



CHAPTER 3

METHODOLOGY

3.1 Apparatus

3.1.1 Aeration Apparatus

The aeration tank studies were performed in a 300 liters tank with four baffles. It was installed extending approximately one-tenth of the tank diameter out from the wall to eliminate vortex conditions. Turbine aeration system was installed in this tank (Metcalf & Eddy, 1991).

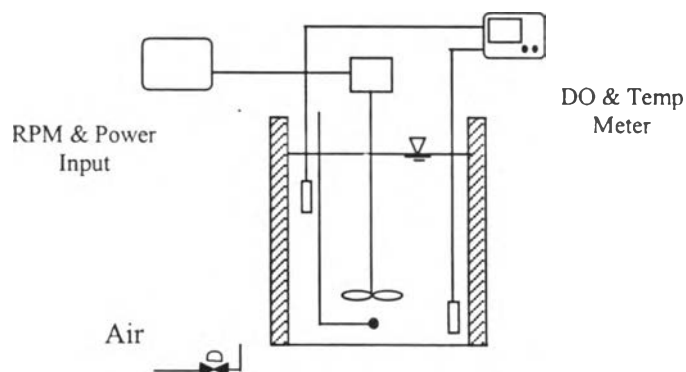
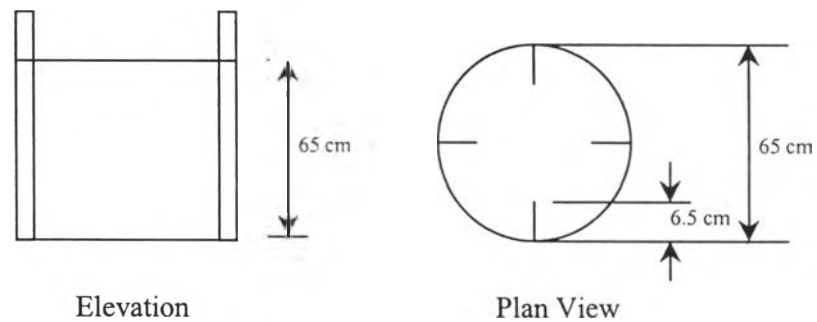


Figure 3.1 Aeration Equipment

3.1.2 Water

For determination of a standard oxygen transfer rate, the water quality should be a public water supply. The unsteady-state clean water test was occasionally conducted in clean water and with surfactant addition in an effort to mask the effect of contaminants in tap water.

3.1.3 Measurement Devices

Two Dissolved Oxygen (DO) meters were used to collect concentration versus time data in non-steady-state reaeration tests that are used to estimate clean water oxygen transfer rate. Conductivity and pH meters are also necessary for parameters measurement.



Figure 3.2 DO, Conductivity and pH Meters

3.1.4 Experimental Chemicals

3.1.4.1 Sodium Sulfite

Sodium sulfite (Na_2SO_3) was used for deoxygenation in accordance with ASCE standard method.

3.1.4.2 Cobalt Catalyst

Analytical-reagent-grade cobalt chloride hydrate, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ was used to catalyze the deoxygenation reaction in accordance with ASCE standard method.

3.1.4.3 Surfactant Addition

Sodium Dodecyl Sulfate (SDS) was used as a surfactant and the optimum oxygen transfer coefficient in the presence of surfactant was tested. The concentrations of surfactant were 5, 10 and 15 mg/L respectively.



Figure 3.3 Experimental Chemicals

3.1.5 Computer Program

ASCE DO parameter estimation program (DO_PAR) was used to analyze data to find parameter estimation. After obtaining the data, the graph between $K_{L,a}$ versus power input per volume was created. (Stenstrom *et.al.*, 1997)

3.1.6 Power Apparatus

For the turbine aeration system test, three-phase induction motor, 0.5 Hp flange-mounted motor, was used to perform these tests. The converter, T-verter, E2-201-H1, was used to control RPMs.

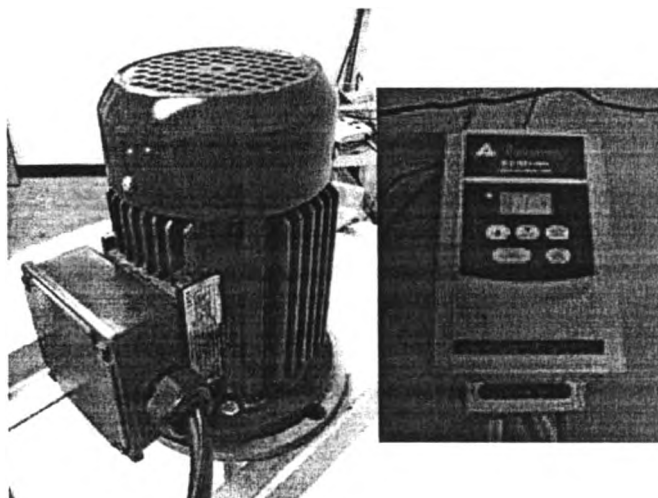


Figure 3.4 Motor and Converter

3.1.7 Air Flow Apparatus

The experiments were performed at 38 L/min of gas flow rate. Air compressor and a fine bubble diffuser were used.

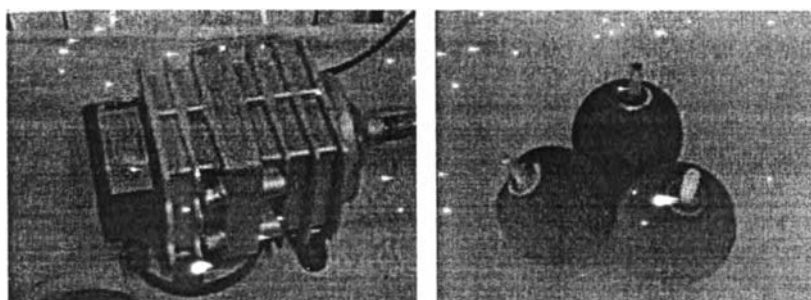


Figure 3.5 Compressor and Diffuser

3.2 Experiment Procedure

3.2.1 Experiment Flowchart

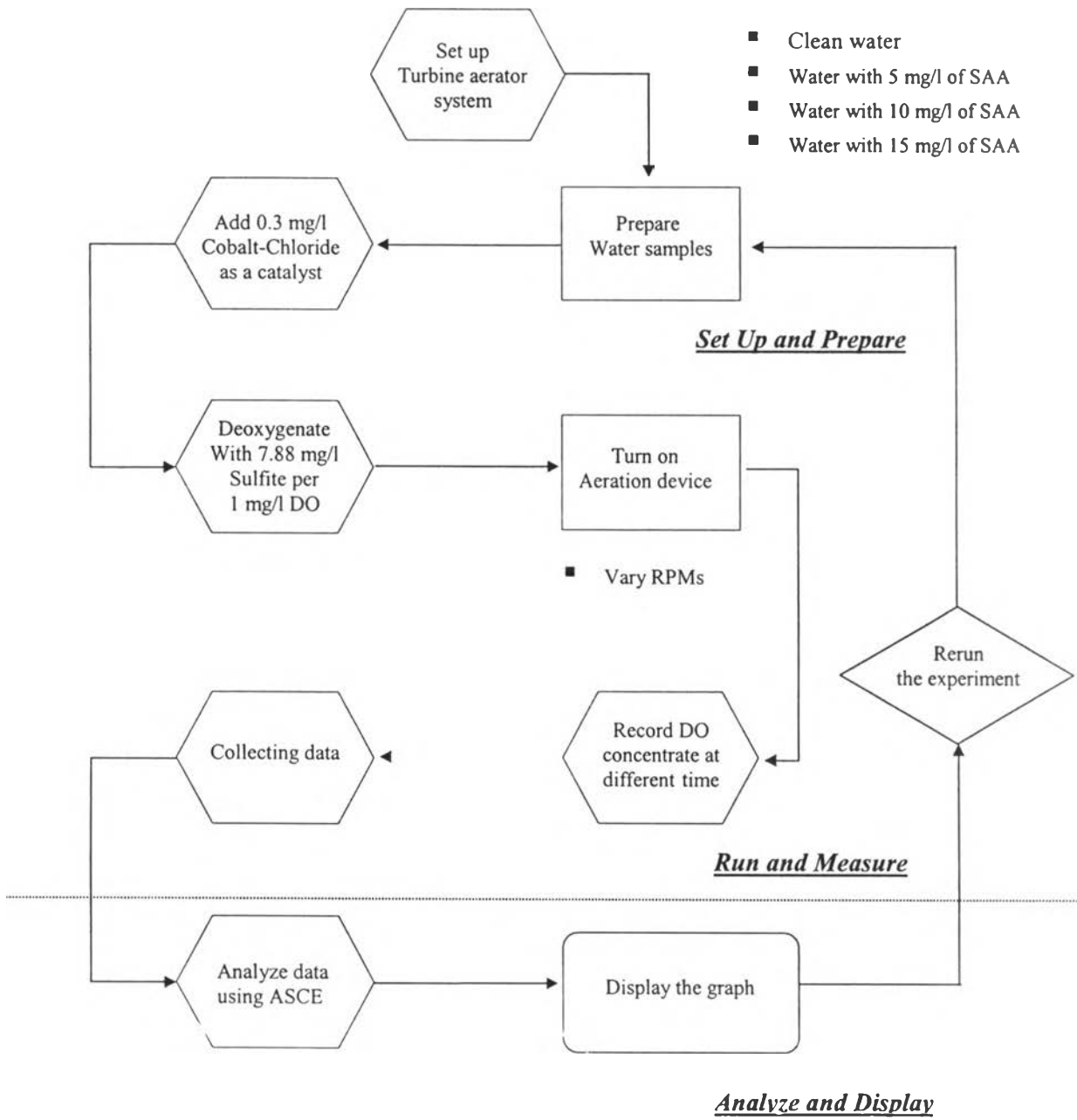


Figure 3.6 Flowchart of the experiment.

- The aeration tank was filled with tap water to the desired volume, approximately 200 liters.
- The desired quantity of analytical reagent grade surfactant (DSS) was dissolved in a 300-ml beaker and mixed in the test tank.
- Approximately 0.3 mg/l Cobalt-Chloride was added as a catalyst and deoxygenate water sample by preparing 7.88 mg/l Sulfite per 1 mg/l DO to deaerate DO in the water.
- The aeration device was turned on. The excess sodium sulfate will allow ample time for the mixing patterns in the tank to develop before the dissolved oxygen begin to rise above zero. The test will be terminated when the dissolved oxygen will reach saturation.

3.2.2 Water Quality

3.2.2.1 Total Dissolved Solids

The water supplied for the initial test was tap water. Subsequent test was conducted in the same water, and, because of the addition of deoxygenation chemicals, the total dissolved solids concentration (TDS) will increase. Repetitive testing may be conducted in the same water, provided that the TDS does not exceed 2,000 mg/L. (ASCE, 1993).

3.2.2.2 Temperature

Water temperature should be between 10°C and 30°C, and also close to 20°C as possible. It is recommended that a standard θ , temperature correction factor, of 1.024 be employed to adjust for temperature. Water temperature shall not change by more than 2°C during a single unsteady-state test (ASCE, 1993).

3.2.3 System Stability

The aeration system should be operated to achieve stable hydraulic conditions prior to starting the oxygen transfer evaluation. For this system, the volume of water under aeration should not vary by more than $\pm 2\%$ during any one test (ASCE, 1993).

3.2.4 Addition of Deoxygenation Chemicals

3.2.4.1 Cobalt Addition

The cobalt catalyst should normally be added once for each test water. A solution of cobalt salt shall be added to the test tank to achieve a soluble cobalt concentration between 0.10 mg/L and 0.50 mg/L in the test water.

The cobalt solution was added prior to the beginning of oxygen transfer testing with the aeration system operating. The solution should be uniformly distributed into the test tank. The cobalt solution should be dispersed throughout the tank by operating the aeration system for approximately 30 min.

3.2.4.2 Sulfite Addition

The theoretical sodium sulfite (NaSO_3) requirement for deoxygenation is 7.88 mg/L per 1.0 mg/L DO concentration. Sulfite additions were made in excess of stoichiometric amounts. The amount excess is dependent on the oxygen transfer rate of the aeration system and the size of the test tank. The amount of excess varies from 20 to 250% and increase for high transfer rate systems. It is significant to note that the amount of excess sulfite used did not affect $K_L a$ values as determined in replicate testing (Boyle *et.al.*, 1989).

Sufficient sulfite solution was added to depress the DO level below 0.5 mg/L at all points in the test water. Consistent repetitive testing results have been observed where the DO concentration has reached zero at all sample points and remained at zero at least two minutes. Results from the initial test and be used to help establish the proper quantity to be added.

Sodium sulfite was dissolved in mixing tanks outside the test tank and distributed uniformly into the test tank.

3.2.5 Determination of Dissolved Oxygen

Dissolved oxygen concentrations were determined at various points in the tank and at various times during the unsteady-state test. This determination was carried out by in situ measurement of dissolved oxygen in the tank by membrane probes (ASCE, 1993).

3.2.5.1 Location Points

The number and location of dissolved oxygen determination points was dictated by the size of the test tank, aeration placement, and mixing pattern in the tank.

Two determination points were used in this experiment. One was at a shallow depth, in the middle of the first half of water height. Another was at a deep location, at the middle of the second half of water height. Shown as Figure 3.1.

The determination points should be located in an attempt to have each sense an equal portion of the tank volume and should be distributed vertically and horizontally to best represent the tank contents. DO probes were secured by appropriate means to minimize movement due to water currents generated by operation of the aeration system during the tests.

3.2.5.2 Period of Dissolved Oxygen Determinations

DO Probes with Continuous Recorders: Dissolved oxygen concentrations were determined at various times during the unsteady-state test using DO probes with continuous recorders. A continuous record of DO versus time was available at each determination point. A minimum of 21 discrete data values was selected from the continuous record for analysis (ASCE, 1993).

Timing Criteria: The purpose of these criteria is to ensure that the data points are representative of the reaeration curve, and that an adequate number of points are obtained in sensitive regions of the curve. The rising part of the curve, up to about 85% of saturation, is sensitive for estimation of $K_L a$, and the stationary part of the curve, above 90% saturation, is sensitive for the estimation of C^*_{α} . Consequently, the timing of DO values used in the data analysis should meet the following criteria for range and balance after preparation and possible low-end truncation. The lowest DO value should be not greater than 20% of C^*_{α} . The highest DO values should be not less than 98% of C^*_{α} (ASCE, 1993).

Balance: The balance of data and timing should meet these criteria below.

- The DO values are measured so that about two-thirds (58%-75%) of the values are evenly distributed over the rising portion of the curve between 20% and 86% of saturation, and about one-third (25%-42%) of the values are evenly distributed over the stationary portion between 86% and 98% of saturation.
- When 21 or more DO values are used, the values can be evenly spaced at approximately equal time intervals over the entire range between the first and last DO value.

3.2.5.3 Test Duration and Dissolved Oxygen Saturation

Dissolved oxygen data should be obtained over as wide a range as possible. Even though low-end values may be truncated to avoid lingering effects of the deoxygenation technique prior to analysis, it is important to collect low dissolved oxygen data so that these effects can be detected. The low dissolved oxygen data shall be established that the sulfite addition has depressed the DO concentration to less than 0.5 mg/L at all determination points. All tests were continued for a time so that the last measured DO value at each determination point is equal to or greater than 98% of C^*_{α} for that determination point (ASCE, 1993).

3.3 Data Analysis

3.3.1 Preparation of Data for Analysis

The purposes of data preparation are:

- To obtain discrete numerical values from continuous probe reading, to plot and examine the data to determine if low-end truncation is necessary,
- To truncate low dissolved oxygen values, and
- To assure that the data values to be analyzed meet the timing criteria

3.3.2 Parameter Estimation

The purpose of the parameter estimation procedure is to determine the best estimates of the three model parameters, K_{La} , C^*_{α} and C_0 so that the model given by equation ... best describes the variation of DO with time at each determination point location in the tank. Parameter estimates were performed for the data at each determination point by the nonlinear regression method (ASCE, 1993).

3.3.2.1 Nonlinear Regression Method

This method which was used in this paper was based on nonlinear regression of the model through the DO-versus-time data as prepare for analysis. The best estimates of the parameters, K_{La} , C^*_{α} and C_0 were selected as the values that drive the model equation through the prepare DO concentration-versus-time data points with a minimum residue sum of squares. Here, a residual refers to the difference in concentration between a measured DO value at a given time and the DO value predicted by the model at the same time (ASCE, 1993).

A computer was required to apply for this method which gave the least square estimates, standard deviations of $K_L a$, C^*_∞ and C_0 , along with an output of the data, fitted values, and residuals. Because of using this method, the prepared data for a particular determination point were entered along with initial approximations of the three parameters. An initial estimate of the three parameters was obtained by examining a plot of DO versus time. The computer then adjusted these initial approximations to minimize the residual sum of squares and reports the final parameter estimates (ASCE, 1993).

For adequate convergence, the initial parameter estimate for C_0 were within two mg/L of the final estimate. Frequently, data were taken with time zero defined early in the test sequence, and this could correctly result in large negative predicted values of C_0 . In these cases, the initial parameter estimate for C_0 might be facilitated by redefining time zero so that C_0 was approximately zero. This redefinition of time zero did not affect the model predictions for $K_L a$, and C^*_∞ (ASCE, 1993).

The values of DO predicted by the model based on the final parameter estimates should be plotted along with the measured values and examined. A visual examination of such a plot indicated any gross mistakes or false convergence occasionally occurs and could be easily remedied, improving the initial parameter estimates (ASCE, 1993).

3.3.3 Power Input Calculation

Power input was calculated from rpm for the mixer. The mixer motor speed controller provided a millivolt output proportional to motor torque. This feature was considered essential for testing since it is not possible to accurately estimate motor torque from impeller characteristics (Stenstrom and Hwang, 1980)