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# Monitoring and controlling of process parameters in the biological phase of wastewater treatment

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**Abstract**
This article presents the methodology for monitoring and controlling the process parameters of the biological stage of wastewater treatment, through the monitoring, control, and data acquisition program SCADA. The introduction of the SCADA software in the field of wastewater treatment has appeared with the evolution of treatment technologies and increasing legal requirements for the quality of emissions. The implementation of this program brings significant benefits to wastewater treatment plants and facilitates the control and monitoring of the technological process in the wastewater treatment plant. By using this software, the cost of energy consumption can be reduced, the operating time of a treatment plant equipment can be tracked, time faults of the installations can be detected in the treatment plant, can be drawn up working graphs and tables with data from technological process etc. The present study highlights the kinetics of the treatment process in the biological treatment stage of the Iași City Wastewater Treatment Plant and the usefulness of the research performed.

**Keywords:** wastewater, SCADA, treatment plants.

## 1. INTRODUCTION

The technological process in a treatment plant is a complex one. It includes a multitude of parameters, and the control and monitoring of this process involve following these parameters carefully, accurately and rigorously, so that wastewater treatment does not endanger the safety of the population and the environment [1].

The monitoring and control of the technological process, along with the evolution of the wastewater treatment field and the ever higher requirements from the legislative point of view, led to the emergence of new technologies for tracking the kinetics of the technological treatment process, including SCADA software.

Monitoring the technological process is a necessity and an obligation precisely to comply with safety standards in terms of water quality, due to the fact that treatment plants are mainly responsible for the depreciation of surface water sources.

Due to the complexity of the technological process in a wastewater treatment plant, this article will present the monitoring and control of the process parameters of the biological stage in the wastewater treatment plant of Iași.

The Iași wastewater treatment plant (Fig. 1), serves the city and the neighboring localities. It has a mechanical-biological process capacity of 2200 l/s in dry periods and reaching periods of precipitation up to 4033 l/s, and the average flow of the treatment plant, depending on the hourly variation of water consumption, is about 1200 l/s.

The Iași wastewater treatment plant has a total area of approximately 300000 m$^2$, of which approximately 120000 m$^2$ usable and consists of the following equipment and hydrotechnical constructions: reception chamber, rare and fine screen, distribution chamber, wastewater pumping stations, grit with grease removal, primary clarifiers, aeration tanks with activated sludge, secondary clarifiers, sludge pumping stations, digesters, gravity thickeners and mechanical sludge thickeners, sludge storage tanks, sludge dewatering plants, blower station, chemical precipitation with $FeCl_3$, biogas cogeneration plant, biogas tank, electrical transformation points, wastewater connection and drainage channels, deep connection station, hydraulic installations and access roads [2].

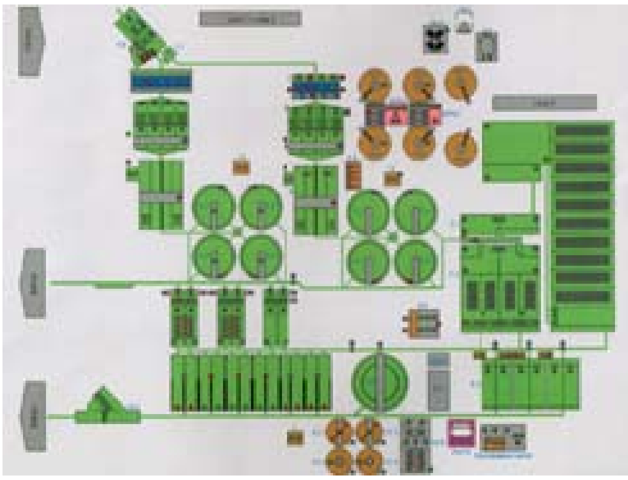

*Fig. 1. Iași WWTP – SCADA view*

The biological treatment stage of the Iași wastewater treatment plant consists of three activated sludge bioreactors, nine longitudinal and one radial secondary clarifiers, a recirculated and excess sludge pumping station, blower station, two-tank pumping station and installation for $FeCl_3$, distribution (chemical precipitation) and pipe networks, channels for connection, distribution and evacuation.

The total capacity of the biological treatment stage is 92228 m$^3$, this being broken down as follows: 35280 m$^3$ of the bioreactor of line 1, 12300 m$^3$ of the bioreactor of line 2, and the rest of 44900 m$^3$ of the bioreactor of line 3 [3].

The process parameters of the treatment plant can be met by putting into operation the required payload capacity. Hence, in line biological stage will operate lines 2 and 3, lines 1 and 2, only line 3 or line 3 and part of line 1, how it currently works, thus fulfilling the condition of taking over and processing the flow.

Iași wastewater treatment plant uses in the biological treatment stage, $A^2/O$ treatment technology (Fig. 2). The scheme aims to reduce nutrients in wastewater by alternating anaerobic, anoxic, and oxic zones, thus achieving the processes of nitrification and denitrification [6].

Phosphorus is being reduced naturally in the anaerobic zone and by chemical precipitation with $FeCl_3$ at the exit of the bioreactors.

The anaerobic zone of the bioreactors comprises 7.9% of the total volume, the anoxic zone 22 %, and the remaining 70.1% is occupied by the oxic zone of the bioreactors [3].

After the bioreactors are the secondary clarifiers, six longitudinal clarifiers for line 1 and a radial clarifier with three more longitudinal clarifiers for lines 2 and 3.

The biological stage of the treatment plant is an advanced biological stage, in which the reduction of nutrients from wastewater is achieved through physical, chemical, biochemical, and hydraulic processes [1], the kinetics of the process being as follows: wastewater from the mechanical treatment stage is mixed with recirculated active sludge (biomass) from the secondary clarifiers, the degree of external recirculation being 75 %, after which it enters the bioreactor.

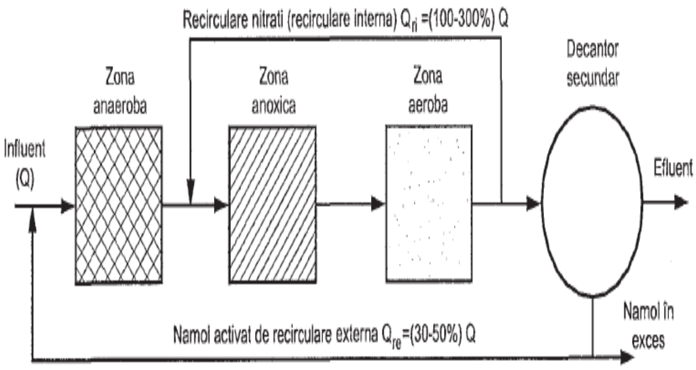


*Fig. 2. The biological process in Iași WWTP* [4]

The active sludge from the bioreactor forms the basis of the technological process, which has in its composition all the species that can metabolize the organic load up to carbon dioxide and water.

The wastewater-activated sludge mixture reaches the anaerobic area of the bioreactor, where due to anaerobic conditions, 39% of the phosphorus concentration is reduced, the rest being reduced by chemical co-precipitation [3].

From the anaerobic zone of the bioreactor, the wastewater-sludge mixture reaches the anoxic zone of the bioreactor, where in the absence of oxygen or in the presence of traces of oxygen (below 0.1 mg $O_2$/l) the denitrification process is performed (Fig. 3) through which the concentration of nitrates in wastewater is reduced.

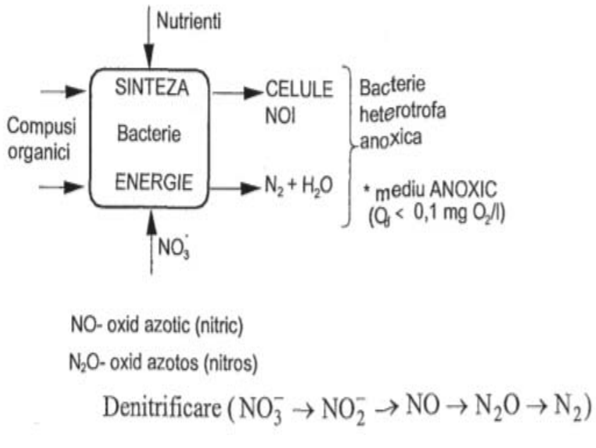


*Fig. 3. The process of denitrification* [4]

Here, microorganisms use organic carbon-based substances as food, thus obtaining the energy needed for development by taking oxygen from nitrates and converting nitrates to nitrogen gas.

The concentration of nitrates downstream of the bioreactor sends through internal recirculation in the anoxic zone 295% of the average flow of the influent.

From the anoxic zone, the wastewater-sludge mixture reaches the oxic zone of the bioreactor, where the nitrification process takes place (Fig. 4), thus reducing the ammonia in the wastewater in the presence of aerobic bacteria that use inorganic carbon from carbon dioxide for development, instead of organic carbon.

Downstream of the bioreactor, phosphorus is reduced by chemical co-precipitation with $FeCl_3$, being reduced 35% of the phosphorus concentration, and the remaining 19% will be discharged with excess sludge, thus achieving a phosphorus removal efficiency of 93%, the same as for nitrogen [3].

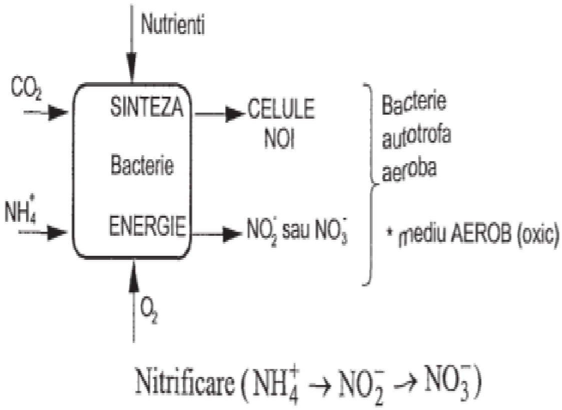


*Fig. 4. The process of nitrification* [4]

From the oxic zone, the wastewater-sludge mixture reaches the final sedimentation zone, where the clarification phase takes place, the treated wastewater is being discharged according to NTPA 001, and the sludge, recirculated and discharged according to the need of the technological process.

## 2. EXPERIMENTAL

The experimental areas in the biological stage of the Iași wastewater treatment plant are the bioreactor of line 3, 1/3 of the bioreactor of line 1, three longitudinal secondary clarifiers of line 1, the three longitudinal secondary clarifiers and the radial one of line 2.

Through the SCADA software, for these areas the processes of nitrification and denitrification, dissolved oxygen concentrations in the oxic zones of bioreactors, flows of bioreactors, degree recirculation of sludge, pressure, temperature and oxygen flow in pipes, etc. were monitored and controlled.

The data obtained from SCADA will be presented graphically and tabularly, revealing the efficiency of the technological process, monitoring and control of process parameters.

The nitrification process in the biological stage is controlled and monitored by means of the two PID regulators (Fig. 5), one for each line, these regulators thus controlling the required amount of oxygen in the oxic zone of the bioreactor.

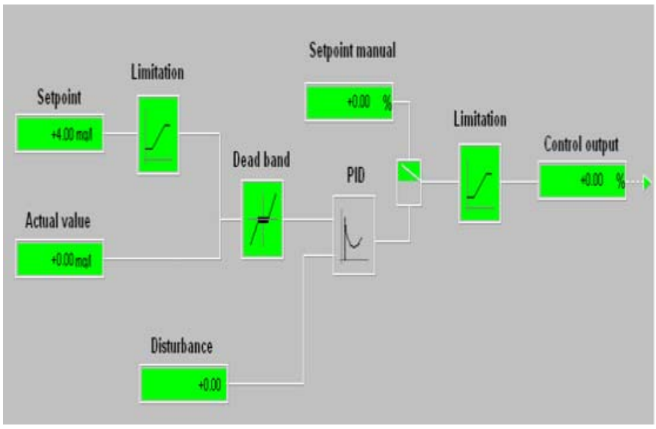


*Fig. 5. PID nitrification control*

Dissolved oxygen sensors are mounted in line 3 and line 1 bioreactors, which measure the dissolved oxygen concentration in the bioreactors and transmit the value to the PID controller, which in turn sends the valve shut-off or opening valve command oxygen, thus trying to maintain the concentration of DO set in the PID.

The flow through the biological stage is fractionated and distributed by means of automatic penstocks placed on each inlet area of the bioreactors, thus regulating the wastewater flow, the penstocks being regulated by means of predefined settings (Fig. 6), depending on the measuring device of wastewater flow.

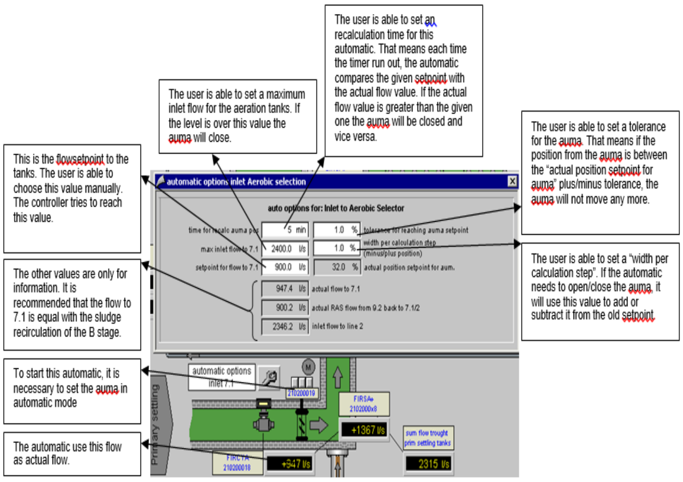


*Fig. 6. PID flow control* [2]

The RAS and SAS are also controlled by means of a PID (Fig. 7), which regulates the frequency of the pumps according to the sludge level in the suction chamber and the sludge requirement of the mechanical thickening installation, while the internal RAS operates according to the values transmitted by the rH sensor.

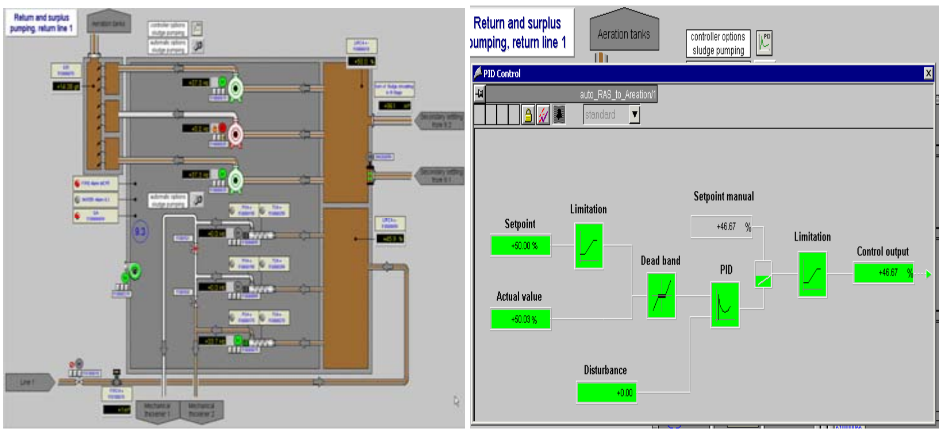


*Fig. 7. RAS and SAS control via PID*

Its oxygen flow, temperature, and pressure (Fig. 8) are also monitored in SCADA by means of mounted sensors, which transmit the signal to the control room.

The distribution of the effluent flow of the bioreactors to the secondary clarifiers is achieved by self-adjusting automatic penstocks which are also controlled by means of predefined settings, thus controlling the sedimentation process in the clarifiers and the amount of recirculated and excess sludge.

The sludge volume index is calculated after harvesting the sludge from the bioreactors, after performing the sludge sedimentation test and determining the sludge concentration, the value of the index being given by the ratio between the amount of sedimented sludge and its concentration.

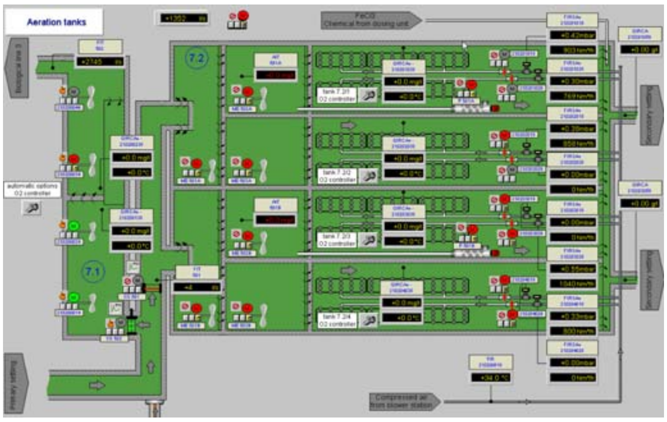

*Fig. 8. Monitoring of air flow, pressure and temperature*

The effluent of the biological stage is also monitored in SCADA by means of measurement and control sensors.

## 3. RESULTS AND DISCUSSION

The process parameters of the biological stage in this article are presented in Table 1 and the period selected for the study was between 11.05.2020-15.05.2020.

Following the study and the results presented in Table 1, it can be seen that the maximum influent flow of bioreactors is reached on 13.05, while the maximum effluent flow is reached on 12.05.

The difference between the influent and the effluent flow is due to the degree of internal recirculation, which represents 295% of the average influent flow of bioreactors. In Table 1, the internal recirculation flow from Iași WWTP bioreactors is represented, while the difference between the influent flows of bioreactors is given by penstocks on the inlet channels of each bioreactor, depending on their opening the flow being distributed in the bioreactors.

Another variant of the difference between the influent and the effluent flow is due to the wastewater pumping stations of the two technological lines and of the supernatant introduced in the wastewater circuit.

We can also observe in Table 1 the higher oxygen requirement in the line 1 bioreactor compared to the line 3 bioreactor, given that the default value in PID for both bioreactors is 3 $mgO_2/l$.

The sludge volume index provides us with important clues about the sedimentation characteristics of activated sludge in the secondary settlers, providing valuable information on the health of the sludge.

Recommended values of this indicator are in the range of 90 $cm^3/g$ - 150 $cm^3/g$, values below 90 $cm^3/g$ indicate a mineralized sludge, and those above 150 $cm^3/g$ indicate a swollen sludge, with weak sedimentation properties, which appear when the sludge leaves together with the effluent of the treatment plant in the emissary [5].

In Table 1, the values of the sludge volume index in the two bioreactors are in the range 113 $cm^3/g$ - 160 $cm^3/g$, the maximum value is found in the bioreactor of line 3 on 14.05, and the minimum in the bioreactor of line 1 in the same day.

The maximum value of the sludge volume index in the bioreactor of line 3 does not necessarily indicate a swelling of the sludge, because this would have been found in a higher value of the TSS parameter in the Iași WWTP effluent, and as we can also see in Table 1, this did not happen. The adjustment of the SVI was made by the excess sludge, the values being also presented in Table 1.

Table 1. Process parameters of Iași WWTP during 11.05-15.05

| Line | Parameters | Date | | | | |
|---|---|---|---|---|---|---|
| | | 11.may | 12.may | 13.may | 14.may | 15.may |
| 1 | Q inf.ww (l/s) | 570 | 827 | 813 | 839 | 484 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Q RASe (l/s) | 757 | 756 | 756 | 752 | 763 |
| | Q RASi (l/s) | 935 | 920 | 914 | 961 | 902 |
| | Q SAS (l/s) | 5,21 | 5,32 | 5,48 | 5,12 | 5,11 |
| | Q air (l/s) | 202218 | 185291 | 247477 | 228000 | 226884 |
| | PID air (mg/l) | | | 3 | | |
| | SVI (cmc/g) | 141 | 127 | 117 | 113 | 119 |
| 3 | Q inf. ww (l/s) | 914 | 722 | 552 | 525 | 775 |
| | Q RASe (l/s) | 1373 | 1297 | 1285 | 1327 | 1270 |
| | Q RASi (l/s) | 1510 | 1530 | 1507 | 1563 | 1524 |
| | Q SAS (l/s) | 8,45 | 8,31 | 8,15 | 8,37 | 8,33 |
| | Q air (l/s) | 101434 | 106978 | 91720 | 95577 | 92746 |
| | PID air (mg/l) | | | 3 | | |
| | SVI (cmc/g) | 147 | 140 | 141 | 160 | 139 |
| 1+3 | Q inf.ww (l/s) | 1136 | 1320 | 1476 | 1373 | 1392 |
| | Q ef. ww (l/s) | 1484 | 1549 | 1365 | 1364 | 1259 |
| | pH (unit. pH) | 7 | 7,5 | 7,6 | 7,8 | 7,7 |
| | BOD (mg/l) | 5 | 10 | 8 | 6 | 12 |
| | COD (mg/l) | 26 | 29 | 30 | 17 | 32 |
| | Nt (mg/l) | 5,77 | 4,48 | 5,77 | 5,72 | 6,75 |
| | Pt (mg/l) | 0,98 | 0,92 | 0,78 | 0,456 | 0,706 |
| | NH4 (mg/l) | 0,071 | 0,06 | 0,082 | 0,132 | 0,074 |
| | NO3 (mg/l) | 22,3 | 14,2 | 23,2 | 22,3 | 26,1 |
| | NO2 (mg/l) | 0,014 | 0,032 | 0,054 | 0,044 | 0,043 |
| | TSS (mg/l) | 8 | 8 | 12 | 9 | 13 |

The parameters of the Iași WWTP effluent indicate a good development of the technological process, high purification efficiencies, and values below the limits of the legal control norms.

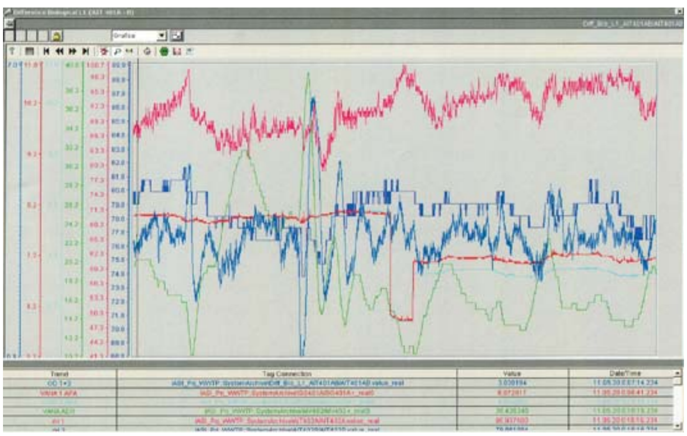

*Fig. 9. Chart with monitored parameters*

The total concentration of nitrogen (Nt) in wastewater during the analyzed period is below the legislative limits and the impact on the emissary being insignificant.

The other monitored nutrient (Pt) also falls within the limits of legal control norms, the lower values of phosphorus being during the use of $FeCl_3$.

The other forms of nitrogen in wastewater, $NH_4$, $NO_3$, and $NO_2$ also respect the limits of legal control norms and indicate a good functioning of the nitrification-denitrification process in Iași WWTP bioreactors (Fig. 9).

The $NH_4$ values in Table 1 are directly influenced by the amount of oxygen used for nitrification. However, the quality of denitrification is closely related to the amount of oxygen found in the anoxic zone. The oxygen reaching this area through internal recirculation pumps have a significant impact on this process, the maximum value of 15.05 being due to a higher concentration of DO in the anoxic area of the bioreactors.

## 4. CONCLUSIONS

The SCADA program was used to monitor and control the process parameters of the biological wastewater treatment plant in Iași wastewater treatment plant, and from the results we see the technical features of the biological stage in Iași wastewater treatment plant highlighting aspects related to the system monitoring and control and the quality of the analyzed parameters.

The control system highlighted in SCADA, indicates the mode of operation by drawing up graphic representations of objects and equipment in the biological stage of the treatment plant.

The monitoring of the technological process in SCADA allows the analysis of the process performance, aiming at the highest possible efficiency of the treatment plant.

The biological stage exposed schematically by the SCADA program, indicates each hydrotechnical construction, object, or equipment, and the input and output parameters are monitored both in the SCADA program in the form of graphical representations and analytically by performing laboratory analyzes.

The monitoring and examination of the process parameters aim at reducing the polluting concentrations in the effluent of the treatment plant, within or below the limits allowed by the legislative norms [7].

The deficiencies of the technological process from the biological stage are identified, analyzed, and remedied through the activity of monitoring, control, and data acquisition of the process parameters from the biological stage of the treatment plant.

A poor quality effluent, which contains loads higher than the legislative limits, has a negative impact on the environment and the emissary, therefore monitoring and controlling the technological process in a treatment plant is necessary and useful, bringing benefits to mankind.

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