COMPARATIVE STUDY OF TERTIARY WASTEWATER TREATMENT BY COMPUTER SIMULATION

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Abstract
The aim of this work is to asses conditions for implementation of a Biological Nutrient Removal (BNR) process in the Wastewater Treatment Plant (WWTP) of Moreni city (Romania). In order to meet the more increased environmental regulations, the wastewater treatment plant that was studied, must update the actual treatment process and have to modernize it. A comparative study was undertaken of the quality of effluents that could be obtained by implementation of biological nutrient removal process like A2/O (Anaerobic/Anoxic/Oxic) and VIP (Virginia Plant Initiative) as wastewater tertiary treatments. In order to asses the efficiency of the proposed treatment schemata based on the data monitored at the studied WWTP, it were realized computer models of biological nutrient removal configurations based on A2/O and VIP process. Computer simulation was realized using a well-known simulator, BioWin by EnviroSim Associates Ltd. The simulation process allowed to obtain some data that can be used in design of a tertiary treatment stage at Moreni WWTP, in order to increase the efficiency in operation.

Key words: process simulation, biological processes, nutrient removal, wastewater.

1. INTRODUCTION

1 .1 Nutrient removal from wastewater

With the aim to prevent eutrophication process, the maximum nutrient (Nitrogen and Phosphorus) concentrations of treated municipal wastewater are restricted by European regulation. The limit values of specific indicators regarding nutrient concentrations are presented in the Urban Wastewater Treatment Directive 91/271/EEC[3].
In order to improve Nitrogen and Phosphorus removal, existing wastewater treatment plants (WWTP) have to be updated by inclusion of a a step for biological nutrient removal, according with the Directive limits. The process of nutrient removal from urban wastewater can be achieved by biological treatment, which was studied by a lot of different authors during the past years [1,2,5,6,7,16].
Nowadays, Biological Nutrient Removal (BNR), is a very well known process and is usually achieved by activated sludge processes with selected anaerobic, anoxic and aerobic conditions [6].
In the past decade, a number of enhanced biological phosphorus removal (EBPR) processes have been developed [9].
EBPR is a modified activated sludge process in which an initial anaerobic unit followed by an aerobic cycling of the activated sludge results in the production of biomass of higher than normal phosphorus content. [9,10,11].
Due to more stringent regulations for secondary municipal wastewater treatment, municipalities are beginning to implement tertiary treatment in their wastewater treatment plants [7]. Tertiary treatment involves removal of either phosphorous or nitrogen or both from the wastewater before it is discharged in a water body. Nowadays, in Romania, biological treatment became an increasingly popular process used to accomplish the nutrient removal from wastewater [8].
There are several processes available that can provide acceptable levels of biological nutrient and BOD removal from wastewater[7].

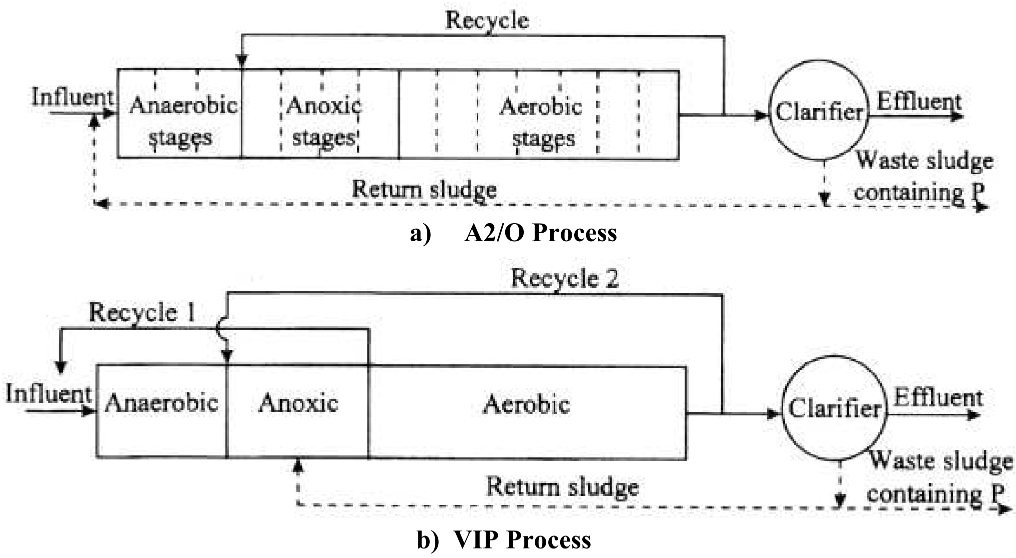

Figure 1 Biological Nutrient removal –Schematic diagrams

Two well-known processes were considered in this study - the Virginia Plant Initiative (VIP) Process and the A2/O Process.
The A2/O (Anaerobic/Anoxic/Oxic) process represents a modification of the A/O (Anaerobic/Oxic) process and it can be used for phosphorus removal [2,15].
Compared with A/O process, in the A2/O process an anoxic area is added (see fig.1).
The process diagram uses anaerobic, anoxic, and aerobic sequence with sludge and internal recycle. The process has stability and produces an effluent of high quality. The process is similar to the Phoredox concept used in Bardenpho process, except that the anaerobic, anoxic and aerobic stages are divided into a number of equal size complete mix compartments [2]. Typically, three compartments are used for the anaerobic stage, three for the anoxic one and four for the aerobic stage. This structure results in a greater sludge production and more phosphorus removal per unit of BOD removed in the system.
The VIP (named for the Virginia Initiative Plant in Norfolk) is similar to the A2/O processes except for the method of sludge recycle, see figure 1. It was designed to reduce nitrates to the anaerobic zone when high removal of nitrates in the effluent is not required. The process consists of three stages: an anaerobic stage, an anoxic stage and an aerobic stage. The RAS is returned from the clarifier to the anoxic zone instead of the anaerobic zone to allow denitrification process.

1 .2 Advantages of wastewater process simulation

Biological modeling and process simulation are essential design tools when is necessary to design biological wastewater treatment processes. Developing a model for biological wastewater treatment processes represent a great advantage for the operation and management of a wastewater treatment plant. The model can be built for a wide variety of specific actions, including design and optimization both in terms of cost and in terms of improving indicators of effluent quality. The model of WWTP can be used to predict effluent quality when a new treatment schema is implemented. It can be a useful tool
to asses changes in plant performances and to improve operational parameters.
There are numerous computer simulators available that run combinations of the various models [13]. Simulators typically have a graphical interface which allows the user to specify the unit processes included in the plant. Given the process layout, the input parameters, and the selected model, the simulator solves the

system of equations to predict the wastewater characteristics throughout the plant [13].
Simulators currently available include: GPS-X, BioWin, WEST, AQUASIM, EFOR, and AQUIFAS.
In the present work was used BioWin3.0 simulator from Envirosim. BioWin software package is a simulation tool for biological treatment of wastewater and can be used in the design stage of wastewater treatment plants and for analysis of treatment processes in order to predict WWTP performance.
The user can define and analyze the behavior of a wastewater treatment plant configuration that has single or multiple wastewater entries.
An essential component of the BioWin package is the facility of modeling biological treatment process. It includes two modules:
a steady-state module - for systems analysis based on a constant load of the influent and a module to achieve dynamic simulation system, which is useful in estimating the operating parameters in order to improve processes. BioWin simulation environment is extremely intuitive and allows the construction of wastewater treatment plant model using a user-friendly interface elements.

2. MATERIALS AND METHODS

2.1 WWT Plant description

The wastewater treatment plant under study is located in city of Moreni, Romania. The plant receives domestic and industrial sewage. It is an wastewater treatment plant comprising from two technological fluxes. The treatment plant uses both mechanical and biological methods to remove pollutants from wastewater. Mechanical treatment consists in screens and four primary Immhof clarifiers. Biological step of the first line has two biological filters and four secondary Imhoff clarifiers. The second technological line uses in the biological step an aerated bioreactor and two secondary clarifiers. Disinfection of effluent is done by chlorination. The final effluent is discharged into the Cricovul Dulce river. The average daily inflow during the period of study was 4320 m3/day, while the plant has a built-in capacity of 13824 m3/day.
Table 1 presents data monitored at Moreni WWTP for mainly indicators of effluent quality.

Table 1. Effluent characteristics of Moreni WWTP

Indicator	Limits	Units	Effluent conc.
TSS	35	mg/l	57.5
COD	125	mg/l	155.64
BOD5	25	mg/l	49.45
$N\text{-}NH_4^+$	2	mg/l	21.70
NO_2^-	1	mg/l	12.75
NO_3^-	25	mg/l	0.07
Total P	1	mg/l	2.925

Monitored data in 2009 shows important overtaking of emission limits especially for Ammonium Nitrogen and Phosphorus. This means that it have to be made efforts in order that final effluent quality meet requirements of NTPA 001/2002 and Directive 91/27/EEC.

2.2 Computer Simulation of biological treatment

To achieve the comparative analysis, it was mainly aimed the model of biological step. Using BioWin3.0 simulator it was realized the model of biological step in two variants of treatment schema: A2/O and VIP process.
Simulations were realized using data of influent composition presented in table 2. The values represents annual average data, monitored in year 2009.

Table 2. Influent characteristics used in computer simulation

Element	**Influent**
Flow [m3/d]	6840
Total COD [mgCOD/L]	440
Total BOD [mg/L]	207
Total Nitrogen [mgN/L]	42
Total Phosphorus [mgP/L]	9.5
pH	7.30

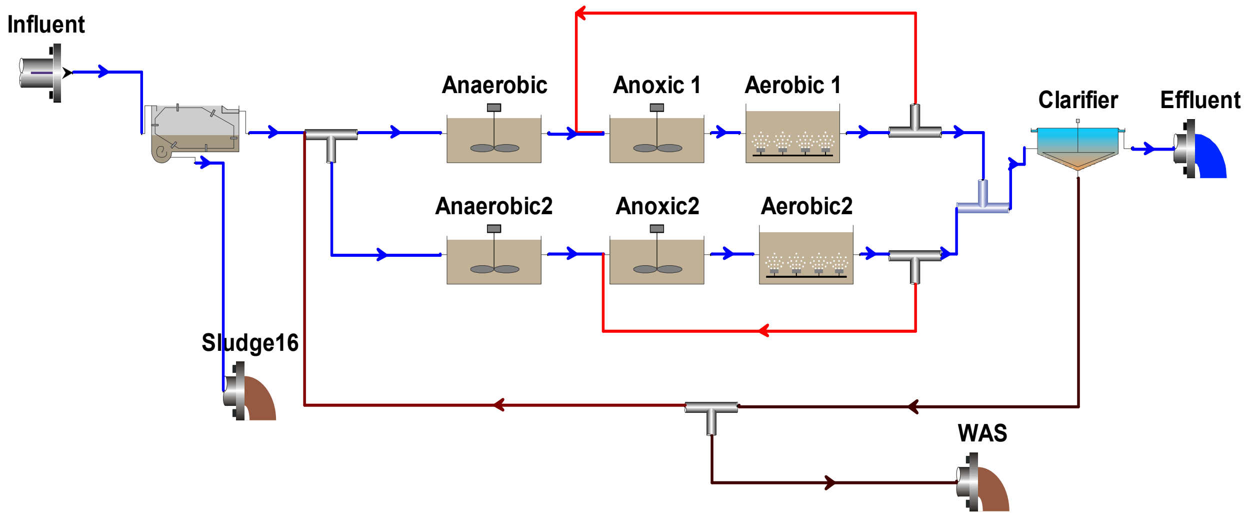

Figure 2 Biowin model of Moreni WWTP based on A2/O process

It can be easily observed that phosphorus concentration in influent is at a high level, so that it would be necessary implementation of a tertiary treatment designed both for the removal of phosphorous and nitrogen from the wastewater before it is discharged from the plant.

2.3 BioWin model for Moreni WWTP based on A2/O process

First of all, it was realized the BioWin configuration of biological treatment according to A2/O treatment process. The BioWin model is shown in the figure 2.
The primary treatment was considered by introducing a primary clarifier. Also, it was considered that the process will be realized using two identical technological line.
There were realized several simulations, changing the values of certain operational parameters (internal recirculation rate, recirculated activated sludge) until the prediction values for effluent quality were satisfactory.
Technological parameters used in simulation for which it was obtained the best results for effluent quality are presented in table 3.

Table 3. Operating parameters for A2/O process

Parameter	Unit	Value
Influent flow rate	m^3/d	6480
Wastewater temperature	°C	20
Return sludge flow rate	% of COD influent	50
Internal recycle rate	% of COD influent	200
Waste sludge flow rate	% of COD influent	5

2.4 BioWin model for Moreni WWTP based on VIP process

Having in view the possibility to make the comparative analysis, it was realized the BioWin model of VIP process, in order to reduce nitrates to the anaerobic zone. It consists of three stages: an anaerobic stage, an anoxic stage, and an aerobic stage. The RAS is returned from the clarifier to the anoxic zone to allow denitrification and to avoid interference from nitrate with the activation of the PAOs in the anaerobic stage. The model is presented in figure 3. There were realized several simulation by changing operation parameters in order to obtain the best variant for effluent quality.

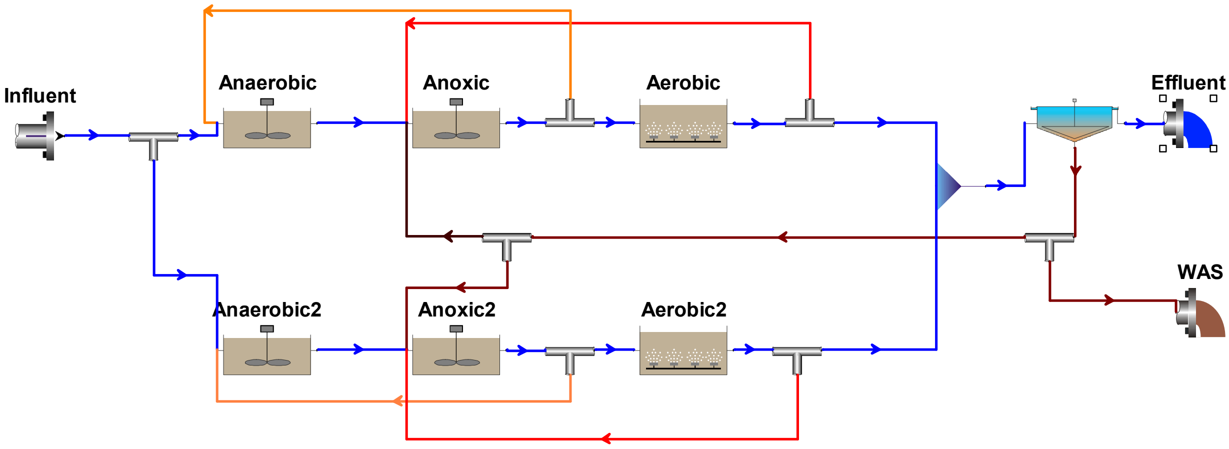

Figure 3 BioWIn Model of Moreni WWTP based on VIP Process

3. RESULTS AND DISCUSSION

The results of computer simulation are presented in table 4. Comparative analysis of effluent quality based on values of some specific indicators lead to conclusion that both systems achieved considerable improvement in the quality of water.
In terms of efficiency of proposed treatment schemes, it can be observed that A2/O process allow a performance by 94% and 77.38% for nitrogen removal.
By comparison, VIP process allowed a performance of 94.32% for phosphorus removal and 75.71% for total nitrogen removal.
Having in view the restrictions imposed by european regulation, it can be observed that A2/O process can lead to obtain an effluent quality better than VIP process regarding total nitrogen values.
Analyzing the two treatment schemes, it appears that in the same conditions for constructive parameters, A2/O treatment schema is more efficient than VIP process, in terms of the degree of reduction of nutrients.

Table 4. Characteristics of effluents and efficiency of treatment scheme

Parameters	A2/O Process			VIP Process		
	Influent Conc. [mg/L]	Effluent Conc. [mg/L]	Reduction of pollutant level [%]	Influent Conc. [mg/L]	Effluent Conc. [mg/L]	Reduction of pollutant level [%]
Total COD	440	30.37	93.10	440	29.96	93.19
Total Carbonaceous BOD	207	2.90	98.60	207	2.81	98.64
Total suspended solids	190.92	2.99	98.43	190.92	2.88	98.49
Volatile suspended solids	175.88	2.31	98.69	175.88	2.22	98.74
Soluble PO4-P	4.75	0.41	91.37	4.75	0.39	91.79
Total P	9.5	0.57	94.00	9.5	0.54	94.32
Total Kjeldahl Nitrogen	42	4.82	88.52	42	4.44	89.43
Ammonia N	27.72	2.74	90.12	27.72	2.28	91.77
Nitrate	0	0.44	n.a	0	1.12	n.a
Total N	42	9.50	77.38	42	10.20	75.71

4.CONCLUSIONS

It can be concluded that both the A2/O treatment and the VIP treatment may be considered valid types of tertiary wastewater treatment for Moreni WWTP.
The computer simulation led to conclusion that the two proposed systems could obtain effluents of excellent quality regarding to physico-chemical
aspects. However, the principal difference is that the VIP Process can be realized with a lower hydraulic retention time(HRT).
In the same time, choosing a treatment scheme must take into account other factors, such as wastewater treatment plant size, total cost of treatment of the whole station, the impact of technology on operations and maintenance. A detailed analysis of the possibility of using advanced treatment scheme for improving nutrient removal at Moreni WWTP will be subject to future research.

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