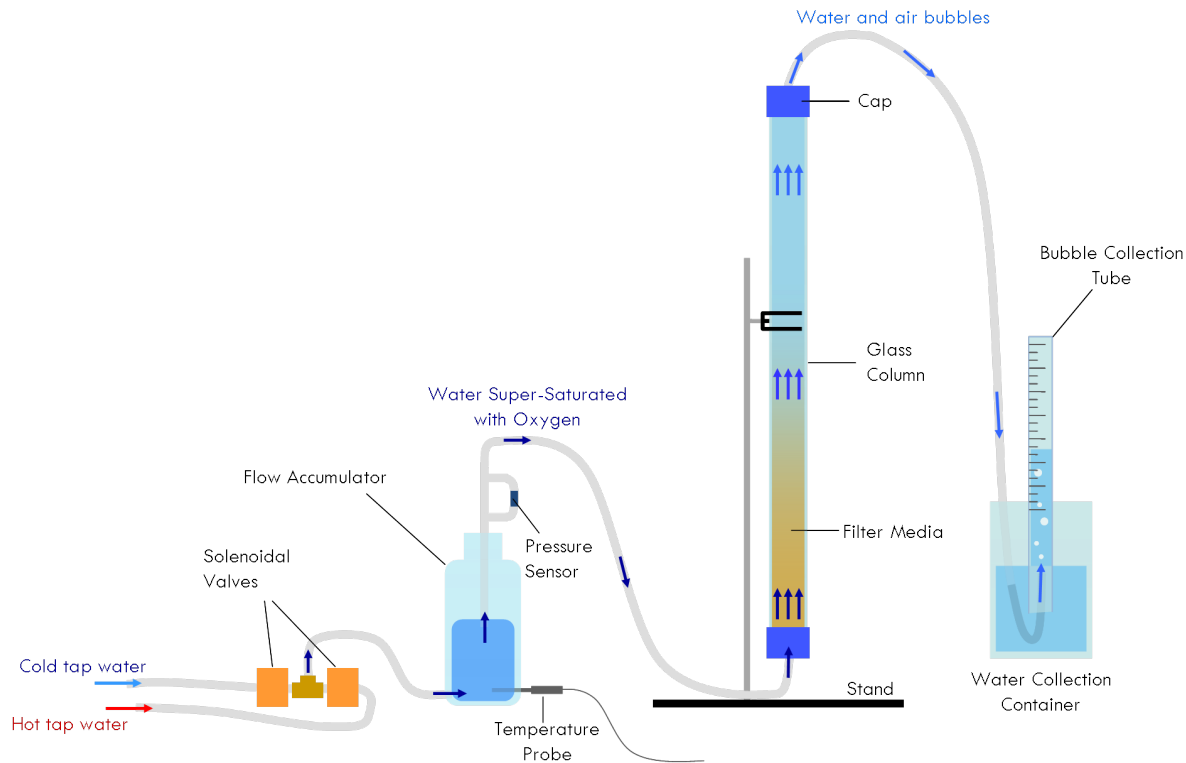# Bubble Volume Measurement Method Development

Bubble Volume Measurement Method Development

Procedure

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First version of the experimental setup that included a bubble collector

Since there were problems with the DO probes we used in the initial experimental setup, we switched to measuring the total volume of the bubbles that form inside the filter column. Using *MathCad*, we used the bubble volume collected to calculate the equivalent DO concentration removed from the water.

The only changes in the setup were to remove the DO probes and instead feed the water leaving the filter column into an inverted graduated cylinder. This cylinder was filled with water at the start of each run and had its mouth submerged in water. As bubbles formed in the filter media, they flowed out into this cylinder and floated to the top, displacing some water and causing the water level inside the cylinder to fall. The air volume was measured every 10 minutes during each run, using the calibrations on the side of the cylinder.

We also tried a new method of testing the quality of the effluent water, using sugar. The sugar test involved collecting the outflowing water in a clear beaker or cylinder and adding some sugar. As the sugar dissolved in the water, if tiny gas bubbles were seen floating to the surface, the water is still super-saturated with gas and our filter method did not work. If no bubbles were seen, then the water was no longer super-saturated, and it could be assumed that the gases were removed.
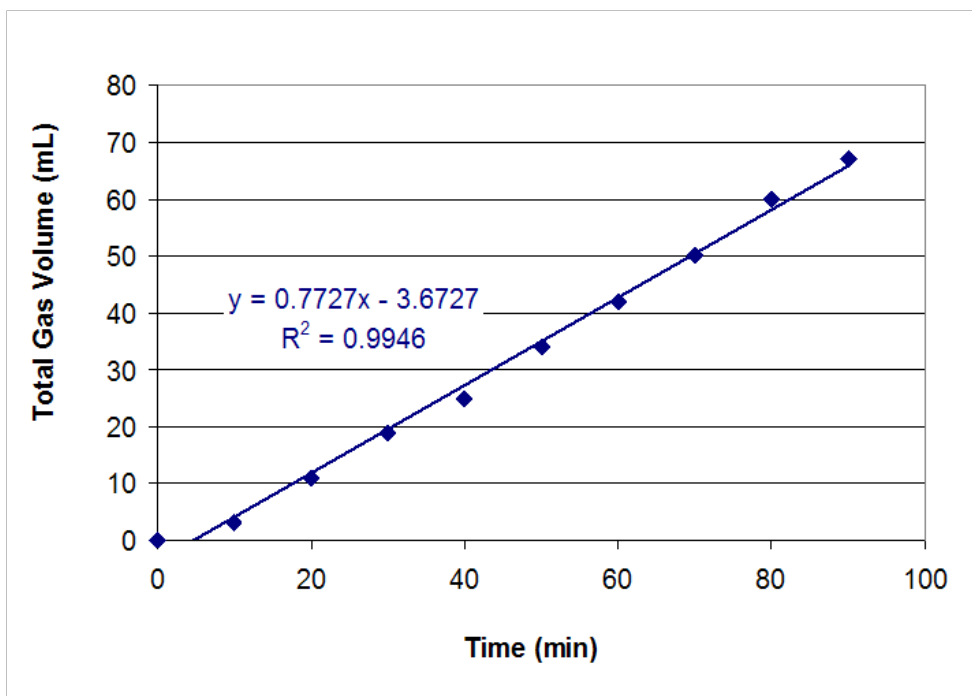
Results

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Figure 1: Total gas volume removed from water vs. time by glass beads. Flow rate: 200 mL/min. Bed depth: 32 cm.

The first experiment run using this bubble collection method used glass beads as the filter media, with a flow rate of 200 ml/min and an unsuspended filter depth of 32 cm. We observed that the performance of the system increased for about 20 minutes, after which the rate of the increase in air volume became relatively constant. These results are illustrated in #Figure 1. After 20 minutes, the line of gas volume vs. time becomes nearly linear. We concluded that the experiment needs run for at least 20 minutes in order for the data to become steady and reliable, and that we would start recording data after at least 20 minutes of runtime.

Since the graph for gas volume vs. time is basically linear, we could accurately fit a linear trendline to the data using Excel, as shown in #Figure 1. The slope of this trendline represents the rate that the gas is being removed from the water, in mL/min. This rate can be converted to equivalent mL of gas removed per liter of water running through the filter column by dividing the slope of the line by the flow rate in L/min. #Table 1 summarizes this process for the first run with glass beads.

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Table 1: Gas removed by glass beads. Depth: 32 cm

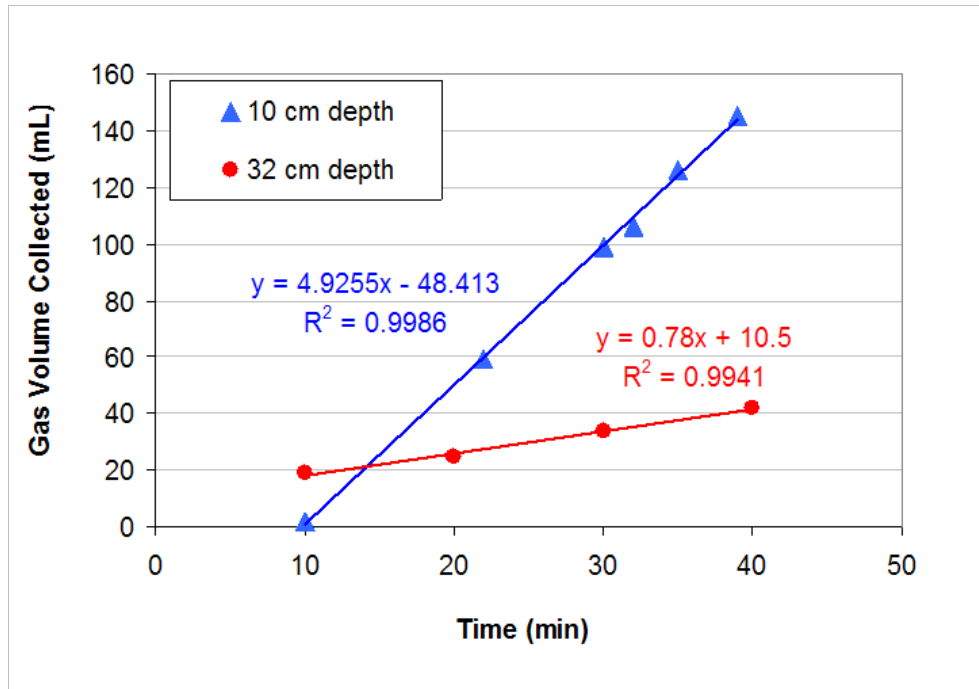| Flow Rate (mL/min)	Slope (mL/min)	Gas Removed (mL/L water)
200	.7727	3.86

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Figure 2: Total gas volume removed from water vs. time by glass beads. Flow rate: 200 mL/min. Bed depths: 32 and 10 cm

Next, we experimented with the glass bead depth. obtaining the results shown in #Figure 2. The data in #Figure 2 was treated the same way as for the first trial (#Figure 1), and #Table 2 shows the resulting gas removal for each bed depth in mL of gas per L of water. As can be seen in the table, at a flow rate of 200 mL/min, the filter depth of 10 cm appeared to remove more gas than the larger glass bead depth of 32 cm.

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Table 2: Gas removed by glass beads at varied depths

Bed Depth (cm)	Flow Rate (mL/min)	Slope (mL/min)	Gas Removed (mL/L water)
10	200	4.9255	24.63
32	200	.78	3.9

This did not make sense, so we repeated the experiment later. #Figures 3 and 4 illustrate these results, showing that a larger filter depth did in fact extract a greater volume of dissolved gas at a faster rate.
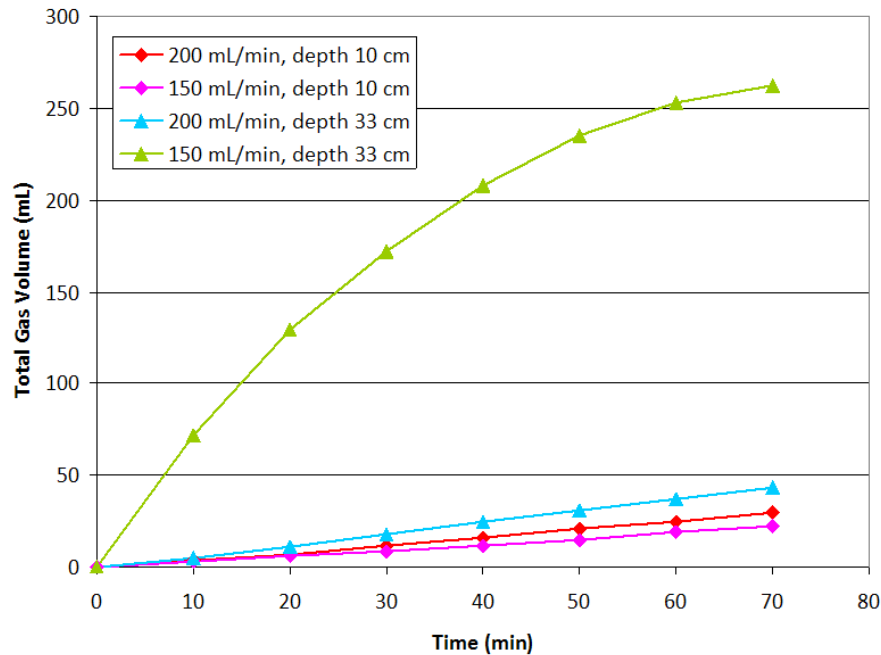
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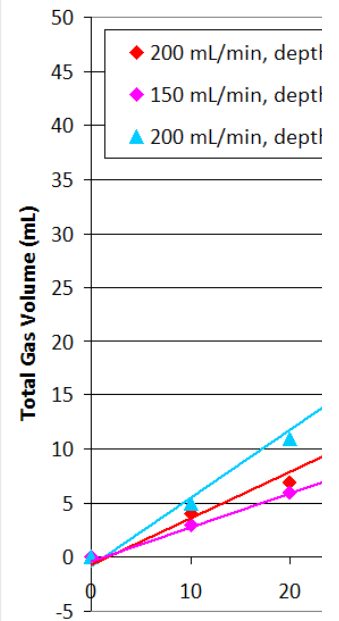Figure 3: Gas volume vs. time at varying depths and flow rates.

Figure 4: Gas volume vs. time at = 150 ml/min and depth = 33 cm.

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Table 3: Gas removed by glass beads at varied depths and flow rates

Bed Depth (cm)	Flow Rate (mL/min)	Slope (mL/min)	Gas Removed (mL/L water)
33	200	.6268	3.14
10	200	.429	2.15
10	150	.3149	1.43

As shown in #Figure 3, the volume of gas removed from the water flowing at 150 mL/min through the 33 cm filter was much greater than that removed at the other flow rates and depths. This was probably because the 33 cm at 150 mL/min run was after the 10 cm runs, which meant we needed to add glass beads to the column. A lot of air came in with the dry beads, and we most likely did not allow sufficient run time afterward in order to allow all the trapped air to escape before we began recording the data. This resulted in the extremely high volumes of gas apparently being removed by our system. By the time we ran that depth at the lower flow rate, the extra air had left and we were gathering only the air being stripped from the water by our filter column.

#Figure 4 shows the same results as #Figure 3 but omits the erroneous 150 mL/min at 33 cm data. Clearly, the greater filter depth resulted in the removal of more dissolved gas than the lower depth. The flow rate was not varied enough to have much impact on the effectiveness of the filter method. Trendlines were once again fitted to the gas volume vs. time curves in #Figure 4, and the resulting gas removals are shown in #Table 3.
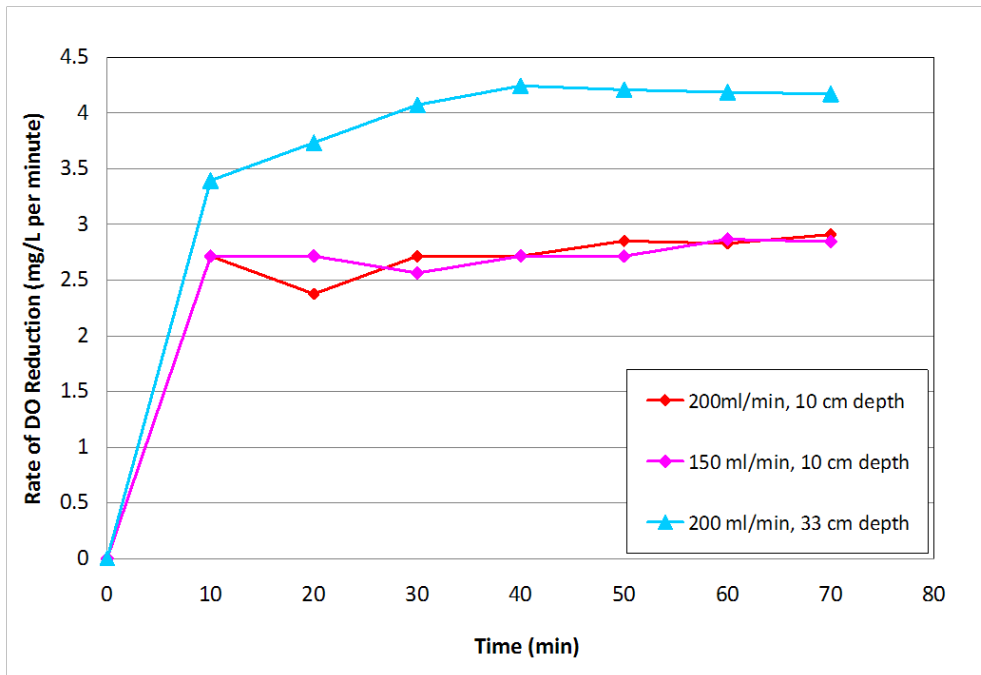
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Figure 5: DO reduction rate vs.time at varying depths and flow rates.

We also used our *Mathcad* program to convert the volume of gas we were collecting to an equivalent concentration of dissolved oxygen being removed from the water. #Figure 5 shows the results of this for the three runs shown in #Figure 4. These values for DO removal could not be taken as accurate, however, because the *Mathcad* program assumes that oxygen is the only gas super-saturating the water. In reality, other gases such as nitrogen could be present. Though the values are not exact, their relative positions on the graph may be used to draw some conclusions.

#Figure 5 shows that the rate of dissolved oxygen removal increased for a short amount of time at the start of each run, but then tended to level off into a steady removal rate as time went on. The higher rate of DO reduction exhibited by the run of the deeper bed depth (33cm) shows again that a deeper bed is more effective.
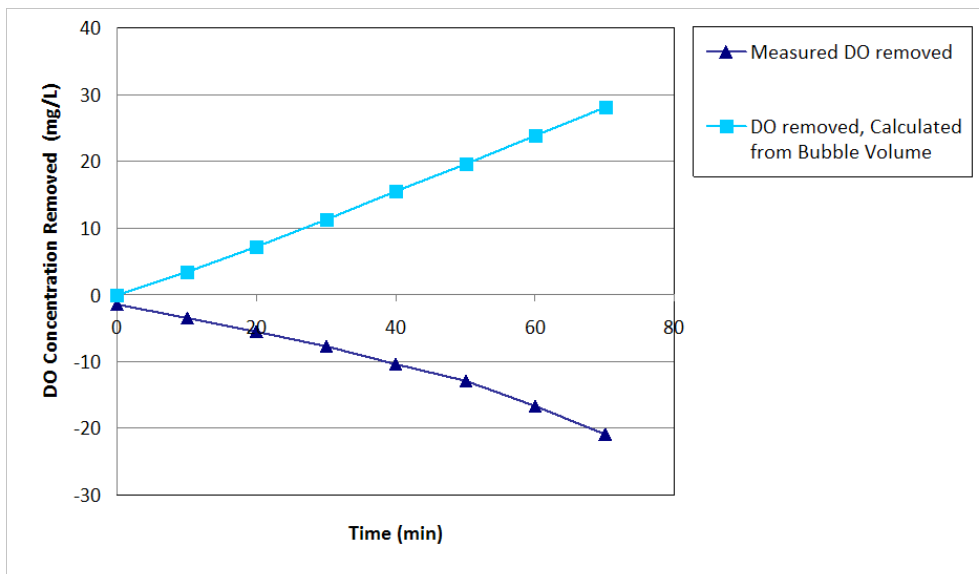
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Figure 6: DO removed, measured by the DO probes as well as by calculating equivalent DO using the collected bubble volume. Sand depth of 10 cm, flow rate of 200 mL/min.

compares the DO removal as measured by the DO probes to our calculations using the total collected bubble volume for the 200 mL/min run at 10 cm depth. The graph reveals a large discrepancy between the DO probes' data and the numbers derived from the actual volume of water collected. Again, although the calculated DO-removal values cannot be trusted for accuracy, the overall trend of the numbers can be used for comparison. The negative DO reduction measured by the DO probes would mean that oxygen was *added* to the water inside the filter column, although the increasing volume of air collected from the water showed that the opposite was true. We concluded from this that our DO probes were definitely not reliable.

The sugar test was performed after several of the runs, but the results varied greatly, even when performed on multiple effluent samples for the same run, or on tap water. Overall, the sugar test results were inconclusive.

Download data for these experiments here

Conclusion

From these results, we may tentatively conclude that greater filter depth removes more dissolved oxygen. However, the method of measuring and recording the volume of gas removed from the water was not precise, and it allowed for a large amount of error and inconsistency. We also cannot be sure that water entering the system was in fact supersaturated, as the temperature outside was growing warmer and varying greatly by the day. As such, we will be able to draw firmer conclusions when the setup includes a method of supersaturating the water and a more accurate and precise method of measuring the collected air volume.

The sugar test proved to be very inconsistent, but it may perform better if a finer sugar is used. This method requires further testing.

After this round of experiments, we altered our setup to include a new bubble collector and a chamber to make sure the water is super-saturated when entering our filter. See the method and results here.