



MICHIGAN STATE UNIVERSITY  
**Civil and Environmental Engineering**

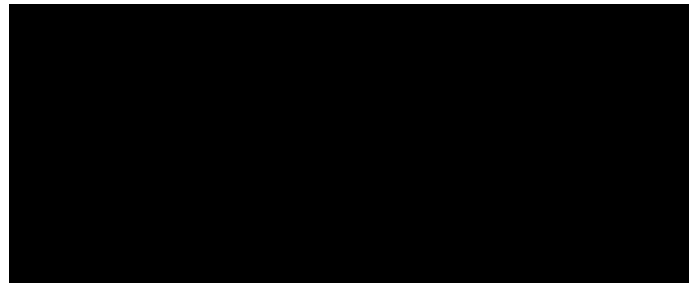
**ENE 806**

**Laboratory Feasibility Studies for  
Environmental Remediation**

**Temperature Effects**

**On**

**Oxygen Uptake Rate**



**February 16, 2010**

## **Abstract**

Dissolved Oxygen (DO) is one of the most important parameters of the activated sludge for the wastewater treatment processes. The effect of temperature on oxygen uptake rate (OUR) of activated sludge is significant and in term influences the outflow water quality. In this study the OUR under different temperatures is examined and the result shows that the OUR will go up steadily along with temperature increase, but the OUR increment between different temperature intervals are distinct. One explanation for this phenomenon is that the OUR is determined by the bioactivity of bacteria. Each class of bacteria has their specific temperature range to grow within. Once this temperature range is exceeded, the growth rate drops off rapidly due to denaturation of key protein, and then decrease the DO consumption.

## **Introduction**

The activated sludge process surely is the most widely used biological process for the treatment of municipal and industrial wastewaters <sup>[1]</sup>. Like all other biological treatment processes, the activated sludge system relies on a mixed culture of bacteria to carry out the basic oxidation of the substrate present, with higher grazing microorganisms also present forming a complete ecosystem with various trophic levels. The main biological groups present are bacteria, fungi, protozoa, rotifers, and nematodes, with flocs a heterogeneous mixture of them all, together with organic and inorganic material. <sup>[2]</sup>

The activated sludge process is designed to be substrate limiting; thus, metabolism sets the rate of oxygen demand. <sup>[3]</sup> During this process, oxygen, as the electron acceptor, must be supplied to satisfy the microorganisms by one of two technologies: diffused aeration or mechanical aeration. In diffused aeration, air is compressed and pumped through diffusers located near the bottom of the aeration. The rising air bubbles cause mixing in the basin, and at the same time, oxygen in the bubbles is transferred to the water through normal mass transfer processes. In mechanical mixing, a mechanical mixer agitates the surface of the aeration basin. The mechanical churning at the surface effectively pumps water droplets through the air, which brings about rapid transfer of oxygen from the air to the water. The mechanical mixing also keeps the flocs in suspension.

Temperature is an important factor affecting biomass activity, which is critical to maintain efficient biological wastewater treatment, and also physiochemical properties of mixed liquor as dissolved oxygen saturation and settling velocity. <sup>[4]</sup> The majority of biological treatment systems operate in the mesophilic temperature range, growing best at 20°C to 40°C. However, aeration tanks operate at temperature of the wastewater, 12°C to 25 °C, or even lower. Van't Hoff's rule states that the rate of biological activity doubles with every 10 degree C rise in temperature within the range 5°C to 35°C. <sup>[2]</sup>

In this work, we measured the real-time DO in the activated sludge from local wastewater treatment facility under different temperatures, demonstrated and analyzed the OUR change within different temperature intervals.

## **Materials and Methods**

### **1. Activated Sludge**

Fresh activated sludge was collected from the wastewater treatment plant of East Lansing; this wastewater treatment facility can provide treatment for an average design flow capacity of 18.75 million gallons per day (MGD). Presently, the average Raw Wastewater Flow (influent) is 13.40 MGD. Treatment processes in use at the plant include aerated grit removal, flow equalization, primary clarification, coarse bubble air diffusers to supply oxygen to the activated biological solids, secondary clarification, disinfection, rapid sand filtration, dechlorination, and post filtration aeration<sup>[5]</sup>. Constant air and substrate was provided during the whole experiment.

### **2. Substrate**

The component of substrate is complex and various, which largely depends on the inflow water quality. As the experiments might last 10 hours or even more, organic matters in the activated sludge are not able to support the metabolism and other bioactivities of the microorganisms. Extra substrate was collected from the primary effluent tank, and 10ml was added into the activated sludge for every 30 minutes during the whole experiment.

### **3. Method**

Field investigation indicates the water temperature in local wastewater treatment facility generally ranges from 9°C to 22°C. We chose 5°C to 30°C as the temperature range in our experiment which covers all the typical temperature values in local area.

5°C was selected as the interval.

Low temperature groups (5°C, 10°C, 15°C and 20°C) were implemented in the conservatory under target temperatures. For 25°C and 30°C, heater was used to control the temperature. Set up equipments as Figure 1. Considered potential instability of the bio-system, DO concentration in three individual reactors with same set-ups were measured to guarantee the data quality. Transfer 1 liter of activated sludge to each beaker, turn on the air pump and make sure the DO concentration is constant. Magnetic Stirrer was used to completely mix the sludge and eliminate the partial temperature difference and DO concentration difference.

After the reading in thermometers kept on target temperature for more than 30 minutes, turn off the air pump and begin to measure the DO concentration at the same time. Each measurement lasted for 10 minutes, which was automatically recorded by LabPro.

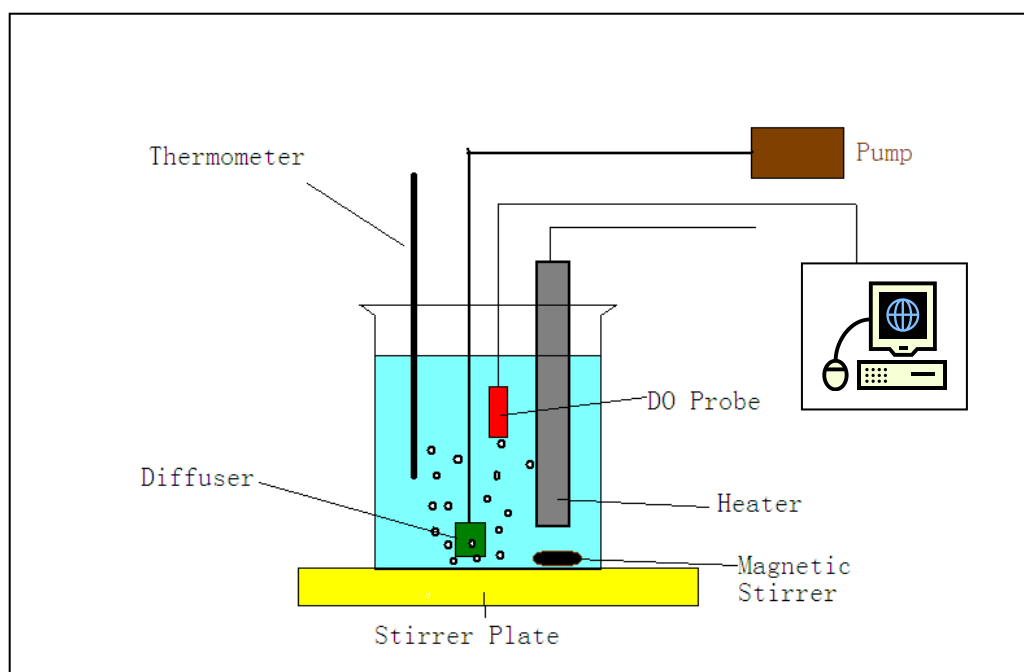


Figure 1 Schematic representation of a single reactor

## Results and Discussion

Theoretically, the DO concentration should remain unchanged with constant temperature and sufficient aeration, which is one of the most important assumptions of our experiment. However, since DO in water might not be completely mixed, as well as the uncertainty of bio-reactions, the DO concentration would fluctuate, at least to some extent. In order to evaluate the potential negative impact on the data quality, the real-time DO concentration under certain temperature (20°C) with sufficient aeration was recorded as Table 1.

Table 1 Statistic analysis of DO concentration with sufficient aeration under 20°C

	Mean <i>mg/(l·s)</i>	Maximum <i>mg/(l·s)</i>	Minimum <i>mg/(l·s)</i>	Error (%)	Standard Derivation
DO1	6.036	6.073	6.001	1.19	0.011
DO2	6.586	6.695	6.507	2.81	0.097
DO3	6.316	6.373	6.273	1.57	0.023

Where  $Error = \frac{Maximum - Minimum}{Maximum} \times 100\%$

According to Table 1, the errors between maximum and minimum values of DO concentration are no more than 3% while the standard derivation is fairly small. Thus, the effect of DO fluctuation can be ignored.

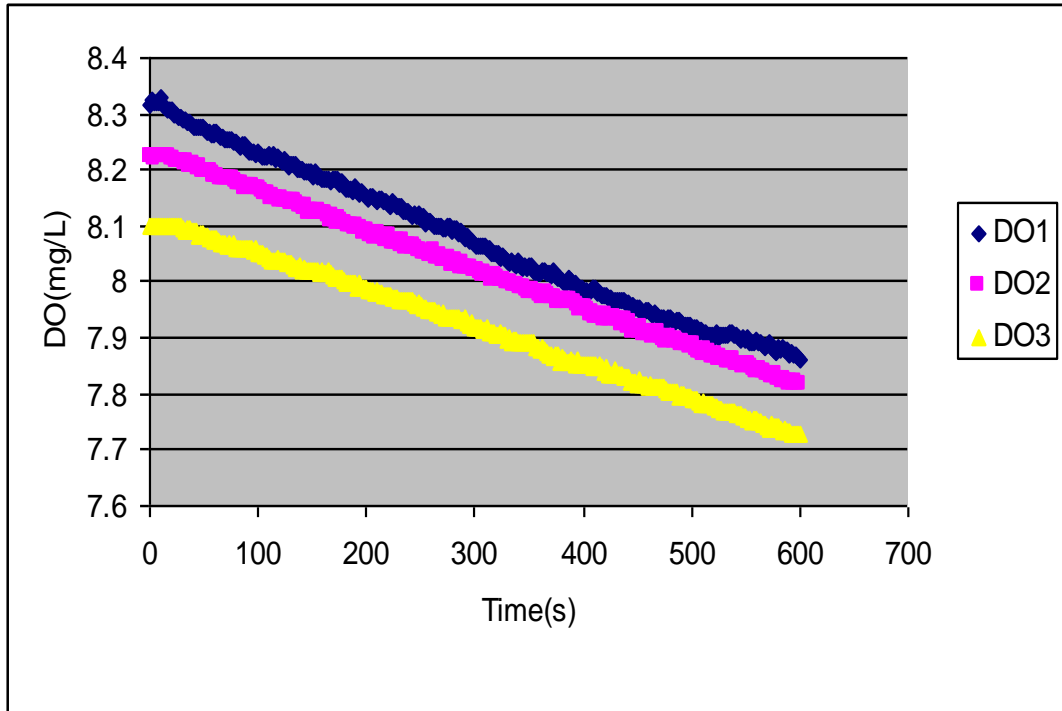


Figure 2 Real-time DO profile under 5°C

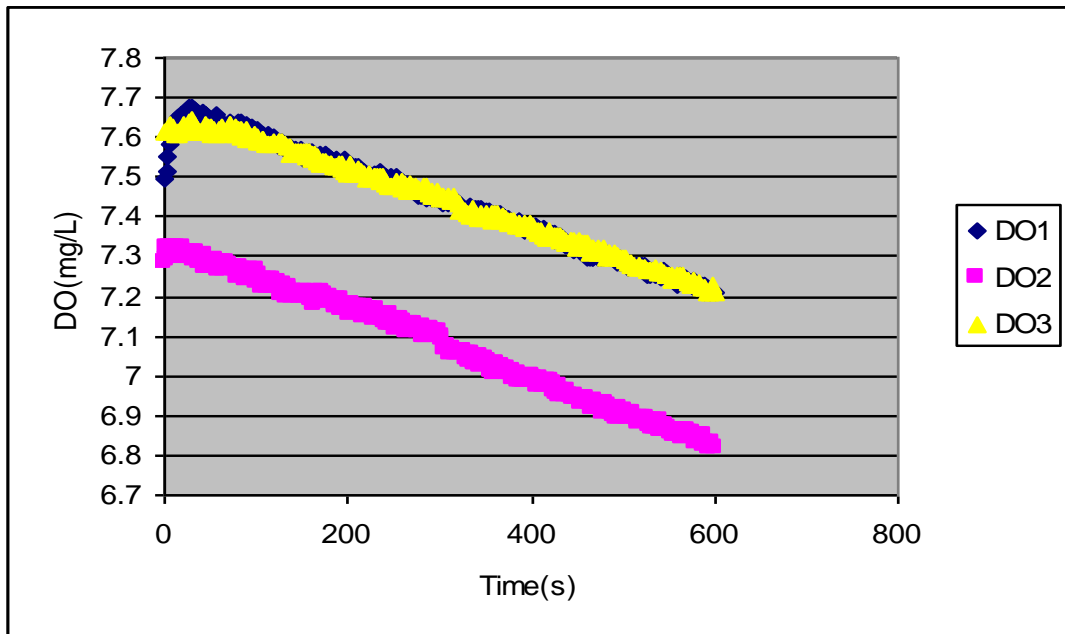


Figure 3 Real-time DO profile under 10°C

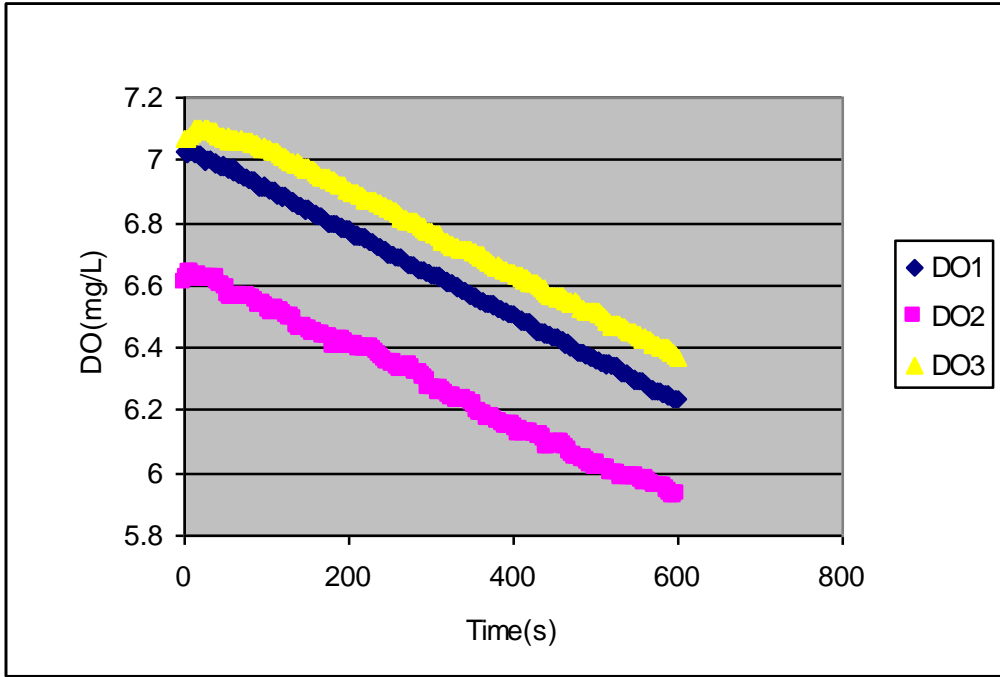


Figure 4 Real-time DO profile under 15°C

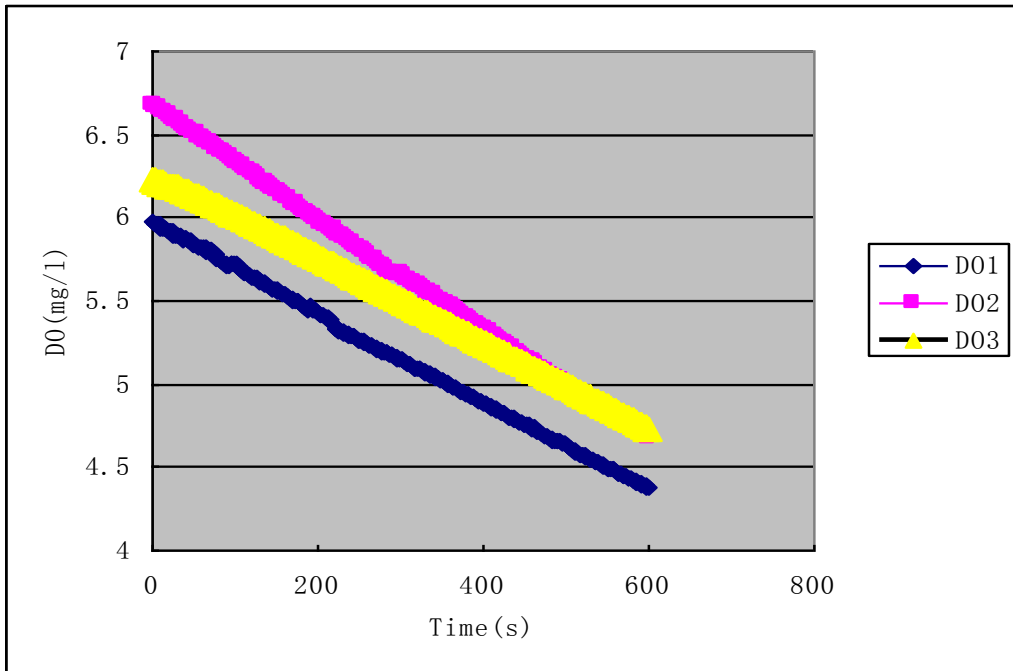


Figure 5 Real-time DO profile under 20°C



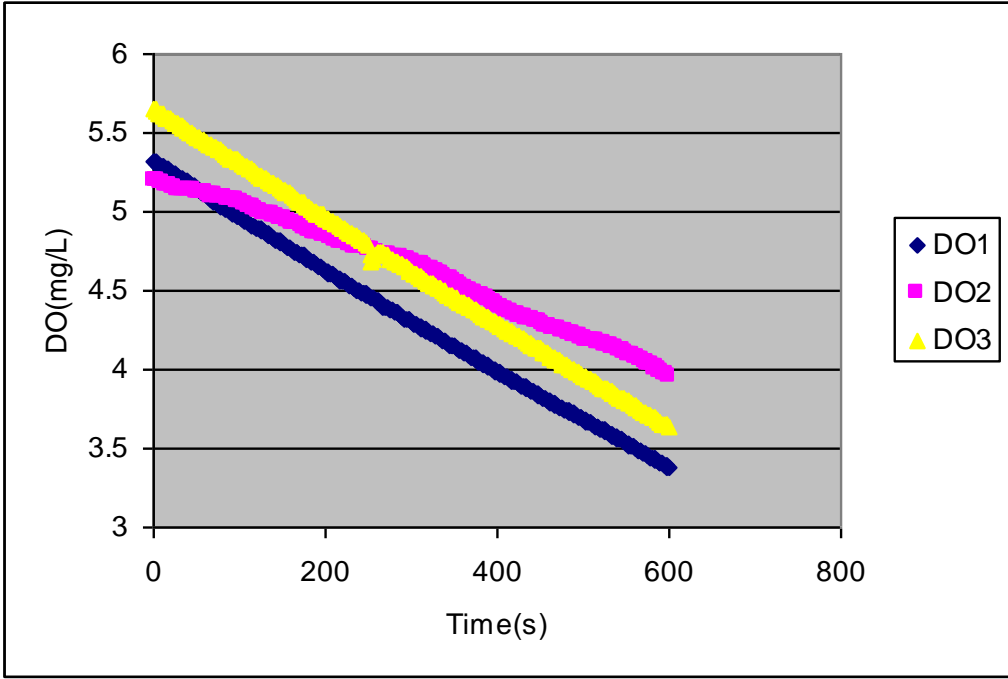


Figure 6 Real-time DO profile under 25°C

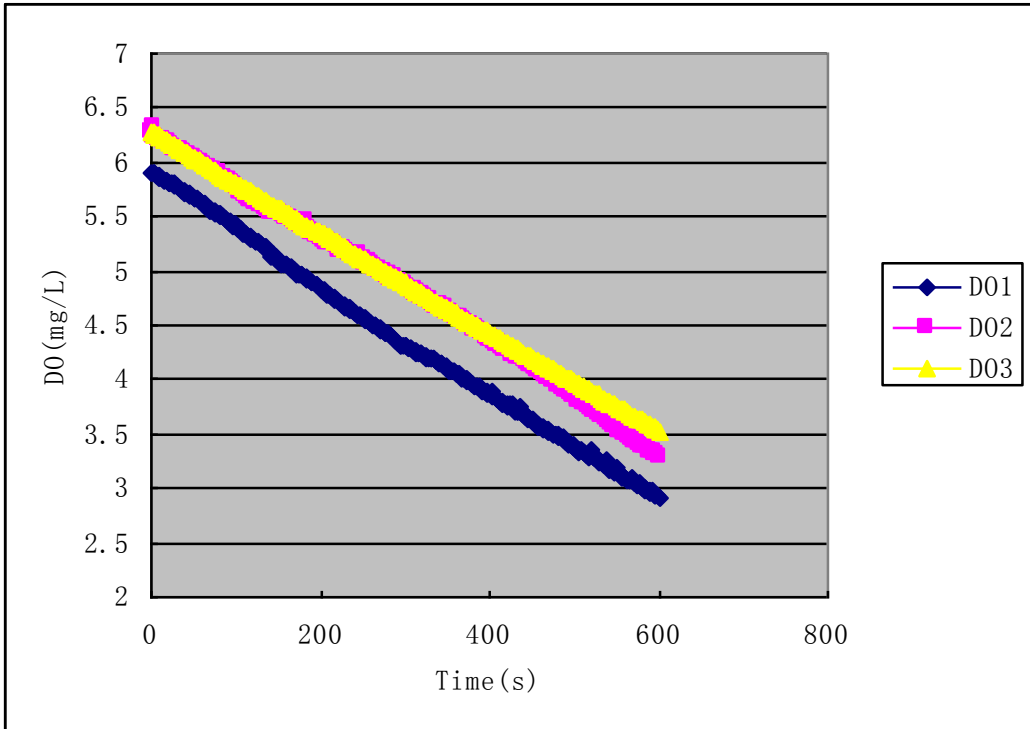


Figure 7 Real-time DO profile under 30°C

Figure 2 to Figure 7 indicate the real-time DO profile under different temperature, based on which, the OUR under each temperature has been summarized into Table 2. Data from DO1 under 10°C was abandoned due to the abnormal DO increase at the beginning of the measurement. DO2 under 25°C was also off the table because of the unreasonable small value.

Table 2 Oxygen Uptake Rate under different temperatures

T \ OUR	5°C	10°C	15°C	20°C	25°C	30°C
DO1	0.0008	<del>0.0008</del>	0.0014	0.0027	0.0032	0.0050
DO2	0.0007	0.0007	0.0012	0.0033	<del>0.0021</del>	0.0049
DO3	0.0006	0.0008	0.0013	0.0025	0.0034	0.0046
Average	0.0007	0.0008	0.0013	0.0028	0.0033	0.0048
Step Increase	/	14.3%	62.5%	115.4%	17.9%	46%

Unit:  $mg/(l \cdot s)$

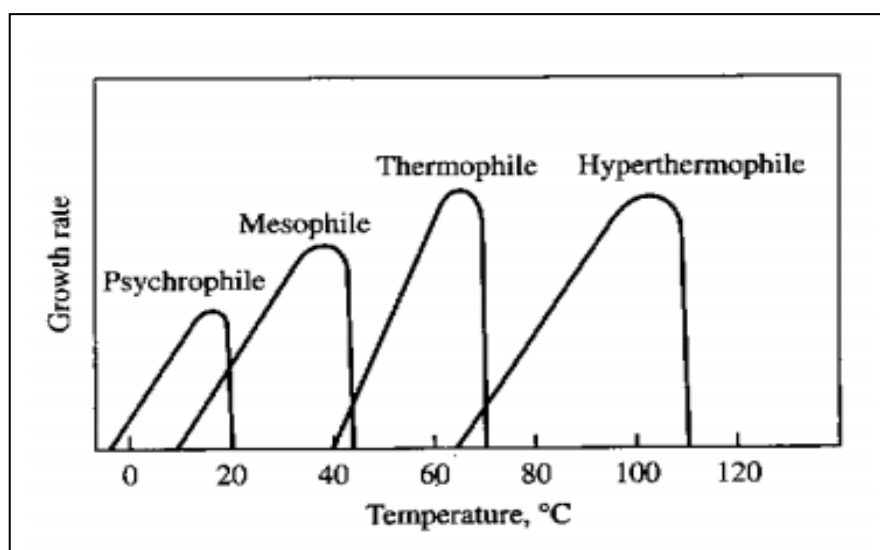


Figure 8 Effect of temperature on growth rate of different temperature classes of bacteria

Table 2 informs us that the OUR steadily increased from 0.0007 at 5°C to at 30°C. However, it is notable that the increment of OUR between each temperature interval were distinct. The OUR only raised 14.3% during the first 5°C interval, and then it quickly went up by 62.5% between 10°C and 15°C. When it came to 20°C, the OUR sharply increased to 0.0028, with 115.4% increment. Interestingly, the OUR only experienced a 17.9% increase in the following temperature interval. Finally, the OUR came to 0.0048 at 30°C, with 46% increase during the last 5°C interval. Due to the absent of other relative data, it is hard to explain the different increments between each temperature. Figure 8 <sup>[1]</sup>, however, might give a possible explanation for this phenomenon. As we know, when growth rate gets faster, more oxygen is needed to support the bio-reactions. The psychrophilic bacteria were the dominate species in the reactor, whose growth rate and DO consumption steadily went up along with the temperature until 20°C. After then, the temperature exceeded the normal range for the psychrophilic bacteria, key enzymes would be destroyed and the organism might not survive. As a result, the DO amount that taken by psychrophilic bacteria would sharply decrease. On the other hand, the mesophile bacteria began to grow at around 8°C and its growth rate would be faster than that of psychrophilic bacteria, as shown in Figure 8. The slow increase of OUR between 20°C and 25°C is due to the offset of DO uptake amount between two classes of bacteria. It can be predictable that the OUR will swiftly go up until temperature reaches 45°C and then it might experiment a slight decrease since the OUR of mesophile bacteria will crash at 45°C while the Thermophile bacteria just begin to grow at 40°C. This prediction largely depends on

the proportion of each microbial species in the activated sludge.

## **Conclusion**

The result shows that the OUR will go up steadily along with temperature increase, but the OUR increment between different temperature intervals are distinct. One explanation for this phenomenon is that the OUR is determined by the bioactivity of bacteria. And each class of bacteria has their specific temperature range to grow within. Once this temperature range is exceeded, the growth rate drops off rapidly due to denaturation of key protein, and then decrease the DO consumption.

## **Reference**

- [1] Bruce E. Rittmann and Perry L. McCarty, Environmental Biotechnology: Principle and Applications. McGraw-Hill Companies, Inc.
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- [3] Environmental Engineering Division, Activated Sludge: A comparison of oxygen and air systems. ISBN 0-87262-362-9. Published by the American Society of Civil Engineers. 1983.
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- [5] <http://www.cityofeastlansing.com/Home/Departments/WasteWaterTreatmentPlant/>