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INTELLIGENT SOLUTIONS FOR WATER

Western University Aeration Project -- Summary of results to date

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Compressor: ¼ HP
Field airflow: 50 LPM

Blower:
Field airflow: 90 LPM

BioCord surface area per treatment tank: 144 m^2

1. Oxygen Transfer Testing (fine vs coarse bubble)

- Comparison of oxygen testing results between coarse bubble (blower) and fine bubble (compressor) aeration, in clean water (standard conditions) and wastewater (field conditions)
- Tests were done with both the blower and compressor running at full/maximum capacity (what would be used in the field)
  - At max capacity, the compressor's measured air flow rate is approximately 50 LPM
  - At max capacity, the blower's measured air flow rate is approximately 90 LPM

Oxygen transfer is an important part of wastewater treatment and accounts for as much as 60% of the energy consumption for the activated sludge process (Stenstrom et al., 2006). It is the rate-limiting reagent (in terms of solubility) so it is important to optimize its delivery to cells.

From O_2 testing, we obtained:

- **K_La** - Volumetric oxygen mass transfer coefficient (measured in kgO2/hr)
  - This coefficient describes how fast the oxygen (gas phase) is transferred to dissolve in a liquid medium (dissolution)

        - Defines how much oxygen is available to the cells for growth
    - Mass transfer coefficients are usually measured in clean water which does not have the same surface tension as wastewater
    - Value is dependent on mixing intensity, air flow rate, bubble size/residence time, surface active agents (salts, etc.) and interfacial tension and SA
- **SOTR** - Standard Oxygen Transfer Rate (measured in kgO2/hr)
    - SOTR is the rate of oxygen transfer (lb or kg) to the test liquid (at standard conditions, per hour)
    - It is a function of K_La, oxygen saturation value (mg/L), and volume of the basin
- **SOTE** - Standard Oxygen Transfer Efficiency (measured as a percentage of the air put into the system)
    - How much of injected oxygen becomes dissolved in liquid
    - Function of (SOTR/SCFM)
- **SAE** - Standard Aeration Efficiency (measured in kgO_2/kWh)
    - SAE = SOTR/power input

The **OUR** (oxygen uptake rate) is that rate at which bacterial cells utilize and uptake oxygen (OTR > OUR). It increases as cell densities increase, until OTR is limiting factor (OTR defines theoretical maximum cell density).

Standard conditions are defined as 20°C, 1 atm, zero salinity, zero DO in water.
Significance of OTE, K_La, alpha values

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38\ ATP$

1.1 In clean water (standard conditions, baseline values)

Aeration testing method: ASCE (American Society of Civil Engineers) standard "Measurement of Oxygen Transfer in Clean Water" (ASCE/EWRI 2-06).

Table 1. Oxygen transfer results for coarse and fine bubble aeration systems in clean water.

	Parameter	**Coarse Bubble**	**Fine bubble**
Oxygen transfer parameters	K_La (kgO2/hr)	5.502	2.520
	K_La at 20°C (kgO2/hr)	6.035	2.754
Aerator/Diffuser g (performance) parameters	SOTR (kgO2/hr)	0.17	0.06
	SOTE (%)	3.45%	3.23%
	SAE (kgO2/kWh)	0.45	0.23

For baseline testing, the coarse bubble diffuser showed higher K_La, SOTR and SOTE values. This was in line with our expectations given the higher airflow rate of the blower (90 LPM) compared to the diffuser (50 LPM). Air flow rate is one of the most significant drivers of K_La, which in turn drives SOTR.

1.2 In municipal wastewater (field conditions)

- Performance results of fine bubble vs coarse bubble aeration (reductions of ammonia, BOD and COD) at full capacity
- Both systems received the same influent -- primary effluent from the Greenway WWTP

Blower - 90 LPM
Compressor - 50 LPM (55% air flow of blower)

Table 1. Oxygen transfer results for coarse and fine bubble aeration systems in wastewater (field conditions).

	Parameter	**Coarse Bubble**	**Fine bubble**
Oxygen transfer parameters	K_La (kgO2/hr)		
	K_La at 20°C (kgO2/hr)		
	α-value, $\frac{KLa\ wastewater}{KLa\ clean\ water}$	0.52	0.90
Aerator/Diffuser (performance) parameters	SOTR (kgO2/hr)		
	SOTE (%)		
	SAE (kgO2/kWh)		

**Data for other parameters are unavailable at this time. Western University is to release this data once the discussion paper has been written.

The alpha-value indicates the difference in aeration performance in clean water vs. field conditions (wastewater). It is the ratio of process to clean water mass transfer and has the biggest impact on the required SOTR in a treatment plant. Alpha is influenced by a number of factors such as TDS, salinity, and other parameters, and typically ranges from 0.4 - 0.85. A higher alpha value means that the oxygen delivery method is more efficient in field conditions, i.e. less negatively impacted by conditions of the wastewater.

Unlike clean water oxygen transfer measurement, no standard has been developed for process water oxygen transfer, however a standard guideline has been published by a joint committee of WEF and ASCE. This guideline was adapted for the methods used during this study.

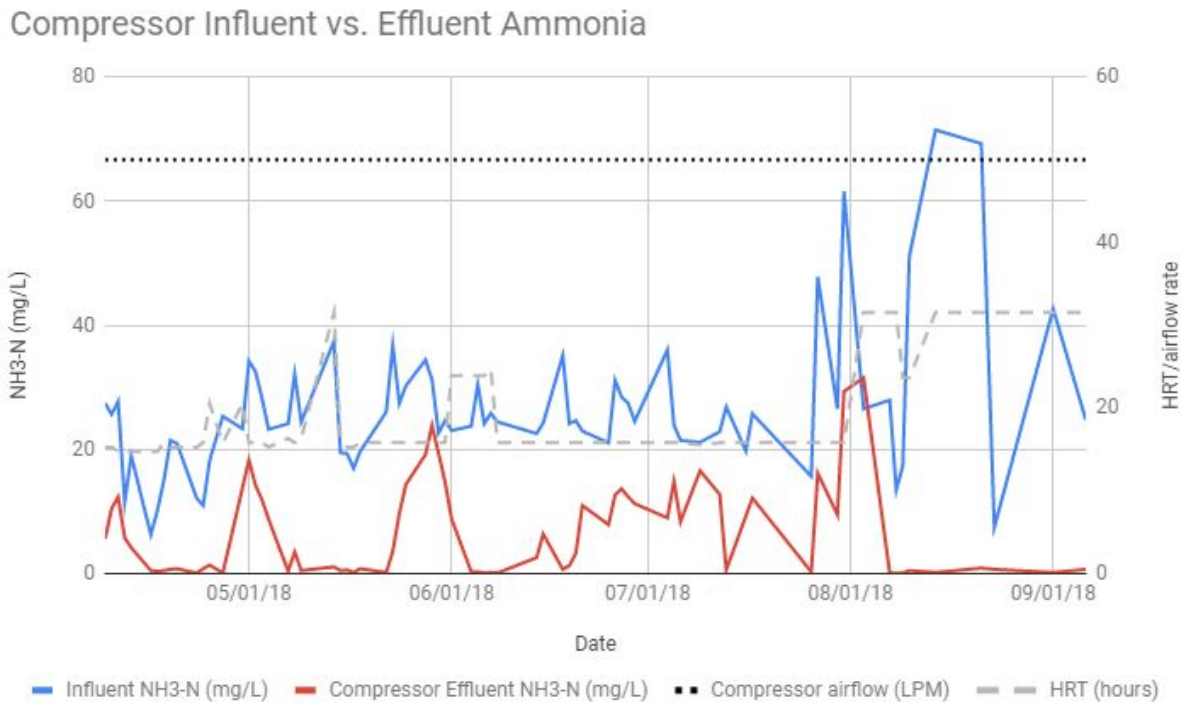
Oxygen transfer testing at the Greenway WWP indicates that the fine bubble aeration system:

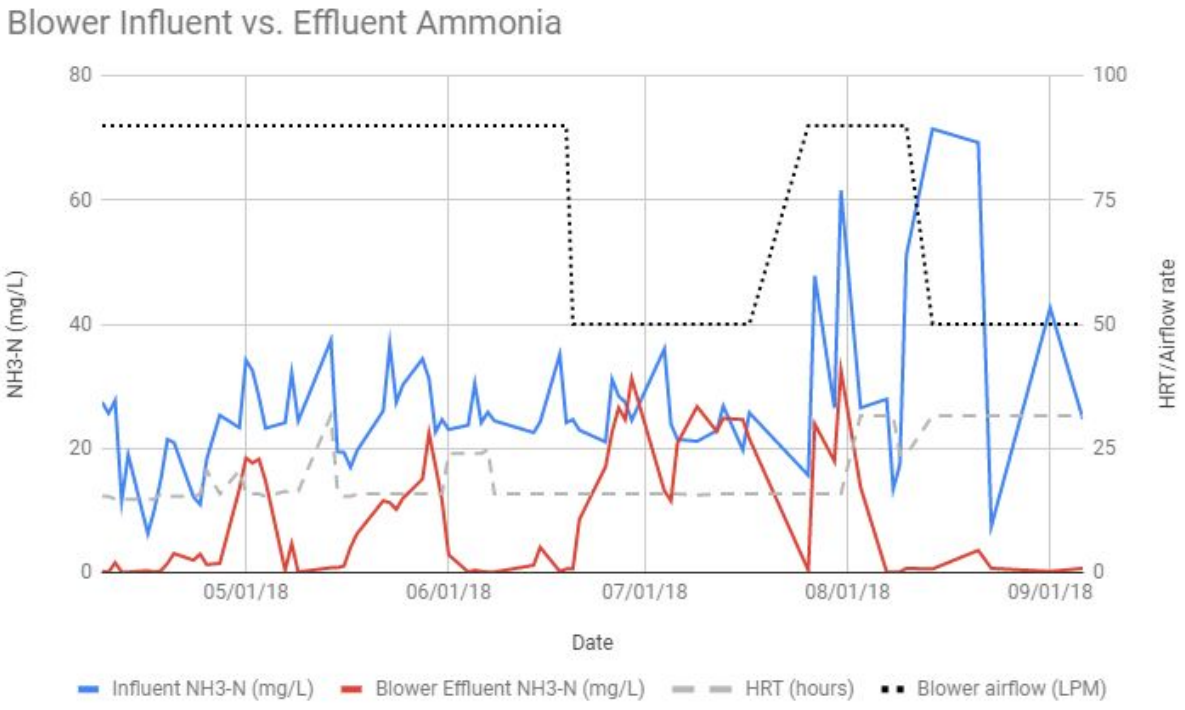
- Delivers 45% less air than the coarse bubble aerator (50 LPM vs 90 LPM) and therefore has lower overall K_La and SOTR values
- Is able to deliver approximately 0.06 kgO2/hr to the treatment system installed at the London Greenway WWTP
- **Has a much higher alpha-value than the coarse bubble aerator, indicating that the required SOTR for sufficient aeration at the Greenway WWTP field conditions is likely to be much less**

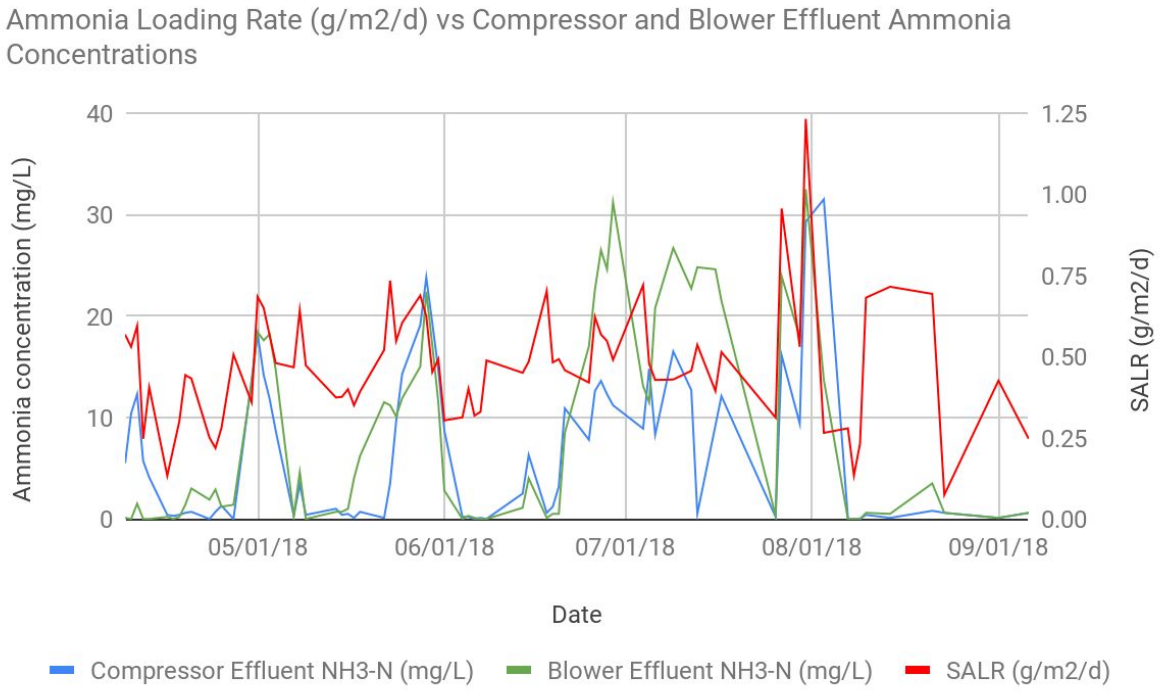
2. Performance Results (Phase I)

During Phase 1, both the compressor and blower systems became acclimatized to the wastewater characteristics of the Greenway WWTP. The graphs below summarize the results seen from April 5 - September 6, 2018. During this time, influent flow rates (and therefore HRTs) were changed based on observed influent characteristics, as there were multiple points during Phase I where influent concentrations spiked due to discharge to the WWTP from nearby industries. HRTs throughout Phase 1 are plotted on the secondary axis. Air flow rates entering the blower and compressor tank are also shown on the secondary axes. The compressor flow rate remained consistent throughout Phase I at 50 LPM, while the blower air flow rate was lowered to 50 LPM at two different HRTs to observe the effect of reduced flow to the treatment capacity of the blower.

2.1 Ammonia - Compressor vs Blower







From the data above, the following observations can be made:

- When both the compressor and the blower are running at their max flow rates, the compressor is delivering approximately 45% less air to the treatment tank. Despite

this, the BioCord system utilizing the compressor and fine bubble aeration was able to reduce influent ammonia concentrations to the same effluent concentrations as seen by the blower.

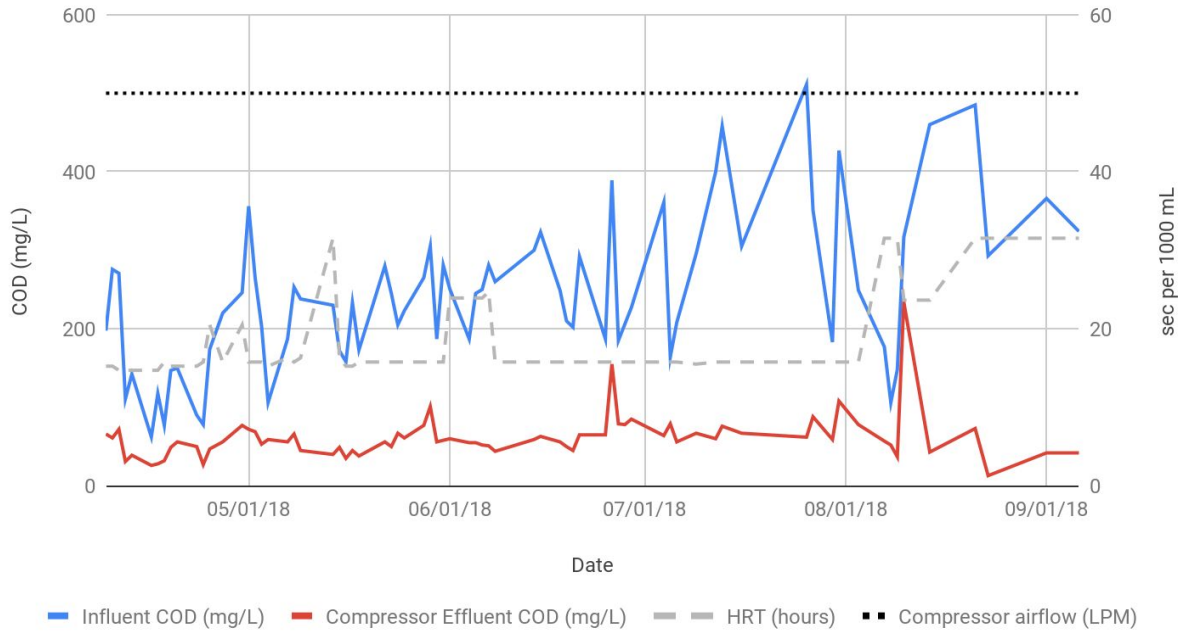
- When the blower's air flow rate was lowered to match the air flow rate delivered by the compressor (50 LPM) at an HRT of 15.78 hours (June 20 - July 16, 2018), the efficiency of the blower treatment tank decreased considerably. It is inferred that the reduction of air flow down to 50 LPM caused the blower treatment tank to lose a significant portion of its capacity due to less efficient oxygen delivery and transfer. However, it should also be noted that during this period, influent COD levels spiked to above-average levels (see section 2.2 below), which likely increased the oxygen demand during this period. Reductions in ammonia removals were also seen in the compressor tank at this time; however, at 50 LPM, the treatment tank utilizing the compressor and fine bubble diffuser still outperformed the blower tank.

- HRT was increased to 31.5 hours on August 3rd, 2018. This was to combat the high influent ammonia and COD concentrations observed at this time and to mitigate the effect of fluctuating results due to high loads from industrial discharge. Maintaining the HRT at 31.5 hours allows for more consistent performance in each tank, such that changes in effluent quality are attributed to changes in air flow delivery rather than fluctuating influent characteristics.

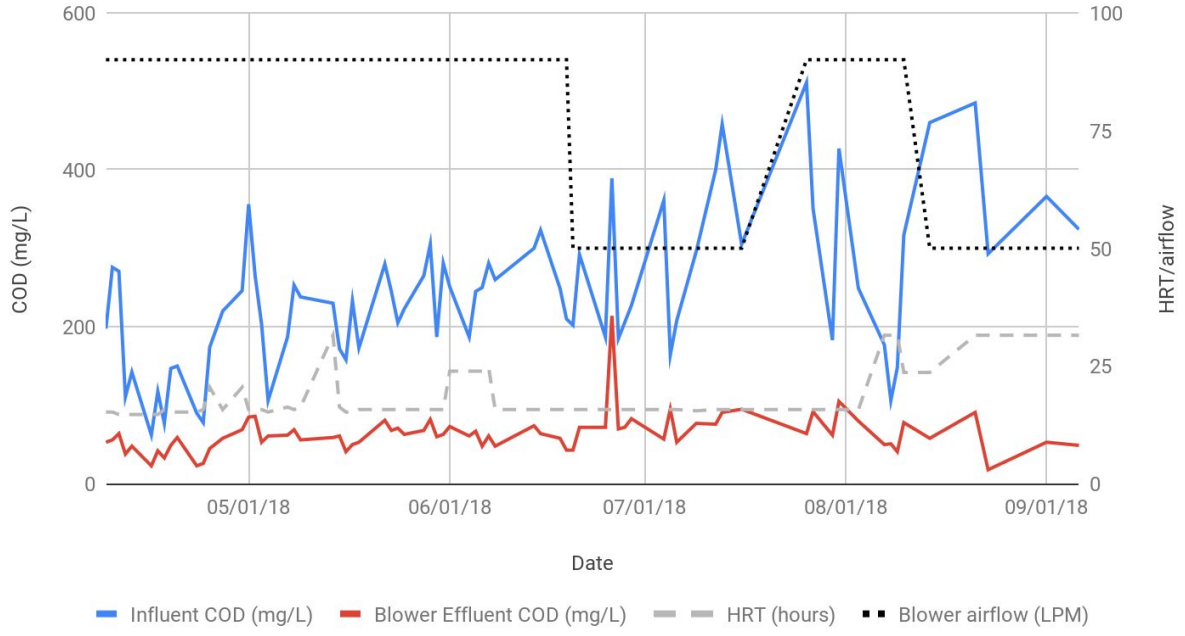
- Air flow rate in the blower/coarse bubble treatment tank was again reduced to 50 LPM on August 3rd, when HRT was increased 31.5 hours. Since this time, effluent ammonia concentrations in both treatment tanks have remained consistently low, despite high influxes of influent ammonia. This indicates that the higher HRT and lower flow rates into the system decreases the oxygen demand of the aeration systems, allowing 50 LPM to be sufficient for high treatment.

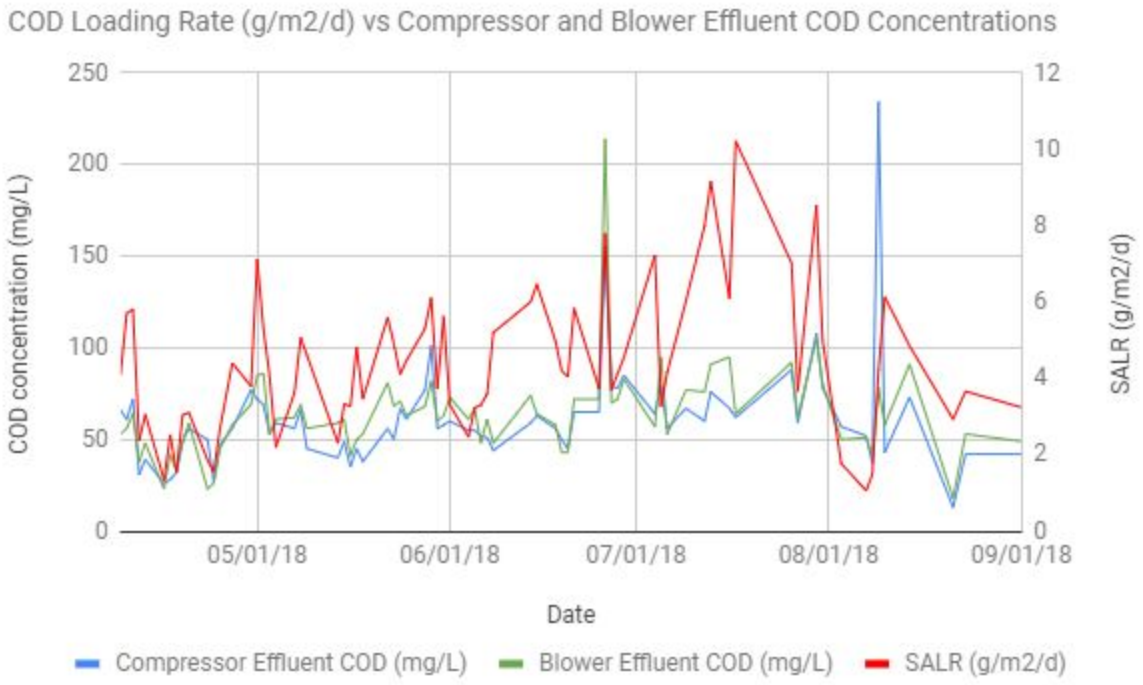
2.2 COD - Compressor vs Blower

Compressor Influent vs. Effluent COD



Blower Influent vs. Effluent COD

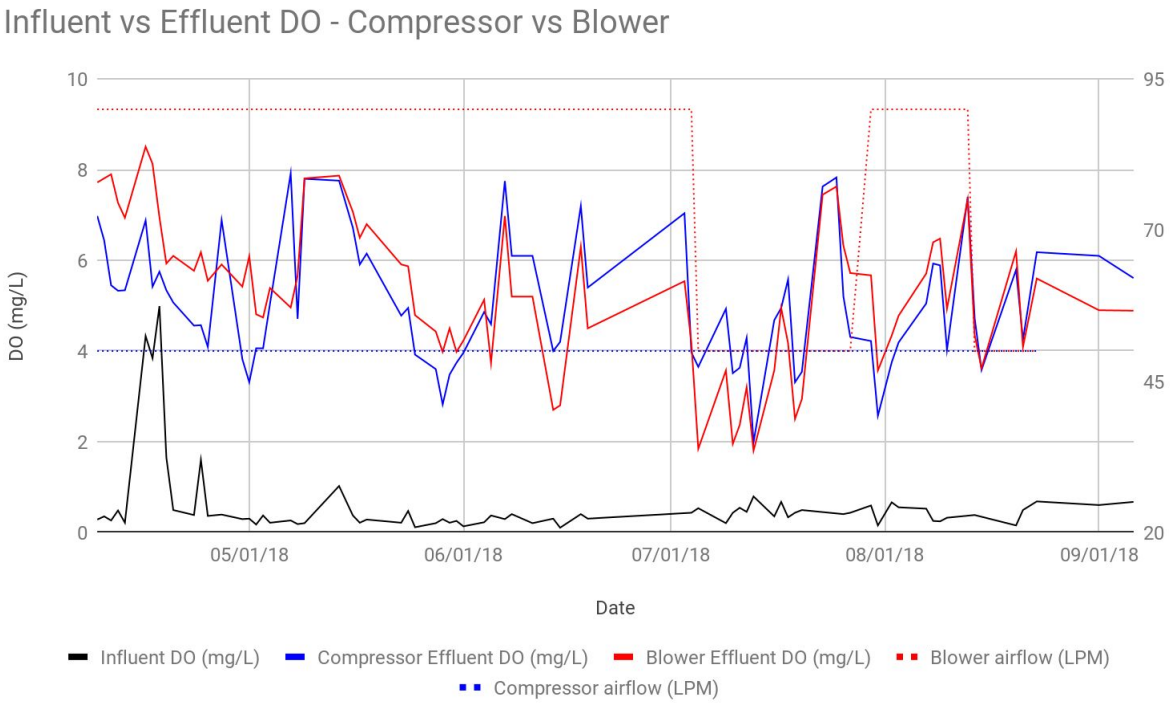




From the data above, the following observations can be made:

- Both systems utilizing fine and coarse bubble diffusion were able to sufficiently reduce influent COD concentrations
- The system utilizing the compressor/fine bubble aeration was able to match the performance of the blower system, despite 45% less air flow being delivered to the tank
- Influent COD concentrations fluctuated considerably during the course of this project phase. Spikes in COD concentrations indicate that the WWTP may have been receiving discharge from nearby industries, which influence oxygen demand and performance of both systems.

2.3 Dissolved Oxygen (DO) - Compressor vs Blower



From the data above, the following observations can be made:

- Influent DO concentrations remained consistently low (<2 mg/L) for the majority of this project period
- Both systems were able to maintain high DO levels in the BioCord effluent
- The compressor/fine bubble aeration system was able to maintain comparable DO levels in the reactor tank, despite 45% less air flow being delivered into the tank
- The data suggests that oxygen delivery of both system is sufficient, and that the limiting factor in oxygen uptake is the rate of diffusion into the wastewater interface