OPTIMISATION OF WASTEWATER TREATMENT PLANTS : DISSOLVED OXYGEN AND SUSPENDED SOLIDS MEASUREMENTS

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ABSTRACT

When wastewater plants were first constructed in the early 1900's, the design criteria was make the effluent look better. More recently, particularly in the last decade, stringent quality standards are being applied to plant effluent, whether by regulatory authorities or environmentally concerned plant management. More often than not now, limits on nitrates, ammonia, phosphates, suspended solids, etc are applied to outfalls. The wastewater not only has to look good, it must also be good. This in turn has caused operators to turn their focus to the biological activity in a treatment plant, particularly in the aeration basin (in conventional plants) or the SBR (sequential batch reactor). Two critical parameters in these tanks are Dissolved Oxygen and Suspended Solids. This paper aims to discuss why these measurements are needed to ensure that the process is optimised and how to apply the sensors so they remain accurate and reliable.

KEYWORDS

Dissolved oxygen, suspended solids, sludge retention time, aeration basin, biological activity, DO, TSS, SRT

1.0 INTRODUCTION

Dissolved oxygen sustains life underwater. In wastewater plants, it is essential the D.O. level is sufficient to support biological activity. In layman's terms, enough oxygen for the good bugs to breakdown the waste. Historically, D.O. levels are maintained at a higher level then necessary. The reason for this operating mode is due to the fact that while higher then optimum dissolved oxygen is not good from a process or monetary standpoint, zero oxygen is catastrophic.

Suspended solids are the food supply for the biology within the aeration basin. The suspended solids supply should be maintained at a fairly stable level that allows for the biological breakdown of the solids. The consequences of having suspended solids levels below the desired range is that the biology will not have an adequate food supply for proper performance. If the suspended solids level is above the desired range it can cause many problems not the least of which are bulking, high sludge retention times (SRT), and poor nutrient removal.

The traditional way to regulate dissolved oxygen and suspended solids has been to either use portable meters to periodically check the values in the basin or to pull “grab samples” and have them analysed in a laboratory. In recent years there has been an increase in the amount of online dissolved oxygen but it is very seldom used for automatic control. The use of continuous suspended solids analysers are still very rare. Even if there are online TSS analysers the normal use is only for monitoring.

While the benefits of online monitoring and control of both dissolved oxygen and suspended solids would seem obvious, the reliability of the sensors has been the single largest obstacle to reaching this goal. Over the last ten years there have been quite a few advances in the technology used to take these important measurements, with the most significant being the ability of the sensors to resist fouling.

2.0 DISSOLVED OXYGEN

The measurement of dissolved oxygen is the most common continuous, online analytical measurement made in a typical secondary wastewater treatment aeration basin. The use of the Winkler Titration method for measuring the dissolved oxygen in the aeration basins has decreased markedly over the few years. One of the main reasons for this is that there are many interferences that will affect the outcome of the titration when used on wastewater. All of these interferences must be compensated for to get accurate dissolved oxygen results. This was a time consuming, exacting, and to some degree a somewhat subjective process.

With the advent of portable dissolved oxygen meters that could be calibrated to a known standard (air) the monitoring of the aeration basin was made much simpler and quicker. While this was an advantage over the titration method in regards to controlling an aeration basin, it was still limited by how many times the measurement was taken. For example, an operator takes D.O. readings with a portable at 1200 and 1600 every day and then uses these readings to manually set the blowers. As long as the process conditions remain the same between those times the plant will run efficiently. However, if the process conditions change during this period it is likely that the oxygen demand will also have changed causing the basin to perform at less then optimum levels.

While using the portable is better then using only a Winkler for D.O. reporting due to the fact that an adjustment can be made right after the reading is taken instead of waiting for the lab result before making any required adjustments. However the portable D.O. meter is still not the complete answer in optimising the aeration basin. To really optimise the oxygen system, and therefore maintain a stable biology in the basin, is necessary to adjust the oxygen delivery system based on the actual oxygen demand. Because this demand is almost always changing it follows that the dissolved oxygen should be monitored on a continuous basis and the result of that continuous reading used to actively control the oxygen delivery system.

In this era of ever higher standards for effluent water quality combined with the fact that everyone is expected to do more with less money, it is crucial that the treatment plant runs at peak performance all the time. Some of the more common results of less the optimum dissolved oxygen levels are listed below.

2.1 Consequences of high D.O. level:

- ♦ Excess electricity consumption, sometimes amounting to tens of thousands of dollars per year
- ♦ Promotion of unwanted organisms, e.g. filimatious biology and nocardia.
- ♦ Pin floc conditions in secondary or final clarifiers.

2.2 Consequences of low D.O. level

- ♦ Insufficient biological activity, worst case is destruction of bio mass.
- ♦ Uncontrolled stressing of bugs, anaerobic zone instead of aerobic zone.

2.3 Dissolved Oxygen Sensors

There are two basic types of D.O. sensors used in wastewater plants - membrane and non membrane. Membrane sensors respond to the migration of oxygen through a semi permeable membrane, while non membrane sensors respond to the oxygen potential between two electrodes. By far, the majority of sensors on the market are of the membrane type. The main reason for this is that a oxygen permeable membrane isolates the measuring electrodes from the solution being measured. This is useful as the membrane also isolates the measuring electrodes from any interferences present in the solution being measured. Some common examples of these interferences include H2S, pH, and conductivity. Another major reason that most sensors are of the membrane type is due to the fact that membrane sensors can be calibrated in air very easily. This is a major plus for operations as no special calibration solutions are required.

There are two types of membrane sensors - polarographic and galvanic. Both types are based on the Clark cell principle. Polarographic sensors rely on a stimulating voltage from the parent analyzer to work, while galvanic sensors will generate an output whenever oxygen is present

Membrane sensor manufacturers have addressed the fouling problems in recent years. Several manufacturers use a floating ball to help clean the sensor by increasing horizontal fluid velocity at the sensor. This method is at best dubious due to the long retention time in basins and the fact the sensor is measuring near the surface. In the last year, some manufacturers now have the sensor 500mm below the ball so the measurement is not near the surface, but they forget to mention how the velocity cleaning can still work.

Another sensor generates minute amounts of chlorine which has been extremely effective in increasing the maintenance interval. The chlorine level is not high enough to kill the bugs, but sufficient to make the membrane surface (and the pores of the membrane) unattractive to bugs. Also, many manufacturers now use automatic air or water jets to clean membranes regularly.

Reliability trials have been carried out at many plants around the world. In most cases, a sensor with both electrochemical (chlorine) and air/water jet cleaning performed best, remaining accurate without maintenance for 9-12 months. Interestingly, the plants had varying industrial loads, indicating the chlorine was minimising biological fouling while the jet was removing oils, greases and fats.

While Oxygen Reduction Potential (Redox or ORP) measurements have been around since early this century, there has been a noticeable push for this measurement recently, particularly in anoxic zones at biological nitrogen removal (BNR) facilities. One reason for this is the misconception D.O. sensors cannot measure below 0.5 parts per million. There are a couple of galvanic sensors that are used to measure below 5 parts per billion in power stations. It follows that if very low parts per billion measurements are accurately made that galvanic type sensors will be able to the low levels of dissolved oxygen in the anoxic zones of a wastewater treatment plant.

3.0 SUSPENDED SOLIDS

Suspended Solids measurements are critical to wastewater plant operations. It is a fact that continuous SS analysers would be more common than flowmeters if the sensors were reliable. Before we consider the sensors, we need to understand the theory associated with the measurement.

The management of Suspended Solids in wastewater plants is playing an ever increasing role in optimising plant performance. Measurements are regularly taken to ensure the plant is balanced and performing correctly. In a conventional biological plant, Mixed Liquor Suspended Solids (MLSS) travel from the aeration basin via the Mixed Liquor Channel to the secondary (final) clarifier. Most of the solids pumped from the secondary clarifier underflow are returned (Return Activated Sludge or RAS) to the aeration basin, and some of the solids are wasted (Waste Activated Sludge or WAS).

The most common method of determining the MLSS levels in the aeration basin is to take a “grab sample” for analysis at a laboratory. This is a problem in that it normally takes between 2 and 24 hours to get the result from the lab. Knowing exactly how much to return, how much to waste and knowing the Sludge Retention Time (SRT) or Sludge Age is impossible with lab tests due to the fact that by the time the MLSS is analysed process conditions have almost certainly changed. Most of the time a profile of the plant's MLSS is built over time so that the operators know what the average value of the mixed liquor at a given time of day and can return or waste based on this historical data. This does not account for changes in influent flow or solids loading that would be out of the ordinary. An example of an unusual flow event could be a severe rainstorm. An example of a unplanned loading change could be food processor cleaning out the storage bins and sending the runoff down the sewer.

3.1 Units of Measurement

It is generally accepted that the term Suspended Solids is used in wastewater plants, while the term Turbidity is more common in water plants. Likewise, it is generally accepted that Suspended Solids is a higher concentration measurement.

The more common units are:

MG/LT Milligrams per litre
PPM Parts per million
NTU Nephelometric Turbidity Unit
FTU Formazine Turbidity Unit
JTU Jackson Turbidity Unit

The only true analysis method is to take a known volume of sample, remove all the liquid and weigh the solids left, i.e. 1 litre of sample when evaporated leaves 10 milligrams of residue which is 10mg/l. (In the wastewater industry, it is accepted that mg/l and ppm are identical.)

Formazine standards (used for Turbidity calibrations), are a hazardous material and inherently unstable even over 24 hours making analyser calibration very difficult and subjective. For example, two analysers can be calibrated at 40 NTU, then put into service. One may read 10 NTU, the other 5 NTU yet both are correct. Thankfully, mg/l is the standard unit in wastewater and the measurement is volumetrically measured. This part of the paper will concentrate on Suspended Solids measurements in wastewater applications.

3.2 Process variables in Suspended Solids measurement

Particle size
Particle weight
Particle colour
Dissolved solids
Liquid Colour

Practically speaking, colour (either particle or liquid) is the only variable capable of causing erroneous readings, especially in the aeration basin and mixed liquor areas. Where plants have 100% sewage inflow the problem is not that severe, but plants taking any percentage of industrial load can expect colour change. There are sensors available with active colour compensation using a phased array light system.

3.3 Sensor variables

Lens material
Cleaning method
Method of calibration

As there is a good possibility the lenses will be scratched or marked at some point, care should be taken to ensure the optical properties of the lenses is the same as water. Standard and optical grade glass lenses have significantly different optical properties to water so a scratch will cause a change in the calibration, necessitating recalibration. Sensors using mechanical cleaning systems such as wiper blades or rotating scrubbers are prone to lens scratching and mechanical failure, necessitating very expensive repairs. There are sensors on the market that use a water or air "jet wash" to clean the optical surfaces. This type of cleaning system has been in use for over three years with good results.

3.4 Calibration

The main method of calibration is interesting, in that it if more often misunderstood. Normally, a process sample is removed in a bucket, and some of the sample is analysed to ascertain the concentration. The sensor is placed in the bucket and the analyzer calibrated accordingly.

What are the problems associated with this type of calibration?

- The most common SS measurement is mixed liquor or aeration basin solids. These are aerated while the bucket sample is not. There is no possible way an optical sensor, or any other sensor for that matter, can be accurate without being calibrated in the same aerated condition as the process.

- A bucket sample will be held for many hours awaiting the lab result. The biology of the bucket will change during this time due to the lack of aeration and the lack of flow. In other words, the bucket has basically become a clarifier or settling vessel while awaiting the lab results.

- A bucket sample requires agitation to keep the solids in suspension during the actual calibration. This is a very subjective criteria at best. How much stirring is enough to keep all the solids in the same state of suspension as the aeration basin?

Another method of calibration is to mix a known concentration of formazine with water, stir this mixture while the sensor is submerged, and then calibrate the analyzer to the formazine solution. This method gives a very repeatable calibration, but due to the differences in particle size and colour has very little actual relationship with process to be measured.

A third method of calibration allows the operator to calibrate the sensor in place. This allows the operator to calibrate the sensor to the process without removing the sensor from the process. The benefits of this method are that the sensor is calibrated to the actual process, the sensor does not need to be removed, and there is no requirement to mix or preserve a sample for calibration.

4.0 CONCLUSION

As permits are becoming tighter and dollars are becoming scarcer it is important to optimise the entire secondary wastewater treatment process. Since the aeration basin is at the heart of the secondary treatment process it is a logical place to look at for improvements in process performance and also for improvements in cost control. By monitoring and controlling the dissolved oxygen and suspended solids in the aeration basin it is possible to achieve both these goals.

When the dissolved oxygen is under control there are two major benefits. First, the biology of the vessel is balanced so that the "bugs" are not stressed due to the lack of oxygen. This also will limit the harmful biology that can become a problem if the dissolved oxygen levels are too high. The second benefit is that the aeration system will work only as hard as required, not more. This normally has the effect of reducing energy costs when compared to systems that operate "wide open", or without any type of dissolved oxygen control.

The control of the suspended solids within a treatment plant allows for many process enhancements. With control it becomes possible to balance the biological loading in the aeration basin. The RAS and the WAS can be controlled to achieve optimum sludge retention time (SRT).

One key element to the success in accurately making continuous, online dissolved oxygen and suspended solids measurements is the ability of the sensors to be self-cleaning. This feature is of growing importance as budgets are tightened.