Dissolved Oxygen Measurement

INTRODUCTION

One of the most important measurements in the determination of the health of a body of water is its dissolved oxygen content. The quantity of dissolved oxygen in water is normally expressed in parts per million (ppm) by weight and is due to the solubility of oxygen from the atmosphere around us. The atmosphere consists primarily of nitrogen and oxygen and since both of these gases are soluble in water, they are present in varying amounts in all natural or manmade bodies of water. These amounts are proportional to the solubility and partial pressure of the two gases (see Table 1).

Temp. °C	Elevation, Feet above Sea Level 0	1000	2000	3000	4000	5000	6000
0	14.6	14.1	13.6	13.2	12.7	12.3	11.8
2	13.8	13.3	12.9	12.4	12.0	11.6	11.2
4	13.1	12.7	12.2	11.9	11.4	11.0	10.6
6	12.4	12.0	11.6	11.2	10.8	10.4	10.1
8	11.8	11.4	11.0	10.6	10.3	9.9	9.6
10	11.3	10.9	10.5	10.2	9.8	9.5	9.2
12	10.8	10.4	10.1	9.7	9.4	9.1	8.7
14	10.3	9.9	9.6	9.3	9.0	8.7	8.3
16	9.9	9.7	9.2	8.9	8.6	8.3	8.0
18	9.5	9.2	8.7	8.6	8.3	8.0	7.7
20	9.1	8.8	8.5	8.2	7.9	7.7	7.4
22	8.7	8.4	8.1	7.8	7.6	7.3	7.1
24	8.4	8.1	7.8	7.6	7.3	7.1	6.8
26	8.1	7.8	7.6	7.3	7.0	6.8	6.6
28	7.8	7.5	7.3	7.0	6.8	6.6	6.3
30	7.5	7.2	7.0	6.8	6.5	6.3	6.1
32	7.3	7.1	6.8	6.6	6.4	6.1	5.9
34	7.1	6.9	6.6	6.4	6.2	6.0	5.8
36	6.8	6.6	6.3	6.1	5.9	5.7	5.5
38	6.6	6.4	6.2	5.9	5.7	5.6	5.4
40	6.4	6.2	6.0	5.8	5.6	5.4	5.2

TABLE 1. Solubility of Oxygen (mg/l) at Various Temperatures and Elevations (Based on Sea Level Barometric Pressure of 760 mm Hg)

Oxygen is the gas that attracts the greatest amount of interest, simply because of its role in the cycle of all living organisms and, specifically for our interest, those bacteria that feed on organic waste. For this reason, it is the gas that is most commonly measured in aquatic environments. It is important to realize that the term "dissolved oxygen" refers to gaseous oxygen dissolved in water, and it should not be confused with combined oxygen as found in the water molecule, H_2O.

Dissolved oxygen is very important in the treatment of domestic wastewater, as well as industrial waste from such sources as the food, pulp and paper, chemical, and metals industries. Most water pollutants from these sources fall into one of two categories:

1. Those that cannot be further broken down but persist in or out of solution.
2. Those that are biologically degradable. There are both organic and inorganic degradable substances, of which the organic tends to represent the large majority.

The primary function of dissolved oxygen in a waste stream is to enhance the oxidation process by providing oxygen to aerobic bacteria so they will be able to successfully perform their function of turning organic wastes into their inorganic byproducts, specifically, carbon dioxide, water, and sludge. This oxidation process, known as the activated sludge process, is probably the most popular and widely used method of secondary waste treatment today and is normally employed downstream of a primary settling tank. The process takes place in an aeration basin and is accomplished by aeration (the bubbling of air or pure oxygen through the wastewater at this point in the treatment process). In this manner the oxygen, which is depleted by the bacteria, is replenished to allow the process to continue. For more detailed information on this process, see the application data sheet number 4950-01, *Dissolved Oxygen Measurement in Municipal Waste Treatment.*

In order to keep this waste treatment process functioning properly, a certain amount of care must be taken to hold the dissolved oxygen level within an acceptable range and to avoid conditions detrimental to the process. It is also important to make the measurement at a representative location on a continuous basis to have a truly instantaneous measurement of the biological activity taking place in the aeration basin.

Methods of Determination

Over the years a number of methods for dissolved oxygen determination have been developed. These methods have been found to vary widely in their sensitivity, susceptibility to electrode poisoning by the presence of undesirable compounds, and, in some instances, sensitivity to a slow flowing or static aqueous media. Some methods require a very clean sample, devoid of extraneous chemical compounds, but only a few are adaptable to continuous on-line measurement. The various methods can be divided into three principle categories:

1. Laboratory methods (Winkler Method).
2. Electrochemical analysis (conductimetric, voltametric, and galvanic).
3. Membrane electrode methods (galvanic membrane electrodes and amperometric membrane electrodes).

For this discussion we will confine ourselves to the membrane electrode methods.

The success of membrane electrodes in the determination of dissolved oxygen stems from the isolation of electrodes and electrolyte from the sample by means of a semipermeable membrane. This membrane acts to protect the electrode from contamination by restricting the flow to gases only, and, in particular, oxygen.

The amperometric membrane technique used by Rosemount Analytical is the most popular method used industry-wide in continuous waste water treatment systems. In this technique the electrodes are driven by an externally applied polarizing voltage. The current flow between the electrodes can be directly correlated to the amount of oxygen present in the stream.

In a typical dissolved oxygen sensor, two electrodes, a gold cathode and a silver anode, are immersed in a specially prepared electrolyte solution and separated from the sample to be measured by a gas permeable membrane (see Figure 1). The transfer of oxygen across the membrane is proportional to the partial pressure of oxygen in the fluid. The chemical reactions that accompany this process are as follows:

Gold cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Silver anode: $Ag + HCl \rightarrow AgCl + e^- + H^+$

The reaction that takes place at the anode is the oxidation of silver to form silver chloride. This reaction is offset at the gold cathode by the reduction of oxygen molecules to hydroxide ions. The resulting current flow is directly proportional to the dissolved oxygen content of the stream.

Application

The typical point for dissolved oxygen measurement in a waste treatment facility is in the aeration basin. The measurement should be made approximately two to three feet below the surface and located near the pond exit since this point is felt by many to be the location at which bacterial activity in the pond can most clearly be determined. The typical range of operation should be somewhere between .5 and 2.0 ppm dissolved oxygen. If the oxygen level falls below .5 ppm there is not sufficient oxygen to keep the bacteria alive. The widespread death of bacteria and the subsequent anaerobic condition may result in biological upset.

If the dissolved oxygen level rises much above 2.0 ppm, there is the danger of over-population of nitrifying bacteria over those micro-organisms that normally perform the biodegrading function. This will increase the oxygen demand to an even greater extent to keep up with this new demand and will ultimately cost the plant an excess in power expenses.

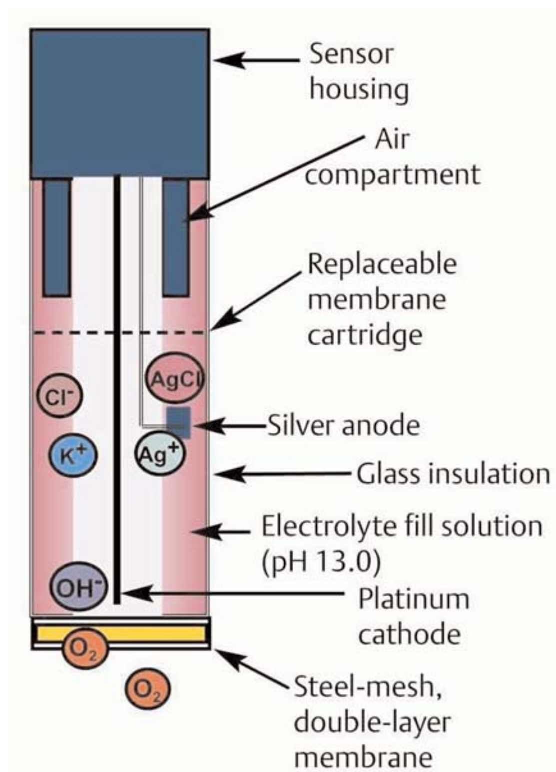

FIGURE 1. Typical Dissolved Oxygen Sensor

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