Development of a Venturi Aeration System for Wastewater Treatment in Low-Resource Settings

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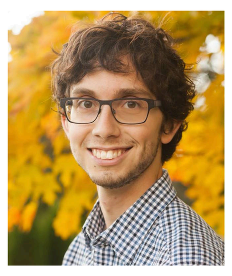
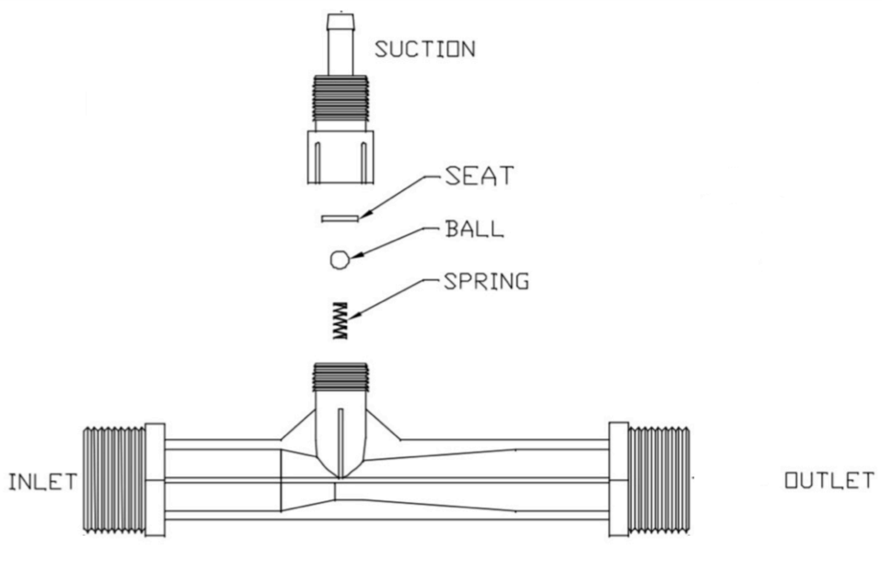


Project Overview

This project reports on the evaluation of the efficiency of a venturi injector aeration system intended for wastewater treatment in low-resource settings. Whereas conventional aerobic treatment systems many times require mechanical mixing and air compressors, venturi injector systems can achieve mixing and aeration requirements relying only on a pump, thus making themselves useful for contexts in which design simplification is favored. This study aimed to test the performance of several aeration devices using venturi injectors and compare them to a "conventional" aeration system using a compressed air feed in order to assess the viability of venturi aeration for the treatment system being developed.

Venturi Aeration

Venturi aeration consists of entraining air bubbles into a water flow by suction. Venturi tubes let water flow through a restriction, thus increasing its speed and lowering its pressure, which lets air penetrate the water flow.



Sketch of a Venturi injector (Mazzei, 2010)

Tested Variables

1. **Water flow rate through the injection system (Q_w/V).**
   Increase in water flow rate will entrain more air bubbles.
2. **Number of venturi injectors connected in parallel (N).**
   Aeration efficiency increases when several venturi nozzles are connected in parallel to the same pump (Dong et. al, 2012).
3. **Injection system depth (D).**
   Deeper aeration depth increases oxygen transfer because of the increased residence time and increased pressure of the bubbles.

Transfer Efficiency Calculation

$$C(t) = C_\infty - (C_\infty - C_0)e^{-k_L a \cdot t} \qquad SOTR = k_L a \cdot C_{\infty,20} \cdot V_{tank} \qquad SOE = \frac{SOTR}{Delivered\ Power}$$

where:

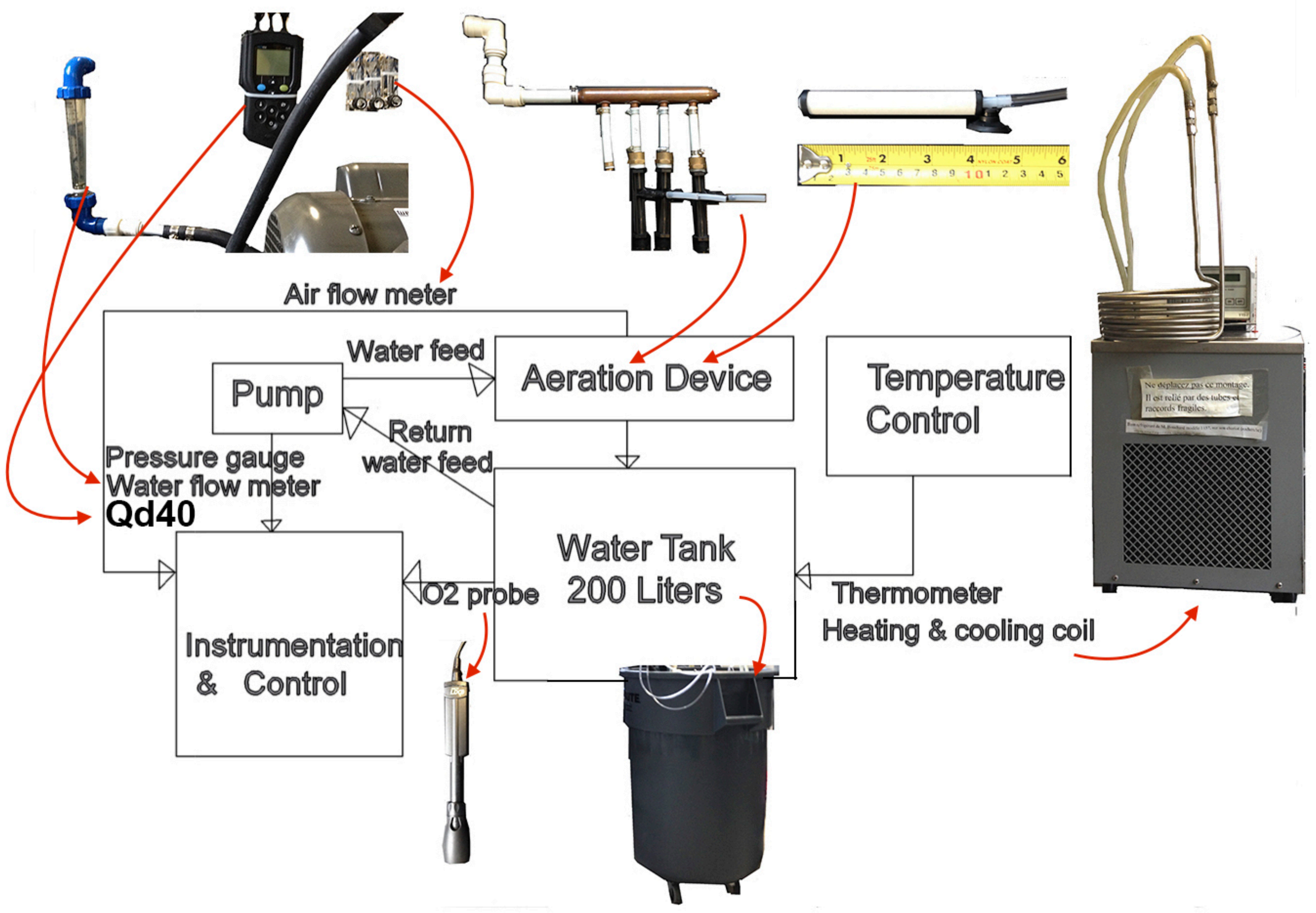
C_∞=Dissolved oxygen saturation concentration (mg/l).
C_t= Dissolved oxygen at time t.
C_0= Dissolved oxygen concentration at t=0 (mg/l).
$k_L a$= Volumetric mass transfer coefficient (h^{-1}).
V_{tank}= Tank volume (l).
$SOTR$= Standard oxygen transfer rate (kg O_2/h).
SOE= Standard oxygenation efficiency (kg O_2/kwh)

Methods

The ASCE (2006) Standard for oxygen transfer testing recommends comparisons of oxygen transfer systems use the following parameters:

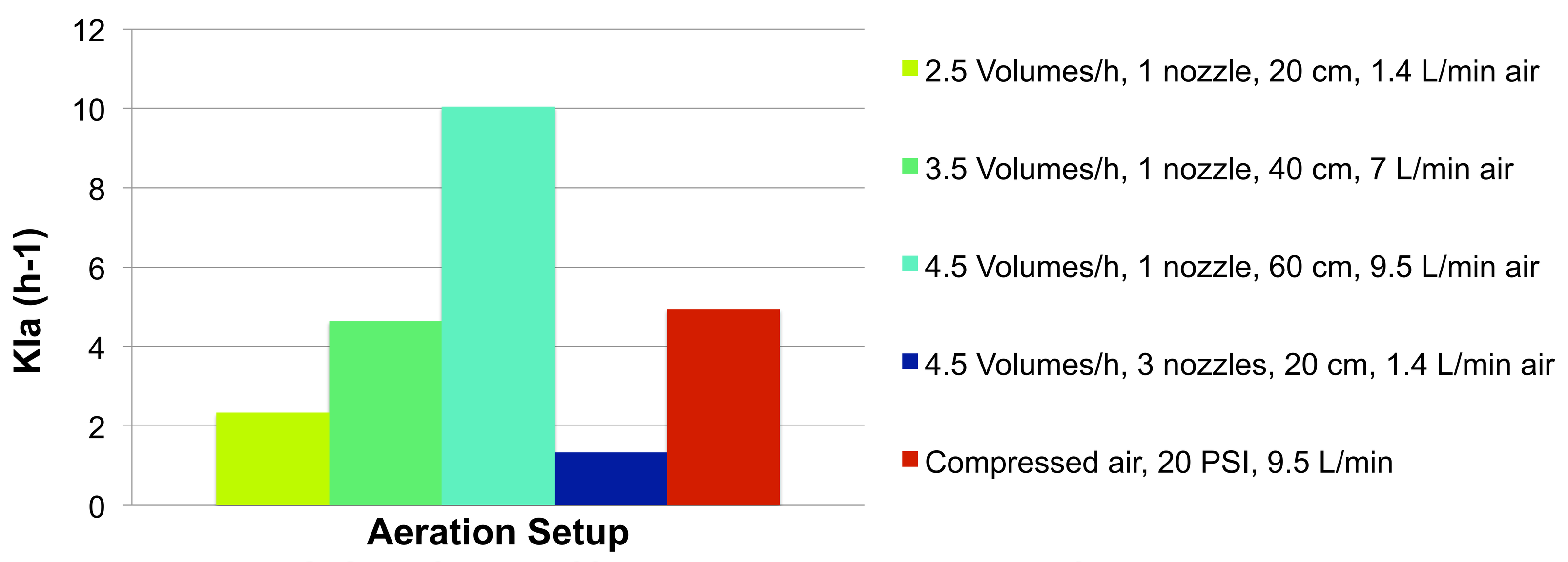
1. **Volumetric transfer coefficient (Kla)**
2. **Standard Oxygenation Efficiency (SOE)**

Experimental Setup

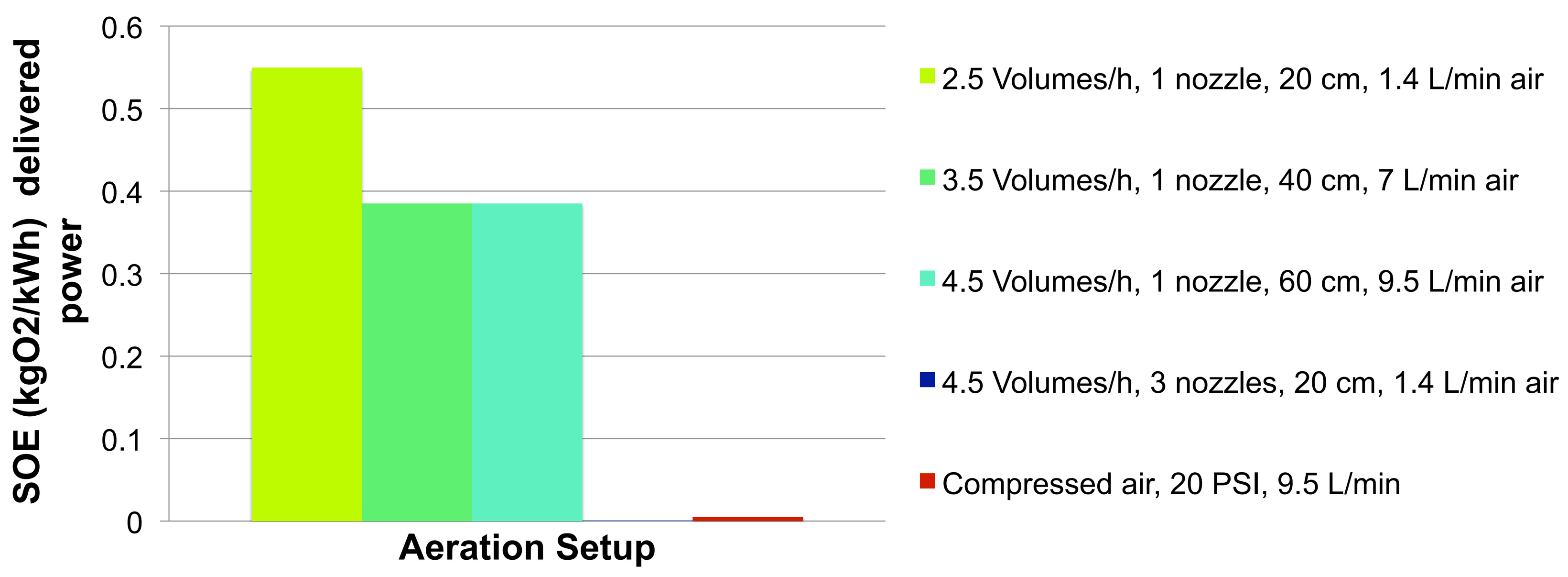


Results

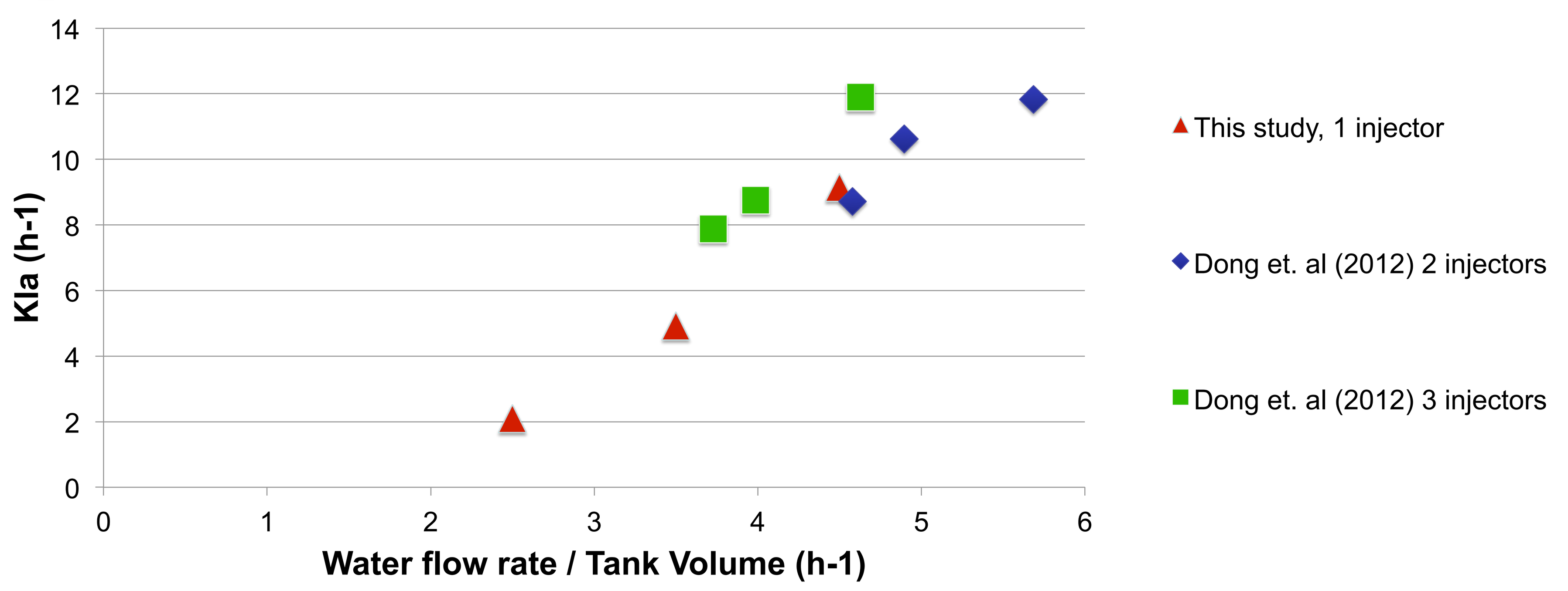
$k_L a$ for different injector configurations



SOE for different injector configurations



$k_L a$ for various water circulation rates through venturi aerators



1. As flow rate increases, $k_L a$ increases and aeration happens faster.
2. The addition of injectors to the system caused a pressure drop which rendered the venturi device inoperative. Future work will remediate this.
3. The observed relationship between water flow rate through the aeration device and the $k_L a$ was observed before (Dong et. al, 2012).
4. At the same air flow rate, the venturi injector yields a higher $k_L a$ than the compressed air system using the porous stone, while the former's transfer efficiency is much higher.

Take home message:

The venturi principle can be used for oxygen transfer and its performance is comparable to that of a traditional compressed air system.

Future Tests

1. Collect more data from clean water tests after fixing problems with configurations using multiple injectors.
2. Aeration tests in wastewater to bring testing conditions closer to field conditions.
3. Aeration tests in reactor prototype to confirm findings of previous tests.

References:

Dong, C; Zhu, J.; Wu, X.; Miller, C. F. (2012) Aeration efficiency influenced by venturi aerator arrangement, liquid flow rate and depth of diffusing pipes. Environmental Technology, 33 (11), 1289-1298.
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