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REGULATION OF OXIDATION DITCH TYPE BIOLOGICAL REACTORS

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Abstract

Wastewater treatment plants operate with water flows and characteristics different from those considered in the design stage, the most common differences being found in carbon concentrations that are lower than those of the design, nitrogen concentrations higher than those considered and a disadvantageous C:N:P ratio. This fact means that, during the entire period of operation, decisions are needed leading to wastewater treatment process optimization. The present paper deals with methods of regulating for a nitrification and simultaneous denitrification biological reactor, based on the determinations made for nitrogen concentrations, dissolved oxygen, pH, blowing speed and results obtained related to the treatment efficiency. The analysis proves that the necessary wastewater treatment efficiency is obtained by balancing the nitrification and denitrification processes accompanied by the reduction of energy consumption through recovering oxygen from nitrates, which can be controlled by blowing speed and detecting the operation mode between sequential or continuous ones. Interpretations and conclusions can support operators in finding solutions to optimize the undertaken process.

Key words: *biological reactor, nitrification, denitrification, oxidation ditch, blower.*

INTRODUCTION

Wastewater treatment plants are designed based on data coming from studies and evaluations performed for the served sewerage systems, being a dynamic process, with different efficiencies depending on equipment type and operational practices (Litu et al., 2019).

In most cases, design data, flow rates and concentrations of pollutants are not achieved in operation; there are significant variations both seasonally and hourly, with major technological implications.

Designers must provide technological levers necessary to regulate technological processes and operating scenarios for these different situations.

In exploited wastewater treatment plants, the common situation comprises wastewater inlets having the following characteristics:

- carbon concentrations/carbon amount, CBO5 - lower than those considered in the design phase;
- nitrogen concentrations, ammoniacal nitrogen - higher than those considered in the design phase;
- C: N: P disadvantage ratio (NP-133, 2013).

Wastewater contains significant amount of C, compounds of N, S, P, H and O variable function the treatment cycle phase (Manea and Ardelean, 2016).

MATERIALS AND METHODS

In the present paper it is presented the regulation of the wastewater treatment process for a biological reactor with simultaneous nitrification and denitrification or oxidation ditch type biological reactor (Figure 1).

The biological wastewater treatment process consists in a transfer of materials between water and cells accompanied to the adsorbtion-desorption processes (Iordache et al., 2019).

The advantage of these biological reactors is that they have minimal energy consumption for internal recirculation between aerated areas (for nitrification) and non-aerated areas (for denitrification).

The disadvantage derives from the same aspect, the large recirculation leading to the denitrification process efficiency reduction.

The regulation of these reactors can be done as follows:

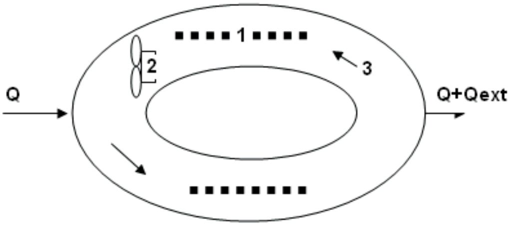


Figure 1. Oxidation ditch type biological reactors, simultaneous nitrification-deintrification;
Q - input flow, Q_{ext} - sludge recirculation flow;
1 - aeration system; 2 - mixing system ; 3 - water - sludge mixture flow into the reactor

1. With continuous operation of the aeration when the blowers are chosen properly: the level of dissolved oxygen in the control section is set and regulated automatically according to the ammonia nitrogen concentration determined in the reactor, usually at the outlet to the secondary decanter; minimum values of dissolved oxygen are set when minimum NH_4 values are recorded. The operator will monitor the evolution of nitrate concentrations and will adjust the aeration program to balance the biological process of nitrification-denitrification.
2. With sequential operation: when minimum NH_4 value is reached, the aeration is stopped to stimulate denitrification on the entire reactor and the aeration is restarted when maximum NH_4 value is reached.

Operating parameters, dissolved oxygen, ammonia nitrogen and nitrate concentrations, pH are determined continuously with specialized equipment (hatch.com, 2020), the values obtained being the basis of process control.

RESULTS AND DISCUSSIONS

The presented results are obtained following the optimization of several similar wastewater treatment plants, which differ in the automation degree and their operating programs.

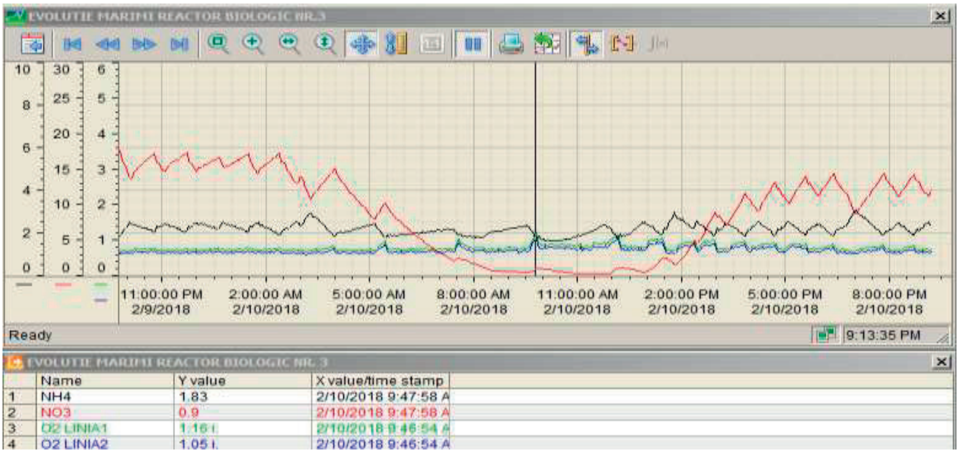
Figures 2 and 3 show the evolution of oxygen, ammonia nitrogen, nitrates concentrations and the aeration system operation for a fully automated station depending on the nitrogen values determined continuously with the monitoring equipment (hatch.com, 2020). Dissolved oxygen levels below 1 mg/l, stimulation of denitrification at night and creation of a technological reserve for the morning peak are observed.

Figure 3 correlates with Figure 2. The sequential operation highlights the "mirror" evolution of NO_3 and NH_4 concentrations in the reactor but also at the discharge; this is a disadvantage for wastewater treatment plants with continuous supply of biological reactors sequentially operated.

The monitored systems highlight correlations between dissolved oxygen values - blower speed - pH value - nitrates and ammonia nitrogen. The consumption of NH_4 in the reactor (system) corresponds to the decrease of oxygen demand, so the increase of O_2 concentrations, the reduction of the blower speed, the increase of NO_3 concentrations and the pH decrease.

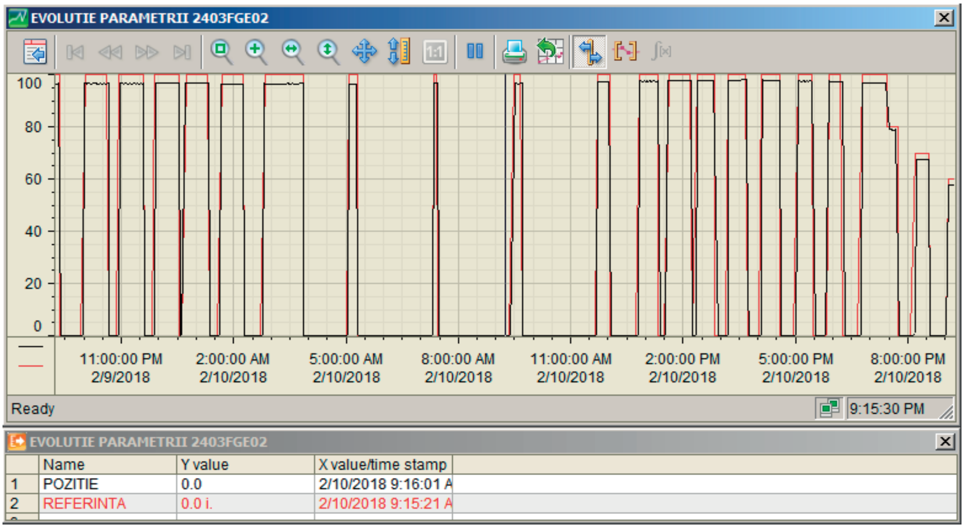
In the absence of NH_4 monitoring or sensors damage, it can be achieved adjustment, balancing of nitrification - denitrification through dissolved oxygen tracking. The increase of dissolved oxygen (obtained by blower speed decreasing) involves NH_4 consumption; when the maximum dissolved O_2 and the minimum blower speed are reached, it is ordered to stop the aeration and to move to the denitrification phase on the entire basin.

For another wastewater treatment plant, the automation system does not allow adjustments according to nitrogen concentrations. In these circumstances, the process regulation is accomplished by blowers timing and operator intervention for fine adjustments.



	Name	Y value	X value/time stamp
1	NH4	1.83	2/10/2018 9:47:58 A
2	NO3	0.9	2/10/2018 9:47:58 A
3	O2 LINIA1	1.16 i.	2/10/2018 9:46:54 A
4	O2 LINIA2	1.05 i.	2/10/2018 9:46:54 A

Figure 2. Evolution of nitrogen concentration values in the biological basin sequentially exploited with imposed NH_4 limits



	Name	Y value	X value/time stamp
1	POZITIE	0.0	2/10/2018 9:16:01 A
2	REFERINTA	0.0 i.	2/10/2018 9:15:21 A

Figure 3. Degree of aeration valves opening of corresponding to timed operation with NH_4 limit

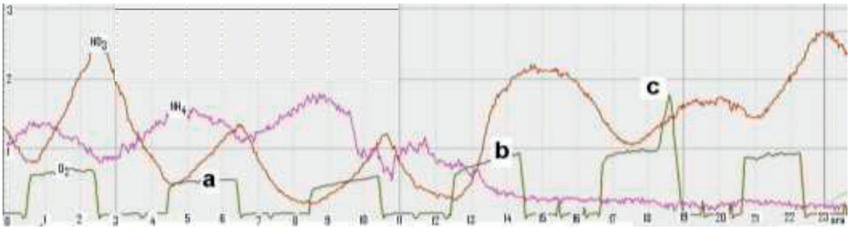


Figure 4. Correlation between dissolved oxygen level and ammonia nitrogen concentration for an oxidation trench type biological reactor sequentially operated; operating situations: a - low NH_4 level, efficient nitrification and denitrification process; b - medium NH_4 level, efficient nitrification, increasing oxygen level, decreasing denitrification efficiency; c - reduced NH_4 level, increasing oxygen level, ineffective denitrification

During the operation period marked “a” in figure 4, in the section of biological reactor output there is observed a correlation between high concentration of ammoniacal nitrogen, low dissolved oxygen concentration (oxygen consumption) and low nitrates concentration, the operation situation corresponds to an efficient denitrification process. During the operation periods marked “b” and “c” in Figure 4, the situation corresponds to a process of excessive nitrification accompanied with ammoniacal nitrogen consumption plus dissolved oxygen and nitrate concentrations increasing; the intervention of the operator and the aeration stopping are required.

Taking into account these correlations, a control program based on dissolved oxygen monitoring can be adopted.

Reaching a maximum set value in the control section corresponds to the oxidation of ammoniacal nitrogen and the transition to the denitrification phase.

The denitrification duration is determined from the NH_4 balance equation on the biological reactor:

$$\text{Reactor volume x } \Delta c(NH_4) = T_{denitrification} \text{ x } Q_{intrare} \text{ x } c(NH_4)_{intrare} \text{ ....(1)}$$

hypothesized the NH_4 concentration increasing within the reactor:

$$\Delta c(NH_4) = (0.5\text{-}1.5) \text{ mg/l ....(2)}$$

In the case of dissolved oxygen regulation, of aeration process, it is possible to achieve the simultaneous nitrification and denitrification and of a continuous aeration flow.

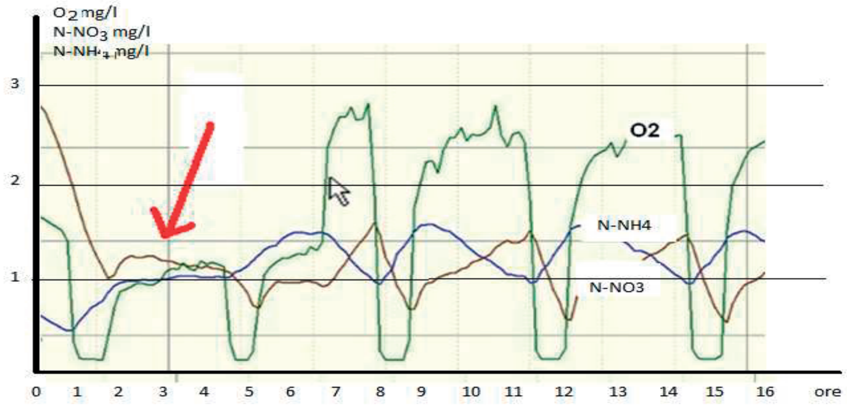


Figure 5. Oxidation trench system with simultaneous nitrification and denitrification operating period (marked area)

The marked period corresponds to the simultaneous nitrification and denitrification process; the achievement of the simultaneity condition derives from the balancing of the entrance nitrogen and carbon quantities with the adopted oxygenation level.

The concentration of ammoniacal nitrogen increasing within the reactor will immediately command the dissolved oxygen concentration reference value growth (Figure 5).

CONCLUSIONS

Ensuring the necessary wastewater treatment efficiencies is achieved by adjusting the technological flow according to the parameters registered at the plant entrance point. Under these conditions, nitrogen is the critical tretament indicator, exceeding nitrates and total nitrogen for treated water being recorded. Balance of nitrification and denitrification processes is required in order to reduce nitrate concentrations for treated water and to reduce energy consumption by recovering oxygen from nitrates.

The principle of elaborating an efficient technological flow is to be changed according to the monitored parameters (technological supply chain, introduction/removal of treatment units/stages, by-pass primary sttling basins, primary settling basins efficiency improvement using coagulants).

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