Floating Floc Aeration Method

Aeration Method

Abstract

The aeration method attempted to use air bubbles as a catalyst to facilitate gas removal from supersaturated water by increasing the gas-liquid interfacial area. The proposed design for the aeration mechanism in AguaClara plants involved connecting a perforated vertical segment of pipe to the transmission line that brings water to the plant to the bottom of the grit chamber. The free-falling influent water would cause a negative pressure difference between the interior and exterior of the pipe, naturally drawing air into the pipe via the perforations.

Following the development of theoretical models for this mechanism (See Theoretical Modeling of Aeration Method), research was performed to test the physical feasibility of the method and to determine the optimal design for the vertical segment. The parameters of interest regarding the design of the pipe were the height of the segment and distribution of the perforations. Of the two parameters, required height was determined to be the major factor governing feasibility. Since there was no practical way to directly test a range of heights in the lab, a reactor was designed to model a volume of water within the pipe with the measured factor being the required aeration exposure time necessary for the removal of the excess gas from the water.

After running many experiments, it was found that the aeration method would not be suitable for our purposes because the rate of gas removal from solution occurred too slowly. Experiments were run with water subject solely to a partial vacuum and also subject to partial vacuum with slight aeration. Although there were discrepancies with data collection, it was found that generally the effect of aeration appeared to be insignificant. We postulated that the method failed because a large volume of the dissolved gas was unable to reach the bubbles introduced into the solution.

The maximum distance a gas molecule would have to travel to reach a bubble is on the order of centimeters, so we calculated the time it would require for a molecule of dissolved oxygen to travel 1 cm - 10 cm. It was found that with a suspending fluid of water at 20 C, a molecule would take about 34 days to travel a distance of 10 cm, while molecules just 1 cm away from the bubbles would require about 8 hours. In either case, it was confirmed that the method as designed would not be feasible. Thus, we have shifted our focus to the sand filter method.

Introduction and Objectives

It is common in laboratories to use gases like nitrogen to strip oxygen out of solutions. The aeration method was based off of this concept but attempts to use air to strip gas out of solutions. This process required a large amount of air to be pumped into the solution, resulting in an influx of bubbles into the water. Theoretically, the bubbles introduced into the system would facilitate gas transfer out of solution by expanding the gas-liquid interface and reducing the time required for the dissolved gases concentration to come to equilibrium with the partial pressure of the gases in the atmosphere.

Because pumps are not sustainable in Honduran towns with water treatment plants designed by AguaClara, another mechanism for providing a high flow rate of air into the influent water was required. The proposed design for the mechanism was a segment of vertical pipe with a drilled orifice that would have a negative pressure difference between the interior and exterior of the pipe caused by the free-falling influent water. By Henry's Law, the negative pressure in the interior of the pipe would naturally cause an influx of air into the influent water to aerate the system.

Henry's Law states:

> *At a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.*

The flow rate of air into the pipe would be a function of the orifice size and the location of the holes on the pipe. A time estimate for the amount of contact time needed between the atmosphere and water for the removal of all or most of the excess gas was to be determined from experimental data. Following the development of a theoretical model (see Theoretical Modeling of Aeration Method), the physical feasibility of the method was tested in the lab. To do this, we designed and had built an airtight apparatus (seen in #Figure 2) that would be able to safely withstand pressure changes of about 100 kPa. The apparatus was used to simulate the interface between the vertical segment and the grit chamber at the AguaClara plants.

General Procedure

The reactor was filled with water and left open to the atmosphere in order to zero the pressure sensor used in the experiment. After calibrating the pressure sensor, the reactor was bubbled furiously for five to ten minutes. Following this, the dissolved oxygen probe was calibrated to read about 8.7 mg /L (near saturation level for pure water under atmospheric conditions) at this dissolved oxygen concentration. The reactor was then sealed off and water was pumped out to create a partial vacuum. The environment established was similar to the conditions that would have existed in the vertical segment of pipe. After the water was put under negative pressure for different periods of time, the reactor was open to atmospheric pressure, simulating the grit chamber conditions. Bubble formation was observed throughout the procedure and a dissolved oxygen probe was used to study the behavior of the dissolved oxygen concentration in reactor throughout the experiments. Please see #Figure 1 for the flow diagram of the aeration system.

Unknown macro: {float}

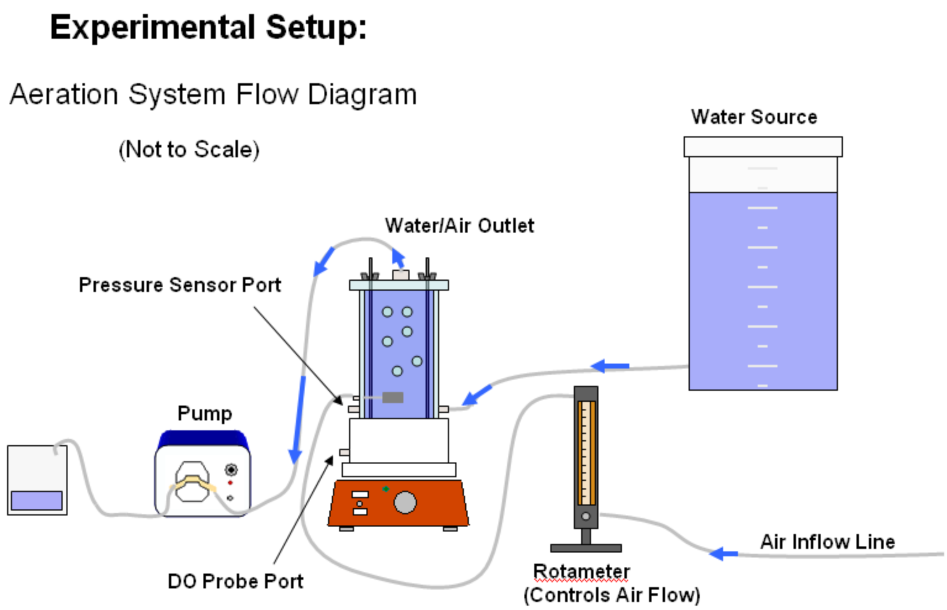

Figure 1: An aeration method flow diagram also indicating components of the aeration system. Click to see larger version.

Unknown macro: {float}

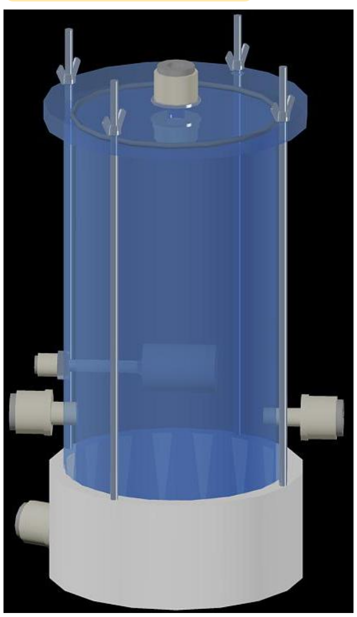

Figure 2: Aeration Apparatus. Click for description and AutoCAD document.

Experimental Methods and Results

DO Removal by Partial Vacuum

- A partial vacuum is created in the container and the effects of the vacuum on dissolved oxygen and bubble formation are observed.

DO Removal by Partial Vacuum and Aeration

- A partial vacuum is maintained in the container while the water is slightly aerated throughout each trial. The effects of the vacuum plus the aeration is observed and recorded.

General Conclusion

From our experiments, we have found that the change in dissolved oxygen that occurs over the span of a few minutes is less than desirable. We wished to see a drop of at least 2 mg/L in that period of time; however, contrary to our initial expectations, the results from our experiments indicate that aerating the water had little affect on the change in dissolved oxygen. Because of this, we determined that the aeration method would not solve the floating flocs problem.

We postulated that the major reason for the failure of the aeration method was that the air bubbles were not easily accessible to much of the dissolved gas volume in the solution. The size of dissolved gas molecule is on the order of 10^{-10} m, while the Aeration Apparatus has an inner diameter of 10.12 cm. To reach the air bubbles infused into the reactor, the bulk of the dissolved gas molecules in reactor would have had to travel over a few centimeters. To validate this reasoning, we used the equation presented below to predict the time an oxygen molecule would need to travel a distance of 1 cm - 10 cm.

$$x \approx \sqrt{D_m t}$$

where
x = distance traveled (in m)
t = time required
D_m = molecular diffusion coefficient of the dissolved gas

For the given conditions of the water in the reactor (that is, temperature at 20 degrees and water viscosity of around 10^{-3} kg/m/s), the diffusivity of an oxygen molecule is around 3.4E-9 m^2/s. Substituting that value into the equation and setting x = 10 cm, yielded a required time of approximately 34 days, which was clearly not acceptable. If we assumed that the bubbles introduced into the reactor would decrease the distance to 1 cm, it would still require about 8 hours. In light of these results, we have decided to shift our focus to the sand filter method.