A Report

On

Measurement of Temperature Effects on Oxygen Uptake Rate in Activated Sludge Treatment

By

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To

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Abstract

The report provides details on the design and fabrication of an experimental laboratory set-up for the determination of the Oxygen uptake rate in activated sludge at various temperatures. The reactors were 2-liter volume glass beakers. Four such tanks held the activated sludge at four different temperatures. Four 75 W Visi- Therm water heaters were used to bring the sludge to the target temperature and maintain it. The temperatures were also checked using digital thermometers. Two Air diffusers were connected from two air pumps for providing oxygen supply. The reactors were placed on stirrer plates and magnetic stirrers were used to ensure good mixing within the reactor. For acquiring the Oxygen levels, we used four Dissolved oxygen probes and Lab view for acquiring the data. The Specific Oxygen Uptake Rate (SOUR), also known as the oxygen consumption or respiration rate, is defined as the milligram of oxygen consumed per gram of volatile suspended solids (VSS) per hour. We measured the OUR at different temperatures and were able to observe trends with change in the temperatures.

Introduction

Wastewater is water plus mass, different kinds of mass like organic mass, biomass etc. These materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants. The wastewater components that are usually of most concern are those that have the potential to cause disease or detrimental environmental effects. Many different types of organisms live in wastewater but some of these microorganisms present in wastewater are also essential contributors to treatment. A variety of bacteria, protozoa, and worms work to break down certain carbon-based (organic) pollutants in wastewater by consuming them. Through this process, organisms turn wastes into carbon dioxide, water, or new cell growth. Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment. Most wastewater treatment systems are designed to rely in large part on these biological processes. Hence, it becomes important to Environmental engineers to measure and evaluate various conditions that affect this vital biological process.

Temperature is a fundamental factor that affects all living organisms. It influences the rates of enzymatically-catalyzed reactions and also the rate of diffusion of substrate into the cells. The average temperature of the earth is about 13°C (56 F), and the majority of living organisms are adapted to live at a moderate range of temperatures around this mean.

The best temperatures for wastewater treatment probably range from 77 to 95 degrees Fahrenheit. In general, biological treatment activity accelerates in warm temperatures and slows in cool temperatures, but extreme hot or cold can stop treatment processes altogether. Therefore, some systems are less effective during cold weather and some may not be appropriate for very cold climates. Wastewater temperature also affects receiving waters. Hot water, for example, which is a byproduct of many manufacturing processes,

can be a pollutant. When discharged in large quantities, it can raise the temperature of receiving streams locally and disrupt the natural balance of aquatic life.

So, this biological treatment that we introduced here is usually called the Activated sludge treatment of wastewater. Activated sludge process is this wastewater treatment method in which the carbonaceous organic matter of wastewater provides energy for the production of new cells for different microorganisms present inside the aquatic environment. The microbes convert carbon into cell tissue and oxidized end products that include carbon dioxide and water.

Aerobic bacteria carries out wastewater treatment in activated sludge systems. The oxygen consumed by these microorganisms is replaced in the system by aerators. The oxygen respiration rate or oxygen uptake rate (OUR) is the microorganism oxygen consumption per unit time and is one of the few accessible parameters to quantify the metabolism rate of the activated sludge. The OUR is proportional to the microorganism concentration and depends on the quality of the incoming wastewater. Thus, this parameter is very suitable for monitoring and control of the activated sludge system. It is a measure for the quality of the activated sludge and may indicate the presence in the influent of sudden high loads of organic material (increase of OUR) or toxic elements (decrease of OUR).

Usually, OUR is estimated by measuring the variation of dissolved oxygen (DO) concentration, that can be measured with a specific electrode. There are basically two configurations for estimating the respiration rate batch units or continuous flow units.

In this experiment, we used sample two-liter volumes of the activated sludge collected from the local treatment facilities in our laboratory scale bio-reactor (glass beakers). The sample was aerated for a time period of ten minutes and after interruption, the change in DO was measured. DO measurements were made using sensors and a real time data acquisition system.

The graph describes a typical profile for our experiment. The slope of the linear portion of the DO profile with time is the OUR and has the units mg O2/ L-s. If the OUR is divided by the VSS of the sludge sample that was used to perform the test, a value known as the SOUR (Specific Oxygen Uptake Rate) can be determined which is the oxygen consumption rate per gram of VSS (mg O2/ g-VSS-h). The SOUR would normalize the response to the mass of organisms and allows comparison of oxygen response for different mixed liquors for each gram of organisms.

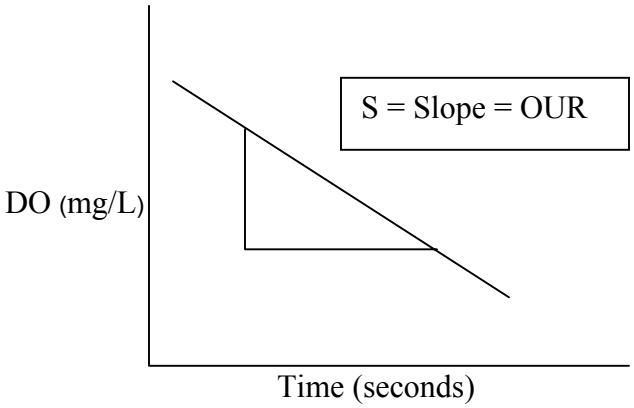

Figure 1. Graphical representation of the DO profile

The main varying factor that we decided to study during the course of this experiment was the effect of Temperature on the OUR of our samples. So, we had our set-up in a temperature-controlled room and also water heaters were installed and the sludge was left for four hours to acclimatize to our target temperatures. We describe more about the setup, the procedures and the results obtained in our following sections.

Materials and Methods

The experimental unit was designed and fabricated using apparatus purchased from different sellers and also using the glassware and other necessary equipment from the lab. The following table provides an overview of the various components of the experimental unit. All components were purchased and used without any modifications.

Parts	Manufacturer	Quantity
Glass Beakers (2 Lt volume)	Pyrex	4($17.50 each)
Stirrer Plates	Corning	4($400 each)
Dissolved Oxygen Probes	Vernier Pro Inc	4($199 each)
Water Heaters (Aquarium)	Visi-Therm Inc	4($15 each)
Air Diffusers (mixing)	Penn-Plax	4($1.99)
Air Pumps	Lung GX700	2($15 each)
Connecting Tubing	Tygon	10 ft approx ($1/foot)
Digital Thermometers	Cole-Parmer	3($17.50 each)

Table 1. List of Equipment

Reactor: The main reactor tank, which carried the sludge were the glass beakers used from the lab. They were 2-liter volume beakers. They were placed over Stirrer Plates and Magnetic stirrers were used inside the tank for sufficient mixing to occur.

DO Probes: Four dissolved oxygen sensors were purchased from Vernier Software & Technology (Vernier, Beaverton, OR). Each of the sensors had to connected to a USB Interface for recording the data. The sensors perform well in terms of measuring change in the DO concentration. Following the procedural manual for physical routine like warming up the sensors first in DI water and then using them were adhered to. In our Appendix for this report, we have included the user guide for future reference. More information about the working of the sensors and testing requirements can be found there.

The DO probes were attached to the walls of the reactor and the end points and distance from the air diffusers were kept uniform to eliminate any effects.

The DO probes were connected to the Vernier Labpro interface which in turn was connected to the computer. This would constitute our data acquisition system. We Connect LabPro to our computer, plug in our sensors, and start the data-collection program. The program will automatically detect which sensors are connected, and the system is ready for data collection.

Figure 2. Labpro Interface

Air Diffusers: The air diffusers were connected to the air pumps via plastic tubing. The plastic tubing providing airflow to the diffuser and was placed in a plastic pipe taped to the reactor wall. These were Aqua mist-Professional diffusers, which gave us instant and bubble to act as the oxygen supply.

Figure 3. Air Diffuser

Water Heaters: The Visi-Therm heater is completely waterproof and submersible. It has a visually adjustable temperature regulator and an easy to adjust dial for maximum control and ease of use. A long-life power lamp indicates on and off cycles of the heater, so you can tell at a glance if the heater is working. The non-ceramic element supports make this heater unusually light, which prevents suction cups from pulling loose. Extremely accurate magnetic switch for precise temperature control.

Figure 4. Water Heater

Below is an Image of the set-up after installing every piece of equipment.

Figure 5. Physical Set-up of the Unit

Lab view Installation

The Interface provided by Vernier Software and Technology, LabPro is used to connect the sensors to the computer. It can either be connected to the serial port or to the regular USB port of the computer. The interface contains two digital and four analog channels for connection of the sensors. It comes with a combination software which can be downloaded from their website, LoggerPro. But, we decided to work on a more relevant software application, whose use can be in so many other areas also, Labview.

Labview is a software application that aids in acquiring, analyzing, displaying, and storing data. It is primarily used by writing graphical programs called VIs. VI is an acronym for Virtual Instrument. These VIs can be separated as front panel, block diagram and the connector. The front panel is the interface for data inputs and outputs. We can operate the front panel by using standard I/O devices keyboard and mouse. Behind the front panel is the block diagram that contains the actual data flow between inputs and the outputs.

These Virtual Instrument graphical programs can be designed from the scratch. Also, the National Instruments Inc, which own proprietary rights to Labview software has some drivers available for Labview users. These drivers if matched with the instrument can be downloaded and used. These VIs can be downloaded from www.ni.com and installed.

The procedure for data acquisition and storage would be as follows. Open Labview and Click to open the VI program specially designed for measuring real time data. An overall block diagram for acquiring data will be displayed. We modified the real time measurement VI to acquire the data for all four probes and designed it to save the data to the excel files in a specified folder. While saving these files, care has to be taken to follow a sequential order with naming them, so as to avoid overwriting over your data. The data points from these files can then be used to create plots to understand the relations between various physical parameters we measured.

Schematic Representation:

The Following schematic shows the various components that make up a single laboratory scale bioreactor that we had designed and fabricated. The Air diffuser, the DO Probe, and the Water Heater, are represented and labeled.

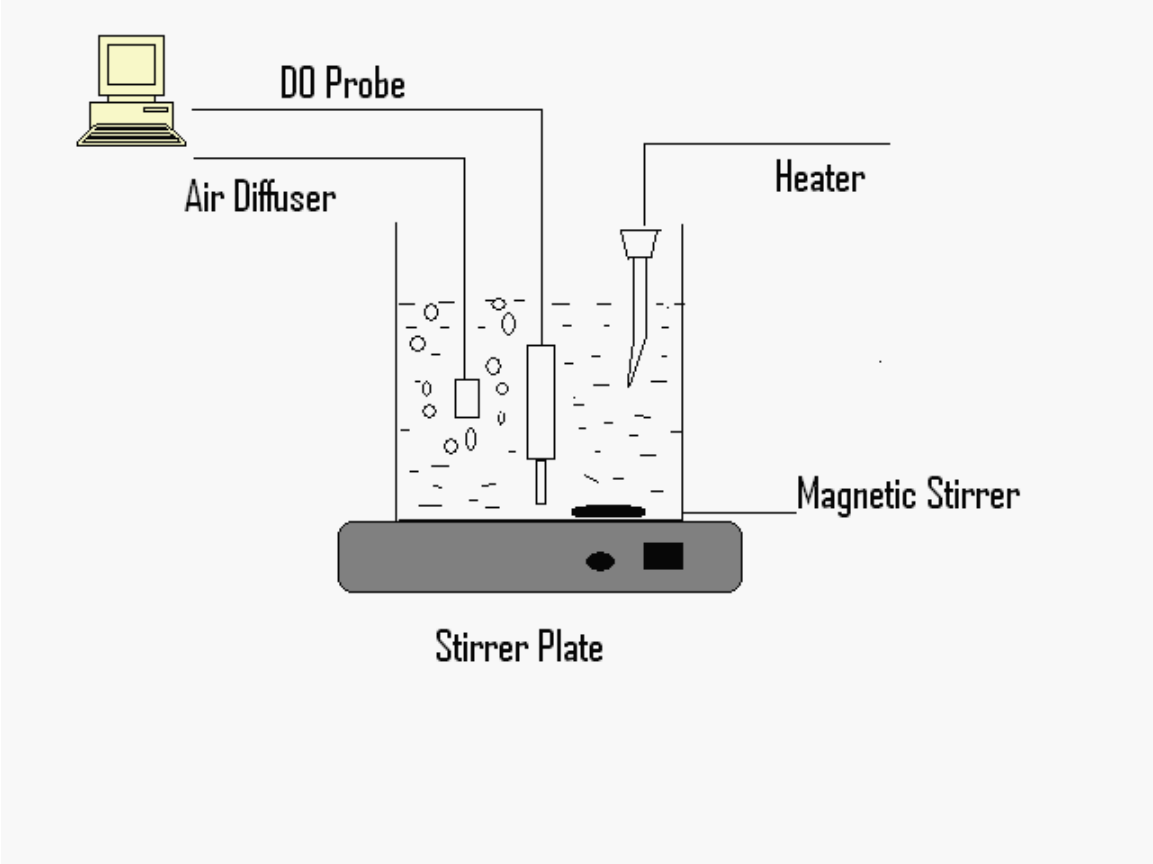

Figure 6. Schematic Representation of a single reactor

Experimental Procedure:

Activated sludge was obtained from the local wastewater treatment facility. Before starting the experiment, the sludge was kept in a container and constant supply of oxygen and substrate were maintained. 1 liter of the activated sludge was then transferred into the reactors 4 hours before the experiment to make the activated sludge acclimate to the new temperature. Simultaneous aeration was provided to the system to ensure sufficient dissolved oxygen. 5 ml of the activated sludge was collected to measure the volatile solids (VS).

In-situ oxygen uptake rate measurement

In our experiment, we used In-situ OUR measurement. To start measuring the DO, the most important step is to turn off the air pump and let the stirrer continue mixing the sludge. This is really important, to allow the biomass and liquids to mix thoroughly. The non-aeration periods were for 10 minutes and then the dissolved oxygen data was measured simultaneously. This data was used to calculate the oxygen uptake rate later.

Plot the real-time data collecting from the labview using scattered curve and use the linear trend line to determine the slope. The slope represents the oxygen consumption rate in mg/L per second.

Put the data into the equation we can get the value of Θ.

$$OUR@20°\mathrm{C} = OUR_T \times \Theta^{(20-T)}$$

Where, $OUR@20°\mathrm{C}$ is the OUR under $20\,°\mathrm{C}$;

OUR_T is the OUR under $\mathrm{T}\,°\mathrm{C}$.

Θ is the temperature correction coefficient.

Results and Discussion

Oxygen Uptake Rate (OUR) is an important indicator for the activity of the sludge. We are interested in evaluating the factors that influence the activated sludge oxygen uptake We know there are three factors can affect the dissolved oxygen saturation, they are temperature, pressure and salinity. (Chapra). We assume that the dissolved oxygen in activated sludge is similar to the DO saturation case. For any biological treatment, temperature and substrate are the two major parts to affect such a process. In this project, we look at temperature and the influence it would exert influence on the OUR. Another aim was to learn setting up a real time data acquisition system.

We set four different temperatures for this experiment; they are 15°C, 20°C, 25°C and 30°C respectively. We choose 5°C as the temperature interval to ensure a wide range and make the result more apparent.

The plots obtained are presented in the following pages.

Real-time dissolved oxygen under aeration period.

During the aeration periods, we recorded the real-time DO and the plot is as follows.

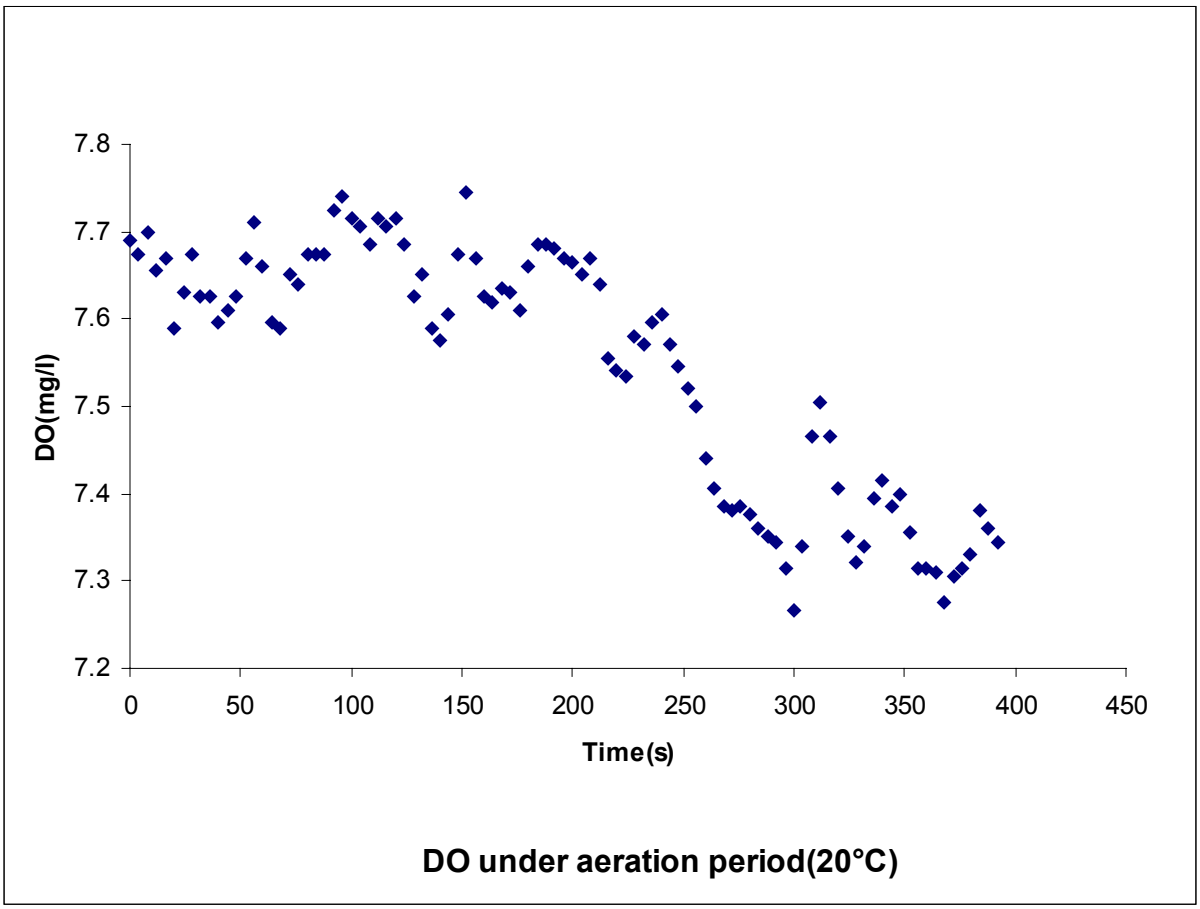

Fig 7. The real-time DO profile at 20 C with aeration

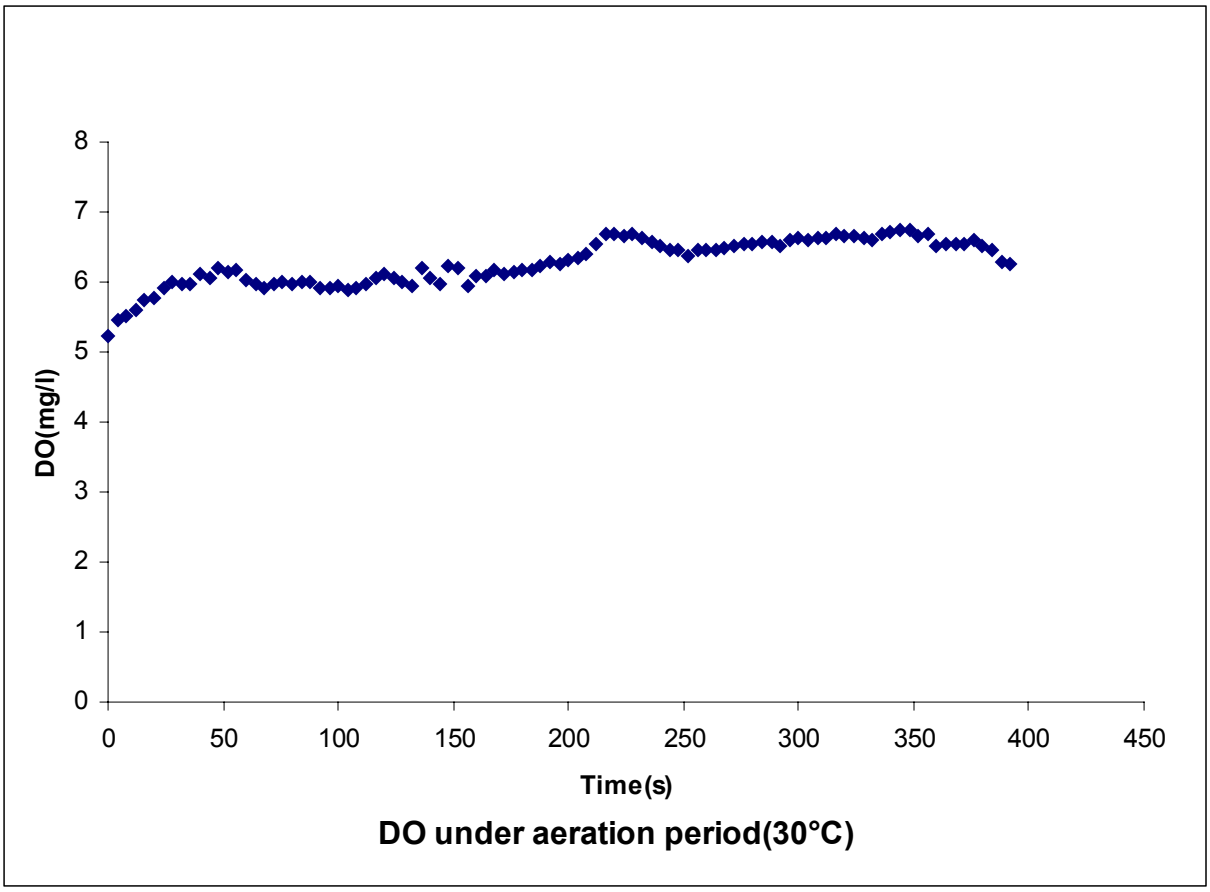

Fig 8. The real-time DO profile at 30 C during aeration

These two charts were taken from the real-time data of the DO under 20°C and 30°C.

We have not observed a decipherable trend for the DO during aeration period. During the aeration, the consumption of the oxygen by the activated sludge is affected by factors like the mixing in the reactor and the amount of the oxygen being supplied.

Real-time dissolved oxygen decrease profile during the transition from aeration period to non-aeration period.

Plot represents the dissolved oxygen during the non-aeration periods along with the aeration.

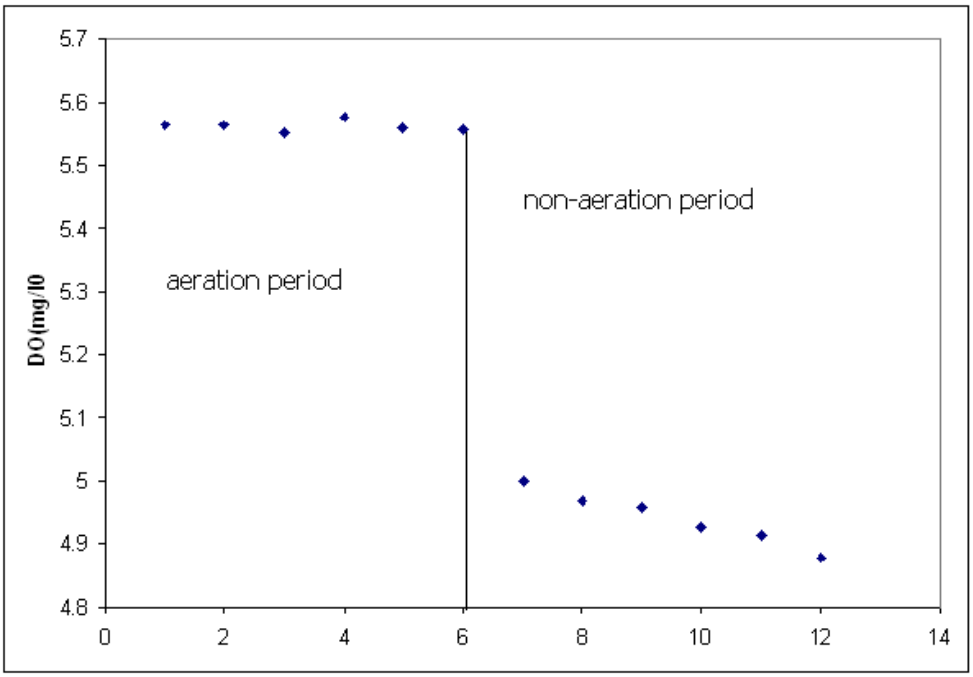

Fig 9. The transition between aeration period and non-aeration period at 30°C

It is observed that the DO dropped dramatically when we cease to supply the oxygen, which means the activated sludge consume the oxygen in a fast way or the sudden cease of the supply of the oxygen result such a big sag. Same trend observed in the other reactors as well.

Real-time dissolved oxygen under non-aeration period

Following are the plots for DO at the four target temperatures.

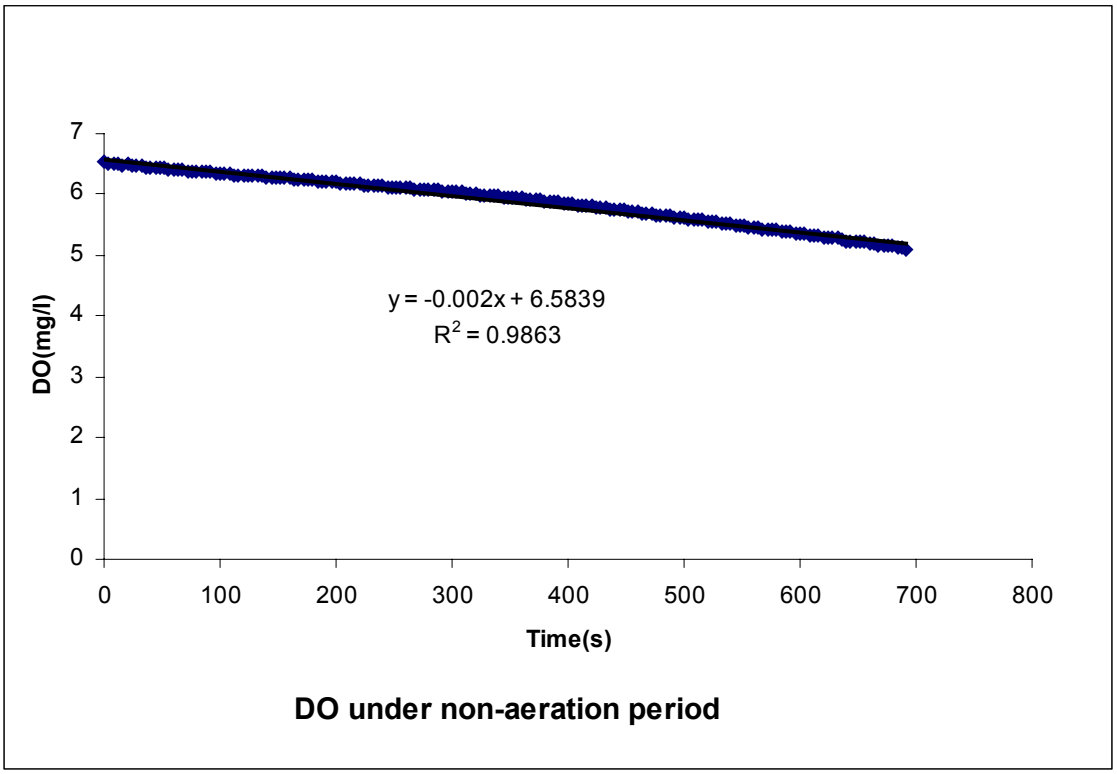

Fig10. The real-time DO under non-aeration time (15°C)

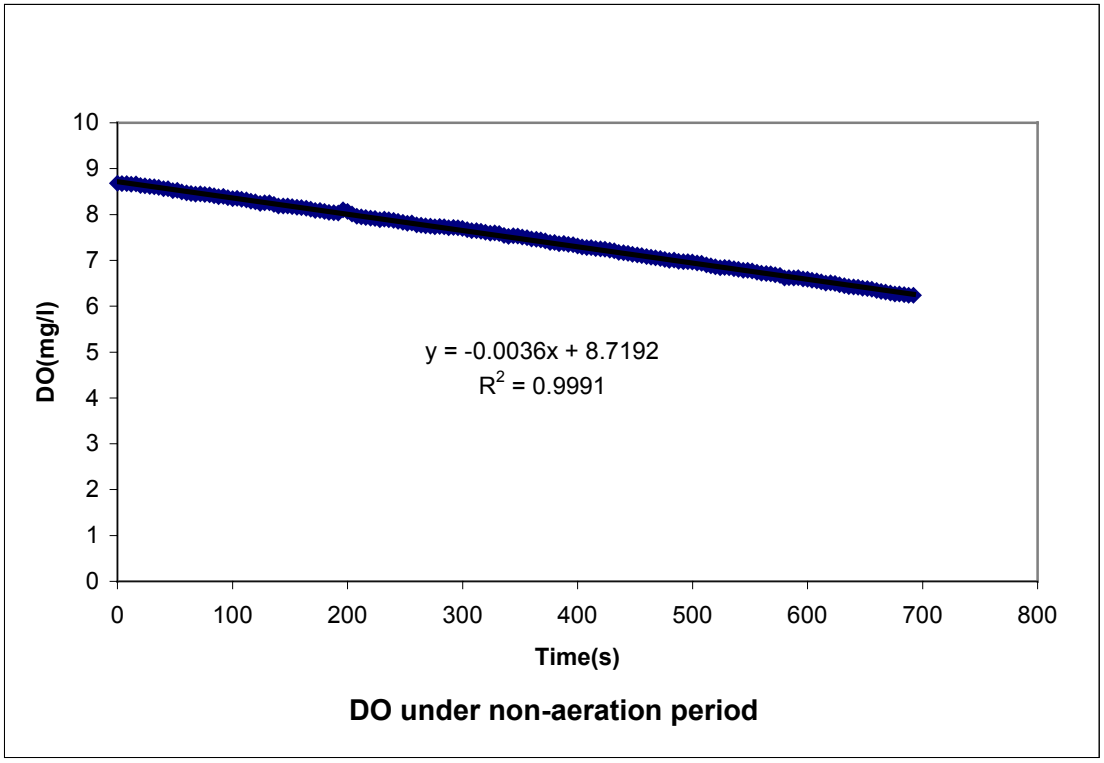

Fig 11. The real-time DO under non-aeration time (20°C)

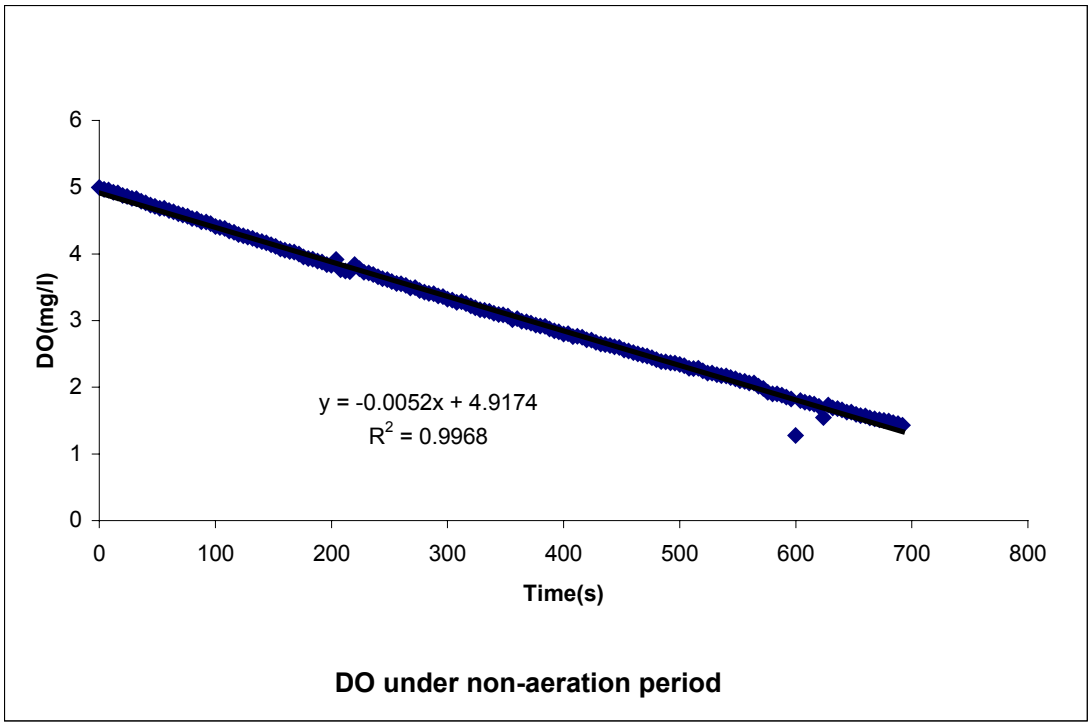

Fig 12. The real-time DO under non-aeration time (25°C)

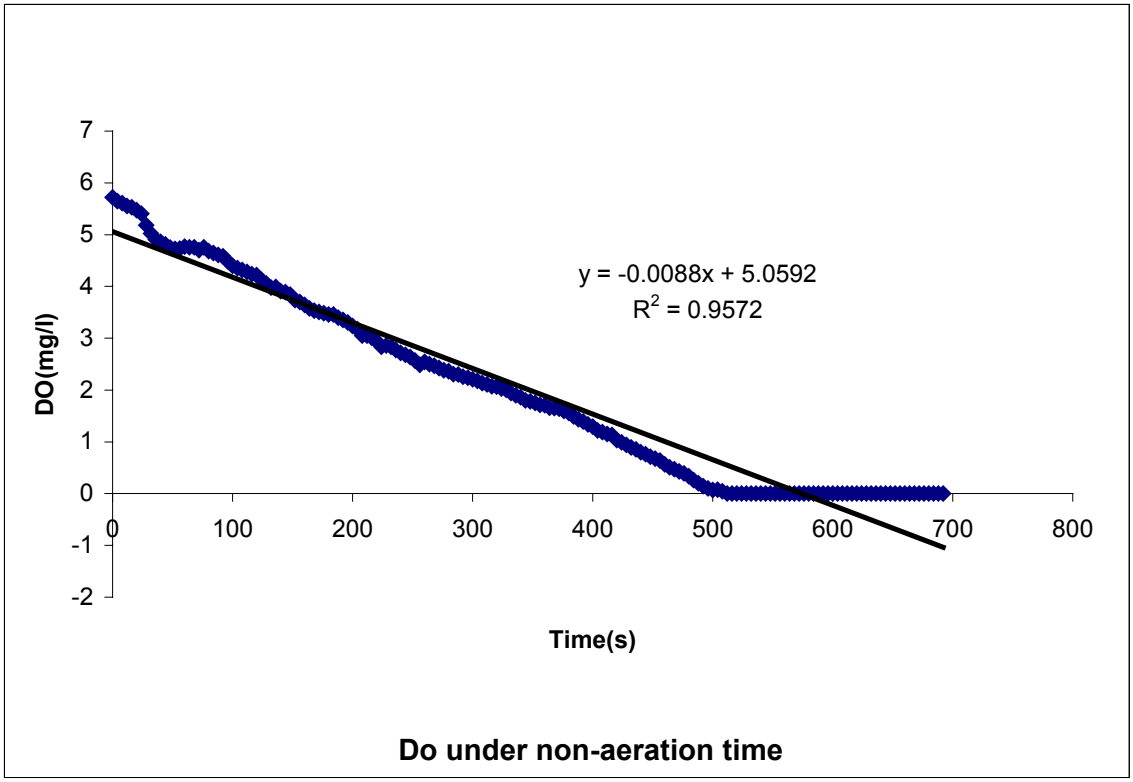

Fig13. The real-time DO under non-aeration time (30°C)

All these four plots indicate the trend of the OUR at different temperature. The slope of these plots (the slope stands for the OUR) increase with the increase of the temperature, which means the higher the temperature, the higher the OUR. It also correlates our assumption that the activated sludges have larger OUR at higher temperature. The reason for this conclusion is that the sludge are more active under higher temperature, reflecting in the activity indicator. it is interesting that all the four real-time is linear curve, differing from other exponential DO curve. The reason might be lied in the fact that activated sludge consume the oxygen in a constant way.

We summarized the OUR under different temperatures in table 3, function it along different temperatures and plot it. The relationship between the OUR under different temperatures is an exponential function. If more experiments were conducted, we might find the empirical equation for the OUR and the temperature.

To measure the specific oxygen uptake rate (SOUR), it is very similar with OUR, only using the value of the OUR divided by the Volatile Suspend Solid (VSS). Hence the shift of the SOUR is proportionally with the OUR. The unit of the SOUR should be (mg/l.s.gVSS). But we were only able to measure the volatile solids during the course of our experiment.

Temperature (°C)	OUR (mg/l-s)
15	0.002
20	0.0036
25	0.0052
30	0.0088

Table2. The value of the OUR under different temperatures

The temperature coefficient Θ is 1.1247,1.0071 and 1.0933 at 15°C, 25°C and 30°C. it is not a constant, which means this coefficient is not applicable in this experiment. To verify the equation of the temperature correction, more experiments under different temperature points should be conducted to verify this empirical equation. Only 4 samples is not an appropriate way to evidence this mathematical statement.

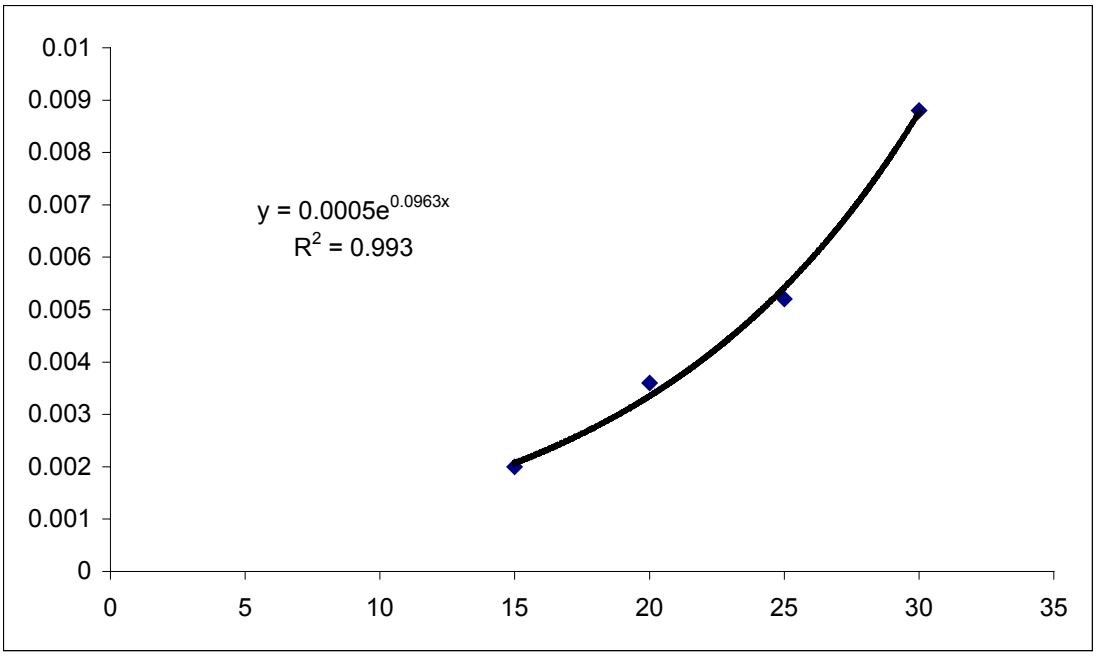

Fig.14 the plot of the OUR Vs. temperature

Conclusions

In our experiment, we could clearly establish that OUR of the activated sludge increases with the temperature. The temperatures range we considered in this experiment covers the most practical activated sludge treatment process temperatures. Results obtained also demonstrate that OUR is a reflection of the activity of the biomass.

Measurement of OUR in activated sludge processes is essential for the satisfactory monitoring of treatment processes. Often oxygen uptake rates (OUR) are determined by using a dissolved oxygen probe to measure the change in dissolved oxygen. This is an efficient and fast process but it provides only a snapshot, at a single point in time, of the oxygen uptake rate reaction in a treatment process. Much more can be learned about the operation of a treatment plant by measuring the oxygen uptake rate over a period ranging from one to four hours after adding wastewater to the mixed liquor. The resulting pattern of oxygen uptake rate can be used to assess biodegradation patterns, to determine the impact of various wastes on treatment plant performance.

Prospective research methods

We were able to conclude that OUR is a good indicator for the sludge's activity. But is it the most appropriate method to illustrate the complex world of the activated sludge, or are there better ways to evaluate the activity of the diverse microbial population present in natural waters?

One way is to measure the active enzymes present in the sludge. During the course of Weimin's research experiences, he used Co-enzyme 420 as an activity indicator for anaerobic granular sludge. Another method is to measure the Adenosine 5'-triphosphate (ATP) that could give a more detailed appraisal about the biological process.

There are more advance microbial techniques such as Fluorescent In Situ Hybridization (FISH), 16 sRNA/DNADNA, hybridization using Polymerase Chain Reaction (PCR); etc that could be used to determine the activity of the activated sludge quantitatively and qualitatively.

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Appendix