



CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Benchscale test of turbine aeration system

In this study, laboratory turbine aeration systems test were performed in a 300-liter tank with the absence and the presence of surfactants (at 5, 10 and 15 mg/L). Power inputs were varied at 280, 420, 560 and 700 RPMs to create mixing power intensities of 13.17, 26.33, 39.50 and 52.67 W/m³, respectively. Temperature was maintained in the 27-29 °C range. Dissolve oxygen (DO) was measured during the tests under unsteady state condition and oxygen transfer parameters were calculated by using ASCE DO Parameter Estimation Program (DO_PAR program; Lee *et al.*, 1997). Total Dissolved Solid (TDS) and pH were also measured and maintained as controlling parameters. ASCE Oxygen Transfer Test Standard (ASCE, 1993) was used as a principle for at least triplicate data set for each condition performed.

In Figure 4.1 showed a raw data from Dissolved oxygen (DO) probes, which are widely used to collect DO concentration versus time data under unsteady-state test (Philichi and Stenstrom, 1989). After that, DO_PAR program was used to estimate the overall oxygen transfer coefficient (K_La) using parameters (DO, temperature, air flow rate etc) from prepared data by converting to the standard values at 20 °C. For the calculation steps of the K_La values, they showed in detail in Appendix A.

Dissolved oxygen (DO) concentration versus time at different power input per unit volume (P/V , which is expressed in W/m³) is shown in Figure 4.1. The initial Dissolved Oxygen (DO_0) concentration in theoretical should be 0 mg/L of DO before starting collection data but in this study would not be. It started from 0.65-1.78 mg/L of DO. To use DO_PAR program, the prepared data for a particular determination point are entered along with initial approximations of the three parameters (oxygen transfer coefficient: K_La , initial dissolved oxygen: DO_0 and saturated dissolved

oxygen: DO^*s). For adequate convergence, the initial parameter estimate for DO_0 should be within 2 mg/L. So time zero does not affect the K_{La} , DO_0 and DO^*s values (ASCE, 1993).

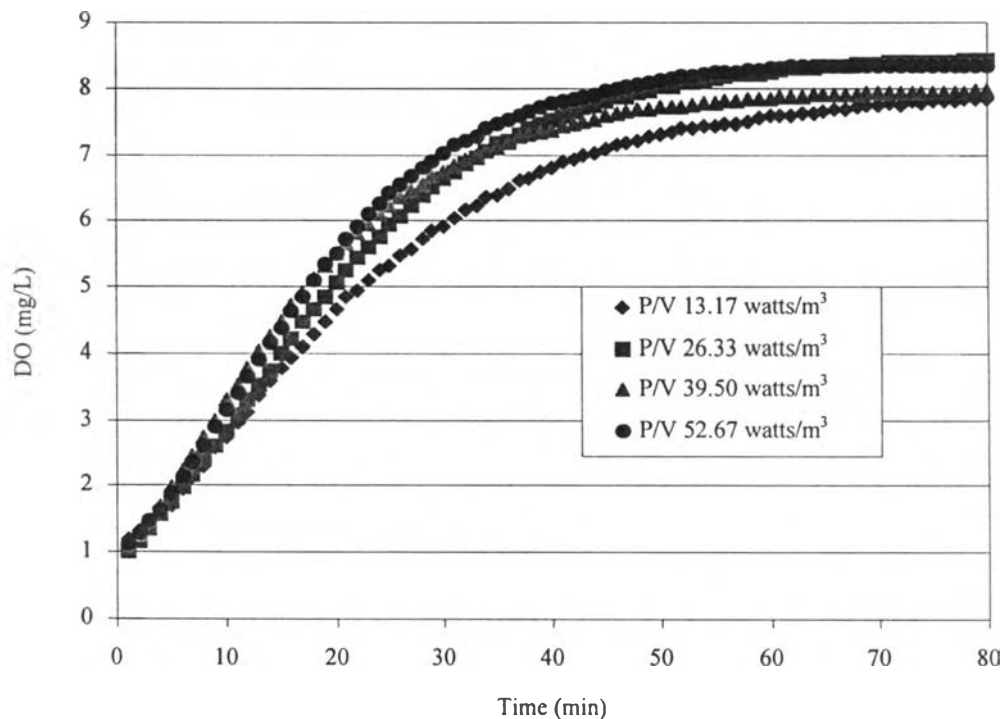


Figure 4.1 Dissolved oxygen (DO) experimental data at different power inputs per unit volume

Figure 4.1 showed two distinct differences in DO reaction curves for four power inputs per unit volume: (1) the slope of the curve was more steep initially at higher power input per unit volume and (2) DO^*s of each power input per unit volume was different, higher DO^*s meant that the temperature at that time was lower. ($DO^*s = 8.65-7.84$ mg/L at temperature 27-29°C). Table 4.1 summarized the average of K_{La} values obtained from this study.

Table 4.1 Average of K_{La} values obtained from the study.

K_{La} values				
Surfactant Concentration	13.17 Watts/m ³ (280 RPMs)	26.33 Watts/m ³ (420 RPMs)	39.50 Watts/m ³ (560 RPMs)	52.67 Watts/m ³ (700 RPMs)
0 mg/L	3.718	4.801	5.510	6.219
5 mg/L	3.726	4.554	5.446	5.874
10 mg/L	3.785	4.738	5.413	5.298
15 mg/L	3.714	4.492	5.249	5.014

4.2 Effect of power input per unit volume on oxygen transfer

The overall oxygen transfer coefficient (K_{La}) of the turbine aeration at four values of power input per unit volume were expressed in W/m³ as 13.17, 26.33, 39.50, 52.67 W/m³. In this study, changing the rpms of motor, which was controlled by the inverter, can vary power intensity. Figure 4.2 showed the effect of power inputs on K_{La} Values.

For clean water, the effect of power input per unit volume on K_{La} value was a straight line. The K_{La} value tended to increase with increasing the power intensity. The higher K_{La} , the more oxygen in the gas phase can be transferred into the aqueous phase.

Effect of power input per unit volume on K_{La} value for water with presence of surfactant (5, 10 and 15 mg/L) was also showed in Figure 4.2. The K_{La} trend value of surfactant 5-mg/L concentration showed tend as similar as K_{La} value of clean water. However, for surfactant concentration 10 mg/L and 15 mg/L, the result did not follow that trend stated above. They tended to decrease at the highest power intensity (52.67 W/m³).

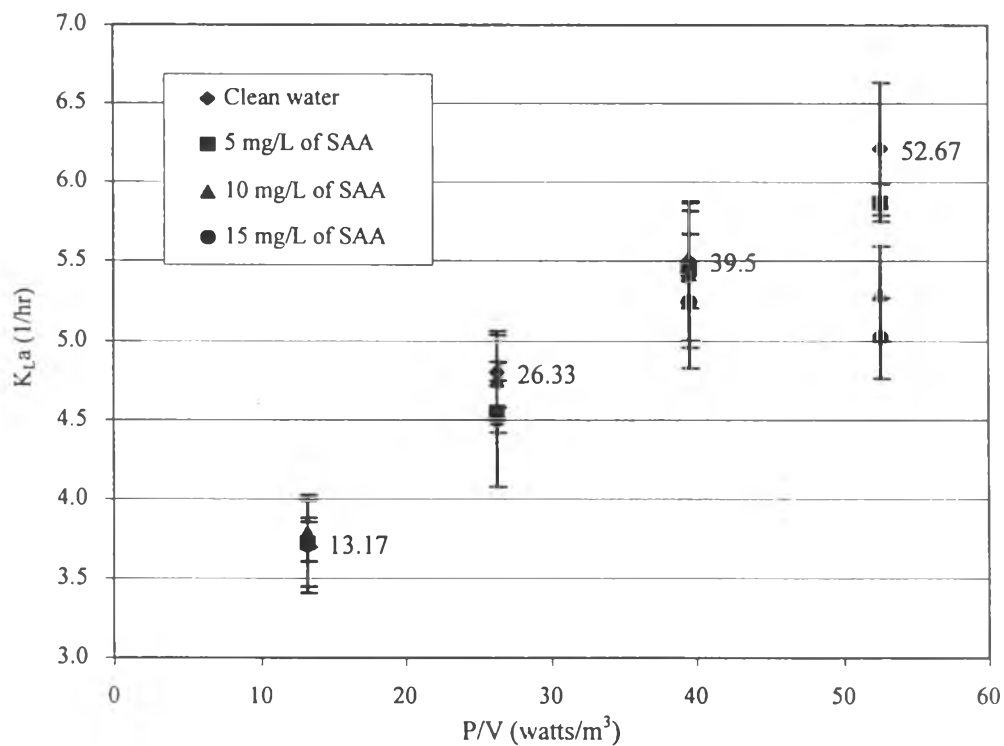


Figure 4.2 Effect of power inputs on $K_{L}a$ values

At the highest power input, 52.67 watts/m³, $K_{L}a$ was lowered from 6.219 hr⁻¹ (for clean water) to 5.014 hr⁻¹ (15 mg/L of surfactant concentration) or 19% reduction. The presence of surfactant tends to stabilize the interface, decrease surface renewal, and increase interfacial viscosity. Increasing of surfactant concentration results in increasing of surfactant adsorption onto the gas/liquid interface. Therefore, it decreases the available surface area for molecule diffusion and forms a hydration layer at the surface (Stenstrom, 2001). Higher surfactant concentration affects the $K_{L}a$ more extensively than lower surfactant concentration. However, at lower power input, 39.5 26.33 and 13.17 watts/m³, the effect of surfactant were some significance. The data reported that surfactant reduced oxygen transfer more significantly at higher power inputs than at lowered power inputs for turbine aeration system.

4.3 Effect of mixing condition on oxygen transfer

Reynolds number (N_{Re}) was used as a turbulent indicator to specify the mixing conditions in this study. Influence of N_{Re} on oxygen transfer was shown in Figure 4.3.

From Figure 4.3, the influence of turbulent on K_{La} values for clean water and with different surfactant concentrations (5, 10 and 15 mg/L) was quite similar to the effect of power input on K_{La} values. For clean water, a linear trend straight line was observed from the effect of turbulent on K_{La} value. K_{La} values increased with increasing N_{Re} . The higher turbulence in water resulted in increasing of agitation. Metcalf and Eddy (1991) confirmed that more power input creates greater turbulent, and greater turbulent leads to better mixing.

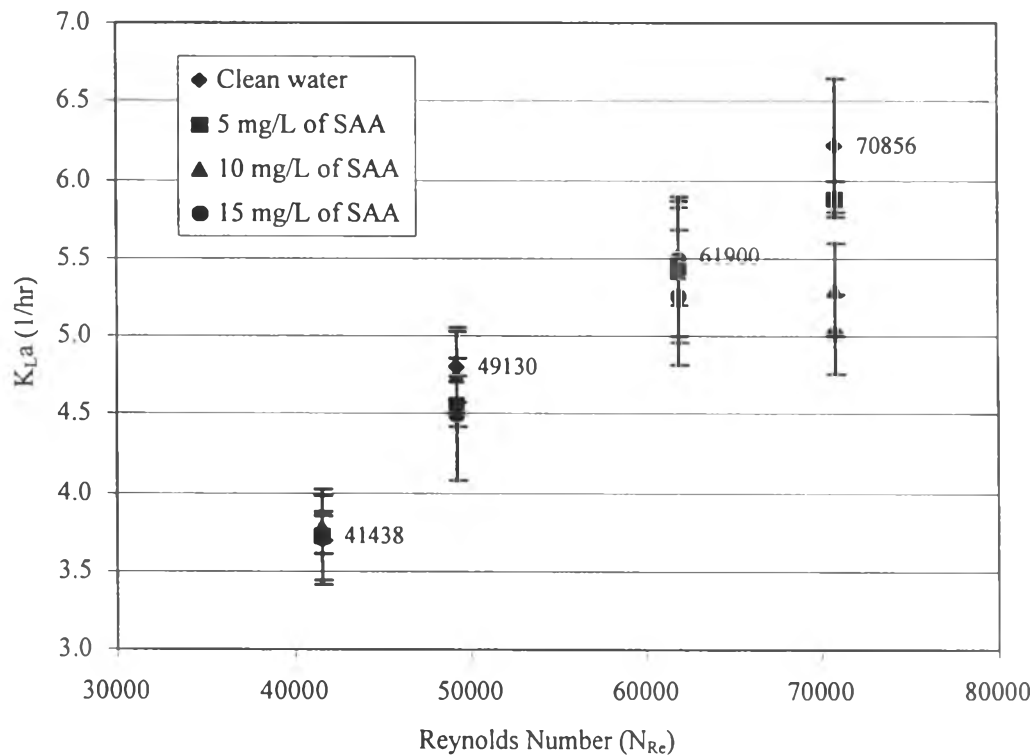


Figure 4.3 Effect of turbulence on K_{La} values

Figure 4.3 also showed the effect of mixing condition on K_{La} value for water with presence of surfactant (5, 10 and 15 mg/L). The trend of K_{La} value from 5 mg/L concentration of surfactant was similar to the trend of clean water. Nevertheless, the results for high surfactant concentrations (10 mg/L and 15 mg/L) were not followed the clean water trend. They tended to decrease at the highest turbulent ($N_{Re} = 70856$).

Stenstrom (1980) stated that when the mixing condition become more turbulent, the effect of surfactant on K_{La} values decreased. However, in the study, at the highest turbulent condition, $N_{Re} = 70856$, of 10 and 15 mg/L surfactant concentration showed the contrast with a previous work. The K_{La} values were more affected by surfactant concentrations. On the other hand, at lower N_{Re} values (represented lower turbulence mixing condition), the effect of surfactant on K_{La} values were less significant comparing between clean water, 5, 10 and 15 mg/L of surfactant concentrations.

4.4 Effect of surfactant on oxygen transfer

The relationship between surfactant concentration and K_{La} value were presented in Figure 4.4. At the highest power input per unit volume, 52.67 w/m^3 , the results indicated that the K_{La} values decreased with increasing surfactant concentration.

The experimental results at the highest power input tended to confirm the findings of an earlier work of Stenstrom (1980). He founded that surfactants could have dramatic effects on transfer rate and surfactant also reduced oxygen transfer and it appeared to be a function of the power input as well as the surfactant concentration. At higher surfactant concentrations, oxygen transfer seemed to be reduced more significantly than at lower surfactant concentrations (Masutani *et al.*, 1991). The influence of surfactants on the oxygen transfer coefficient (K_{La}) is a result of two competitive effects, on one hand on the liquid-phase oxygen transfer coefficient (K_{La}) and on the other hand on the specific interfacial area. As they usually reduce bubble size, they increase the specific interfacial area (Wagner and Popel, 1996). At the same

time, they increase the resistance to the transfer and make the interface more rigid, in which both effects decrease the liquid-phase oxygen transfer coefficient ($K_{L,a}$). The resulting effect is generally a reduction of the overall oxygen transfer coefficient ($K_{L,a}$) in the presence of surface active agents (Hwang and Stenstrom, 1984; Wagner and Popel, 1996).

However, the results at lower power input (13.17 W/m^3 , 26.33 W/m^3 and 39.50 W/m^3) contrasted with Stenstrom (1980) work. The values of $K_{L,a}$ for power input per unit volume of 13.17 W/m^3 were really similar regardless of surfactant concentrations. At high power inputs (26.33 W/m^3 and 39.50 W/m^3), the effect of surfactant concentration was also minimal.

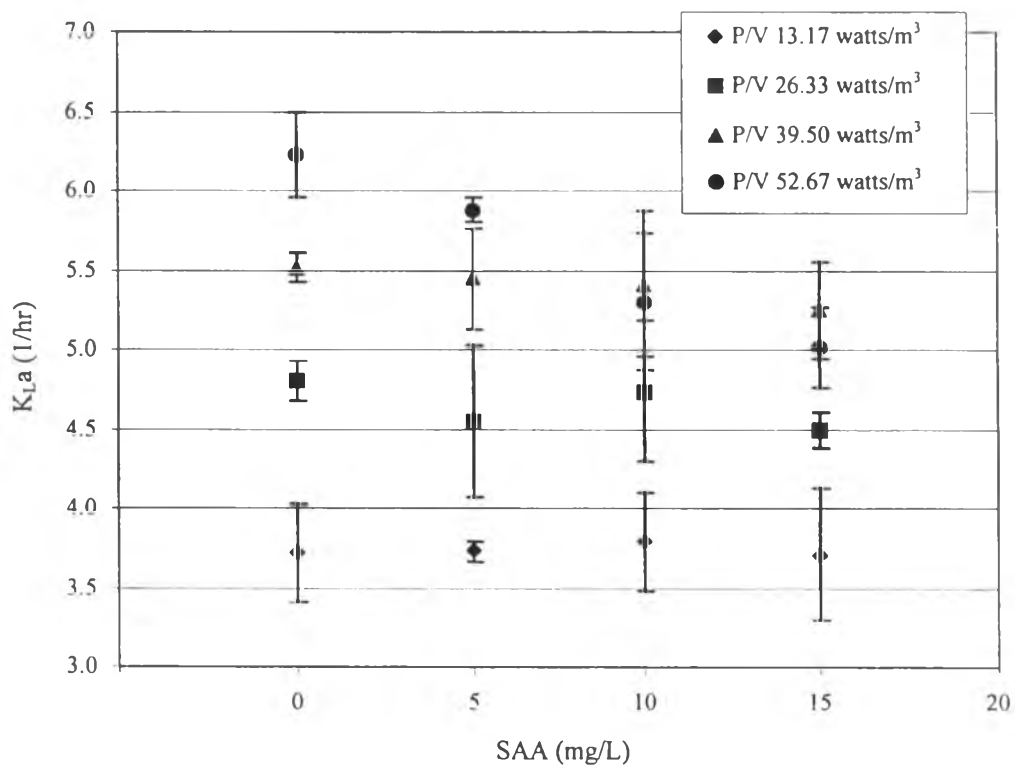


Figure 4.4 Effect of surfactant concentrations on $K_{L,a}$ values

4.5 Proposed equation of oxygen transfer coefficient as a function of power inputs per unit volume and surfactant concentrations

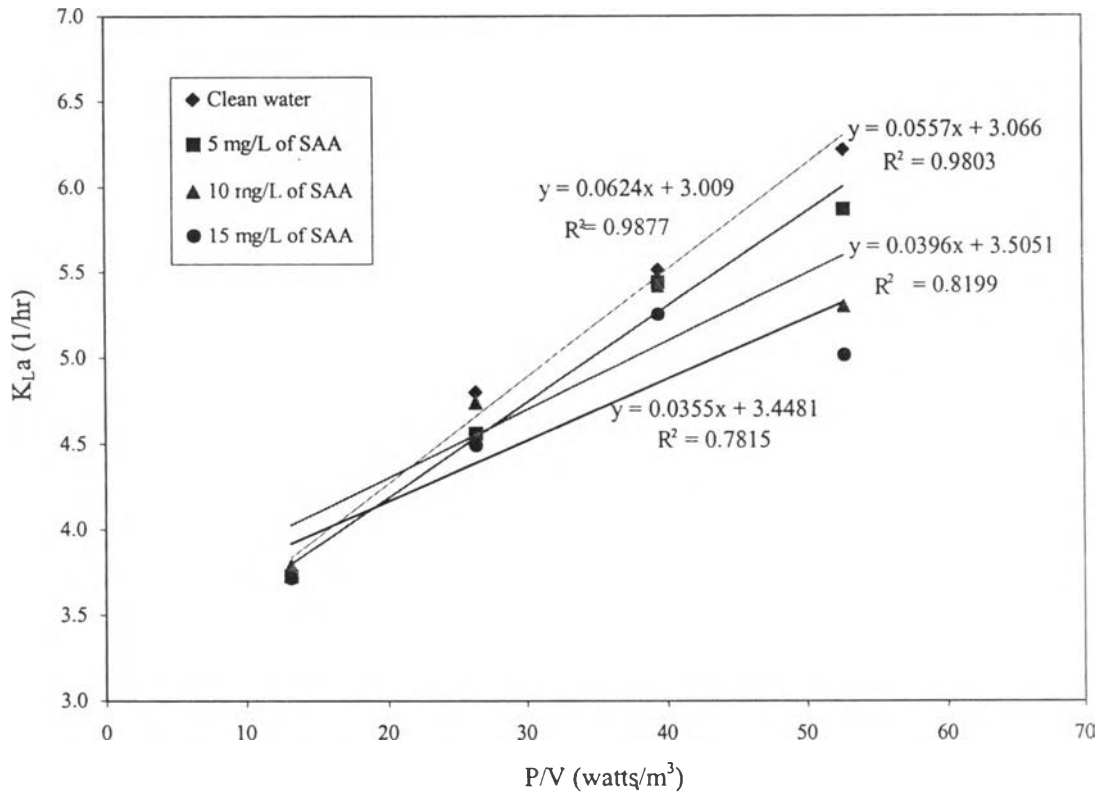


Figure 4.5 Proposed fitted trend lined for the relationship between K_{La} and power input per unit volume with different surfactant concentration

The relationship of experimental results between K_{La} values, surfactant concentrations and power inputs was noticed that higher concentration of surfactant affected K_{La} values. Especially, at the highest power input per unit volume the reduction of K_{La} was decreased significantly. The proposed linear equations were used to fit the K_{La} values for clean water, 5, 10 and 15 mg/L of surfactant concentration. Figure 4.5 showed the fitted equations of oxygen transfer coefficients as a function of power inputs per unit volume at each surfactant concentration

Table 4.2 summarized the fitted equations and their statistical data. The R^2 values range were 0.7815 - 0.9877 which can be used to predict the K_La values as a function of power input at difference surfactant concentrations under any similar condition.

Table 4.2 Proposed equations for estimating K_La as a function of power input at different surfactant concentrations

Surfactant concentration	Proposed equations	R^2
0 mg/L	$Y = 0.0624x + 3.009$	0.9877
5 mg/L	$Y = 0.0557x + 3.066$	0.9803
10 mg/L	$Y = 0.0396x + 3.5051$	0.8199
15 mg/L	$Y = 0.0355x + 3.4481$	0.7815

which are; $Y = K_La$ and $x = P/V$