DISSOLVED OXYGEN MONITORING IN WASTEWATER

by
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Introduction

Once secondary treatment is used in the controlled process of wastewater treatment, the measurement of dissolved oxygen (DO) is important in two locations of the plant – in the bioreactor, or aeration basin, and the outfall, if the water is going into natural waterways. The purpose of the former is to make certain that the biology in the aeration process has enough DO to remain alive, and the latter is to make sure that the DO is high enough in the water leaving the plant to sustain life.

Initially, laboratory meters and wet tests were used in this measurement, and then, in the 1950's, somewhat reliable portable meters were used to monitor DO. Not long after that, continuous DO meters were put into use, not only to measure the DO continuously, but to often control the aeration process in the bioreactor. Certainly, this continuous monitoring capability also gave plant management the ability to record DO measurements continuously.

Since the late 1970's there have been numerous technologies used for this very important measurement, with seemingly hundreds of companies promoting every possible technology to reliably provide this DO information. Finally, since the late 1990's a technology has been introduced to the industry that has been tagged "the ultimate answer" to DO measurement.

We have now had a decade of "optical dissolved oxygen sensing" in wastewater; and, in 2003, a marketing push for this technology has resulted in the industry being almost "forced" into this over-rated theory. It is time that we debunk optical DO technology for what it really is and regain an open forum within which the management and Operations personnel of the wastewater industry can have a choice – based on responsible forethought and understanding.

Some Facts

Viable Technologies – there are really only 3 ways to "automatically" measure DO with a sensor – open electrode, electrochemically, and optically.

- The open electrode technology was a patented technology out of Europe that used the water around the sensor as the carrier of electrical current for the ionic measurement of DO. Not a bad idea, except that in wastewater there are many other gases in the water that react with the sensor's electrodes, much in the same way as dissolved oxygen. So, readings were very inaccurate, the sensor had submerged mechanical parts, and it was a very expensive technology to purchase and support.
- Electrochemical sensors *actually* measure only dissolved oxygen because the electrolyte, anode and cathode within the sensor are specifically tuned

to the gas being measured. These sensors actually use the oxygen in the water outside the sensor, so there is absolutely no more accurate method of measuring DO. There are two electrochemical technologies –

  - Polarographic DO sensors require an electronic linearization process initialized from the parent electronics in order to maintain a stable reading. So, malfunctioning electronics can cause problems with this measurement.
  - Galvanic sensors, on the other hand, actually utilize the oxygen being measured as ‘fuel’ for the measurement process. An electronic conversion device (instrument) is not even necessary. So, a galvanic sensor, in reality, does not even require electronics, except to perform the functions of correcting the DO reading for temperature, partial pressure, and salinity.

  The resounding “wives tales” that so viciously put this highly objective and factual measurement in the back seat were primarily focused on the “membrane” which separated the environmental liquid from the internals of the sensor. More on this later.

- Optical DO sensors were initially developed for the clinical industry, especially for the measurement of oxygen in blood. Basically, a coating of some type of platinum based fluorescing material is placed on a clear “cap,” or substrate. This material must come into contact with the medium being measured. An LED of a specific wavelength of light, located inside the cap, excites, or ignites, the fluorephores located in the external material if DO is present; the time of the light’s degradation determines the amount of dissolved oxygen that is present in the water. The single, and only, advantage to this type of measurement is that the measurement does not require the movement of water for a stable reading.

Wastewater Treatment DO Applications – As previously mentioned, there are two primary applications for DO measurement in a wastewater treatment plant –

1. In the bioreactor, or aeration basin, the bacteria that are utilized to break down organic solids require dissolved oxygen.
   a. Most plants try to maintain in excess of 1.8 ppm of DO for this purpose in the bioreactor. This basin is also the largest single energy consumer in the plant, so precise control of DO is desired, more of a reason for automated DO monitoring. The oxygen is fed to the bioreactor via some method of diffusing compressed air or liquid oxygen into the basin. Diffusing oxygen into water takes time, so these basins are either very deep or moving very fast in order to give oxygen bubbles time to break down or diffuse before they surface. So, in *absolutely every* aeration basin there is moving water, well in excess of the amount of movement required to constantly provide fresh DO to a dissolved oxygen sensor.
   b. The aeration basin is the suspended solids breakdown stage of the secondary treatment process. Water flowing into the basin from the primary clarifier always carries relatively high concentrations of

organic and inorganic solids. A large portion of this solids' content consists of particles with sharp edges and extremities (sand is an example). With all of the water flowing through this basin and agitated by the aeration process, the sharp extremities of the particulate matter can become very aggressive to coatings of any kind.

2. With respect to the measurement of DO in outfalls, not every plant is required to do it, but for those that are – there is as much flow in the outfall as there is throughout the plant, so flowing water is never a concern.
3. There are other applications for DO in wastewater plants but they are usually performed on a plant-by-plant basis. Some of these applications might be the measurement of DO in digesters, in MBR slurry tanks, or in special closed liquid oxygen reactors. But all of these applications have flow and highly abrasive characteristics, as noted above.

Applying a DO Sensor to these Applications

We have discussed the technologies that are available for DO measurement in a wastewater plant and we have outlined the plant requirements for that measurement. So why has the industry bounced around from technology to technology in DO measurement over the years, while other measurements like flow and level have become relatively technologically static? There are two answers to this question – (1) the wetted surfaces of the measurement devices utilized in the technologies, and (2) the marketing efforts of the companies which provide DO monitors.

With respect to the DO sensors themselves, they are required to operate in some of the most unfriendly environments in the plant – and on the planet. And because the best DO measurement technologies (galvanic and optical) seem to have weaknesses like coatings and membranes, then maintenance and calibration stability become reasons that these sensors just can't be left alone. Couple these problems with the handling of Operations personnel that have far more important things to do than change caps, membranes and wait for calibration, and you have the genesis of dislike, distrust and generally a disdain for DO measurement sensors.

When it comes to marketing these sensors we find continual mis-statements, inaccuracies, and competitive innuendo in industry's advertising and technical papers. Inaccuracies from the descriptive (luminescence vs. fluorescence), to the constant mention of flow requirements, to the "tenderness of membranes" are used so often as to make any knowledgeable Operator believe that maybe his plant doesn't flow at all or that Teflon® must tear like wet paper!

Certainly, these are just the games that marketing people play, but we have a tendency to forget that we are all working within a municipal environment where whatever is purchased for the operation of our plant is paid for by us – the public. Finally, it is time for us to look at the facts squarely, identify truth from fiction, and make dissolved oxygen a measurement that Operations' personnel can rely on, without the continual maintenance and calibration requirements that exist today.

Strengths and Weaknesses

This article concentrates on the galvanic and optical DO sensor technologies. They are the dominant technologies in our industry today. But first, one thing must be addressed, while there is really only one way to measure DO galvanically, there are several ways to build an optical DO sensor head or cap using fluorophores. But, these are subtle differences, so we will not detail all of them here, and we will lump them all together for brevities' sake.

The optical DO sensor's strengths –

- There is no flow required for a stable DO reading.
- There is no liquid electrolyte inside the sensor.

The optical DO sensor's weaknesses –

- The actual measurement of DO is not direct, but a complex process of light quench correlation mathematics.
- An expensive fluorophore coating, or foil, must come into contact with the medium being measured for dissolved oxygen. Because this material is developed from a rare earth, the final coating is brittle and easily scratched.
- A second dark coating of a polymer must be spread over the fluorophore in order to –
    - Protect the fluorophore from crumbling or scratching
    - Protect the fluorophore from ambient light

  This polymer coating will scratch or tear when subjected to aggressive environments – shortening the life of the sensor tip.
- Because of the weaknesses of these coatings, the sensor tips are usually removable and must be replaced every 3 to 12 months.
- Sensor accuracy at very low DO levels under 1ppm, in wastewater applications, is poor. Continuous denitrification measurements are usually impossible.
- Aggressive chemical or physical sensor tip cleaning systems are too aggressive for optical sensor tip coatings.
- Manual tip cleaning is required often if a wastewater system is high in fats, oil and grease.
- Calibration takes long periods of time and the sensor must be in a special environment.
- Optical DO systems are very expensive initially, and the cost of ownership is very high due to the need to replace expensive sensor tips or caps so often.

The galvanic DO sensor's strengths –

- It is a direct reading measurement – whatever DO is in the water, is what is being reported electronically from an electrolytic process inside the sensor.
- The membrane being used to separate the water and the internals of the sensor is Teflon®, an inert polymer that is indestructible in almost any chemical complex or abrasive environment like Unox aeration, digesters, and MBR slurries. These membranes can be supplied in up to 10 mil thicknesses, allowing for toughness under any environmental abrasive condition.
- Sensor recharging is not required for years. Membranes, electrolyte and sacrificial anodes will last for many years in wastewater applications. Galvanic sensors that utilize pure platinum cathodes are impervious to being poisoned by other outside gases.
- *Continuous* DO measurements under .2ppm (denitrification applications) are possible with galvanic sensors.
- Galvanic sensors can be self-cleaned as often as necessary with chemicals, high pressure water or air, or mechanical cleaners of any kind.
- Galvanic sensors are not affected by ambient light in any way.
- The calibration of a galvanic DO sensor is performed in under 1 minute while the sensor is in air. Usually a single pushbutton operation.
- The initial cost of galvanic DO systems is very low and the cost of ownership is less than $5 USD every few years.

Galvanic DO sensor weaknesses –

- A minimal flow is required for a stable reading because the sensor is actually "using" the oxygen that it is measuring directly.

<u>Conclusion</u>

It is time to bring the wastewater treatment industry back to reality in one of the most important measurements required in these plants. It is possible to make a dissolved oxygen system like a pump or a valve. Put it into place, calibrate it, apply a reliable, aggressive cleaning system and you will not have to worry about the accuracy of DO readings for years. And this can be from any location in any wastewater plant, no matter how aggressive or abrasive the process might be.

The one thing that you can count on is that such a product will not be an optical DO sensor. The manufacturers of these products want you to continue to buy their "razor blades" and that means that your Operations personnel will continue to be burdened with ongoing maintenance and sensor handling as part of their daily routine. There is no place in the wastewater treatment industry for this kind of antiquated technology in such an important measurement as dissolved oxygen.

The galvanic dissolved oxygen sensor has tens of thousands of customers that know what this article is trying to address. They already know that marketing is not the answer to this important measurement. They are already using a reliable, accurate technology for their DO applications. Can they learn more about how to lengthen the time between calibrations, when electrolyte should be changed, or what a thicker membrane will do for them? Of course they can. But the need to change to a technology that has never deserved a place in the toughest application for measuring dissolved oxygen, is not in their best interest.

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