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CONTINUOUS ADJUSTMENT WITHIN WASTEWATER TREATMENT PLANTS OPERATION TO MEET NATURAL RECEPTORS DISCHARGE CONDITIONS

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Abstract

Wastewater treatment plants are designed for input data considered constant and are checked for maximum values according to the imposed loads. During operation, the values of flows and loads at the wastewater treatment plant entrance point change within wide limits. In order to achieve the treatment efficiency, exploitation measures are adopted to ensure the water discharge within the legal admissible limits. These safety measures involve additional operating costs or risk in discharging water with quality indicators not allowed compared to those required by current legislation. Technological adjustment mechanisms must be provided in the design and operation stages.

The present paper highlights a procedure for technological processes regulating when occurs significant loads variation at the wastewater treatment plant entrance point and demonstrates its importance.

Key words*: natural receptors discharge conditions, wastewater treatment plant, treatment efficiency.*

INTRODUCTION

Sewage systems serve communities with the aim of taking over domestic or industrial wastewater, transporting it to wastewater treatment plants and disposing it in quality conditions that do not affect the environment. The treated water can be discharge or used for agricultural purposes (Panaitescu, 2014) and sludge, by-product of the wastewater treatment, must be discharged or used in correlation with their qualities (Preda, Tanase, Vrinceanu, 2017). The importance of the quality indicators values at the discharge point of wastewater treatment plants is special cause to the fact that wastewater is relatively nutrient-rich, has contaminating potential and could degrade the environment (Sanderson et al., 2019), effluents could be source of nutrient for different aquatic systems (Kendall, Doctor, Young, 2014) that unbalance when they are not well treated.

Sewage systems could be separative or unitary, the realized variants implying, through the collected and transported waters, flows time-variable in wide range. Flow variations depend on the hourly consumption coefficients for domestic activities, the industrial activities type, the sewage system, the water supply networks losses, the amount of water coming from the drainage systems, the meteorological phenomena.

Wastewater treatment plants host physical, chemical, biological processes difficult to describe and manage in particular cause to the variability of quantities and characteristics of inlet water (Nasr et al., 2021). The use of appropriate techniques leads to remove wastewater pollutants such as organic matter and nitrogen, diminishing wastewater adverse effects (Bassin et al., 2021).

Under these conditions, the amount of water, the concentrations and the quantities of pollutants at the entrance to the wastewater treatment plants register significant hourly variations. For each sewage system and wastewater treatment plant is important to make Mathematical models of the transport system, measurements of flows and concentrations at the plant admission point, as well as the implementation of operating procedures adapted to the conditions recorded at the entry section.

In order to highlight the hourly variations of the quality indicators for the wastewater at the plant admission point, laboratory measurements of the main indicators were performed in different stages.

MATERIALS AND METHODS

CASE STUDY NO. 1

Following the main indicators for a treatment plant designed for 100,000 equivalent inhabitants (e.i.) by measurements over 8 days, the variation of the wastewater suspensions concentration before the treatment plant entering point is represented (Figure 1).

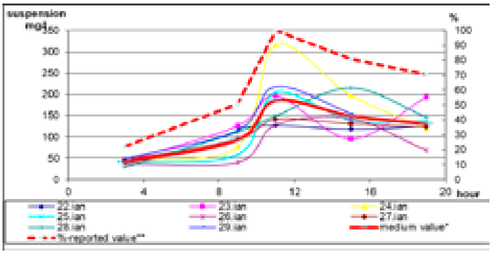

Figure 1. Variation of suspension concentrations at the treatment plant entrance point: *hourly average values, **reported values - percentage of hourly average from the value of the maximum hourly average

Wastewater suspension concentration at the treatment plant entrance point registers hourly variations between 40 mg/l and 320 mg/l. The minimum value is recorded during the night, corresponding to a low water consumption, a high degree of dilution due to water loss and settling and deposition at low flow rates in the sewage system. The maximum value corresponds to the morning hours, when there are registered high water consumption, and the highest transit flows.

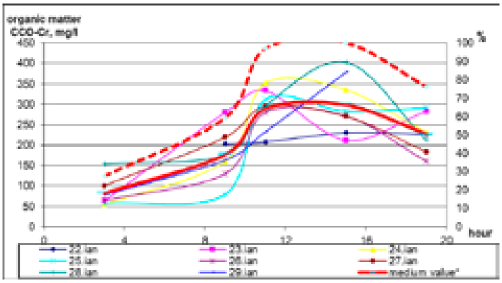

Figure 2. Chemical oxygen consumption variation, CCO-Cr for wastewater at the treatment plant entrance point: *average hourly values, **reported values - the percentage of the hourly average from the value of the maximum hourly average

Also, for the same time period, the CCO variation for raw wastewater is recorded and represented.

The quality indicator chemical oxygen consumption, CCO-Cr has a similar evolution as suspension concentration, the registered values being situated between 50 mg O_2/l and 400 mg O_2/l.

Regarding the ammonia nitrogen content in the wastewater at the treatment plant entrance point, the same significant variations identified in the previous indicators presented are found; the recorded values are between 5 mg/l and 30 mg/l. There are relatively close values for the time period (16.00-20.00) hours close to about 60% of the maximum value recorded in the morning. The morning peak value recorded can be justified by the wastewater load, also by the anaerobic fermentation processes in the sewage system and the deposits entrainment at flow rate and speed corresponding to the peak consumption.

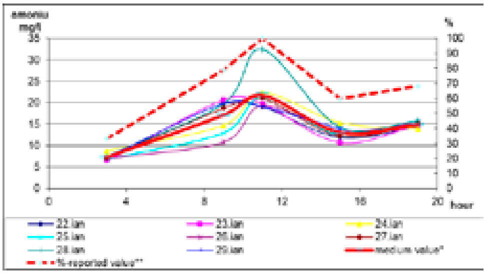

Figure 3. Variation of wastewater ammonia nitrogen content at the treatment plant entrance point: * hourly average values, ** reported values - percentage of hourly average from the value of the maximum hourly average

The analysis of the pollutant concentrations evolution at the treatment plant entrance point highlights the following characteristic periods:

- period between 1.00 am and 9.00 am is characterized by low concentration due to low socio-economic activity;
- peak values concentration is registered between 10.00 am and 1.00 pm;
- the landing period between 1.00 pm and 1.00 am.

Low flow rates during night involve reduced flow speed in sewage pipes, suspension settling and fermentation processes. Increased flow rates during morning involves self-cleaning phenomena in the transport pipes. Concentration peak concentration corresponds to the transport time, to the length of the sewage system.

The evolution graphs identify the minimum suspension concentration (c.ss.min) being 20% of the maximum determined value, the minimum chemical oxygen consumption is 25% of the maximum value, and the minimum ammonia nitrogen concentration is 30% of the maximum value.

The collected wastewater quantities by the sewerage systems are established according to the calculation flows of the water supply systems they serve. Large water supply systems involve minimum flow, night rates are of about 40-60% of the maximum flow value. The high flows can be motivated by the distribution networks water losses, the economic activity and large drainage surfaces. Under these conditions, the pollutants quantities values at the wastewater treatment plant entrance point change in the range of 100% to (10-15)%.

Corresponding to the treatment plant load evolution, the technological processes must be adapted and adjusted for the two characteristic periods:

- with reduced load between 1.00 am and 11.00 am;
- with high load for the rest of the day.

Depending on the treatment plant technological type, the discharged water minimum concentrations values will be registered between 6.00 am and 3.00 pm, the maximum values will be found between 4.00 pm and 0.00 am.

CASE STUDY NO. 2

Performing the same type of measurements for a wastewater treatment plant operated for 30,000 e.i., the results obtained previously are confirmed.

Presented hourly flows evolution in wastewater treatment plant during 3 days (Figure 4), there are found reduced flows of wastewater during the night, indicating minimum volumes of water from infiltration due to water supply network water losses; minimum flow value is about 12.5% of the maximum flow value recorded. Flow variations during operation indicate the presence in the sewage system of some wastewater pumping stations with large storage volumes.

During the same period, the measurements of the suspended matter quantities at the wastewater treatment plant entrance point show significant variations between the night and day operating regimes; the suspended matter quantities change in wide limits, from 10 kg/h to 250 kg/h.

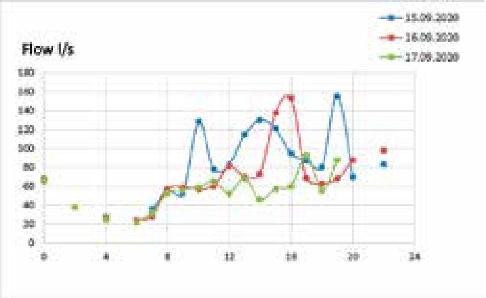

Figure 4. Hourly flows evolution in wastewater treatment plant of 30 000 e.i. during 3 days

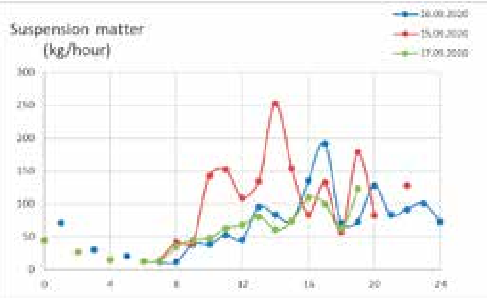

Figure 5. Suspension matter quantities evolution at the wastewater treatment plant of 30000 e.i. entrance

Ammonia nitrogen indicator evolution at the wastewater treatment plant entrance point highlights significant variations between the two operating regimes, the minimum value being 3 kg/h and the maximum one of 40 kg/h.

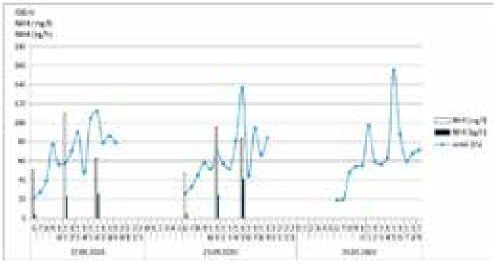

Figure 6. Flows and ammonia nitrogen quantities evolution at the wastewater treatment plant of 30 000 e.i. entrance point

CASE STUDY NO. 3

Wastewater treatment plants equipped with specific devices for quality indicators continuous monitoring highlight the hourly variations. For one of those, serving 100000 e.i., Figure 7 shows the evolution of ammonia nitrogen determined continuously.

Figure 7. Ammonia nitrogen and chemical oxygen consumption evolution for a wastewater treatment plant of 100000 e.i.

The continuous measurements performed in the wastewater treatment plant show that the values obtained using laboratory equipment and presented previously lead to the same conclusions regarding the hourly evolution of the concentrations and quantities of pollutants.

Determining the pollutants and flows quantities allow the adoption of efficient exploitation measures and the reduction of the exploitation costs by: adapting the technological treatment chain, regulating the reagent doses, regulating the internal and external recirculation flows, regulating the aeration systems, balancing the nitrification and denitrification processes corresponding to the amounts of nitrates, ammonia nitrogen and the C:N ratio.

PROCESSES ADJUSTMENT OF WASTEWATER TREATMENT PLANTS

The mechanisms for regulating the processes in the wastewater treatment plants depend on the pollutant's concentrations at the entrance point and on the degree of treatment required (NP 133, 2013).

Mainly, the process control mechanisms in urban wastewater treatment plants are related to: technological treatment chain, coagulant dose in primary decanters and chemical dephosphorylation, dissolved oxygen level, activated sludge concentration, internal recirculation, external recirculation, technological times for the nitrification and denitrification phases at the stations with sequential operation, the nutrient doses including additional carbon.

In Romania, the treatment required degree is high, the treatment plants with a capacity of over 10,000 e.i. have the task of reducing the nutrients to low values with the need to adopt complete channels with nitrification and denitrification.

Due to the low limits for ammonia nitrogen imposed by the environmental protection legislation specified in operating permits issued (total nitrogen values less than 15 mg/l) low-capacity plants also must take additional measures to reduce nitrogen through denitrification processes.

From the energy point of view, the highest consumption is recorded for biological basins aeration and for the internal recirculation necessary for denitrification in the case of wastewater treatment plants with a pre-denitrification stage.

The sequentially functioning basins do not have internal recirculation systems, the energy consumption being mainly coming from the aeration, mixing and pumping of the water in the discharge phase.

The other processes, those related to wastewater supply, sludge management and automation are found at treatment plants regardless of the architecture adopted.

In the case of sequential operation plants, the size of the batch depends on the wastewater ammonia nitrogen concentration and the degree of treatment required. Consequently, the size of the batches could be variable, with large volumes during the technological gap and with long durations at high concentrations of ammonia nitrogen.

In the case of sequential systems operated with pre-denitrification phase and discharge limits, ammonia nitrogen less than 2 mg/l, nitrates less than 25 mg/l and total nitrogen less than 10 mg/l, the batch size will involve a final concentration at feeding and pre-denitrification phase less than 7 mg/l of N-NH_4; after the nitrification phase (which involves the assimilation of 15%-20% of nitrogen, there will be a concentration of about 6 mg/l of N transformed mainly up to 1.5 mg/l of N-NH_4 and the difference 4.5 mg/l of N-NO_3 (4.5 x 4.427≈20 mg/l NO_3).

Under these conditions, the size of the batch is given by:

$$V_{batch} \langle \frac{7}{C_{NH_4 entrance}} . V_{reactor} \qquad (1),$$

where:

V_{batch} - volume of the supply batch at one cycle;

$C_{NH_4 entrance}$ - ammonia nitrogen concentration at the wastewater plant entrance point;

$V_{reactor}$ - biological reactor total volume.

When inlet concentration of 30 mg/l NH is registered, the batch size will be a maximum of 23% to ensure discharge with concentrations of NH_4 < 1.5 mg/l and NO_3 < 20 mg/l.

When adopting the continuous monitoring of NH_4 and NO_3 indicators in the biological basin, the water supply and the duration of the biological process phases will be automated based on the determined values, as follows: wastewater supply until reaching the level of 7 mg NH_4/l, denitrification until upon removal of NO_3, aeration to (1-1.5) NH_4 and NO_3 < 20 mg/l.

Sequential operation reactors do not ensure reliability in the case of ammonia nitrogen high concentrations wastewater. High values of concentrations require the use of a treatment flux with low batch and successive denitrification-nitrification phases that are repeated on low feed volumes and check the relationship (1); the aim is to use carbon from wastewater and obtain a high CBO_5/NO_3 ratio.

In the case of treatment plants having pre-denitrification and recirculation basin, the value of the recirculation flow verifies relationship (1) applied at the denitrification compartment exit point:

$$Q_{entrance} \cdot \frac{C_{NH_4 entrance} - 7}{7} \langle Q_{recirculation},$$

so:

$$Q_{recirculation} \rangle Q_{entrance} \cdot \frac{C_{NH_4 entrance} - 7}{7} \qquad (2)$$

The design norm NP 133-2013 stipulates that the internal recirculation rate (r_i) is calculated:

$$r_i = \frac{C^D_{N-NO_3}}{C^{efl}_{N-NO_3}} - r_e \qquad (3),$$

where:

r_e - external recirculation rate;

$C^D_{N-NO_3}$ - nitrogen concentration to be denitrified;

$C^{efl}_{N-NO_3}$ - nitrogen concentration permissible for discharge.

The application of relationships (2) and (3) implies close results for discharge conditions of NO_3 < 25 mg/l.

Ammonia nitrogen concentrations variations in entrance wastewater impose to change the recirculation flow value; at present, the regulation according to the plant entrance flow is usually used.

In case of biological reactor equipped with NO_3-NH_4 monitoring equipment, the technological flow can be controlled and the internal recirculation can be regulated according to the values determined at the denitrifyication compartment discharge point. Monitoring at the end of the NO_3-NH_4 biological stage and automation according to these values implies the increase of the response time to the change in the treatment flow due to the process inertia. The internal recirculation will be adjusted in order to ensure the following condition at denitrification compartment exit point:

$$N - NH_4 + N - NO_3 \langle 7 \text{ mg/l} \qquad (4)$$

In practice, the internal and external recirculation are regulated as a percentage of the inlet flow without taking into account the variable concentrations of nitrogen at the wastewater treatment plant entrance point. Ensuring the compliance for the entire operation period involves high recirculation rates and unjustified electricity consumption. The qualitative and/or quantitative control of the input flows creates the mechanisms for the adoption of the necessary and sufficient recirculation with the reduction of the operating cost and ensuring the process reliability. Based on the determined values, the wastewater treatment plant operation can be performed based on the adoption of recirculation rates based on the nitrogen concentrations at the entrance point; these rates must be changed hourly, values determined by statistic calculation or by continuous flow measurements.

CONCLUSIONS

The wastewater quality conditions at the treatment plant entrance point are continuously changing, registering cyclical exploitation situations, with characteristic periods: periods with low loads during the night and early morning, periods with peak loads recorded between 9 am and noon, periods with relatively constant loads in the afternoon.

In order to ensure the necessary wastewater treatment efficiencies, performant process control systems are required, depending on the pollutant quantities at the treatment plant entrance point and the effect of the pollutant concentrations in the discharged water.

Classical systems have control methods depending on the measured inlet flows and the dissolved oxygen concentration. The paper highlights the hourly variations of concentrations and quantities at the entrance point of some monitored treatment plants for the main indicators: suspensions, ammonia nitrogen and carbon. The usual adjustments cannot ensure the process regulation because the variations of the quality indicator concentrations variations change in the limits of (20-100)%, and the hourly pollutant quantity variation in a range of (10-100)%.

In the case of pre-denitrification treatment processes and related recirculation, the classical system provides percentage recirculation depending on the treated flow. In the design phase, the recirculation flows calculation is determined based on the amount of nitrate to be denitrified, amount that depends on the concentration and amount of ammonia nitrogen of the inlet biological reactor wastewater flows. The optimization of the denitrification process can be achieved only by nitrate and ammonia nitrogen indicators monitoring in the denitrification compartment; process monitoring and automating by measuring the exhaust indicators implies inertia due to technological times and the instability of regulation process. In the denitrification phase, the highest nitrogen reduction efficiency is registered, this must be controlled. Excessive recirculation flows can alter the denitrification process by transferring oxygen and reducing the C: N ratio, especially during periods of low load.

If the wastewater treatment plant does not have nitrate and ammonia nitrogen measuring equipment, the recirculation rate required for denitrification can be adjusted by introducing correction coefficients depending on the treated water flow and the values of hourly average ammonia nitrogen concentrations determined similar to those presented in this scientific paper.

REFERENCES

Bassin, J.P., Duarte Castro, F., Rocha Valerio, R., Pontes Santiago, E., Lemos Ribeiro, F., Bassin, I.D. (2021). *The impact of wastewater treatment plants on global climate change in Water conservation in the era of global climate change*, pp. 367-410.

Kendall, C., Doctor, D.H., Young, M.B. (2014). *Treatise on geochemistry*, second edition, Vol.7, pp. 273-327.

Nasr, M., Mohamed, K., Attia, M., Ibrahim, M.G. (2021). *Sustainable management of wastewater treatment plants using A.I. techniques in Soft computing techniques in solid waste and wastewater management*, pp.171-185.

NP 133-2013 - Normativ privind proiectarea, executia si exploatarea sistemelor de alimentare cu apa si canalizare a localitatilor (Norm regarding the design, execution and operation of water supply and sewage systems of localities)

Panaitescu, C. (2014). Study regarding the use of sludge and efluent from wastewater plants in agriculture, *Scientific Papers Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering*, *vol. III*, pp. 9-12.

Preda, M., Tanase, V., Vrinceanu, N.O. (2017). Levels of persistent organochlorine compounds in sewage sludge form wastewater treatment plants, *Agrolife Scientific Journal vol.6, no.2*, pp. 161-166.

Sanderson, H., Brown, S.R., Hania, P., McAllister, A.T, Majury, A., Liss, S.N. (2019). *Management of Emerging public health and risks - multidisciplinary approaches to the changing environment, Chapter 7.* pp. 147-187.