oxygen, 20 °C, and clear water) using the following equation:

$$SOTR = (K_la)_{20} \times DOC_{20} \times V \times 10^{-3} \quad \textbf{(4)}$$

where:

SOTR = standard oxygen transfer rate, kgO_2/h.

DOC_{20} = dissolved oxygen at saturation for 20°C and standard pressure, mg/L.

V = volume of water in tank, m^3.

The ideal gas law was used to correct the air flow meter data collected at test temperature and pressure to standard conditions. The compressibility factor deviation was neglected at the modest pressures achieved (i.e. assumed Z=1).

Power usage was calculated by the polytropic compression curve which expresses the relation of absolute pressure, P, to volume, V, as:

PV^n=constant (Perry et al., 1993).

Using the adiabatic assumption that n is equal to the ratio of specific heats, Cp/Cv, commonly known as k, is valid for blowers where the compression ratios and discharge pressures are low (WPCF, 1988).

Equating the work done in a compression cycle to the weight of gas moved through a resistance yields the adiabatic head. This head times the mass flow rate gives an expression for the work per unit time, or power. For air k=1 (Perry et al., 1993) and thus:

$$kW_{ad} = 9.73\times10-66.67\,Q_1P_1\left[\left(\frac{P_2}{P_1}\right)^{0.286}-1\right] \qquad \textbf{(5)}$$

where kW_{ad} is adiabatic power (kW),

Q_1 is air volumetric flow rate (l min^{-1}) and

P_1, P_2 are blower inlet and discharge pressures (kPa).

The standard aeration efficiency (SAE) was calculated by dividing the transfer rates by the delivered blower power calculated from equation (5) (adapted from ASCE, 1992):

$$\text{SAE (kg } O_2 \text{ kWh}^{-1}) = \text{SOTR} / kW_{ad} \qquad \textbf{(6)}$$

3. RESULTS AND DISCUSSION

3.1. Water Flow Rate.

Numerous researchers have developed empirical and theoretical descriptions of the fluid delivery function for various air-lift configurations (Nicklin, 1963; Castro and Zielinski, 1980, Bronikowski and McCormick, 1983; Reinemann, 1987; Wurts et al., 1994). However, the predictive accuracy of such tools is somewhat restricted because of the significant effect of specific configuration details such as entrance conditions and injector type. For the air-lift design tested in this research, Polynomial regression provided the best-fit model for empirically derived water flow rates for airlift pumps, water delivery increased with air injection until it reach to the peak then it decreased, as shown in Fig. 2. Water flow also increased with the depth of submergence, but decreased with lift height. Thus, Table (1) illustrates the constants, regression determination and standard error for an equation for predicting fluid flow.

Figures (2) shows the water flow rate (l min^{-1}) for three pipe lengths (0.5 (L1), 1.0 (L2) and 1.5m (L3)), three pipe diameter (5.0 (D1), 7.5 (D2) and 10cm (D3)) and three submergence ratio (70% (S1), 80% (S2) and 90% (S3)) respectively, at different airflow rates (8.4-3387.0 liters min^{-1}).

The no-flow conditions described by Murray et al. (1981) were approached in our test at 0.5m length in the diameter pipes 7.5cm at 70% submergence ratio and 10.0cm at 70% and 80% submergence ratio.

Pickert (1932) cautioned that only flows from airlifts of identical submergence and length could be compared with each other. Recognizing that caution, we compared the flow rates of our 5.0cm diameter and 1.0m length air-lift pump with air injected at 72 liters min^{-1}, at submergence ratio 70, 80 and 90% (Fig. 2) with flow rates studied by Loyless and Malone (1998).

Our flow rates were 72, 102 and 138 liters min- l, respectively, for the 70, 80 and 90% submergence ratio, compared with the rates of 50.3, 68.6 and 102.5 liters min^{-1} studied by Loyless and Malone. These differences were probably due to differences in air diffuser. Our measurements were made with the leaky pipes as an air diffuser. Loyless and Malone measured flow with use air stone as an air diffuser.

Table 1: The constants, regression determination (R), standard error (SE) and the peak for an equation for predicting water flow as a polynomial regression ($Y=a+bX+cX^2+dX^3+eX^4$)

Pipe Diameter*	Length & Submergence**	a	b	c	d	e	SE	R	Peak
D1	L1S1	-0.15	-0.23	1.3×10^{-2}	-1.3×10^{-4}	4.0×10^{-7}	0.86	0.99	72
	L1S2	-2.84	0.76	-2.0×10^{-3}	-2.8×10^{-5}	1.0×10^{-7}	2.67	0.98	72
	L1S3	-11.1	2.58	-3.1×10^{-2}	1.5×10^{-4}	-2.8×10^{-7}	7.84	0.96	72
	L2S1	-4.12	1.22	-4.1×10^{-3}	5.1×10^{-6}	-2.2×10^{-9}	7.20	0.98	198
	L2S2	8.73	1.50	-5.5×10^{-3}	7.3×10^{-6}	-3.3×10^{-9}	11.0	0.97	198
	L2S3	47.7	1.49	-5.7×10^{-3}	7.7×10^{-6}	-3.6×10^{-9}	15.8	0.95	198
	L3S1	-6.9	1.37	-4.4×10^{-3}	5.5×10^{-6}	-2.4×10^{-9}	6.5	0.99	258
	L3S2	13.9	1.45	-4.1×10^{-3}	4.2×10^{-6}	-1.4×10^{-9}	14.1	0.97	258
	L3S3	71.5	1.22	-3.6×10^{-3}	3.6×10^{-6}	-1.2×10^{-9}	11.7	0.98	258
D2	L1S1	-	-	-	-	-	-	-	-
	L1S2	-28.0	0.80	-4.5×10^{-3}	8.7×10^{-6}	-9.5×10^{-9}	0.4	0.99	129
	L1S3	-9.8	1.83	-1.3×10^{-2}	4.0×10^{-5}	-4.7×10^{-8}	0.2	0.99	129
	L2S1	-59.6	1.57	-4.5×10^{-3}	5.3×10^{-6}	-2.4×10^{-9}	1.2	0.99	368
	L2S2	-28.2	1.91	-5.4×10^{-3}	5.9×10^{-6}	-2.3×10^{-9}	8.6	0.99	368
	L2S3	76.3	1.58	-4.5×10^{-3}	4.8×10^{-6}	1.8×10^{-9}	7.5	0.99	368
	L3S1	-19.1	1.32	-1.8×10^{-3}	9.8×10^{-7}	-1.7×10^{-10}	15.5	0.98	478
	L3S2	31.2	1.49	2.2×10^{-3}	1.2×10^{-6}	-2.2×10^{-10}	19.3	0.98	478
	L3S3	159.0	1.19	-1.8×10^{-3}	9.6×10^{-7}	-1.7×10^{-10}	20.3	0.98	478
D3	L1S1	-	-	-	-	-	-	-	-
	L1S2	-	-	-	-	-	-	-	-
	L1S3	-66.4	2.31	-1.4×10^{-2}	3.6×10^{-5}	-3.5×10^{-8}	0.54	0.99	189
	L2S1	-98.3	1.11	-2.4×10^{-3}	2.5×10^{-6}	-1.2×10^{-9}	2.8	0.99	415
	L2S2	-87.3	1.96	-4.8×10^{-3}	4.9×10^{-6}	-1.9×10^{-9}	2.13	0.99	415
	L2S3	94.9	1.37	-2.7×10^{-3}	2.0×10^{-6}	-5.9×10^{-10}	16.8	0.98	415
	L3S1	-86.3	1.50	-1.6×10^{-3}	6.7×10^{-7}	-1.0×10^{-10}	11.2	0.99	912
	L3S2	-26.2	1.90	-2.7×10^{-3}	1.0×10^{-6}	-1.6×10^{-10}	25.1	0.99	912
	L3S3	4.6	-0.007	6.5×10^{-6}	-2.3×10^{-9}	2.9×10^{-13}	0.12	0.99	912

* D1=5.0cm, D2=7.5cm, D3=10.0cm.
** L1=0.5m, L2=1.0m, L3=1.5m.
S1=0.7, S2=0.8, S3=0.9.

The effect of diameter of airlift pump was evaluated. For example, in a airlift operated with about 200.0 liters min^{-1} of air injected at a submergence ratio of 90%, the flow in a 0.5, 1.0 and 1.5m length airlift increased about 32.0, 14.0 and 26.0% respectively, when the diameter of airlift pump was increased from 7.5 to 10.0cm.

The effect of length of airlift pump was also evaluated. For example, in a 5.0, 7.5 and 10.0cm diameter airlift operated with about 200.0 liters min^{-1} of air injected at a submergence ratio of 90%, the flow rate was about 19.0%, 45.9% and 96.0% greater when the airlift length was 1.5m than when it was 1.0m, respectively.

The flow rates presented in figure 2 are about 19.6-85.3% greater than the maximum flows obtainable from airlifts of similar size with similar rates of air injection at difference of submergence ratio. For example, in a 5.0cm diameter airlift operated with about 200.0 liters min^{-1} of air injected at a length of 1.5m, the flow rate was about 27.6% greater when the submergence ratio was 80% than when it was 70%, and about 19.6% greater when the submergence ratio was 90% than when it was 80% (Fig. 2). The flow in a 7.5cm diameter airlift increased about 36.4% when the submergence ratio was increased from 70% to 80%, and about 27.8% when the submergence ratio was increased from 80% to 90% (Fig. 2). Changing the submergence ratio in a 10cm diameter airlift from 70% to 80% increased flows about 85.3%, whereas changing the submergence ratio in the same diameter airlift from 80% to 90% increased flows about 55.2% (Fig. 2). The depth of submergence or, conversely, the vertical lift, affected flow rates in proportion to the diameter of the airlift. The effect of change in depth of submergence on flow was only slight in small-diameter airlifts, but was very substantial in large diameter pipes.

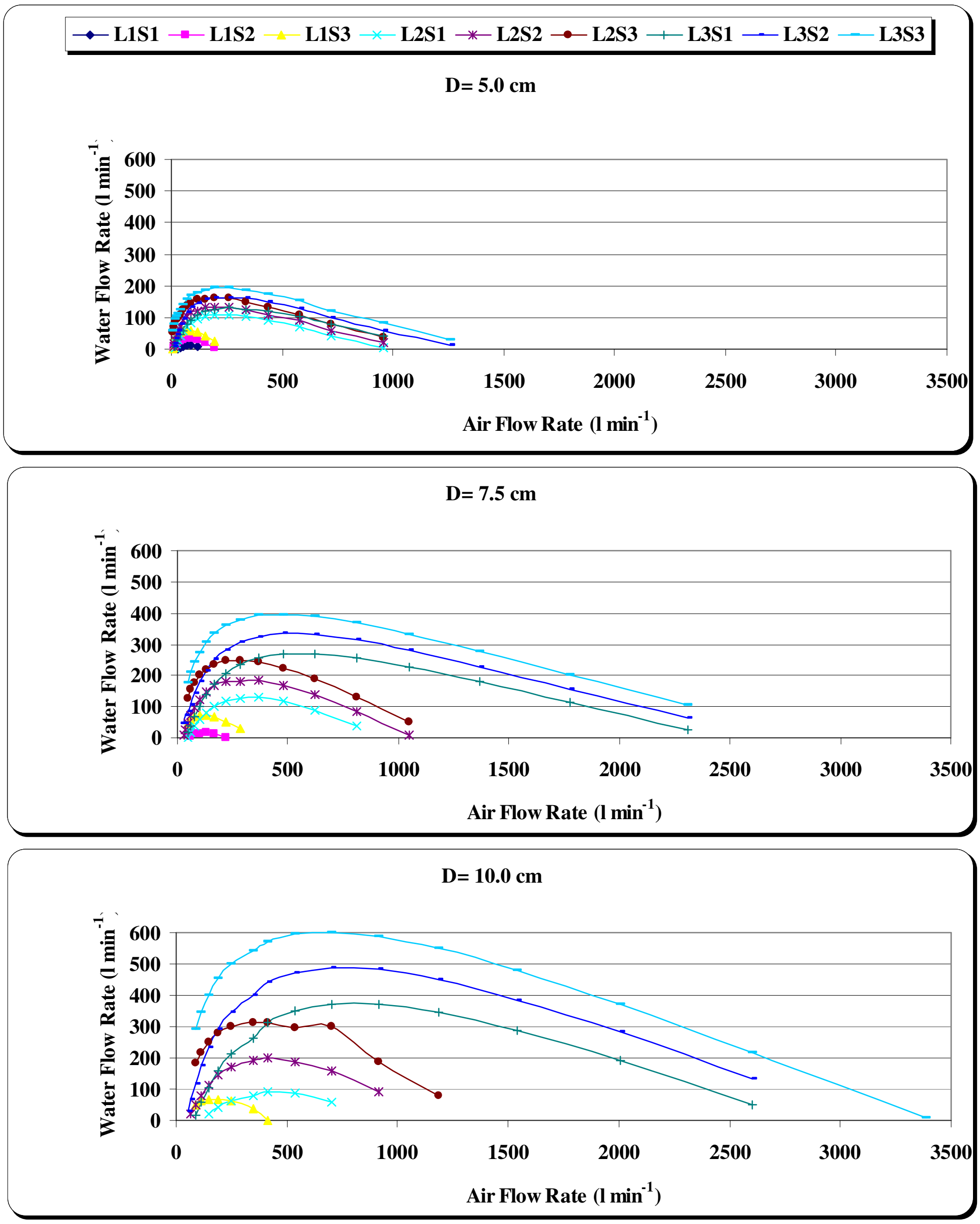

Figure: 2. Water flow rates of airlift pumps.

3.2. Standard Aeration Efficiency (SAE).

Figure (3) shows the standard aeration efficiency ($kgO_2\ kWh^{-1}$) for three pipe lengths (0.5, 1.0 and 1.5m), three pipe diameter (5.0, 7.5 and 10cm) and three submergence ratio (70%, 80% and 90%) respectively, at different airflow rates (0.25, 0.50, 0.75 and 1.0$m^3\ min^{-1}$). The results clarity that the standard aeration efficiency (SAE) increased in narrow range with increasing the air flow rate, which was 0-90.0, 0-167.6 and 0-349,4 for 5.0, 7.5 and 10.0cm airlift diameter, respectively. After this range it decreased in increasing the air flow rate. For example, in a 1.5m length it decreased from 3.72-0.24, 4.24-0.37 and 4.18-0.39 $kgO_2\ kWh^{-1}$ when the air flow rate increased from 19.2-1260, 45.0-2310 and 86-2604 l min^{-1} at 90% submergence ratio for 5.0, 7.5 and 10.0m airlift diameter, respectively. This may be due to increasing the flow rate required more power and according to Boyd and Moore, 1993, the SAE is inversely proportional to the power.

The effect of diameter of airlift pump was evaluated. For example, in a airlift operated with about 200.0 liters min^{-1} of air injected at a submergence ratio of 90%, the standard aeration efficiency in a 0.5, 1.0 and 1.5m length airlift increased about 38.0, 30.0 and 40.0% respectively, when the diameter of airlift pump was increased from 7.5 to 10.0cm.

The effect of length of airlift pump was also evaluated. For example, in a 7.5 and 10.0cm diameter airlift operated with about 200.0 liters min^{-1} of air injected at a submergence ratio of 90%, the standard aeration efficiency was about 12.1% and 20.9% greater when the airlift length was 1.5m than when it was 1.0m, respectively.

For example, in a 7.5cm diameter airlift operated with about 200.0 liters min^{-1} of air injected at a length of 1.5m, the standard aeration efficiency was about 6.8% greater when the submergence ratio was 80% than when it was 70%, and about 5.5% greater when the submergence ratio was 90% than when it was 80% (Fig. 3).

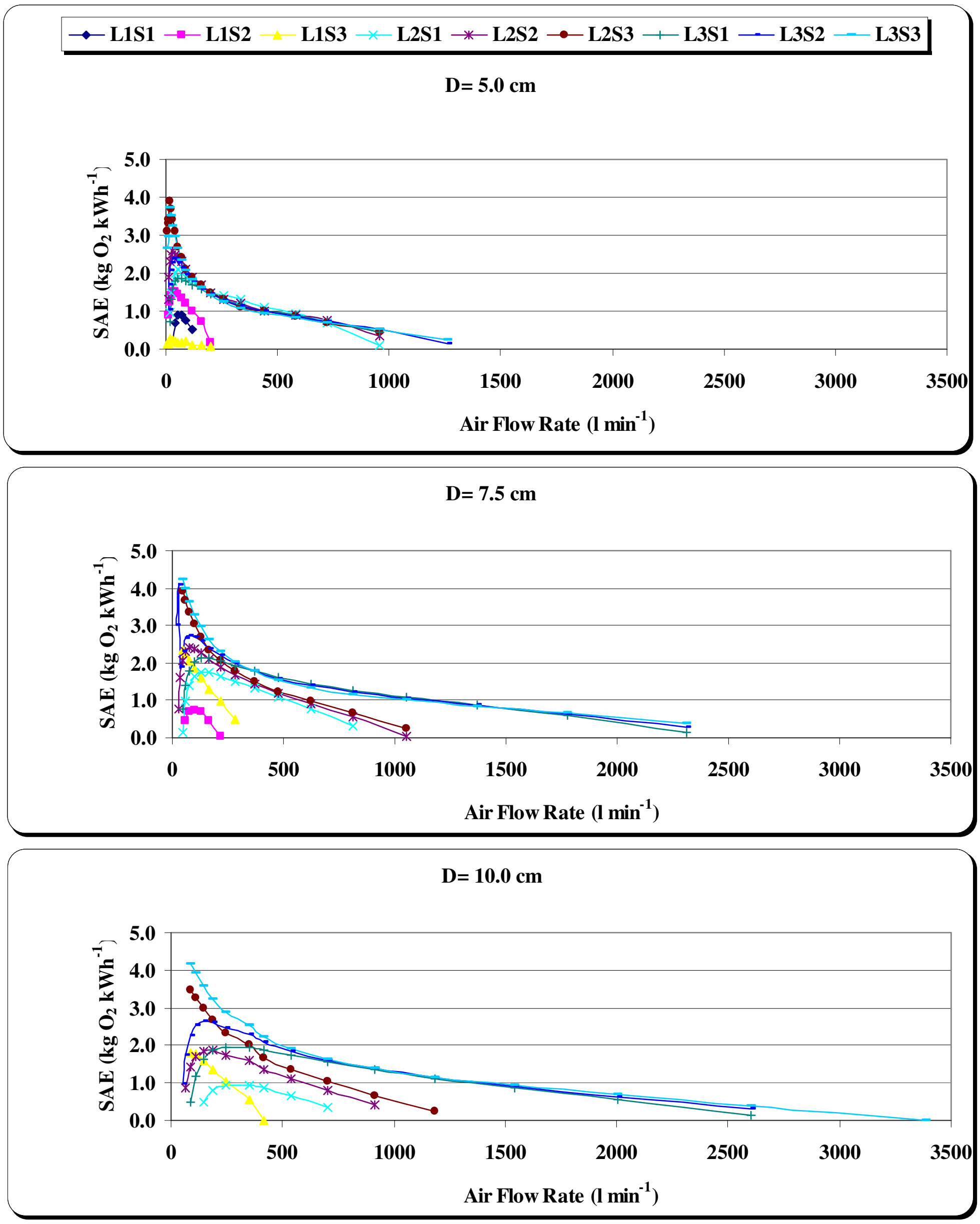

Figure: 3. Standard aeration efficiency (SAE) of airlift pumps.

3.3. Feasibility Study.

On the basis of the cost of materials, installation, and operation, we found 7.5 and 10cm diameter and 1.0m length airlift pumps to be more appropriate than either larger or smaller ones for decertifying 0.02 to 2.0 hectares ponds. According to Soderberg (1995), one airlift pump per 0.02 or 0.05 hectare pond prevented stratification when 110 liters min^{-1} of air was injected into the vertical riser at a point 90 cm below the surface of the water. In larger ponds 7.5 and 10 cm diameter pumps have been installed at the rate of 20 per hectare.

This means that, a regenerative blower with a nameplate rating of 1.12 kW (1.5 hp) can serve airlift pumps required per one hectare. Vertical lift was essentially 10cm as these airlifts were adjusted for maximum flow to produce circulation and vertical mixing of water in ponds.

On the other hand, extensive fish farming in Egypt is mainly dependent on paddle wheel for aeration, where, one hectare needs eight paddle wheels which require 4.0 kW (Boyd, 1986).

This means replacing paddle wheels with airlift pumps saves almost 72 % of the energy required for aeration.

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<u>الملخص العربى</u>

دراسة على مضخات الدفع الهوائي كنظام للضخ والتهوية في الزراعة المائية

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مضخات الدفع الهوائي تستخدم منذ وقت طويل في الزراعة المائية لتدوير وتهوية المياه داخل أحواض الاستزراع المائي. ولهذا كان الهدف من هذا البحث هو دراسة تأثير كل من كمية الهواء المدفوعة وقطر وطول الطلمبة وكذلك نسبة انغماس الطلمبة على كل من التصرف والكفاءة النسبية للتهوية لكل طلمبة. ولتحقيق هذا الهدف تم اختيار ٣ أقطار من المواسير ٥,٠، ٧,٥ و ١٠,٠سم ولكل منها ٣ أطوال مختلفة ٠,٥، ١,٠ و ١,٥ متر. تم اختبار كل من هذه الطلمبات عند معدلات تصرف هواء ما بين بين ٨,٤-٣٣٨٧,٠ لتر\دقيقة، وكذلك أيضاً عند نسب انغماس ٧٠، ٨٠ و ٩٠% داخل حوض التجربة، وهو عبارة عن حوض أبعاده ١,٠م عرض، ١,٠م طول و ١,٥م إرتفاع. تم قياس كل من ضغط الهواء قبل وبعد ضاغط الهواء وسرعة الهواء داخل الأنابيب بعد خروجها من الضاغط. تم أيضاً قياس تصرف الطلمبات من خلال هدار مستطيل. تم تقدير كل من معدل انتقال الأكسجين القياسي (SOTR) والكفاءة القياسية للتهوية (SAE) وذلك للحكم على أداء تلك الطلمبات كنظام للتهوية.

أظهرت النتائج الآتي:

أولاً: عند استخدام الطلمبات كنظام للضخ.

١- زيادة كمية الهواء المدفوع أدت إلى زيادة تصرف جميع الطلمبات حتى الوصول إلى أعلى تصرف، بعدها يأخذ التصرف فى الانخفاض بزيادة كمية الهواء المدفوع. فعلى سبيل المثال، في الطلمبة التى قطرها ٧,٥سم وطولها ١,٠م ونسبة الانغماس بها ٨٠%، زاد تصرفها من ٧,٧٤ – ١٨٤,٩٨ لتر\دقيقة عند زيادة كمية الهواء المدفوع من ٢٦,٧ – ٣٦٨,٤ لتر\دقيقة، ثم أخذ فى الانخفاض من ١٨٤,٩٨ – ٧,١٤ لتر\دقيقة عند زيادة كمية الهواء المدفوع من ٣٦٨,٤ – ١٠٥٠,٠ لتر\دقيقة.

٢- أدت زيادة كل من قطر و طول الطلمبة إلى زيادة تصرفها. فعلى سبيل المثال، عند دفع كمية من الهواء حوالي ٢٠٠ لتر\دقيقة وكانت نسبة الانغماس بها ٩٠%، زاد التصرف فى الطلمبات التى أطوالها ٠,٥، ١,٠ و ١,٥متر بنسبة ٣٢,٠، ١٤,٠ و ٢٦,٠%، على الترتيب عند زيادة قطر الطلمبة من ٧,٥ إلى ١٠,٠سم. كما زاد التصرف فى الطلمبات التى أقطارها ٥,٠، ٧,٥ و ١٠,٠سم بنسبة ١٩,٠، ٤٥,٩ و ٩٦,٠%، على الترتيب عند زيادة طول الطلمبة من ١,٠ إلى ١,٥ متر.

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٣- تأثير نسبة انغماس الطلمبة على التصرف تم تقييمها أيضاً. فعلى سبيل المثال، في الطلمبة التى قطرها ٧,٥سم وطولها ١,٥م عند دفع كمية من الهواء حوالي ٢٠٠ لتر\دقيقة ، زاد تصرفها بنسبة ٣٦,٤% عند زيادة نسبة الانغماس من ٧٠ – ٨٠%، كما زاد تصرفها بنسبة ٢٧,٨% عند زيادة نسبة الانغماس من ٨٠ – ٩٠%.

ثانياً: عند استخدام الطلمبات كنظام للتهوية.

١- زيادة كمية الهواء المدفوع أدت إلى زيادة الكفاءة القياسية للتهوية لجميع الطلمبات ولكن فى مدى ضيق جداً وهو من صفر-٩٠,٠، من صفر-١٦٧,٦ و من صفر-٣٤٩,٤، لكل من الطيمبات التي أقطارها ٥,٠، ٧,٥ و ١٠,٠سم على الترتيب. بعد هذا المدى الضيق تأخذ الكفاءة فى الانخفاض بزيادة كمية الهواء المدفوع. فعلى سبيل المثال، في الطلمبة التى طولها ١,٥م ونسبة الانغماس بها ٩٠%، إنخفضت الكفاءة من ٣,٧٢-٠,٢٤، ٤,٢٤-٠,٣٧ و ٤,١٨-٠,٣٩ كجم أ$_{٢}$\ك وات ساعة، وذلك عند زيادة كمية الهواء المدفوع من ١٩,٢-١٢٦٠,٠، ٤٥,٠-٢٣١٠ و ٨٦,٠-٢٦٠٤,٠ لتر\دقيقة، للطلمبات التى أقطارها ٥,٠، ٧,٥ و ١٠,٠سم على الترتيب.

٢- أدت زيادة كل من قطر و طول الطلمبة إلى زيادة الكفاءة القياسية للتهوية. فعلى سبيل المثال، عند دفع كمية من الهواء حوالي ٢٠٠ لتر\دقيقة وكانت نسبة الانغماس بها ٩٠%، زادت الكفاءة القياسية للتهوية فى الطلمبات التى أطوالها ٠,٥، ١,٠ و ١,٥متر بنسبة ٣٨,٠، ٣٠,٠ و ٤٠,٠%، على الترتيب عند زيادة قطر الطلمبة من ٧,٥ إلى ١٠,٠سم. كما زادت الكفاءة القياسية للتهوية فى الطلمبات التى أقطارها ٧,٥ و ١٠,٠سم بنسبة ١٢,١ و ٢٠,٩%، على الترتيب عند زيادة طول الطلمبة من ١,٠ إلى ١,٥ متر.

٣- تأثير نسبة انغماس الطلمبة على الكفاءة القياسية للتهوية تم تقييمها أيضاً. فعلى سبيل المثال، في الطلمبة التى قطرها ٧,٥سم وطولها ١,٥م عند دفع كمية من الهواء حوالي ٢٠٠ لتر\دقيقة ، زادت الكفاءة القياسية للتهوية بنسبة ٦,٨% عند زيادة نسبة الانغماس من ٧٠ – ٨٠%، كما زادت الكفاءة القياسية للتهوية بنسبة ٥,٥% عند زيادة نسبة الانغماس من ٨٠ – ٩٠%.

ثالثاً: الأهمية الاقتصادية:

بناءً على تكاليف الخامات والتركيب والتشغيل نجد الطلمبات التي أقطارها ٧,٥ و ١٠,٠سم بطول ١,٠م هى الأكثر مناسبةً للأحواض التى تبلغ مساحتها ٠,٠٢-٢,٠هكتار. حيث أن الطلمبة الواحدة تكفى لتدوير وتهوية حوض مساحته ٠,٠٥هكتار عند معدل ضخ الهواء ١١٠لتر\دقيقة وعند نسبة انغماس ٩٠%. تحت الظروف السابقة نجد أن ضاغط الهواء بقدرة ١,٢ ك وات يستطيع تشغيل الطلمبات اللازمة لتهوية حوض مساحته ١,٠هكتار.

فى حين يعتمد نظام الاستزراع الانتشارى المتبع فى مصر على العجلة ذات الزعانف فى التهوية. ويحتاج الهكتار إلى ثمانية منها بقدرة ٤,٠ وات.

وهذا يعنى أنه باستبدال العجلة ذات الزعانف بطلمبات الدفع الهوائي يتم توفير ٧٢% من الطاقة المستخدمة فى التهوية.