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THE HENRY SAMUELI SCHOOL OF ENGINEERING

ENVIRONMENTAL PROCESS LAB

EPL

MASTER THESIS IN

ENVIRONMENTAL ENGINEERING

Effect of Mixing on Oxygen Transfer from Fine-Bubble Diffusers

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Abstract

Every community produces both liquid, solids waste and air emissions. The liquid part of the produced waste also known as "Wastewater" derives essentially from the water supply of the community after it has been used.

Wastewater treatment practice started to evolves in industrialized countries by the end of 19th century after the thousand of victims caused by cholera epidemic.

The goal of wastewater treatment engineering is to protect public heath and the environment in a manner commensurate with environmental, economic and political concern.

Biological treatments have always been the most used type of treatments for both municipal and industrial wastewater. The reason is the high efficiency and the easy management in spite of chemical treatments.

The aeration process goal is to transfer the higher amount of oxygen from gas phase to liquid phase by following the two film model theory

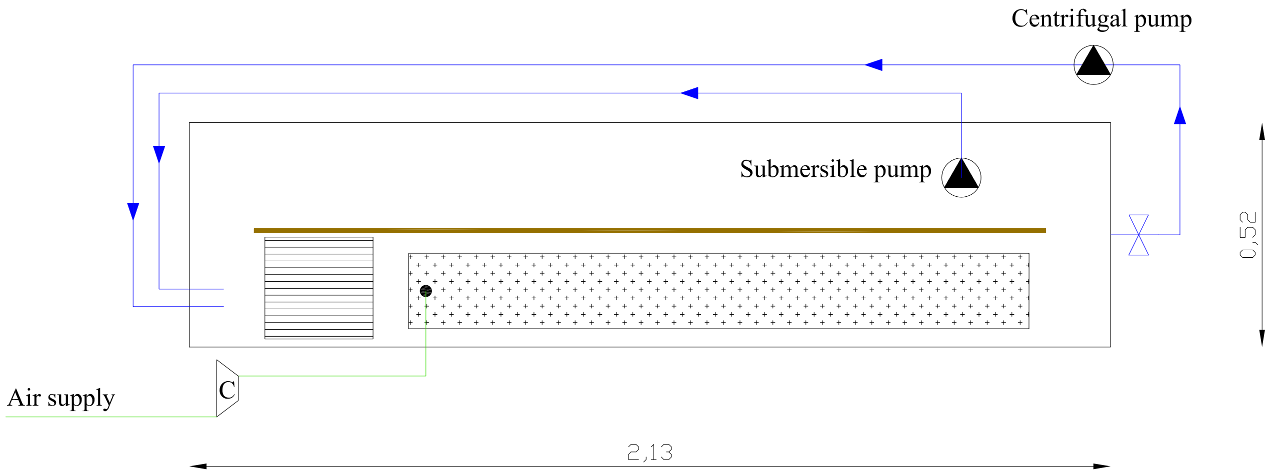
$$dC/dt = kLa \cdot (C_{\infty}^{*} - C)$$

It appears clear that oxygen transfer is an important part of wastewater treatment process and accounts for a large part of the total energy consumption. The objective of this Master thesis is to investigate the effects of turbulence in gas transfer.

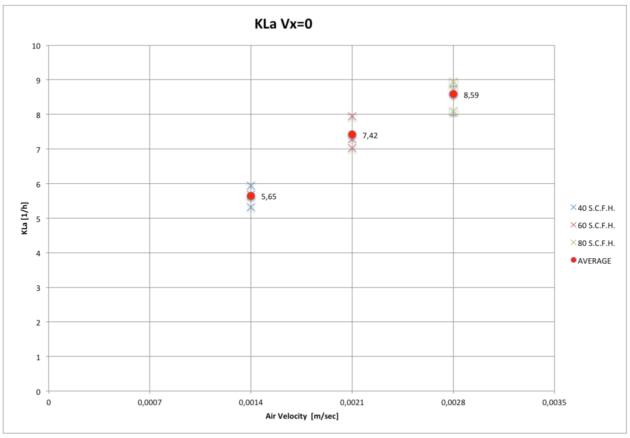
In a lab scale tank (x4x2ft. LxHxW) an inducted turbulence was generated by using a centrifugal pump and a submersible pump in order to have a homogeneous velocity profile similar to a full scale tank. Water flow was stabilized by a suitable built flux conditioner, and turbulence velocity component was measured by a 2-D Acustic Doppler Velocimeter (ADV). Horizontal liquid velocity was measured by using a floMate Marsh Mc-Birney, while Dissolved Oxygen was measured by two DO probes mod. Y.S.I.-59 by following the A.S.C.E standard guidelines for oxygen transfer parameters estimation in Clean Water.

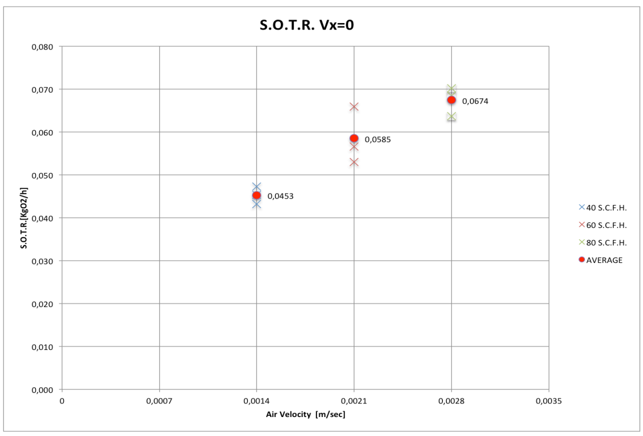
Airflow guaranteed the increase of air side turbulence by one Aerostrip diffuser.

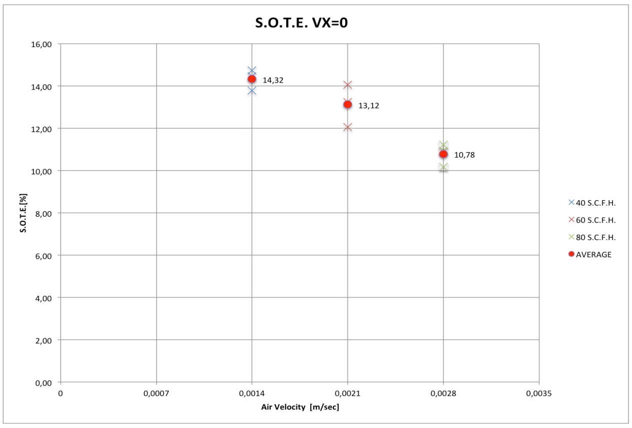
A total of 53 clean water tests were conducted by comparing three different liquid velocities (0; 0,06 and 0,12 m/sec) and four different airflow rate (0; 40; 60; and 80 S.C.F.h.).



Since the increase of both turbulent component of water and air flow induce an increase in the system turbulence, and therefore the oxygen transfer, the goal of this research was to correlate the turbulence density (RMS-y) in the system with the increase of the gas flow and/or liquid velocity in the tank. The research analyzed data from two different aspects: liquid phase turbulence (obtained by increasing liquid velocity) and gas phase turbulence (increasing air flow). To determine the best solution: Volumetric Mass Transfer Coefficient, Standard Oxygen Transfer Rate, Standard Oxygen Transfer Efficiency and RMS-y was evaluated case by case modifying system turbulence inducted by the liquid or gas flow or both.
The results obtained by increasing only air velocity, shows these behavior.





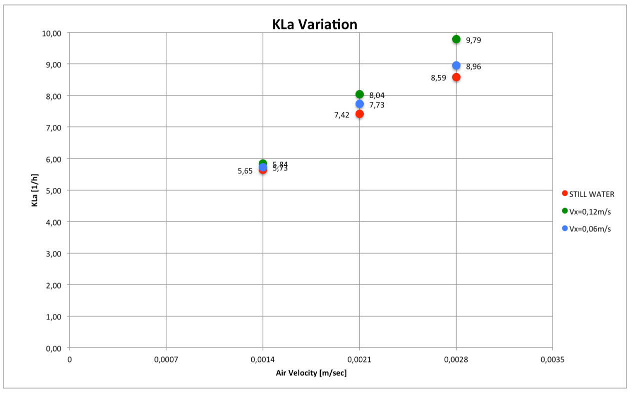


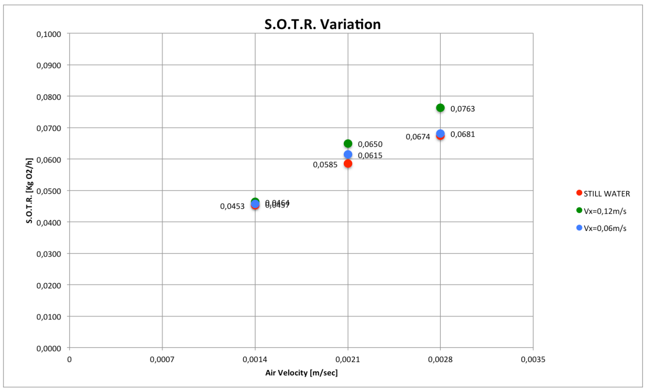
Both the volumetric mass transfer coefficient Kla and the standard oxygen transfer efficiency S.O.T.R. increase linearly (with different slopes) by increasing the air flow rate in the diffuser, while the S.O.T.E. has the opposite trend. This decrease is caused by several factors:

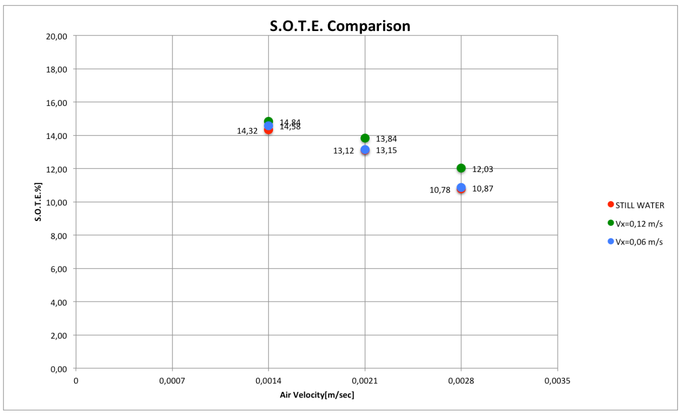
- Increase in the size of the nascent bubbles due to a membrane stretch
- Increase of airflow rate
- Decrease of the bubble retention time in the liquid phase.

The same trend, with different average values can be observed analyzing the results obtained by increasing liquid velocity.

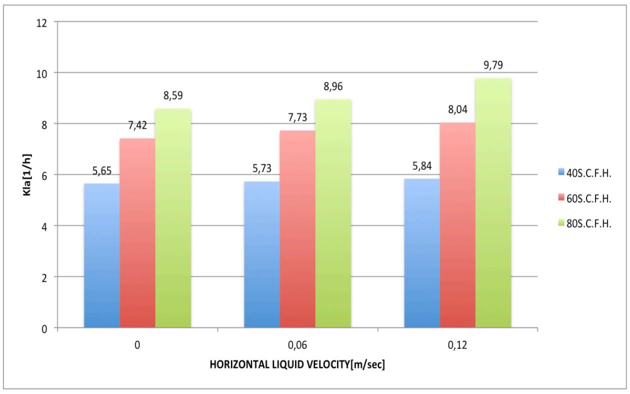
A sum of the results for all the experiments is showed in the next graphs:

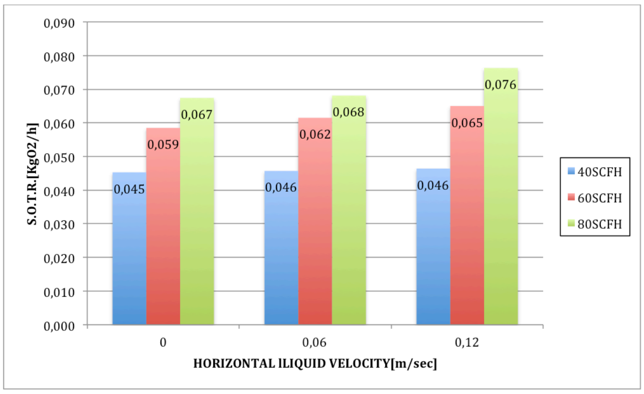


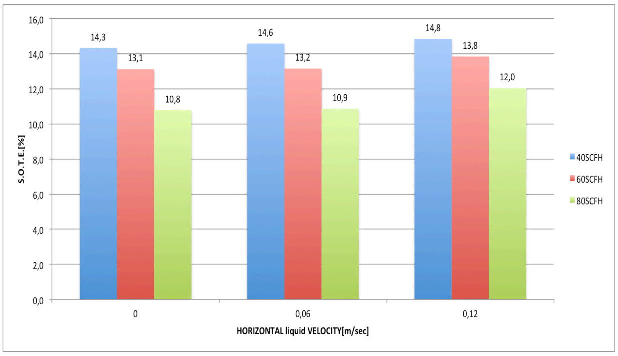




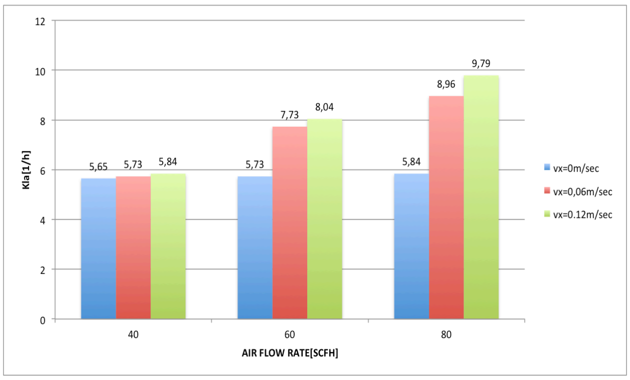
In this graph (Fig. 37) it can be seen that the Volumetric Mass Transfer Coefficient KLa and the Standard Oxygen Transfer Rate increase by increasing both air velocity (parallel to horizontal axis) that Liquid velocity (moving parallel to the vertical axis). In accordance with previously said on the S.O.T.E. variation, the liquid-side turbulence increase produce a consistent rise in the global efficiency of the oxygen transfer, that otherwise is supposed to decrease by the increasing amount of air trough the diffuser (by moving parallel to the horizontal axis).
The percentage growth obtained by increasing the air velocity at a fixed liquid velocity is shown in the next three graphs:

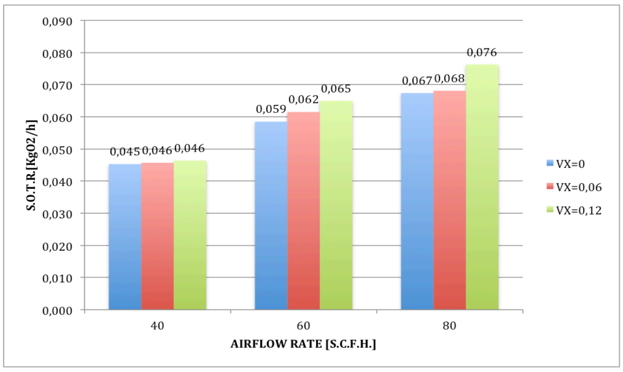


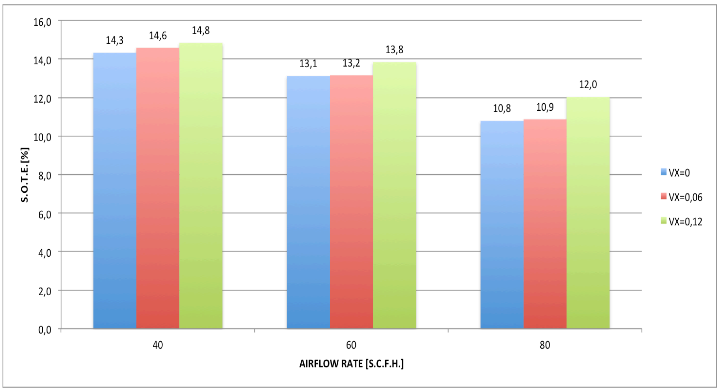




The results obtained by increasing liquid velocity at a fixed air velocity is shown in the next three graphs:





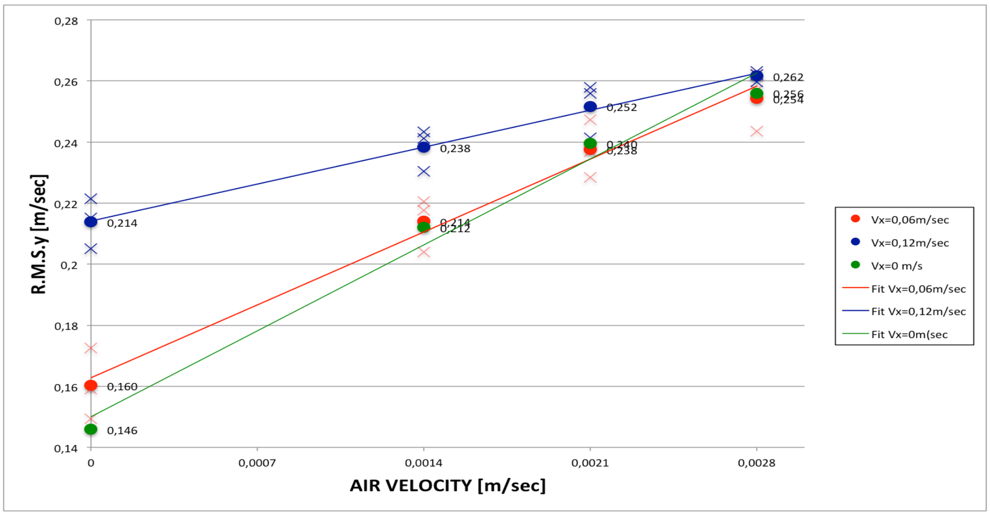


As expected, the higher amount of percentage increase of Kla and S.O.T.R. is obtained by fixing the liquid velocity and increasing the air velocity, while: if the airflow rate is fixed, the increase is very low. This means that: if an increase of Kla or S.O.T.R. is needed, the best thing to do is to increase the Air-side turbulence by increasing the AFR.

For the Standard Oxygen Transfer Efficiency, among the same horizontal liquid velocity, the global efficiency decreases when the airflow rate increases. But, on the contrary, the results obtained by fixing the airflow rate and increasing the liquid-side turbulence shows an increase of the S.O.T.E.

This last assumption means that, in order to have a global increase of the oxygen transfer efficiency, increase the liquid side turbulence, by increasing the horizontal liquid velocity, is the best choice.

Lastly, to have a parameter that indicates the overall system turbulence with any configuration, RMS.y was calculated for any case of study. The results are shown in the next graph



It can be noticed that the overall turbulence parameter increases linearly when the air velocity (and then the airflow rate) increases.
By plotting the results from the two different liquid velocity, it can be seen that the enhancement in term of overall turbulence is confirmed at increasing liquid velocity, but, for higher airflow rate, the difference between the results obtained from the three measured liquid velocity decrease. This means that: for high values of airflow rate the effect of liquid-side turbulence on the overall turbulence is very low, while the same effect is estimable at lower airflow rate, or better, that for high amount of air blowed through the diffuser, the overall system turbulence is Air side controlled.