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Experimental Studies on Aeration in Water*

Nam Won Paik, D.P.H.E., Ph.D. and Kyou Chull Chung, M.D., Ph.D.

Department of Preventive Medicine, Catholic Medical College, Seoul, Korea

INTRODUCTION

The main purpose of the aeration units in activated sludge process is to enable micro-organisms to metabolize the constituents of the waste effectively by supplying sufficient oxygen for their respiration.

Normally, aeration is achieved by bringing the mixture of waste and sludge into intimate contact with air. The main type of aeration unit is diffused air unit in which air is injected into the liquid in the form of bubbles.

The object of these laboratory studies is to compare the performance of three laboratory scale aeration systems at various depths of submergence, aerating water with and without the addition of a surface active agent.

MATERIALS and METHODS

General laboratory procedure for each test

1. Two samples were used in the experiment.
   (i) Tap water
   (ii) 0.04 ml/l detergent in tap water
2. The D.O.(Dissolved Oxygen) in the samples were lowered using the following procedure.
   (i) 8 litres of water was placed in the bucket.
   (ii) Deoxygenation was carried out by bubbling nitrogen through a diffuser, placed in the water. The D.O. was reduced to less than 10% saturation.
   (iii) In cases where surface active agent was added to the sample, the detergent was added while stirring was being carried out.
3. The sample was aerated recording the D.O. at 1 minute intervals until it reached 90% saturation.
4. The temperature of the sample was recorded and the D.O. concentration was determined by titration method. at the end of experiment.

Details of the tests carried out

1. Comparison of coarse and fine bubble oxygenation capacity over a range of depths of submergence:

   3 tests on tap water were run using a fine and coarse bubble aerator in parallel at 3 depths of submergence, maintaining the airflow rate at 260 ml/min.
2. Effect of addition of detergent on oxygenation capacities of fine and coarse bubble aerators:

   A test after addition of 0.04 ml/l detergent was carried out at 4.5 inches(11.4 cm) of submergence using a fine and a coarse bubble aerator at 260 ml/min.

RESULTS

The results of experiment are shown in Table 1 and Figure 1.

The value of K_La in coarse bubble aeration at the depth of 3.8 cm shows higher value than that at the depth of 11.4 cm, and this seems to be derived from experimental errors. The K_La values were determined from graphs of the semilogarithm of the oxygen deficit plotted against time.

The α values were calculated for the 0.04 ml/l detergent as in Table 2.

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Table 1. The results of aeration experiment

Bubble size	Composition of liquid	Depth of immersion		Overall transfer coefficient, K_La at 10°C	Oxygenation capacity, gm/hr at 10°C	Aeration efficiency, %
		inches	cm			
Fine	Tap water	7.5	19.0	2.70hr^{-1}	0.236	5.21
Fine	Tap water	4.5	11.4	1.88	0.164	3.62
Fine	Tap water	1.5	3.8	1.07	0.093	2.05
Coarse	Tap water	7.5	19.0	0.81	0.071	1.56
Coarse	Tap water	4.5	11.4	0.64	0.056	1.22
Coarse	Tap water	1.5	3.8	0.73	0.064	1.41
Fine	Tap water +0.04 ml/l detergent	4.5	11.4	2.04	0.178	3.92
Coarse	Tap water +0.04 ml/l detergent	4.5	11.4	1.06	0.093	2.05

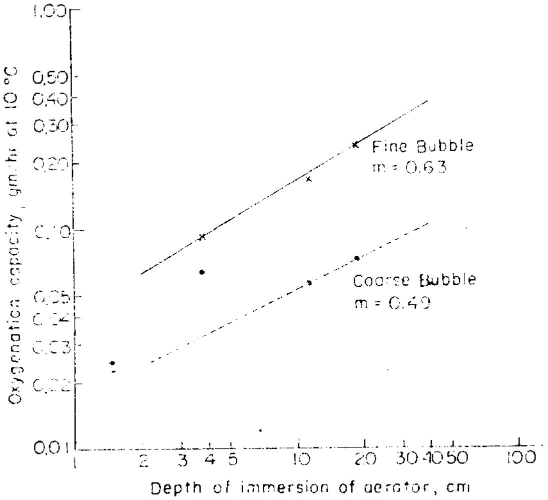

Fig. 1. Effect of liquid depth on oxygeantion capacity by bubble sizes.

Table 2. α values for the detergent for fine and coarse bubble aerations

Bubble size	Composition	Depth, cm	α value
Fine	0.04 ml/l	11.4	1.08
Coarse	0.04 〃	11.4	1.66

DISCUSSION

1. Basic considerations

The overall transfer coefficient(hr^{-1}, K_La, $K_L\cdot\frac{A}{V}$) was calculated from the following equation (Eckenfelder, 1968),

$$K_La=\frac{\log(C_S-C_L)t_1-\log(C_S-C_L)t_2}{t_2-t_1}\times 2.3\times 60\cdots(1)$$

where C_S(mg/l) = saturation concentration of dissolved oxygen in water at 10°C in equilibrium with normal air at a barometric pressure of 760 mmHg.

The measurement of oxygenation capacity, R, in gm/hr at 10°C was carried out from the following equation(Downing, 1960),

$$R=\frac{V\cdot C_S\cdot K_La}{10^3}\cdots\cdots(2)$$

where V = the volume of the water in litres.

The aeration efficiency, E, was determined from the following equation,

$$E=\frac{R}{O_S}\cdots\cdots(3)$$

where O_S = oxygen supplied,

$$=(Q)(\rho)\left(\frac{0.232\ \text{lb } O_2}{\text{lb air}}\right)\left(\frac{60\ \text{min}}{\text{hr}}\right)\cdots(4)$$

Q = air flow, ft^3/min,

ρ = air density $=0.0808\left(\frac{Pa}{14.7}\right)\left(\frac{429}{Ta}\right)$

Pa and Ta = pressure and absolute temperature.

2. Factors affecting K_L and K_La

(1) Effect of depth of immersion

The overall transfer coeffient, K_La, is affected by the liquid depth and bubble diameter as follows;

$$K_La=\frac{C\cdot G_S\cdot H^{\frac{2}{3}}}{d_B\cdot V} \quad \cdots\cdots(5)$$

where G_S = air flow,
H = liquid depth,
d_B = mean bubble diameter, and
C = constant.

Since d_B is proportional to G_S over the range of air flows normally encountered,

$$K_La=\frac{C'\cdot G_S^{(1-n)}\cdot H^{\frac{2}{3}}}{V} \quad \cdots\cdots(6)$$

A modification of equation (6) is used to characterize the oxygen transfer from diffused aeration equipment in water:

$$R=C''\cdot G_S^{(1-n)}\, H^{\frac{2}{3}} \quad \cdots\cdots(7)$$

Figure 1 shows that the oxygenation capacity increases with increasing depth to an exponent of 0.63 for the fine bubble and 0.49 for the coarse bubble system. The deviation of these exponents from the $\frac{2}{3}$ power in equation (7) probably was attributed to the difference of the tank width.

(ii) Effect of surface active agent

The presence of surface active agents has a marked effect on the oxygen transfer rate, as they affect both the liquid film coefficient, K_L, and the A/V ratio and hence K_La. A surfactant concentrates at an interface so that the interfacial concentration will be greater than that in the body of the liquid. As a result, a film of absorbed surfactant molecules is concentrated at the interface, which provides a barrier to molecular diffusion. The surface concentration of surface active molecules will increase with increasing solution concentration to a maximum. Further increase in solution concentration will yield no additional increase in surface concentration. This has been defined as the critical micelle concentration, above which increased concentration of surface active molecules will aggregate only in the bulk of solution. Under equilibrium conditions, K_L will decrease with increasing surfactant concentration to the critical micelle concentration. Since at this level the interface is completely covered, increased concentration of surfactant will have no further effect on K_L. In diffused air systems K_L will decrease with increasing surface concentration, becoming a constant above the critical micelle concentration. At higher surfactant concentrations, the increase in interfacial area due to small bubble size may exceed the decrease in K_L causing an increase in K_La. Table 2 shows the increased α values in these experiments for the solution of 0.04 ml/l detergents, where

$$\alpha=\frac{K_La\text{ of the 0.04 ml/l detergent solution}}{K_La\text{ of pure tap water}}$$

(iii) Effect of temperature

The temperature effect can be defined by the relationship;

$$K_t=K_{10^\circ C}\,\theta^{(T-10)} \quad \cdots\cdots(8)$$

The temperature effect of K_L, θ, has been reported to vary from 1.016 to 1.037. When considering K_La in bubble aeration systems, the effect of temperature on the bubble size and velocity must also be included, since this will affect A/V. Conway (1966) showed a typical value to be 1.024 which was used in these studies.

(iv) Effect of velocity and bubble size

The size of air bubbles released by diffused aeration devices is related to both the orifice diameter and the air rate. The interfacial area volume ratio will be $\frac{6G_S\cdot H}{d_B\cdot v_B\cdot V}$

where v_B = bubble velocity.

In Figure 1, the oxygenation capacity for fine bubble was greater than that for the coarse bubble aerator.

CONCLUSIONS

1. The oxygenation capacity increased with the increasing depth of immersion of aerator to an exponent of 0.63 for the fine bubble and 0.49 for the coarse bubble system.
2. The overall transfer coefficient increased in the presence of 0.04 ml/l detergent.
3. The oxygenation capacity decreased with the increasing bubble size.

REFERENCES

Conway, R.A. and Kumke, G.W. : *Field Techniques for Evaluating Aerators*, J.A.S.C.E. (SA 2)