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Sales and Service Agreement 63014 *"Sample Analysis"*

BOC ESP Testing - SUMMARY OF RESULTS

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Notation

ASCE	American Society of Civil Engineers
CW	Clean water
DO	Dissolved Oxygen
ESP	EcoSystem Plus chemical
ppm	Parts per million
k_La	Volumetric mass transfer coefficient in clean water (t^{-1})
SOTE	Standard oxygen transfer efficiency in clean water (%, or $mass_{O2,transferred}\ mass_{O2,fed}^{-1}$)
SOTR	Standard oxygen transfer rate in clean water ($mass_{O2,transferred}\ time^{-1}$)
α	Alpha factor = Oxygen transfer correction factor for process water
αk_La	k_La in process water (t^{-1})
αSOTE	SOTE in process water (%, or $mass_{O2,transferred}\ mass_{O2,fed}^{-1}$)
αSOTR	SOTR in process water ($mass_{O2,transferred}\ time^{-1}$)

Introduction

Measurements of oxygen transfer in water were carried out to calculate the rate of oxygen transfer from diffused gas with and without the addition of an external chemical. The ASCE Standard (2006) adopted here is applicable to laboratory-scale oxygenation devices with small volumes of water as well as to full-scale systems with water volumes typical of those found in the activated sludge wastewater treatment process. This testing method is based upon removal of dissolved oxygen (DO) from the water volume by an oxygen scavenger (sodium sulfite, catalyzed by cobalt chloride) followed by re-oxygenation to near the saturation level (>96% of saturation). The DO inventory of the water volume is monitored during the re-aeration period by measuring DO concentrations at frequent intervals and throughout the water volume.

The primary results of this testing are expressed as:

- the standard oxygen transfer rate (SOTR, $mass_{O2,transferred}\ time^{-1}$)
- the volumetric oxygen transfer coefficient (k_La, $time^{-1}$)
- the standard oxygen transfer efficiency (SOTE, $mass_{O2,transferred}\ mass_{O2,fed}^{-1}$)

Standard conditions are defined as 20^oC, 1atm, zero (0) DO, zero (0) salinity. In practice, when the clean water TDS is below 2000 mg l^{-1}, the salinity correction is not measurable and all tests in tap water can be deemed as clean water tests.

Methods

Experiments were conducted in a laboratory environment using a small-scale tank (volume = 21 liters, 16 liters of water plus 5 liters of freeboard) following the procedure outlined in the American Society of Civil Engineers, Measurement of Oxygen Transfer in Clean Water (ASCE, 2006). The oxygen transfer is determined from the increase of the previously, artificially lowered DO concentration. The addition of sodium sulfite (Na_2SO_4, stoichiometric amount: 7.8 mg l^{-1} per 1.0 mg l^{-1} of DO) and cobalt chloride catalyst ($CoCl_2$, 0.1 mg l^{-1}) reduces the DO of the water in the tank to less than 0.5 mg l^{-1}.

The DO of the water was measured using a fast electrochemical DO probe (YSI 58, Yellow Springs, OH) connected via digital/analog converter to a computer to sample, store and analyze the data. Due to space constraints within the testing column, a single YSI 58 was used. Since the column could only accommodate one DO probe, two other YSI 58 devices were maintained external to the test tank for QA/QC. The calibration of the DO probe used in the tests was verified before and after each run by comparison with the external probes. Satisfactory QA/QC tests were those when the DO discrepancy was within 0.5 mg l^{-1}. All runs reported here passed the QA/QC tests.

> *A set of tests in clean water and at incremental air flow rates (1,2,3 l min^{-1}) was performed to establish a clean water baseline for SOTR, SOTE, k_La.*

Five 200ml solutions of decreasing ESP concentration (10% to 0.001%) and one DI water (control) were prepared. 16 liters of water were placed in the tank along with Na_2SO_4 and $CoCl_2$. The air supply apparatus was assembled to provide air at a constant flow rate, bubbled through each solution (to strip the ESP), before entering the water column through a bubble diffuser.

> *A second set of tests in water with the addition of ESP at the same incremental air flow rates (1,2,3 l min^{-1}) was performed to measure αSOTR, αSOTE, αk_La.*

All DO data sets were processed with the ASCE DOPar v3.0.3 software (downloadable at http://www.seas.ucla.edu/stenstro/DOPar3-0-3.zip) that provides a log-linear regression and exponential fit analysis of the data.

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Apparatus

The air supply passed through a regulator to reduce and control the pressure before entering the rotameter (Fig. 1). Passing through a volatilization chamber the air bubbled through prepared solutions of DI water and ESP before entering the water column through the diffuser. Airflow rates of 1, 2 and 3 l min^{-1} were selected for testing.

The mass of the solution in the volatilization chamber was measured before and after each experiment, thus providing the quantity of solution consumed through the experiment. The chemical dose was calculated as the mass of chemical consumed divided by the volume of water in the column. This is the scenario where 100% of the chemical is transferred from the gas line to the liquid. However, the chemical mass transfer efficiency cannot be measured, hence the ESP doses or concentrations in the column reported below are the maximum possible, but not necessarily the actual values.
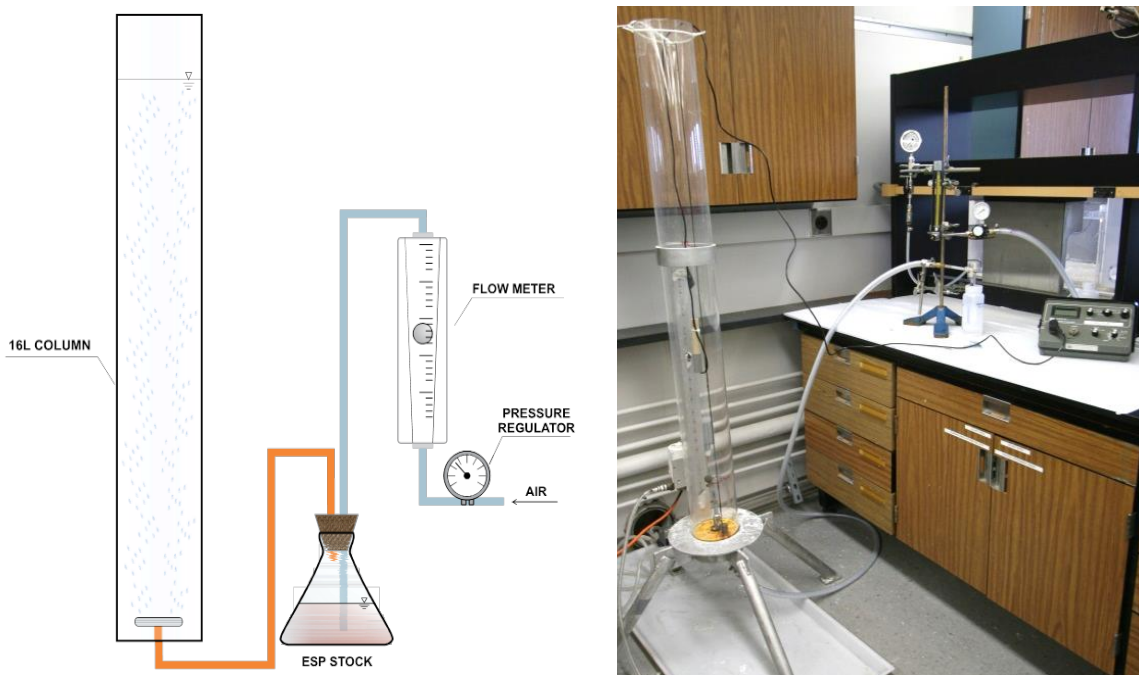
Figure 1. Schematic of the experimental setup (left) and photograph (right) showing the testing column, the chemical dosing unit, the flow regulation/metering set up, and the YSI 58 DO meter.

Results

The results below (Fig. 2) show the volumetric oxygen transfer efficiency ($k_L a$, h^{-1}) in clean water (blue symbol) and in process water (at increasing air flows, with increasing darkness of the symbol from yellow to black) vs. the dose of ESP chemical added to the air line. Note that the dose reported here is the maximum attainable concentration in the column at 100% ESP transfer efficiency, and represents a ceiling but not necessarily the actual value (this cannot be known unless water quality tests are performed).
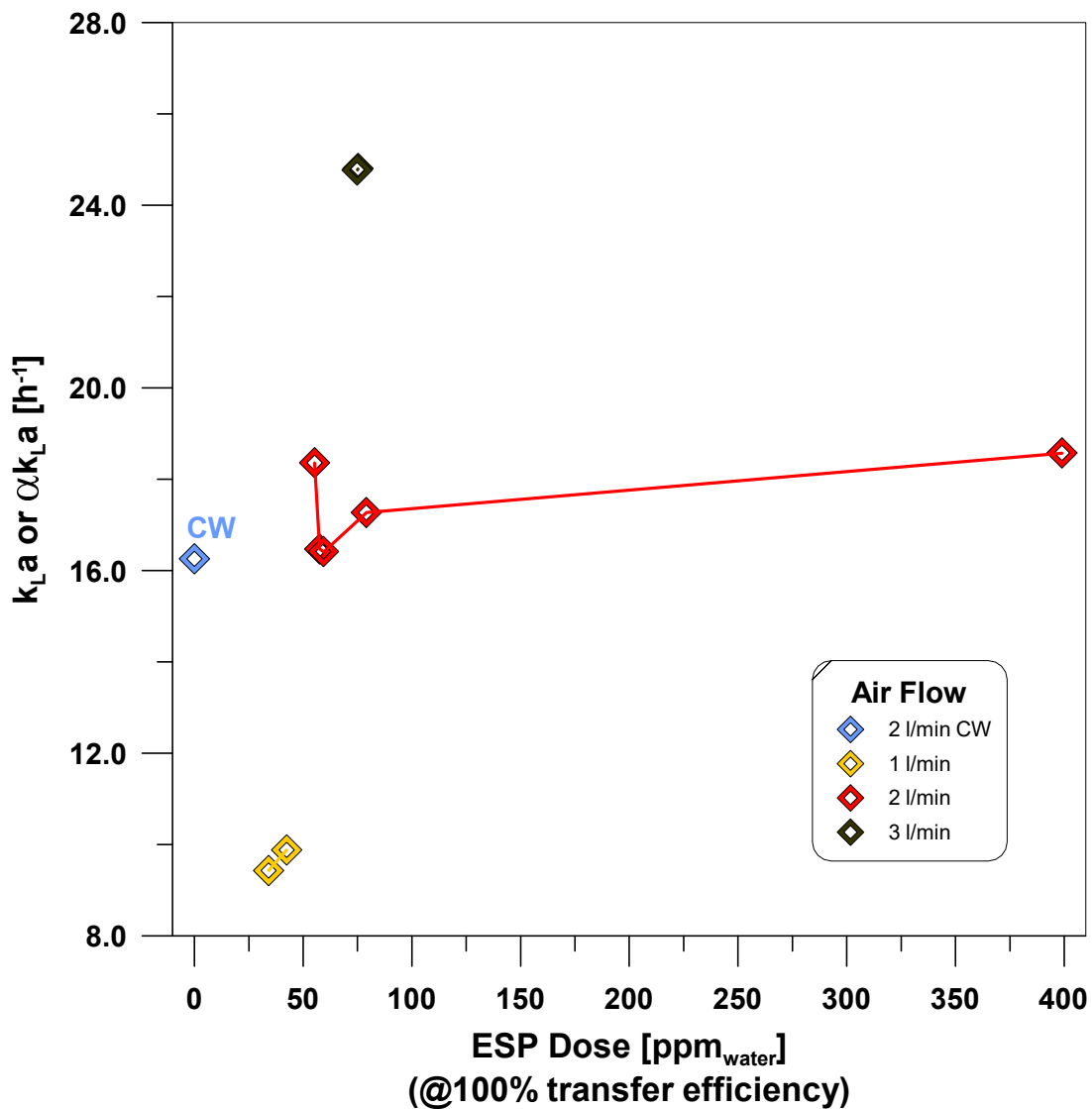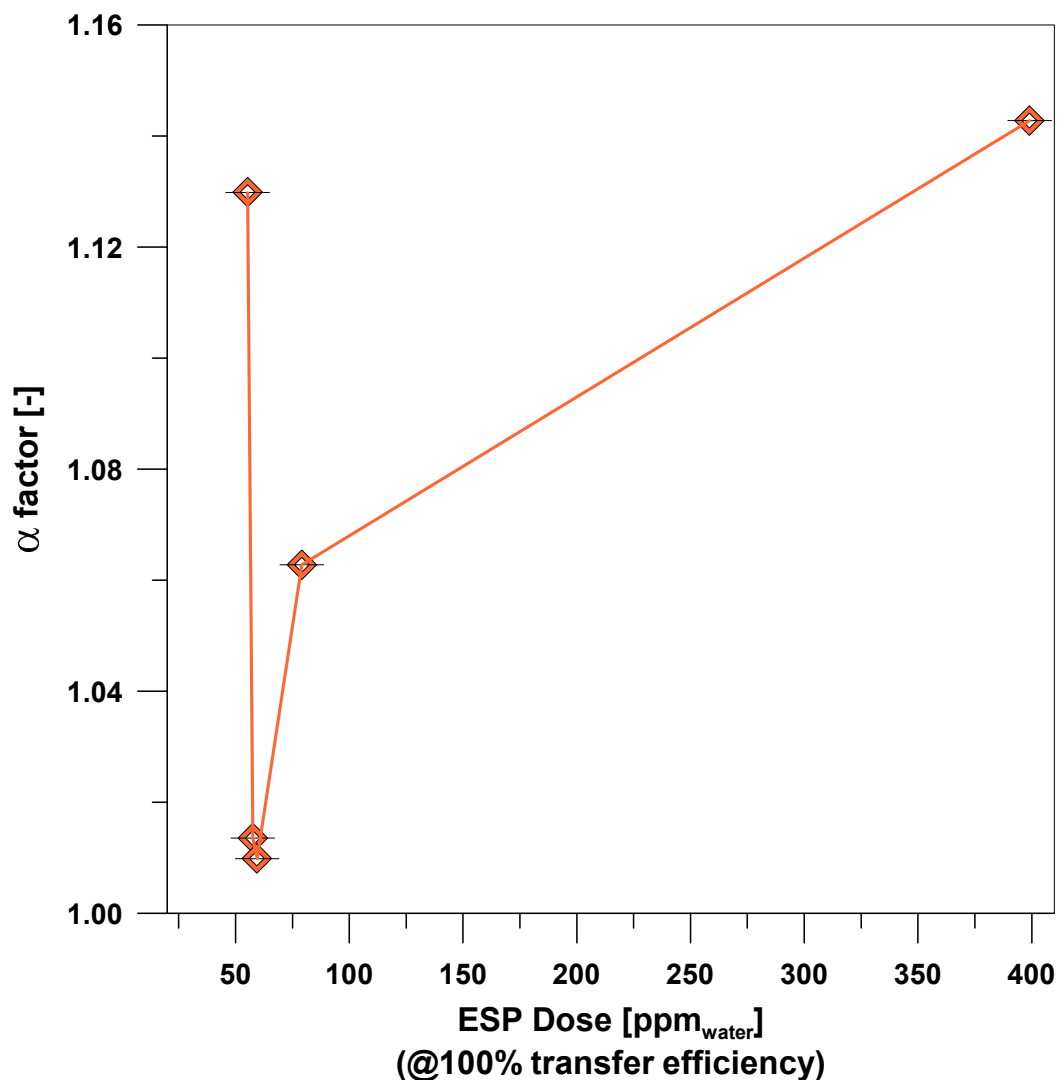

Figure 2. Volumetric mass transfer coefficient $k_L a$ vs. incremental ESP dose,
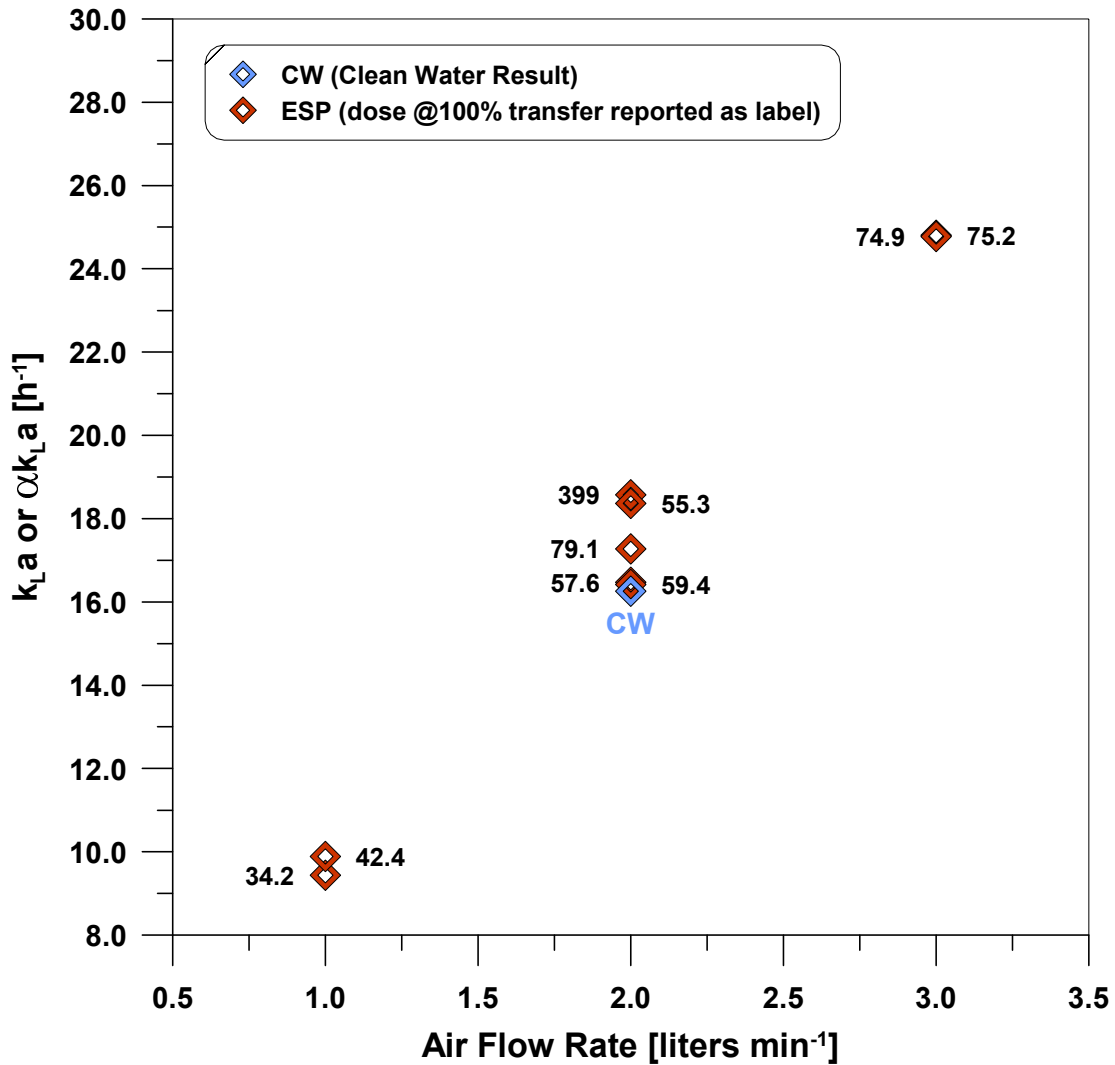
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calculated at 2 l/min air flow.

The results below (Fig. 3) show the alpha factor [$\alpha k_L a / k_L a = k_L a$(process water) / $k_L a$ (clean water), dimensionless] at an air flow of 2 l min^{-1} vs. the dose of ESP chemical added to the air line. The points in this plots are the ratio of the red symbols and the blue symbol in Fig. 2. Note that the dose reported here is the maximum attainable concentration in the column at 100% ESP transfer efficiency, and represents a ceiling but not necessarily the actual value (this cannot be known unless water quality tests are performed).

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Figure 3. Alpha factor vs. incremental ESP dose, calculated at 2 l min^{-1} air flow.

The value of k_La vs. the air flow rate are plotted in Fig. 4. In this graph k_La is used for clean water and αk_La is for solutions containing ESP.

Figure 4. Volumetric mass transfer coefficient k_La vs. air flow.

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The standard oxygen transfer efficiency SOTE is plotted in Fig. 5. Analogously to Fig. 4, the clean water results are labeled SOTE and the solutions containing ESP are labeled αSOTE.
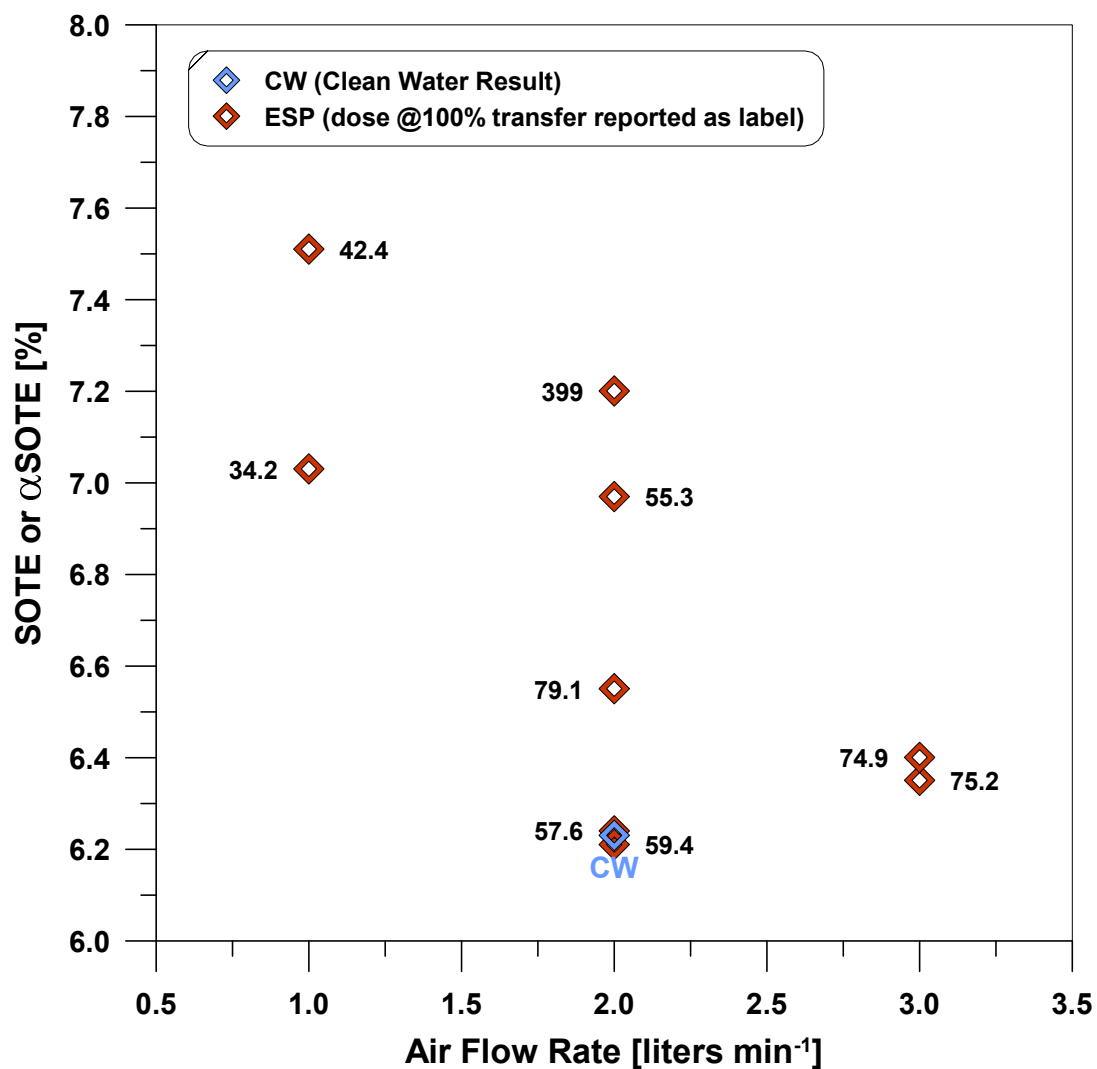

Figure 5. Standard oxygen transfer efficiency SOTE vs. air flow.

References

ASCE (2006) *Measurement of oxygen transfer in clean water*, ASCE Standard,

Appendix - Data Summary

AFR (l/min)	Duration (min)	Stock Dm (g)	Dilution (v/v)	ESP Consumption (g/l AIR)	ESP Consumption (g/IW) @100%eff	ESP Consumption (ppmW) @100%eff	kLa (h-1)	aSOTE (%)	alpha
1.00E+00	6.60E+01	5.47E-01	1.00E+04	3.61E-03	3.42E-02	3.42E+01	9.43E+00	7.03E+00	
1.00E+00	7.50E+01	6.79E-01	1.00E+04	5.09E-03	4.24E-02	4.24E+01	9.88E+00	7.51E+00	
2.00E+00	6.40E+01	9.22E-01	1.00E+04	2.95E-03	5.76E-02	5.76E+01	1.65E+01	6.24E+00	1.01E+00
2.00E+00	6.40E+01	9.51E-01	1.00E+04	3.04E-03	5.94E-02	5.94E+01	1.64E+01	6.21E+00	1.01E+00
2.00E+00	6.40E+01	6.39E+00	1.00E+04	2.04E-02	3.99E-01	3.99E+02	1.86E+01	7.20E+00	1.14E+00
2.00E+00	6.30E+01	8.85E-01	1.00E+04	2.79E-03	5.53E-02	5.53E+01	1.84E+01	6.97E+00	1.13E+00
2.00E+00	7.20E+01	1.27E+00	1.00E+03	4.56E-02	7.91E-02	7.91E+01	1.73E+01	6.55E+00	1.06E+00
3.00E+00	6.40E+01	1.20E+00	1.00E+04	2.57E-03	7.52E-02	7.52E+01	2.48E+01	6.35E+00	
3.00E+00	6.40E+01	1.20E+00	1.00E+04	2.56E-03	7.49E-02	7.49E+01	2.48E+01	6.40E+00	
2.00E+00	6.50E+01						1.63E+01	6.23E+00	1.00E+00