CHAPTER 4

RESULTS AND DISCUSSIONS

Comparative tests were carried out on aeration system using 3 blades propeller aerator with different power inputs per unit volume and with three surfactant concentrations following the ASCE Oxygen Transfer Test Standard (ASCE, 1993). At least triplicate data set for each condition was performed.

Experimental data (DO, time, and temperature) for each test were used as input parameters for the DO_PAR program (Lee *et al.*, 1997) in order to obtain the overall oxygen transfer coefficient (K_La) for each test. Oxygen transfer coefficients were reported at a water temperature of 20°C. An example of the input and the executed output from DO_PAR program was presented in details in Appendix B. Table 4.1 and 4.2 summarized the average K_La values from DO_PAR program in this study.

Table 4.1 The average K_La values obtained from DO_PAR program on the aeration experiments of 10.7 cm propeller diameter

Oxygen transfer coefficients (K_La) (hr^{-1})				
	Power Inputs / Volume			
Surfactant Concentrations	**13.2** Watts/m^3 (632 RPMs)	**26.3** Watts/m^3 (798 RPMs)	**39.5** Watts/m^3 (914 RPMs)	**52.7** Watts/m^3 (1005 RPMs)
0 mg/L	1.758 ± 0.349	3.202 ± 0.197	4.168 ± 0.236	5.680 ± 0.015
5 mg/L	1.048 ± 0.025	2.769 ± 0.049	3.571 ± 0.063	5.102 ± 0.094
10 mg/L	0.572 ± 0.051	0.873 ± 0.058	1.290 ± 0.141	2.151 ± 0.009

Table 4.2 The average K_La values obtained from DO_PAR program on the aeration experiment of 15 cm propeller diameter

Oxygen transfer coefficients (K_La) (hr^{-1})				
Surfactant Concentrations	**Power Inputs / Volume**			
	13.2 Watts/m^3 (362 RPMs)	**26.3** Watts/m^3 (455 RPMs)	**39.5** Watts/m^3 (519 RPMs)	**52.7** Watts/m^3 (571 RPMs)
0 mg/L	2.337 ± 0.269	4.938 ± 0.974	7.118 ± 0.881	7.536 ± 0.056
5 mg/L	2.111 ± 0.176	4.292 ± 0.115	4.727 ± 0.158	5.770 ± 0.044
10 mg/L	0.996 ± 0.144	3.046 ± 0.392	4.131 ± 0.094	4.418 ± 0.102

4.1 Effect of power inputs per unit volume on oxygen transfer for clean water

Effect of the power inputs per unit volume on oxygen transfer in clean water could be explained by using K_La term. Higher K_La indicated more oxygen in the gas phase can be transferred into the aqueous phase. Power intensity in aeration mixing can be varied by increasing the RPMs of the motor. Figure 4.1 showed the effect of aeration power intensity on K_La. When the power input on the aerator was increased from 13.2 to 26.3, 39.5, and 52.7 Watts/m^3, the oxygen transfer coefficients were enhanced compared with the power input at 13.2 Watts/m^3 by 82, 137, and 223% for 10.7 cm propeller diameter and by 111, 205, and 223% for 15 cm propeller diameter, respectively. The more power intensity increased the agitation in the water and resulted in the increase of the flow velocity. The increase in oxygen transfer due to the velocity should be imputable to the neutralization of the vertical circulation of water (Gillot *et al*, 1999). The K_La values increase with increasing the power intensity. These results confirm the findings of the earlier work that the more RPMs, the more agitation will be (Metcalf and Eddy, 1991 and Stenstrom, 2001).

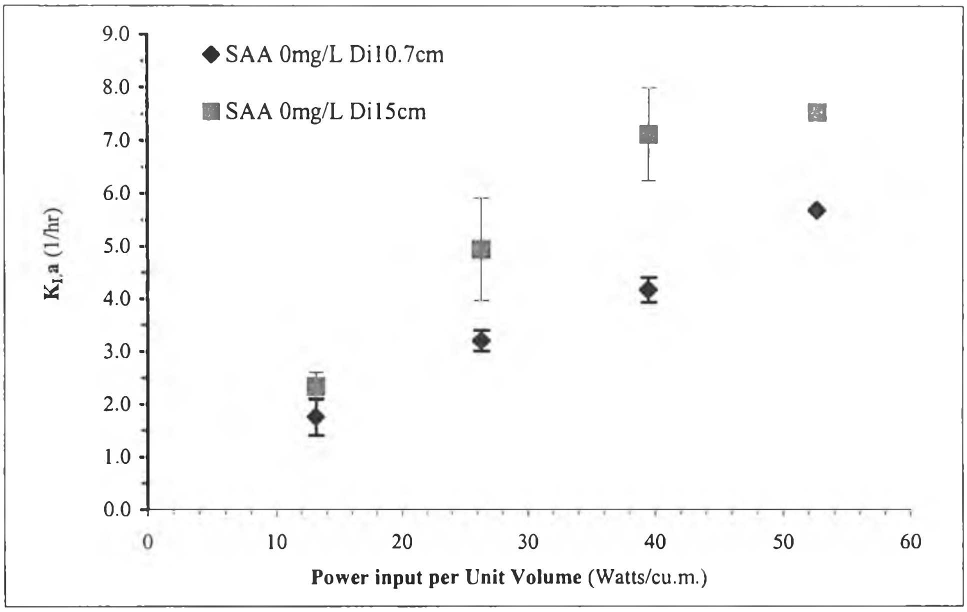

Figure 4.1 Effect of power intensity on K_La values in clean water for both aeration tests with 10.7 cm and 15 cm propeller diameters

4.2 Effect of mixing condition on oxygen transfer for clean water

Figure 4.2 showed the effect of mixing condition on oxygen transfer coefficient. Reynold's number (N_{Re}) was used in this study to specify the mixing condition. Higher Reynold's number values represented more turbulent mixing condition. From Figure 4.2, the K_La values increased with increasing Reynold's number. The reason of these results were quite similar to the effect of power input to K_La values because the more turbulent condition resulted from the more power input. The higher turbulence in water resulted in increasing of agitation. It confirmed a previous work that more power input creates greater turbulence, and greater turbulence leads to better mixing (Metcalf and Eddy, 1991).

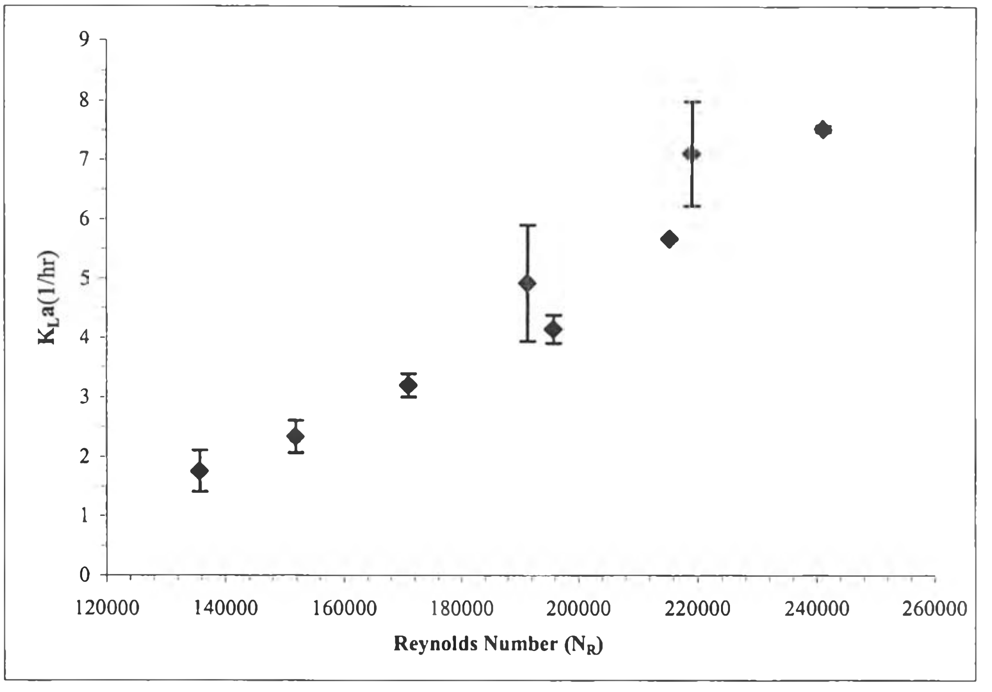

Figure 4.2 Effect of turbulence on K_La values in clean water

4.3 Effect of surfactant on oxygen transfer

Figures 4.3 and 4.4 showed the influence of the surfactant concentration on oxygen transfer coefficient at different levels of power intensity for both 10.7 cm and 15 cm propeller diameter, respectively. Experimental results confirmed the findings of earlier works by Stenstrom and Hwang (1980) and Wagner and Popel (1996). Generally, the presence of surfactant reduced oxygen transfer and the effect appeared to be a function of power input as well as surfactant concentration. The presence of surfactant tended to stabilize the interface, decreased surface renewal, and increased interfacial viscosity. Increasing of surfactant concentration resulted in increasing of surfactant adsorption onto the gas/liquid interface. Therefore, it decreased the available surface area for molecular diffusion and a hydration layer formation (Masutani *et al.*, 1991 and Stenstrom, 2001).

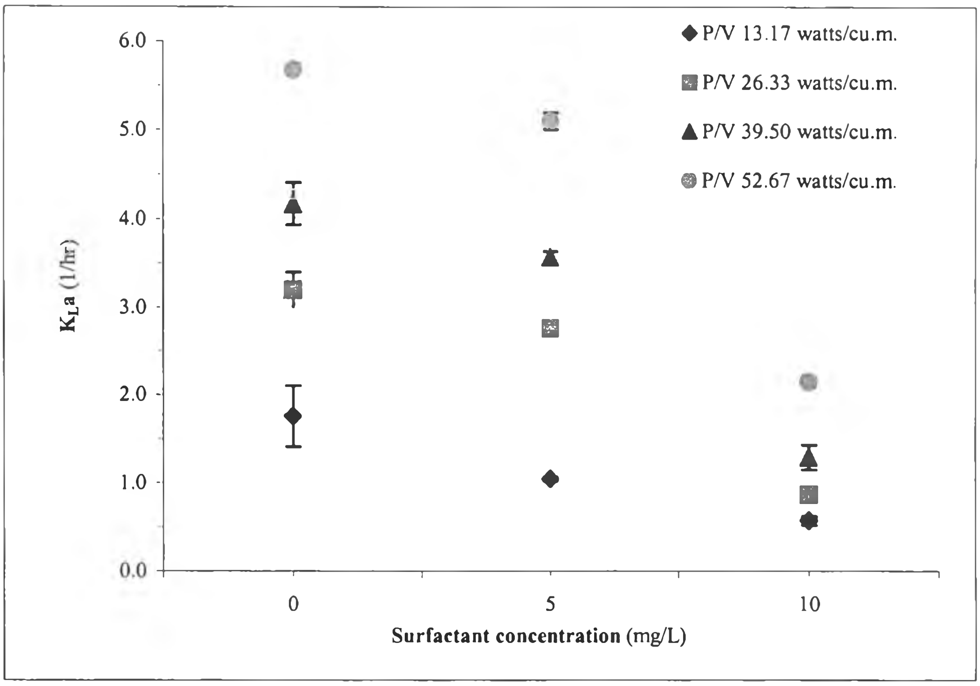

Figure 4.3 Effect of surfactant concentrations on K_La values for 10.7 cm propeller diameter

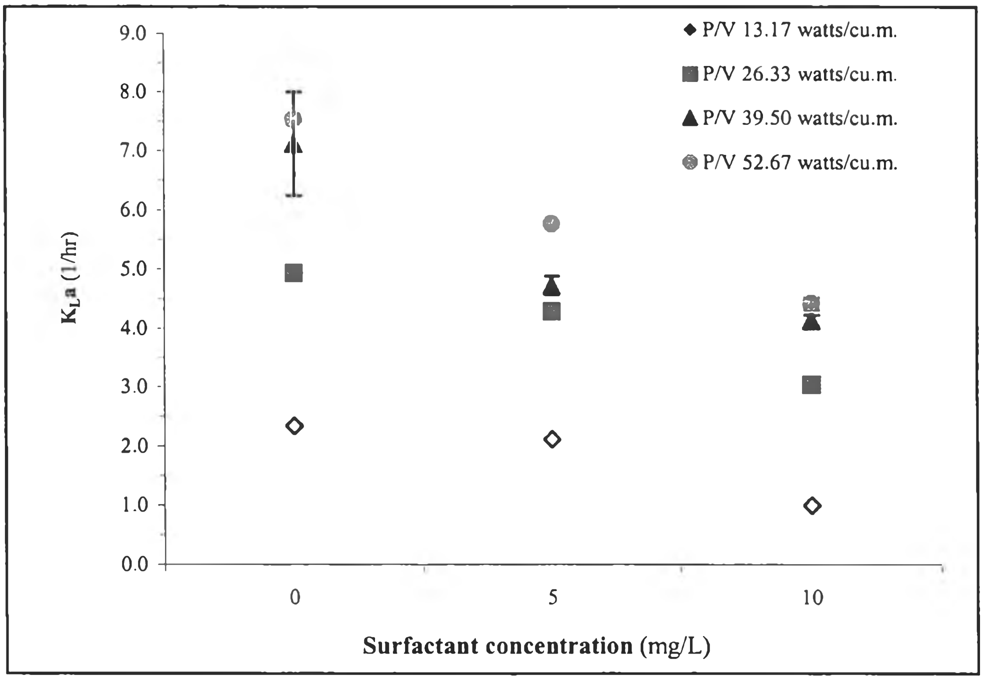

Figure 4.4 Effect of surfactant concentrations on K_La values for 15 cm propeller diameter

4.4 Effect of power input on oxygen transfer for water with surfactant

The effect of power input on the K_La values was shown in Figure 4.5 and 4.6 for 10.7 cm and 15 cm sizes of propellers, respectively. At the same power input, the presence of surfactant severely depressed oxygen transfer. For example, at 52.67 watts/m^3, K_La was lowered from 5.680 hr^{-1} (clean water) to 2.151 hr^{-1} (10 mg/L SAA) or 62.1% reduction for the 10.7 cm propeller diameter. The reduction for the 10.7 cm propeller diameter at the lowest power input is 68.9%. The effect of surfactant on K_La was more considerable at the lower power intensity. For 15 cm propeller diameter, at the highest power input, a 41.4% reduction in the value of K_La compared with 57.4% reduction at the lowest power input. Indeed the ionization of anionic compounds in water produced electrostatic repulsive forces that reduced coalescence probability and hence leaded to bubble diameters lower than those measured in clean water (Gillot *et al*, 1999). Therefore, the presence of surfactant diminished the bubble size. The bubble size could be increased with the velocity due to the more power input. Even though the effect of surfactant decreased K_La values, the more power intensity could reduce this effect and increased the K_La values. From these results, it can be noted that the lower power input, the effect of surfactant to K_La values are much more than at the higher power input. These results are consistent with the previous work that the more power input reduce the effect of surfactant (Stenstrom and Hwang, 1980).

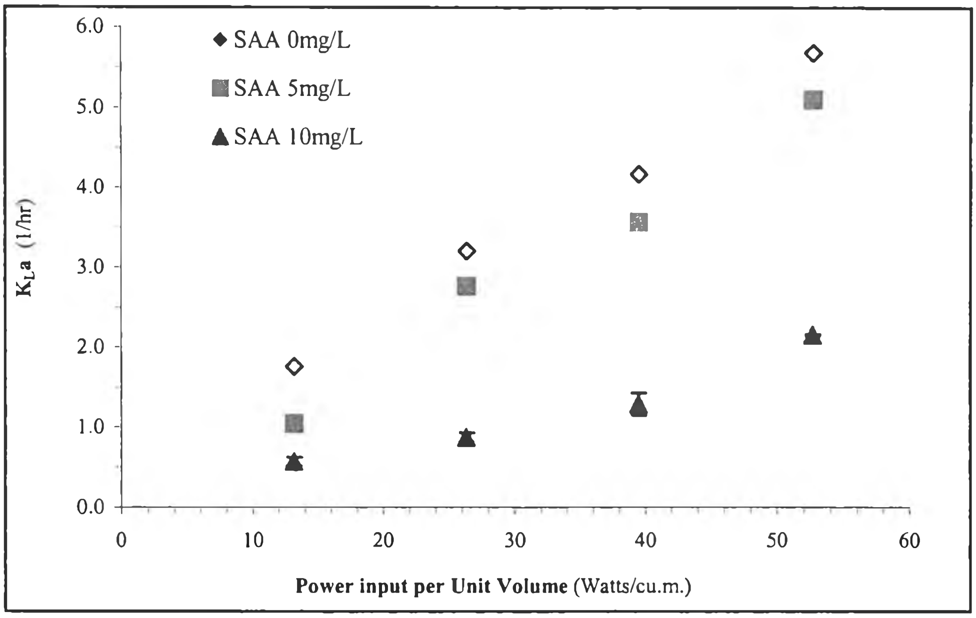

Figure 4.5 Oxygen transfer coefficient as a function of power input and surfactant concentration using 10.7 cm propeller diameter

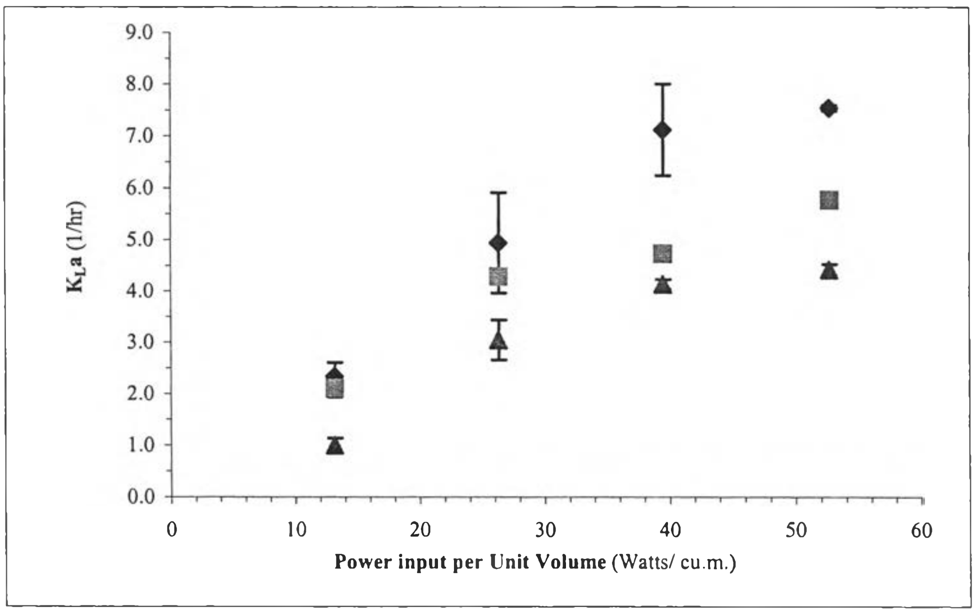

Figure 4.6 Oxygen transfer coefficient as a function of power input and surfactant concentration using 15 cm. propeller diameter

4.5 Effects of mixing condition on oxygen transfer for water with surfactant

Figure 4.7 and 4.8 showed the effect of mixing conditions on K_La values for 5 and 10 mg/L surfactant concentrations, respectively. As previously discussed, the higher surfactant concentration, the lower the oxygen transfer coefficient. However, when the mixing condition became more turbulent, the effect of surfactant to K_La values decreased. An increase in power input created a great turbulent condition, which resulted in an increase in flow velocity. For example, at lowest turbulence, 5 mg/L of surfactant concentration, the reduction of K_La value compared to clean water was 40.4%. At highest turbulence, K_La value was reduced 23.4% comparing to clean water. It can be seen that the more turbulent reduced the effect of surfactant in water. This confirms the previous work (Stenstrom, 2001). It can be noted that the effect of turbulent condition still increased oxygen transfer but surfactant concentration was not. Figure 4.7 and 4.8 illustrate the effect of turbulence and surfactant concentration on K_La values.

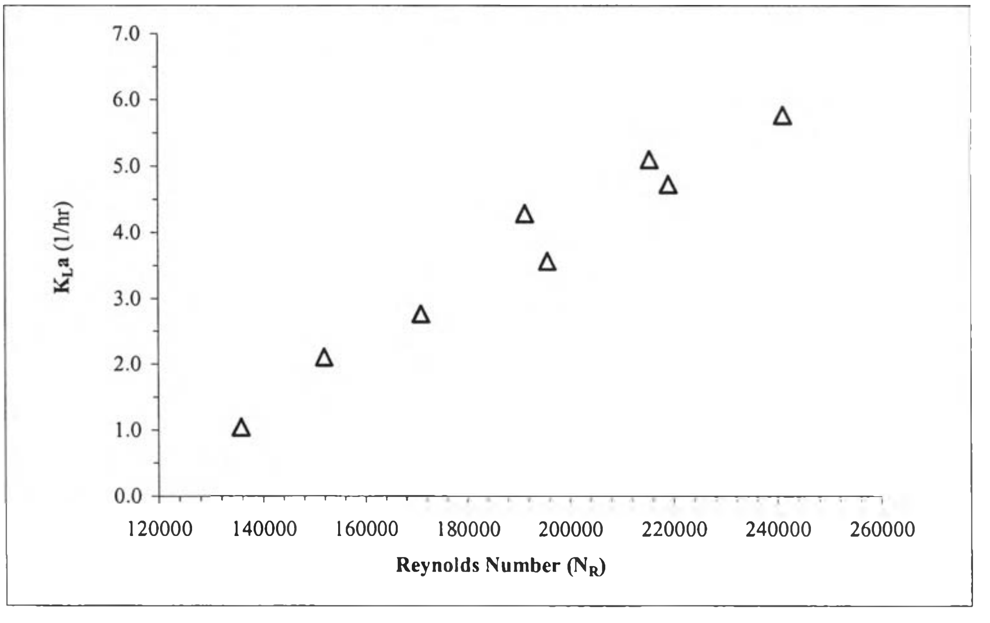

Figure 4.7 Oxygen transfer coefficient as a function of turbulence at 5 mg/L of surfactant concentration

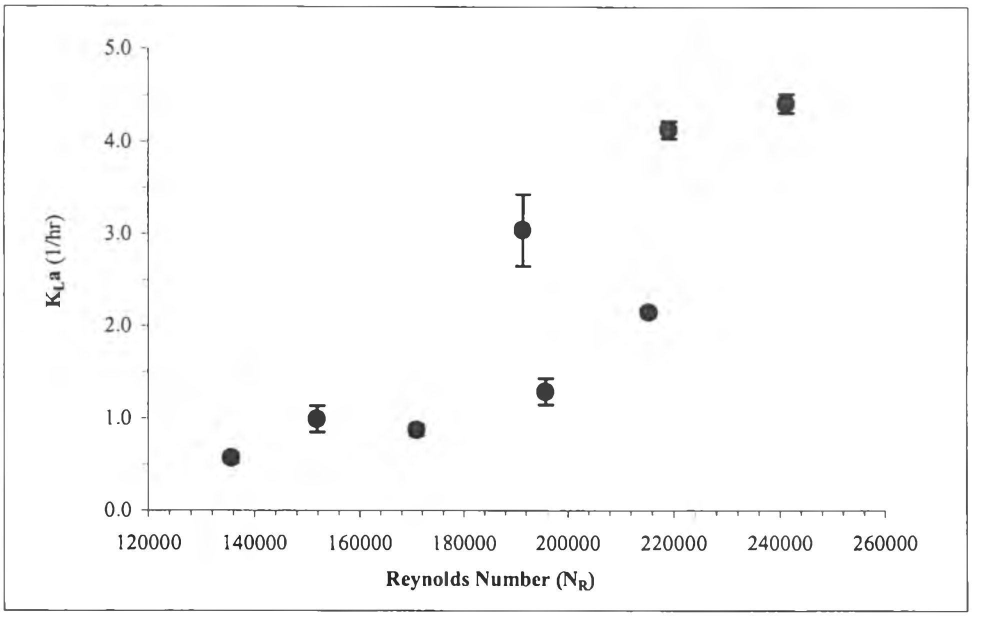

Figure 4.8 Oxygen transfer coefficient as a function of turbulence at 10 mg/L of surfactant concentration

4.6 Proposed equations of oxygen transfer coefficient as a function of power input and surfactant

Experimental results showed the trend of the effects of power input and surfactant concentration on the K_La values. It can be concluded that the quantity of surfactant concentration affected the oxygen transfer. The higher the surfactant concentration, the more reduction of the oxygen transfer would be. The linear regressions were used to fit the experimental data to obtain the relationship between the K_La and surfactant concentrations and power inputs.

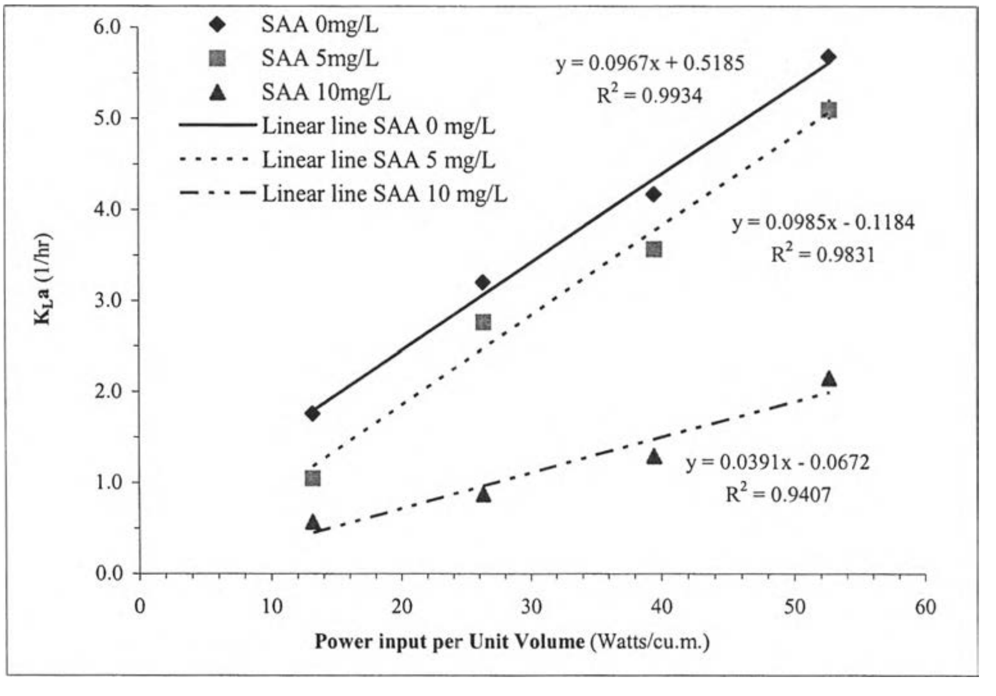

Figure 4.9 Influence trends for K_La by power input and surfactant for 10.7 cm propeller diameter

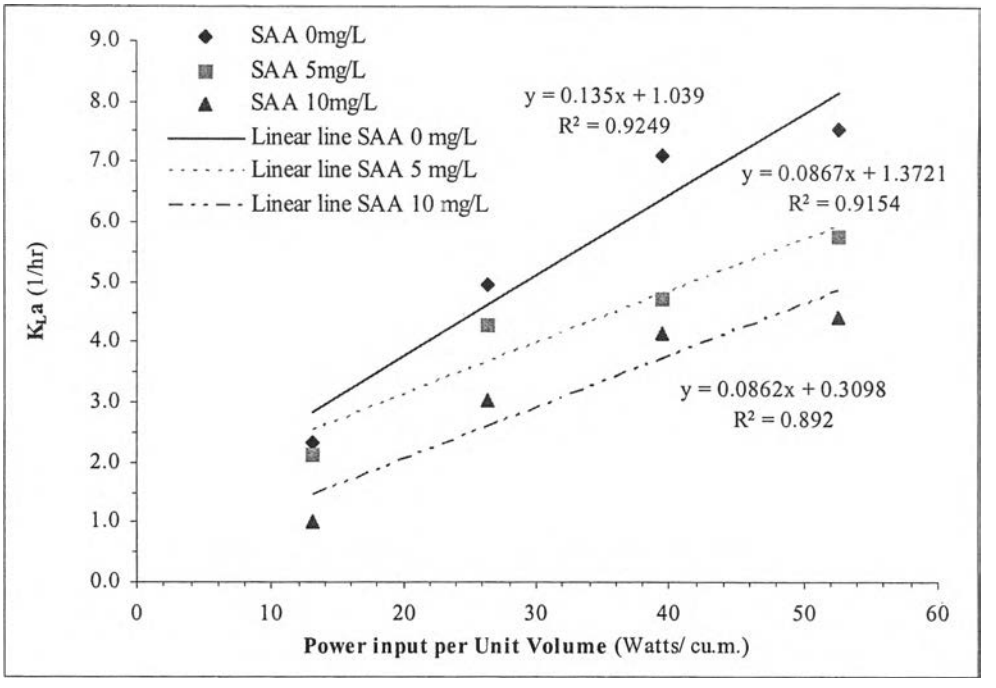

Figure 4.10 Influence trends for K_La by power input and surfactant for 15 cm propeller diameter

Table 4.3 and 4.4 showed the proposed equations for K_La values in each power input at different surfactant concentrations. The R^2 values in each equation were in the range of 0.8920 to 0.9934. These R^2 values are in the acceptable range and can be applied to estimate the K_La values as a function of power input at different surfactant concentrations under the conditions in this study.

Table 4.3 Proposed equations for estimating K_La as a function of power input at different surfactant concentrations for 10.7 cm propeller diameter

Surfactant concentration	Proposed equations	R^2
0 mg/L	K_La = 1.2734 Power + 0.5185	0.9934
5 mg/L	K_La = 1.2964 Power – 0.1185	0.9831
10 mg/L	K_La = 0.5153 Power – 0.0671	0.9407

Table 4.4 Proposed equations for estimating K_La as a function of power input at different surfactant concentrations for 15 cm propeller diameter

Surfactant concentration	Proposed equations	R^2
0 mg/L	K_La = 1.7774 Power + 1.0388	0.9249
5 mg/L	K_La = 1.1413 Power +1.3720	0.9155
10 mg/L	K_La = 1.1352 Power + 0.3096	0.8921

4.7 Effect of power input on standard oxygen transfer rate for water

The results of K_La values can be concluded as standard oxygen transfer rate (SOTR). The results of SOTR were shown in the Table 4.5 below.

Table 4.5 Summary of SOTR values in propeller diameter sizes

SOTR values (Kg O_2/hr)				
Propeller sizes	**Power inputs per unit volume**			
	13.2 Watts/m^3	**26.3** Watts/m^3	**39.5** Watts/m^3	**52.7** Watts/m^3
10.7 cm	0.006	0.012	0.016	0.022
15 cm	0.008	0.018	0.027	0.028

The trend of SOTR is similar to these K_La values. The higher power input, the more SOTR. The following two figures showed the relationship between SOTR and power input for 10.7 cm and 15 cm sizes of propellers. The trends of these graphs are similar to the trend between K_La values and power input.

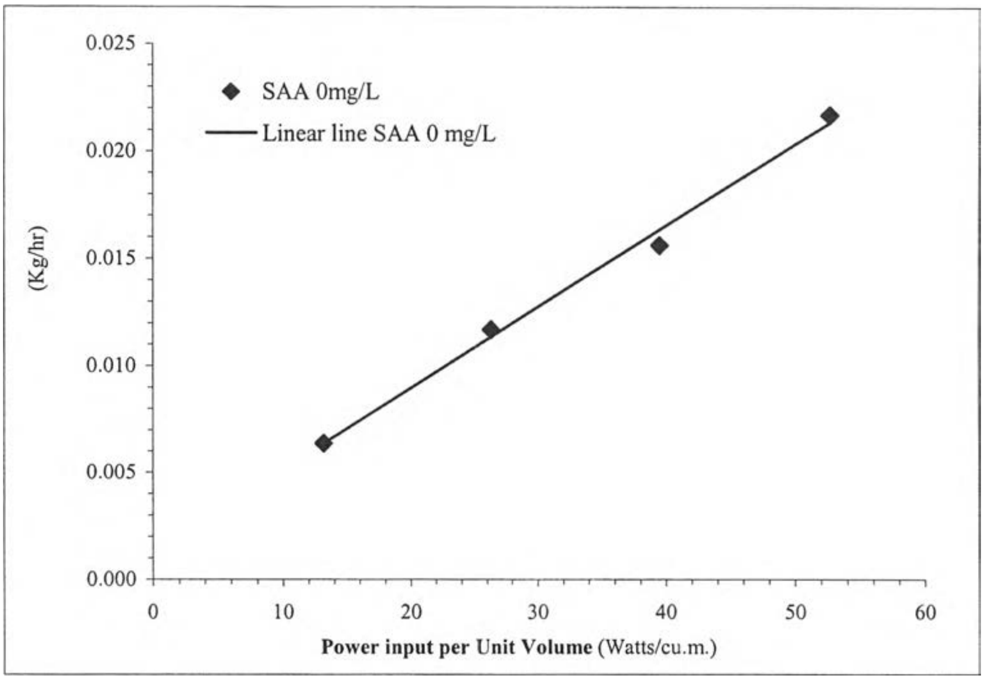

Figure 4.11 Effect of SOTR as a function of power input to K_La for 10.7 cm propeller diameter

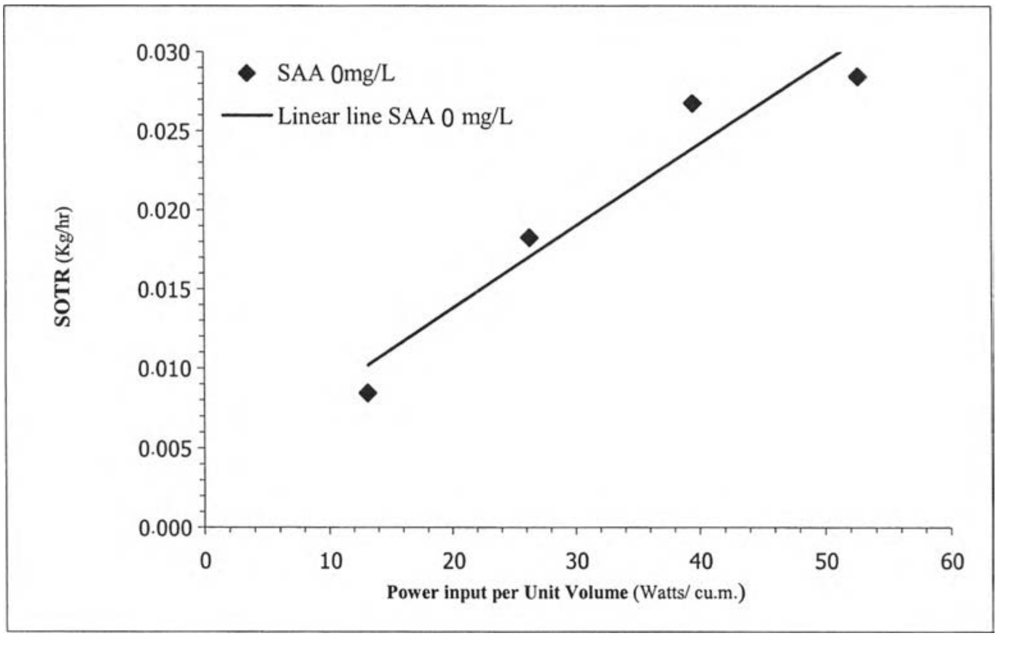

Figure 4.12 Effect of SOTR as a function of power input to K_La for 15 cm propeller diameter

The relationship between obtained SOTR and power input for each condition is shown in Table 4.6.

Table 4.6 Proposed equations for estimating SOTR [Kg-O_2/hr)]as a function of power input

Propeller sizes	**Proposed equations**	R^2
10.7 cm	SOTR = 0.0004 Power + 0.0014	0.9938
15 cm	SOTR = 0.0005 Power + 0.0033	0.9295

4.8 Standard aeration efficiency as a function of power input

SAE of two sizes of propellers is shown in the Table 4.7. The highest SAE values for 10.7 cm and 15 cm propeller diameter is at the highest power input, 52.7 watts/m^3.

Table 4.7 Summary of SAE [Kg-O_2/(Kw-hr)] values for each propeller diameter

Propeller sizes	**Power inputs per unit volume**			
	13.2 Watts/m^3	**26.3** Watts/m^3	**39.5** Watts/m^3	**52.7** Watts/m^3
10 cm	0.547	0.960	0.791	1.381
15 cm	0.842	2.071	2.290	2.456

4.9 Reduction in oxygen transfer for water with surfactant

Table 4.8 Summary of percent reduction of K_La values compared with K_La of clean water for 10.7 cm propeller diameter

Surfactant Concentration	**Percent reduction of K_La** (%)			
	13.2 Watts/m³ (632 RPMs)	**26.3** Watts/m³ (798 RPMs)	**39.5** Watts/m³ (914 RPMs)	**52.7** Watts/m³ (1005 RPMs)
5 mg/L	42.9	13.5	14.3	10.2
10 mg/L	68.9	72.7	69.1	62.1

Table 4.9 Summary of percent reduction of K_La values compared with K_La of clean water for 15 cm propeller diameter

Surfactant Concentration	**Percent reduction of K_La** (%)			
	13.2 Watts/m³ (362 RPMs)	**26.3** Watts/m³ (455 RPMs)	**39.5** Watts/m³ (519 RPMs)	**52.7** Watts/m³ (571 RPMs)
5 mg/L	9.7	13.1	33.6	23.4
10 mg/L	57.4	38.3	42.0	41.4

For 10.7 cm propeller, 5 mg/L of surfactant concentration, K_La values were decreased less significantly for 26.3, 39.5, and 52.7 watts/m^3 in the range about 10% to 15%. But for the lowest power input, 13.2 watts/m^3, power input seemed to influence to K_La value because the reduction of K_La values can be a result of the lower agitation with the lower power input. The percent reduction for this value was significant. For 10 mg/L of surfactant concentration, the ranges of the percent reduction for K_La values were about 62 to 73. The more surfactant concentration affected to K_La values significantly although the more power inputs were performed.

It can be seen that the effect of power intensity was not different when the highest surfactant concentration was presented.

For 15 cm propeller, 5 mg/L of surfactant concentration, the differences of reduction percentage were not significant. For 10 mg/L of surfactant concentration, the reduction percentages were significant. The range was about 38% to 58%. The less of power intensity resulted in higher reduction percentage. The variation of the percent reduction of these K_La values in each size of propeller, surfactant concentration and power intensity can be the results of the agitation in water, the formation of the bubble, and the volatilization of surfactant. The different power intensity affect to the characteristic of the presence of surfactant into water. The variation of power intensity can also affected to the formation of bubble and volatilization of surfactant. Shape and size of bubble formation are different in the variation of power input. The rising of surfactant up to water surface and then transform into foam or volatile into the air are the different in each power input. The amount of the lingering surfactant and the dispersion of surfactant concentration, which still present in water at different power intensity, can resulted in different reduction of K_La values.