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Performance evaluation of column diffused aeration system by using different hole diameter and surface area

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Abstract
Column diffuse aeration experiments were conducted in two types of aeration tank i.e., semi open and fully open tank with 200 L capacities sintex-renotuff water tank made up of FDA grade materials to study the effects of variable geometric parameter of total hole surface area (10%, 20% and 30%), diffuser pipe diameter (1.27 cm, 1.91 cm and 2.54 cm) and diffuser hole diameter (0.2 cm, 0.4 cm and 0.6 cm) on standard aeration efficiency (SAE). To evaluate the optimum condition among above three geometric parameter at a time one of each is kept constant while other two parameter were remained varied. The comparison result for semi open aeration tank and fully open aeration tank showed that the values of standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) for fully open aeration tank was always maximum than semi open aeration tank. The standard aeration efficiency for both semi open and fully open aeration tank varies from 0.0111 Kg O_2/KWh to 0.0230 Kg O_2/KWh and 0.0104 Kg O_2/KWh to 0.0245 Kg O_2/ KWh respectively. Besides this, the best result drawn in this investigation for the standard aeration efficiency for fully open aeration tank is found as 0.0245 Kg O_2/ KWh at optimum geometric parameter of diffuser pipe diameter (DPD) of 1.27 cm hole diameter (DHD) of 0.2 cm and hole surface area (THSA) of 30% while for semi open aeration tank it is found as 0.0230 Kg O_2/KWh under optimum geometric parameter of hole diameter of 0.2 cm and hole surface area of 30% respectively.

Keywords: Diffuse aerator, Standard oxygen transfer rate, Standard aeration efficiency, Variable geometric parameter

Introduction
Since introduction of the activated sludge process in the early 1900s, many different types of subsurface or diffused aeration devices have been designed and developed to dissolve oxygen into wastewater. These have ranged from simple individual orifices (holes and slots) drilled in a section of pipe to elaborate devices made up of small diameter particles fused together. However, aeration brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulphide, and volatile organic chemicals (VOCs) (Toombes *et al.* 2005) [6]. In its broadest sense, Aeration or re-aeration is the physical process of oxygen transfer or oxygen absorption from the atmosphere acts to replenish the used oxygen. Aeration is one of the fundamental parameters required to maintain dissolved oxygen for the aerobic bacteria that feed on organics whether in treatment facilities or in streams and rivers (A. Baylar, 2010) [1]. Vrtical pumps, pump sprayers, propeller-aspirator-pumps, paddle wheels, and diffused air systems are probably the most widely used aerators in the field of aquaculture (Boyd, 1998) [3]. Aerators increase the interfacial area between air and water, thus enhancing the oxygen transfer and simultaneously provide water circulation which prevents the stratification in the water body (Boyd *et al.* 1984) [4]. Transfer of oxygen into water is a three stage process in which gaseous oxygen is transferred to the surface film, diffusion through the surface film, and finally movies into the liquid bulk by convection. Air bubble size varies from extremely fine to coarse, depending on the diffusion device used. Some common diffusers are porous diffusers (air stone), porous diffuser pipe, nonporous diffusers, perforated pipe, airlift pumps, and U-tube systems (Lawson, 1995) [5]. Most diffused-air systems released large volumes of air at low pressure. The minimum operating pressure increases with increasing hydrostatic pressure above the diffuser, since enough pressure must be provided to force air from the diffuser against the total pressure (atmospheric plus hydrostatic) at the discharge point (Boyd, 1990) [2].

Methodology

Column diffuse aeration experiments were conducted to evaluate Standard oxygen transfer rate (SOTR) and Standard aeration efficiency (SAE) by using different geometric parameter. Mainly the experiments were done by using 83cm length of total 27 pieces of Upvc pipes with varying diameter i.e. 1.27cm, 1.907cm and 2.57cm. The possible no of holes (diffuser) on pipe are made based on the assumed total holes surface area in percentage which is ranges from 10% – 30% and assumed holes diameter which ranges from 0.2 cm to 0.6 cm respectively.

The aeration basin is filled with tap water and its temperature and DO determined under the test conditions. Oxygen transfer test is conducted in 200 liters water tank. Initially the water of the tank is deoxygenated by using 10 mg of sodium sulphite per liters volume of water and 0.1 mg of cobalt chloride per liters volume of water in per mg/l of DO present in water. When the water present in the water tank becomes completely deoxygenated, at that time aerator is operated and level oxygen measured by DO meter, readings are taken at equal time intervals until 80% saturation achieved. At least twenty DO readings are taken at the equal intervals in each experiment, by varying the height of level of water in tank. Thus we can calculated the standard oxygen transfer rate (SOTR) and standard oxygen aeration efficiency (SAE) from the following equations:

$$K_{Lc}a_{20} = K_La_T \times 1.024^{(20-T)} \qquad \ldots(2.1)$$

Where,

$K_{LC}a_{20}$ = standard oxygen transfer coefficient (h-1) of column diffused aeration system.

C_S= oxygen transfer concentration at 20°C (mg/L)

C_0= initial oxygen concentration where time is zero

V= volume of water (m^3)

$$SOTR=K_La_{20}\times(C_S-C_0)\times V \qquad \ldots(2.2)$$

$$SAE=SOTR/P \qquad \ldots(2.3)$$

Where,

P= power (KW)

Results and Discussion

Three different diameter diffuser pipes; 1.27 cm, 1.91 cm and 2.54 cm were used to evaluate the standard oxygen transfer rate (SOTR) at different holes surface area (10%, 20% and 30%) and different diffuser hole diameter (0.2 cm, 0.4 cm and 0.6 cm). Total twenty seven numbers of experiments were conducted in this series. The values of SOTR increases with the increases of THSA at particular values of DHD. The maximum values of SOTR were found as 0.0181 kg O_2/h, 0.0157 kg O_2/h and 0.0139 kg O_2/h at DHD of 0.2 cm, 0.4 cm and 0.6 cm respectively. It was observed that the variation of SOTR between the different values of DHD at 10% of THSA was found as minimum, whereas at 30% of THSA value the variation of SOTR was seen as maximum. For the performance evaluation of any aeration system, standard aeration efficiency (SAE) is needed. In this apart, the SAE for different diameter of diffuser pipes (1.27 cm, 1.91 cm and 2.54 cm) were evaluated at different diffuser hole diameter (0.2 cm, 0.4 cm, and 0.6 cm) and different holes surface area (10%, 20% and 30%). After that the SAE value was find out for varying all the variable component and the results is draw by plotting Figure and comparing them all.

SAE for different values of DHD was varies from minimum value of 0.0156 kg O_2/KWh to maximum values of 0.0230 kg O_2/KWh at THSA of 10% and 30% respectively. However, selection of the best type of aeration system mainly depends on the standard aeration efficient. Higher the value of standard aeration efficiency, the aeration system selection is the best way. So, in this case by providing the optimum combination of geometric parameters of DHD value at 0.2 cm and THSA value at 30%, the maximum efficiency can be achieved.

It was found that with increasing value of THSA i.e. 10% to 30%, the variation of SAE for different values of DHD was also increases.

The minimum and maximum variation of SAE for particular value of DHD were found at THSA value of 10% and 30% respectively. The selection of best type of aerator is primarily depending upon the value of SAE. So higher the value of SAE more will be the efficient and maximum value of SAE for DHD of 0.6 cm was found to be maximum at optimum combination of geometric parameter i.e., at DPD of 1.27 cm and THSA of 30% respectively.

Table 1: SOTR at diffuser pipe diameter of 1.27 cm, 1.91 cm and 2.54 cm

Diffuser holes diameter 1.27 cm			
THSA (%)	0.20	0.40	0.60
	SOTR(kg O_2/h)		
10	0.0136	0.0130	0.0123
20	0.0174	0.0157	0.0136
30	0.0181	0.0157	0.0139
Diffuser holes diameter 1.91 cm			
10	0.0145	0.0106	0.0088
20	0.0159	0.0133	0.0103
30	0.0172	0.0170	0.0116
Diffuser holes diameter 2.54 cm			
10	0.0133	0.0126	0.0090
20	0.0139	0.0129	0.0110
30	0.0148	0.0134	0.0116

Table 2: SAE at diffuser pipe diameter of 1.27 cm, 1.91 cm and 2.54 cm

Diffuser holes diameter 1.27 cm			
THSA (%)	0.20	0.40	0.60
	SAE (kg O_2/KWh)		
10	0.0173	0.0165	0.0156
20	0.0221	0.0199	0.0173
30	0.0230	0.0199	0.0176
Diffuser holes diameter 1.91 cm			
10	0.0184	0.0135	0.0111
20	0.0202	0.0168	0.0130
30	0.0218	0.0216	0.0148
Diffuser holes diameter 2.54 cm			
10	0.0133	0.0126	0.0090
20	0.0139	0.0129	0.0110
30	0.0148	0.0134	0.0116

Conclusion

The performance of column air diffuse aerators increasing process depends almost entirely on the amount of surface contact with the air and water. This contact is controlled primarily by the size of the water droplet or air bubble. The model assumes a complete mixed liquid with a uniform DO concentration throughout the tank. After adding the sulfite, the probe of DO meter was connected to a data logger which logged the DO concentration in mg/L once every 30 second interval. The tests were conducted until 80% saturation was achieved.

Standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) values increases with the increase of total hole surface area (THSA) at constant values of diffuser pipe diameter (DPD) for a particular value of diffuser hole diameter (DHD). Higher value of standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) were found in fully open aeration tank than semi open aeration tank in most of experiments. The aeration cost estimation of the column air diffuse aerator system under pond condition was found as Rs 33.82/hr.

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