ADVANTAGES OF DEVICES FOR OPTICAL MEASUREMENT OF DISSOLVED OXYGEN CONCENTRATION IN WASTEWATER

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This article analyzes and compares electrochemical and optical methods for measuring the dissolved oxygen in sewage and consideration of the advantages of the optical method for measuring the oxygen metric.

Keywords: wastewater, dissolved oxygen, electrochemical method, optical method, electrolyte, membrane, LED, photodiode.

In our republic, special attention is paid to the creation of high-performance systems for controlling the parameters of technological environments in industrial wastewater treatment and use systems by using the methods of synthesis and construction of process control systems in wastewater treatment facilities, by creating opportunities for rapid control and management of technological parameters. In the action strategy for the further development of the Republic of Uzbekistan, among other things, "... reducing the consumption of energy and resources in the economy, widely introducing energy-saving technologies in production, ... building and modernizing household waste processing complexes, strengthening their material and technical base » tasks are defined. It is important to control the aeration process by measuring the concentration of dissolved oxygen in the wastewater in the implementation of these tasks, including the treatment of industrial wastewater. As a result, energy is saved in the air transfer system, which accounts for 65% of the electricity costs in the wastewater treatment process.

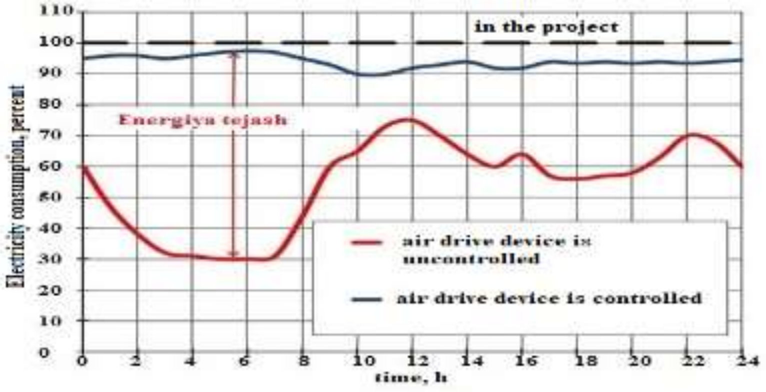

Figure 1. Comparison of electrical energy consumption of uncontrolled and controlled air drive device

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The essence of energy saving is the difference in electrical energy consumed for controlled and uncontrolled air transfer modes in the air tank (Fig. 1). Let's say coefficient of efficiency (black dashed line) of the 100% real air spraying equipment. During the operation of the selected equipment (uncontrolled air spraying equipment), the amount of electricity consumed during the day (blue line) changes depending on the temperature (or density) of the outgoing air. The amount of electricity consumed on any day of the year should not exceed the value set by the project (black dotted line).

In the implementation of controlled processes in the technological project, it is recommended to choose controlled air spraying equipment according to the principles of interaction: 1. Use of current frequency converter in the adjustment process, 2. Mechanical adjustment of output or input directions. use of changing equipment. The amount of electricity saved is the difference between the two "curves" - the blue and red lines (Fig. 1) [1,2,8,9].

Dissolved oxygen concentration as the main indicator of biological wastewater treatment determines the nature and speed of processes in aerotanks. Temporal or spatial separation of aerobic and anoxic or anaerobic zones is a prerequisite for carbon decomposition, nitrification, denitrification and biological removal of phosphorus. One of the important tasks of process monitoring in wastewater treatment plants is to control the provision of conditions specific to different zones. For this, it is necessary to obtain information about the amount of oxygen in the activated sludge. Thus, from the point of view of the technological process, it is necessary to accurately measure the oxygen concentration.

An increase in the concentration of oxygen in the aerotank is also undesirable for economic reasons. The amount of energy required for wastewater aeration depends on the following parameters:

The specific air consumption during the aeration process is determined as follows [2,3,10,11]:

$$q_{air} = \frac{q_O\left(L_{en} - L_{ex}\right)}{K_1 K_2 K_m K_3\left(C_a - C_O\right)}$$

where:

L_{en} and L_{ex} – complete biochemical need for oxygen of treated wastewater entering the biological treatment system(BOD$_{full}$), mg/l;

q_O – specific consumption of oxygen, mg/mg BOD$_{full}$;

C_a – water solubility of atmospheric oxygen, mg/l;

C_O – the concentration of dissolved oxygen in the aerotank, mg/l;

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K_1 – coefficient taking into account the type of aerator;

K_2 – coefficient taking into account the air driving depth of the aerator;

K_m – coefficient taking into account the temperature of the wastewater;

K_3 – coefficient taking into account the ratio of the rate of oxygen transfer in the active turbid mixture to fresh water.

We determine the power of the air-driving devices supplying air to the aerotank from the following formula [3,4,15,16]:

$$N = \frac{z \cdot Q_{air} \cdot 0{,}278}{1000 \cdot \eta}$$

where:

η – coefficient of efficiency of device.

z – the work done by the devices.

The amount of energy required to supply oxygen to the activated sludge, and the cost of this process, increases with increasing oxygen concentration.

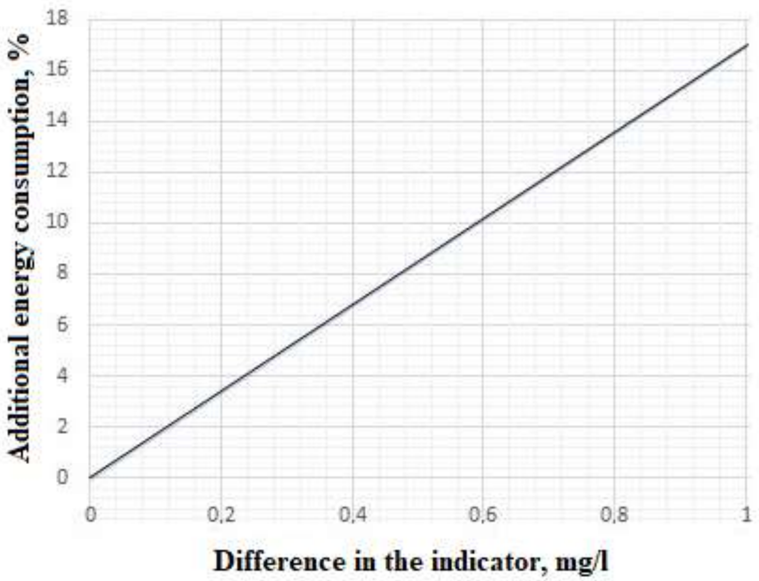

Figure 2. Dependence of the difference in oxygen concentration indicator on additional energy consumption.

The electrochemical method of measuring dissolved oxygen concentration has been used in treatment plants for many years. Basically, an electrochemical cell always has an anode and cathode made of different metals and immersed in an electrolyte. On membrane sensors, the electrolyte chamber is separated from the sample by a gas permeable membrane, through which oxygen molecules from the sample diffuse into the electrolyte until the partial pressure of oxygen is equalized on both sides of the membrane. In membraneless sensors, the role of the electrolyte is played by the sample itself.

Electrochemical measurement is divided into galvanic and polarographic (electrolytic) measurement methods. In a galvanic measuring device, the potential difference between the anode and the cathode occurs spontaneously and is determined by the electrochemical voltage. This is enough to restore oxygen at the cathode and start the corresponding oxidation process at the anode. The potential difference between the anode and cathode is proportional to the oxygen concentration in the sample. Galvanic measuring cells are self-polarized, in other words, they are ready to work immediately after switching on.

In polarographic measurement, the potential difference between the anode and the cathode is insufficient to restore the oxygen molecules. Therefore, in order to initiate an electrochemical reaction, it is necessary to additionally apply an external polarization potential, after which a current proportional to the oxygen concentration in the electrolyte is measured under constant potential conditions. A stable potential difference between the cathode and the anode is not established instantly, for which a certain amount of time is spent, known as "polarization time". Depending on the type of sensor, polarization can last up to 2 hours. If the batteries are not used to keep the sensor polarized, then the sensor will switch to operating mode only after the polarization is completed after switching on. The figure below shows the Clark device based on polarographic measurement [3,4].

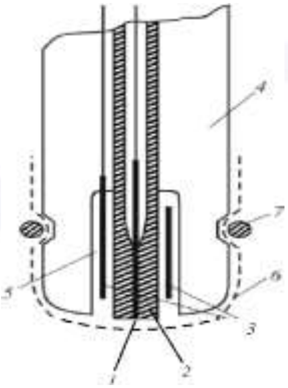

Figure 3. Structure of the Clark device (1-platinum working electrode, 2-insulated part of the working electrode, 3-equalizing electrode, 4-device body, 5-space for electrolytes, 6-membrane, 7-ring for regulating membrane).

A new optical method for measuring dissolved oxygen overcomes the shortcomings inherent in traditional electrochemical measurement methods. A new principle called LDO is based on the phenomenon of luminescence. This phenomenon is defined as the ability of certain materials (phosphors) to radiate, not as a result of heating, but as a result of other stimuli. The LDO method uses light as an excitation source. By choosing the appropriate material and the wavelength of the light, it is possible to achieve the intensity of the fluorescent radiation and the reduction of the concentration of oxygen in the solution around the phosphor.

During the measurement, the blue LED emits a light pulse, which passes through the transparent substrate and is partially absorbed by the phosphor layer. In this case, electrons in phosphorus molecules move to a higher energy level (excited state). Within a few microseconds, the electrons return to their initial state through several energy gaps and emit the energy difference in the form of longer-wavelength (red) radiation (Figure 4).

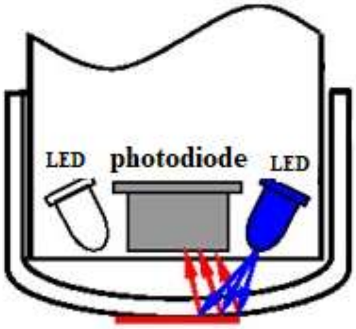

Figure 4. Structure of the optical measuring device with red and blue light-emitting diodes.

If at the same time oxygen molecules come into contact with phosphorus, they absorb the electron energy in the excited state and make it possible to return to the original state without emitting quantum light (transition without radiation). With an increase in the concentration of oxygen, this process leads to a decrease in the intensity of the emitted "red" radiation (luminescence). The oxygen molecules cause the phosphorus to vibrate, causing the electrons to move from the excited state to the stable state more quickly. Thus, the luminescence time is reduced.

Both effects of oxygen can be attributed to a phenomenon termed "fluorescence quenching." Their effect is that in Figure 5, the light pulse sent by the blue LED falls on the phosphor layer at t = 0, which then emits red radiation. The maximum intensity (Imax) and the return time of the red radiation depend on the surrounding oxygen concentration (the return time is determined by the time between the start of excitation and the decrease of the red radiation level to the maximum intensity by 1/e).

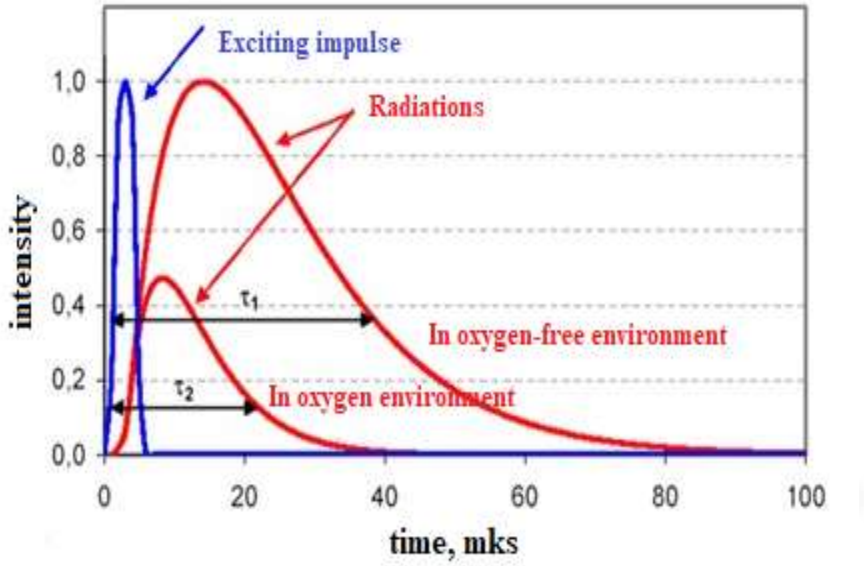

Figure 5. Curves of the intensity of red and exciting blue radiations.

The return time of the luminescence is analyzed to determine the oxygen concentration. Thus, accurate measurement of oxygen concentration is achieved.

The measuring device is constantly controlled by a red LED installed on it. Before each measurement, it emits a light beam with certain characteristics, which is reflected by the phosphor and enters the optical system. Therefore, it is possible to detect and compensate for any changes in the measurement system without delay [5,6,7,12,13,14].

As a result of the conducted research, the currently widely used electrochemical method for measuring the concentration of e-ion in wastewater requires continuous service to users. Membrane and electrolyte cleaning, calibration, replacement, anode cleaning, and documentation of all these activities are required. Only in this way, the measurement of the device can be kept within certain limits. The reliability of the obtained measurement results largely depends on the quality of these works. A real alternative appeared only with the development of a new optical analysis method. Compared with electrochemical methods, the following conclusions were made about the advantages of optical measurement in terms of accuracy and its application:

- The time to measure the oxygen concentration in the optical method is reduced - this process is essentially a process with minimal error. Corrosion or damage of the fluorescent materials in the cover of the device affects only the intensity of the emitted radiation, not its return time, which is determined only by the concentration of oxygen

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in the analyzed sample. Before measurement, all optical parts of the system are automatically adjusted to the red LED model, which eliminates the possibility of incorrect calibration of the sensor by the user;

- In the optical device, electrolytes, electrodes and membranes are replaced by an oxygen-sensitive phosphor layer installed on its cover. Once a year, this cover is simply changed to a new one. Membrane and electrolyte are not interchangeable;
- Electrochemical devices measure current or voltage due to the reduction reaction of oxygen to hydroxide ion at the cathode. The concentration gradient created by this process causes oxygen molecules to pass from the sample through the membrane into the internal electrolyte. A decrease in oxygen concentration directly on the surface of the membrane must be eliminated by constant stirring or by placing it in a sample flow of sufficient velocity. It does not consume oxygen during optical measurement. Oxygen molecules interact only with the oxygen-sensitive layer of phosphorus. This type of measurement does not require flow and can be measured under static conditions without stirring;
- If electrochemical membrane fouling occurs, this will limit the diffusion of oxygen molecules and lead to inaccurate readings. There is no oxygen consumption in the optical measurement method. Contamination accumulated on the sensor only affects the return time, but does not cause the measurement results to be incorrectly recorded;
- If gaseous hydrogen sulfide enters the membrane of an electrochemical device, it reacts with the metal anode and forms a layer of metal sulfide that is very difficult to remove. This process causes permanent damage to the electrochemical device. The phosphorus used in optical measurement is resistant to hydrogen sulfide (as well as other chemical compounds), which allows it to be used in difficult conditions;

In optical measurement, it is necessary to contact the oxygen molecules dissolved in the cover of the device with the sensitive layer of phosphorus. A sample-immersed device provides a response time of several seconds. To increase the response time and the average value of the signal, you can use the buffering function built into the secondary converter (controller;

In optical measurement, the sensitivity of the device (the ratio of the change in the return time of luminescence to the concentration change) increases with a decrease in the oxygen concentration. This allows very high precision measurements in the low concentration range.

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