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Studies Related to the Biological Treatment of Wastewater within the Wastewater Treatment Plant of Iași City

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***Abstract* – This paper includes an analysis of the biological treatment process existing within the water supply and sewerage of Iași City. The main objective of biological treatment is the removal of solid organic substances from wastewater, the stabilization of sludge, the reduction of nutrients loads etc. The Iași City Wastewater Treatment Plant was developed in several stages since year 1968. Nowadays, the facility operates at a design flow rate of 4 m^3/s during dry weather and 8 m^3/s during heavy rainfalls. This study is focused on the following aspects: wastewater treatment plant's diagram, the wastewater parameters inside the treatment plant, the biological treatment process analysis and a few conclusions.**

Keywords – wastewater, wastewater treatment, sludge, biological treatment

1. INTRODUCTION

Wastewater is water used in various sectors (domestic, social, industry etc.) and that cannot be reused because it represents a hazard for environment. Therefore, due to its loads in polluting compounds, acquired after use, this water must be purified before being discharged into a natural emissary (be it river, lake, sea etc.).

The collected wastewater from Iași City area is conveyed by the sewerage network towards the wastewater treatment plant through a final main collector having a length of 1320 m and a section of 2250/2500 x 3.

The hydraulic capacity and the polluting load of wastewater collected by the sewerage network, which is conveyed towards Iași Wastewater Treatment Plant, is as it follows:

- Qus. av. day = 2,2 m^3/s;
- Qus. max. day = 2,985 m^3/s;
- BOD5 = 56,000 kg/day (293 mg/l);
- COD = 102,567 kg/day (537 mg/l);
- TSS = 65,33 kg/day (341 mg/l);
- TKN-N = 8,400 kg/day (45,9 mg/l);
- TP-P = 1,680 kg/day (8,8 mg/l);
- Qh max. (dry weather) = 10,630 m^3/h;
- Qh max. (wet weather) = 29,640 m^3/h;
- water temperature during a year ranges between 12°C and 26°C.

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The Iași Wastewater Treatment Plant in Iași was developed in stages since 1968, reaching now a design flow rate of 4 m^3/s on dry weather and 8 m^3/s on heavy rainfall time.

Along the development of wastewater treatment plants, the workflow was hierarchally designed and the plants became separated into sewerage treatment stage in order to better control the process.

The treatment stages are:

- mechanical stage, that includes of pumping stations, fine and coarse screens, fat separator, sand remover, primary clarifier etc. and where the suspensions and a small part of organic load are retained;
- biological stage, that includes biological reactors, secondary sedimentation etc. and where carbon-based biodegradable compounds are retained;
- the advanced treatment stage includes bioreactors, secondary sedimentation etc, and it's the stage where nutrients (nitrogen and phosphorus compounds) are neutralized in biochemical processes in order to protect the emissary against eutrophication;
- the tertiary treatment stage, where the water quality can be improved for immediate use.

At the same time, due to the complexity of wastewater treatment plants, it is common to say that the plants include two main treatment lines:

- the water line;
- the sludge line.

2. DIAGRAM OF THE WASTEWATER TREATMENT PLANT

The wastewater treatment plant full process flow is shown in Figure 1:

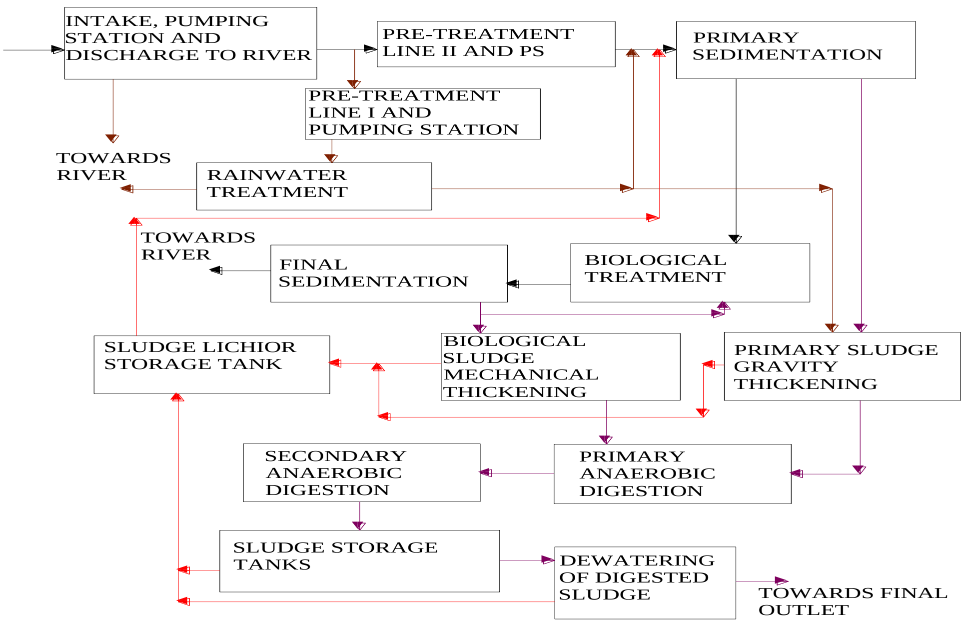

Fig. 1 Wastewater treatment plant process diagram

As shown in diagram above (Fig. 1), the sewerage treatment process takes place as follows.

Wastewater from Iași City and neighboring localities, conveyed by gravity and by pumps, reaches the intake chamber provided with a pumping station and a discharge system towards the river. From here, the wastewater conveyed by gravity, reaches the pre-treatment stage and the pumping station (Line 1 treats rainwater, while Line 2 treats the wastewater).

After pretreatment and pumping, the wastewater gets into the primary clarifiers, then, gravitationally; the wastewater continues its route towards the biological stage, then to the final clarifier.

Once the water travelled through this circuit, the treated water will comply with directives and laws in force and is to be discharged into the emissary (i.e. Bahlui River).

In the plant, the processing of wastewater within all treatment stages generates sludge, a harmful product for the environment. Because it damages the environment, the sludge produced will also be treated before it is to be rendered to the nature circuit.

After treatment of rainwater, the treated water is gravitationally sent into emissary and some of the sludge is pumped to the intake of the primary clarifier, the remainder being sent to the gravitational thickening system for primary sludge (also by pumping).

The sludge from the primary sedimentation process is pumped towards the gravity thickening system for primary sludge, then pumped towards the primary and secondary anaerobic digestion tanks, and from here towards the sludge storage tanks, the digested sludge dewatering facility and then towards final disposal.

The resulting sludge after final sedimentation is also pumped to the sludge mechanical thickening system (excess sludge) and to biological treatment (return sludge).

The biological sludge from the mechanical thickening process reaches the primary anaerobic digesters, intersecting the sludge from the primary sedimentation and continuing its route towards final elimination.

The supernatant (sludge liquor) from mechanical and gravity thickening processes, sludge storage tank and dehydration process of digested sludge will reach the sludge liquor storage tank, and from there it will be reintroduced into the wastewater circuit in the wastewater treatment plant before the intake of the primary sedimentation stage.

3. WASTEWATER CHARACTERISTICS

Wastewater, as well as drinking water supplied to population, industry etc., features various physical, chemical, bacteriological and biological characteristics, that vary from locality to locality and provide data on its quality.

The characteristics of wastewater in the Iași wastewater treatment plant are presented in Table 1:

Table. 1. Wastewater characteristics within Wastewater Treatment Plant.

	1	2	3	4	5	6	7	8	9	10
m^3/d	191.3	197.0	195.2	191.1	4.11	1.59	253	4.29	1.35	5.63
COD (kg/d)	102.7	104.9	67.14	23.89	513	306	253	820	1.35	2.17
BOD (kg/d)	56.06	57.05	36.51	4.78	103	118	126	317	673	991
TKN (kg/d)	8.40	8.59	7.73	382	8	21	76	57	135	192
NO_3 (kg/d)	0	24	24	1.53	33	9	0	24	0	24
TP (kg/d)	1.68	1.81	1.6	191	4	5	1,61	14	108	121
STM (kg/d)	65.25	69.5	25.02	6.69	35.5	79.9	50,5	1.59	2.66	4.26

The wastewater characteristics shown in Table 1 can indicate the plant's efficiency.

The wastewater treatment plants efficiency is:

- COD – 76,7 %;
- BOD5 – 91,5 %;
- TSS – 89,7 %;
- TKN – 77,2 %;
- TP – 88,6 %.

The primary sedimentation efficiency is:

- BOD5 – 36 %;
- TSS – 64 %;
- TKN – 10 %;
- TP – 11 %.

The efficiency or the treatment rate is an indicator for the proper functioning of the plant’s technological process.

4. ANALYSIS OF THE BIOLOGICAL TREATMENT PROCESS

The biological treatment of wastewater aims to rectify the wastewater’s quality by means of microorganisms activity. The main goal of a biological treatment is the removal of solid organic compounds from wastewater, the stabilization of sludge, the decreasing of nutrient loads etc.

In the Iași wastewater treatment plant, the biological treatment of wastewater is carried out by an artificial method, this being the active sludge bioreactor treatment, with A2/O process (two anaerobic zones and one oxic zone).

Active sludge bioreactors are constructed, according to the A2/O scheme, as a device including 3 zones: the anaerobic zone, the anoxic zone and the aerobic zone (oxic zone).

Biochemically controlled oxidation-reduction processes take place in these zones, this leading to the decomposition of organic matter down into CO2, H2O and biomass, through catabolic and anabolic processes, hydrolysis, nitrification, denitrification etc.

The capacity of the biological step is 92,480 m3 for bioreactors.

This bioreactors volume was divided into three zones and arranged on three technological lines:

- Line 1 – 38 %, with a capacity of 35,280 m3, 7,9 % anaerobic volume, 22 % anoxic volume and 70,1 % aerobic volume;
- Line 2 – 13,3 %, with a capacity of 12,300 m3, 7,9 % anaerobic volume, 22 % anoxic volume and 70,1 % aerobic volume;
- Line 3 – 48,7 %, with a capacity of 44,900 m3, 7,9 % anaerobic volume, 22 % anoxic volume and 70,1 % aerobic volume.

The biological processing capacity refers to the following parameters:

- BOD5 – 36,513 kg/d;
- COD – 67,144 kg/d;
- TKN – 7,733 kg/d;
- TP – 1,605 kg/d;
- TSS – 2,502 kg/d.

The main process parameters are the following:

- active sludge age – 8,7 days;
- SRTaerob – 6,62 days;
- active sludge production – 0,972 kg SS/kg BOD/day;
- excess sludge – 35,830 kg SS/day;
- SVI – 110 cm3/g;
- active sludge concentration MLVSS 3,701 mg/l;
- Vd/Vat – 0,239;
- active sludge aeration tanks – 311,600 kg SS;
- HRTanaerobic – 0,7 h;
- QIR – 250 %;
- QER – 75 %;
- MLSS – 4,1 g/m3;
- oxygenation capacity COpeak – 5,659 kg O2/h, with a peak factor (1,47) calculated in order to ensure a concentration of 2 mg/l solved O2 for H – 3,45 m and Twater – 26 °C.

The plant, in the biological treatment zone, features three Phoredox type phrases, as it is shown in the diagram in Fig. 2:

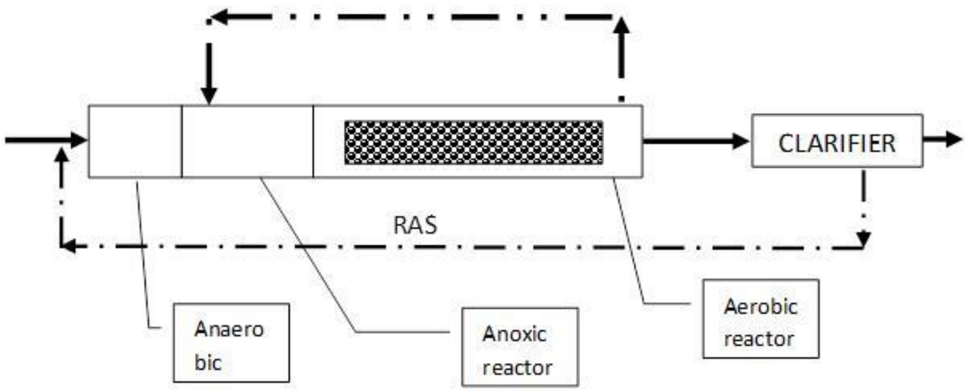

Fig. 2 The biological zone – process diagram

The nitrogen and phosphorus balance

The nitrogen incorporated in biomass cand be assessed as it follows:

$$N_{SAS} = CBO * 5\% \quad (1)$$

$$N_N = TKN_{in} - TKN_{out} - N_{SAS} \quad (2)$$

$$N_D = N_N - NO3_{out} \quad (3)$$

where:

- BOD - the amount of biodegradable matter (187 mg/l);
- TKN_{in} - influent nitrogen (39,6 mg/l);

- TKN_{out} - effluent nitrogen (2 mg/l);
- N_{SAS} - nitrogen in sludge (9,4 mg/l);
- N_{N} - nitrogen in nitrification zone (28,2 mg/l);
- N_{D} - nitrogen in de-nitrification zone (22,2 mg/l);
- $NO3_{out}$ - nitrate effluent (6 mg/l).

The phosphorus balance is estimated as it follows:

$$P_{BioP} = 1{,}5\% * CBO \tag{4}$$

$$P_{SAS} = 1\% * CBO \tag{5}$$

$$P_{chem} = P_{in} - P_{out} - P_{SAS} \tag{6}$$

where:

- P_{BioP} - phosphorus incorporated in sludge, via BioP technique (2,8 mg/l);
- P_{SAS} - phosphorus incorporated in sludge, via normal absorbtion (1,9 mg/l);
- P_{in} - phosphorus affluent (8,2 mg/l);
- P_{out} - phosphorus effluent (1 mg/l);
- P_{chem} - phosphorus removed via chemical reaction (2,5 mg/l).

Calculation of sludge age

All biological reactions are influenced by temperature, especially nitrification and the reduction of nitrate to nitrogen. This factor affects the choice of sludge age and the lower is the temperature during biological process, the higher is the sludge age.
The age of aerobic sludge is estimated as:

$$SRT_{aero} = 1{,}45 * 3{,}4 * 1{,}103^{15 - T\,min} \tag{7}$$

$$SRT_{dim} = SRT_{aero} * \frac{1}{1 - Vd / Vat} \tag{8}$$

The adopted values are:

- SRT_{aero} = 6,62 days (aerobic sludge age at minimum temperature);
- SRT_{dim} = 8,7 days (total sludge age).

Production of biological sludge

The specific sludge production and the total production (digesters losses not included) are:

- SP_{dc}-BOD related sludge production (30,720 kgSS/day);
- SP_{BioP} - extra sludge production, BioP process (1,658 kgSS/day);
- SP_{chem} - chemical treatment sludge production (3,450 kgSS/day);
- SP_{tot} - total sludge production (approx. 35,830 kgSS/zi).

Biological tanks volumes

The total value of necessary sludge X_T and reactors total volumes V_{at} shall be:

$$X_T = SP_{tot} * SRT_{dim} \tag{9}$$

$$V_{at} = \frac{X_T}{MLSS} \tag{10}$$

where:

- sludge amount – approx. 311,600 kgSS;
- MLSS concentration – 3,701 mg/l;
- total volume – 84,193 m^3;
- V_d/V_{at} ratio – 0,239;
- denitrification volume – approx. 20,150 m^3;
- nitrification volume – approx. 64,030 m^3.

The anaerobic reactor volume will be:

$$V_{an} = Q * (1 + RAS) * HRT_{anaerob} \tag{11}$$

where:

- flow on reactor’s inlet (affluent+RAS) - 14,362 m^3/h;
- RAS coefficient – 75%;
- HRT inside reactor – 0,5 h;
- anaerobic volume – 7,181 m^3;
- sludge fraction in anaerobic condition - approx. 7,9%.

5. CONCLUSIONS

As we have studied a topic on wastewater, we consider necessary and useful to give some conclusions.

Following the analyzes carried out on the biological treatment of wastewater in the wastewater treatment plant, we found the following:

- the decreasing of concentrations and quantities of polluting substances within the limits of directives and laws in force;

- decreasing of eutrophicants in the wastewater treatment plant’s effluent;

- decreasing the amount of sludge resulting from technological processes;
- ensuring the compliance of concentrations and quantities of polluting substances within the limits of the directives and laws in force;
- the wastewater treatment plant produced sludge: possibility of its reintroduction into the natural circuit and its recovery, after a proper treatment;
- decreasing power consumption;
- power production;
- the efficiency or purification degree provided by technological process;
- protecting the environment and caring for the population.

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Note:

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