

A PERSPECTIVE FOR POOR WASTEWATER INFRASTRUCTURE REGIONS: A SMALL-SCALE SEQUENCING BATCH REACTOR TREATMENT SYSTEM

Narcis Barsan^{*}, Valentin Nedeff, Antonina Temea, Emilian Mosnegutu,
Alexandra Dana Chitimus, Claudia Tomozei

*Department of Environmental Engineering and Mechanical Engineering, "Vasile Alecsandri" University of Bacau,
157, Calea Marasesti, Bacau 600115, Romania*

**e-mail: narcis.barsan@ub.ro; phone: (+40) 742 32 501; fax: (+40) 742 32 501*

Abstract. Development of infrastructure in sewerage systems is essential for improving the living conditions and human health. Considering this situation, research was oriented to the use of a small Sequencing Batch Reactor (SBR) treatment system as a small-scale plant in certain sewers. This type of treatment system was chosen because it can be adapted to the quantitative changes of flows. The most important advantages of SBR process include the possibility of modifying the operating cycle, the elimination of secondary clarifiers and the satisfying control of operations that constitute the treatment. Comparing the problems in Romania and Senegal, regarding wastewater treatment, the present paper aims to identify the best methods and techniques to treat the municipal wastewater in small treatment plants with sequential operation. This paper examines the possibility of using SBR process to treat the municipal wastewater characterized by low flow. This paper also presents a comparative analysis of the degree of purification achieved in a SBR wastewater treatment plant, as well as legislative regulations in Romania and Senegal. Finally, the paper identifies the possible uses of the treated wastewater in different household activities.

Keywords: municipal wastewater, Sequencing Batch Reactor (SBR), legislative regulations.

Received: 27 February 2017/ Revised final: 11 February 2017/ Accepted: 12 April 2017

Introduction

According to the National Statistics Institute from Romania, at the end of 2010, only 777 localities (big villages and towns) had sewerage systems and wastewater treatment plants. Statistics data also show that from the total volume of insufficiently treated wastewater discharged into the main natural water bodies, the highest percentage is municipal wastewater [1].

In Romania, over 40% of the population lives in rural areas where wastewater infrastructures are poor or even missing [1,2]. Thus, two general methods of wastewater treatment of centralized or decentralized systems remain complementary in solving the environmental pollution problems due to wastewater discharge. The problem of sludge produced after municipal or industrial wastewater treatment should also be taken into consideration, as well as the complexity of reduction and/or neutralization of toxic compounds [3-5].

The state of Senegal was taken as an example in the present research because its wastewater infrastructure is poor, lacking even in

crowded areas. Thus, the sewerage and treatment system in the capital Dakar covers only 24% of the housing system infrastructure according to data from ONAS (Senegalese National Sanitation Organization) [6].

Implementation of decentralized treatment systems for domestic wastewater must be done in accordance with the applicable technical and economic criteria, respectively the small treatment plants must be adapted to the specifics of each house or housing complex.

Considering the situation, the research was oriented to the use of a small Sequencing Batch Reactor (SBR) treatment system in the wastewater treatment plant. This type of treatment system was chosen because it can be adapted to the quantitative changes of flows [7]. The mechanical-biological SBR systems divide the treatment process using a single basin, in which operation is defined by the operating time. Thus, the SBR treatment takes place in a single basin, with sequential operation. A complete cycle is composed of the filling, reaction, settling, discharging of treated wastewater and sludge

evacuation. The most important advantages of SBR processing include the possibility of modifying the operating cycle, the elimination of secondary clarifiers and a better control of operations that compose the treatment [7-14].

Considering the SBR treatment systems, it can achieve a high degree of treatment for all indicators of wastewater quality, especially for municipal wastewater [13,16]. Consequently, the present study has identified some possibilities for treated wastewater use in some housekeeping activities.

The comparative study proposed in this paper reveals the degree of purification/treatment achieved by a SBR treatment system in analysis associated with legal regulations from two countries: Romania and Senegal.

Materials and methods

For this study the wastewater from the sewer system of the "Vasile Alecsandri" University of Bacau campus was used.

The experimental installation

Taking into account the recommendations from the literature and standard regulations for construction of small wastewater treatment plants, it was realized a small pilot plant operating based on SBR method and using as pre-treatment a septic process [7].

Respecting the five phases of operation for a SBR treatment process, the operating cycle of the SBR compartment of the experimental installation is composed of [7-12]:

- a. The filling phase, which is achieved without homogenization of the wastewater. A SBR basin is usually filled in a single phase, but in the experimental installation the filling phase was divided into four equal sub-phases;
- b. Reaction phase, which runs in aerobic and anaerobic conditions which alternate according to the operating time;
- c. Settling phase, in which the sludge flocs settles at the bottom of the basin;
- d. The evacuation phase of the treated wastewater from SBR compartment is realized from a superior level without agitation of the sludge settled on the bottom of the basin;
- e. Sludge recirculation phase is done after each cycle, but in a small quantity. The large quantity of sludge remains in the basin for the next cycle to provide the biological substrate.

The experimental installation was composed from two main systems: a cylindrical

basin with two compartments and an automation system. The components of the experimental installation are presented in Figure 1.

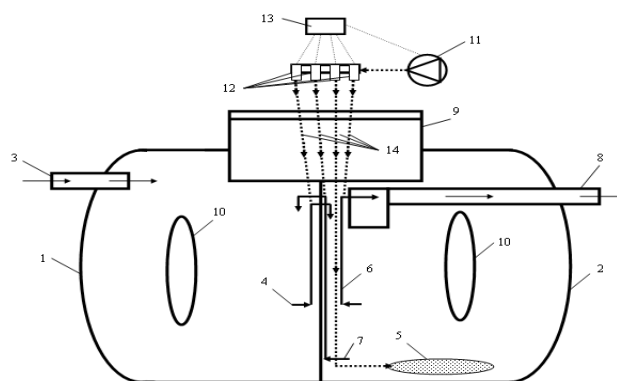


Figure 1. The experimental installation.

1 - the septic basin; 2 - the SBR basin; 3 - the inlet for wastewater; 4 - the air-lift system for supply the SBR basin; 5 - the air diffuser; 6 - the air-lift system for evacuation of treated wastewater; 7 - the air-lift system for sludge recirculation; 8 - the outlet pipe for treated wastewater; 9 - the access in the installation; 10 - the Plexiglas pane; 11 - the air pump; 12 - the solenoid valves; 13 - the programmable controller; 14 - the air supply connections.

To determine the wastewater quality indicators, such as total suspended solids, temperature and dissolved oxygen, during the experimental period, there were used the following equipment: modular measuring system DIQ/S 182 XT; Optical IQ sensor FDO 700 IQ for dissolved oxygen; IQ SENSOR NET for total suspended solids (TSS); immersed thermometer Hach 44600.

For the other quality indicators determined in laboratory conditions there were used Odyssey DR/2500 Spectrophotometer (for determination of COD, phosphorus and nitrogen); OxiTop (to measure BOD₅); inoLab Multi Level 1 (determination of pH, dissolved oxygen).

To determine the nitrogen, ammonium salicylate method UniCell™ was used. In order to analyze the total phosphorus content it was used the Digestion Method 8190, UniCell™ Vials (acid persulfate digestion method), while for COD value determination - Method 8000 Reactor Digestion Method UniCell™ [15]. For BOD₅ measurement it was used the respirometer method. Respirometer Systems is based on a pressure measurement in a closed system: microorganisms in the sample consume the oxygen and form CO₂. This is absorbed by NaOH, creating a vacuum which can be read directly as a measured value in mg/L BOD₅.

Operation of experimental installation

The treatment installation was placed above the ground, in an enclosure, where the temperature was maintained constant.

Taking into consideration the volume of wastewater resulted from a small household, the experimental installation was fed with a volume of 0.9 m³/24 h. By using the method presented below, the best treatment degree in the experimental plant was obtained after processing the experimental measured data [7,8-14,16].

The operation of the SBR compartment has been automated using a programmable controller, so that the operating time (total time) for one cycle (t_c) is defined by the Eq.(1) [9-14]:

$$t_c = t_a + t_r + t_s + t_e + t_m \quad (s) \quad (1)$$

where, t_a is the time for filling of SBR compartment (s);

t_r is the reaction time (s);

t_s is the sedimentation time (s);

t_e is the time for discharging of treated wastewater (s);

t_m is the sludge recirculation time (s).

Taking into consideration all times that constitute an operating cycle of the experimental installation, the period for each phase was set. Also, at the establishing of the experimental time for each phase it was taking into account the best result obtained using this experimental installation. Thus, each term of the above equation is:

a) t_a is composed from four equal sub-phases as in Eq.(2), each one with duration of 143 seconds, which means that:

$$t_a = 143 \text{ (s)} \cdot 4 = 572 \text{ (s)} \quad (2)$$

To reduce the effects of changes in quantitative and qualitative characteristics of the influent between each sub-phases of the filling, an interval of 3000 seconds has been selected.

b) t_r is composed of nitrification time (t_n) and denitrification time (t_d). According to specialized scientific literature, the alternation of nitrification and denitrification phases in a biological treatment process creates the optimum condition for treating the nitrogen and phosphorus compounds from processed wastewater. Also, to create the specific conditions for aerobic treatment in the SBR compartment, the nitrification time has been set to have a higher value compared to denitrification time. In order to realize a high treatment capacity in the

experimental installation, in a total operation cycle, the nitrification and denitrification times were set to be repeated 35 times. So, the reaction time is represented in Eq.(3).

$$t_r = (t_n + t_d) \cdot 35 \quad (3)$$

$$= [360 \text{ (s)} + 240 \text{ (s)}] \cdot 35 = 21000 \text{ (s)}$$

c) t_s was set to 3600 seconds, taking into consideration that the sedimentation process from SBR compartment can be influenced by some internal or external factors of the process.

d) t_e was set to ensure a constant volume of wastewater in the SBR compartment, its value being equal with the total filling time (572 s).

e) $t_m = 10$ seconds. In a SBR treatment plant the sludge recirculation is not necessary, but in the experimental installation a small quantity of active sludge has been recirculated in the septic compartment in order to accelerate the biochemical reactions.

The total time of one operating cycle of the experimental installation is graphically represented in Figure 2, its value being given by Eq.(4).

$$t_c = 572 + 21000 + 3600 + 572 + 10 \quad (4)$$

$$= 25754 \text{ (s)} = 7.15 \text{ (h)}$$

Results and discussion

Respecting the working conditions from above, the experimental study was realized during a period of 20 days between 11÷31 July 2011, which corresponded to summer conditions. Before this period, the experimental installation was primed without active sludge or biological reactive addition so, in the two compartments of this experimental installation, a specific culture of microorganisms adapted to the type of tested domestic wastewater was growing.

The data presented in Table 1 show that the wastewater used in the experimental study present the specific characteristics of small sewer networks. Degree of loading with organic matter shows that wastewater is mainly from domestic type of activities conducted in the university campus. Also, the data of entry (inputs) shows that the wastewater used in this study can be treated by using a mechanical-biological treatment process respectively a SBR system consisting in a mono-block treatment plant.

Figure 3 presents the degree of purification (treatment degree) achieved in the experimental installation for the analyzed five quality indicators.

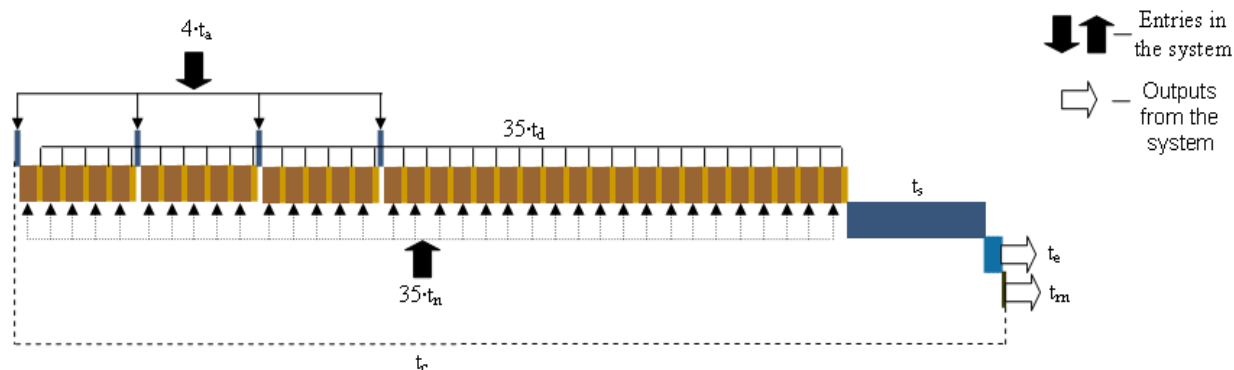


Figure 2. Graphical representation of the operating times in the experimental installation.
 t_r - reaction time; t_n - nitrification time; t_d - denitrification time; t_s - sedimentation time;
 t_e - discharging time of treated wastewater; t_{rn} - sludge recirculation time.

Table 1

The obtained results and maximum allowable values for the analysed quality indicators.

Quality indicators	Values in the influent	Values in the effluent	Maximum allowable values NS 05-061*	Maximum allowable values NTPA 001**
Temperature (°C)	24.1	24.8	-	35
pH (unit. pH)	7.2	7.5	6÷9	6.5-8.5
Total suspended solids(TSS) (mg/dm ³)	197	34.3	50	35
Biochemical oxygen demand (BOD ₅) (mg O ₂ /dm ³)	104.3	24.34	40	25
Chemical Oxygen Demand (COD) (mg O ₂ /dm ³)	214.4	43.54	100	125
Ammonium (NH ₄ ⁺) (mg/dm ³)	10.24	3.75	30	2
Phosphorus (mg/dm ³)	1.68	0.87	10	1

*NS 05-061 Senegalese Standard of wastewater disposal in natural effluent [17];

**NTPA 001/2005, Romanian Standard of wastewater disposal in natural effluent (91/271/EEC) [18].

By comparing the concentration values of the quality indicators at the inlet of the experimental installation with the degree of purification (treatment degree) presented in Figure 3, we can say that the used system has a good efficiency, being in majority higher than 50%. Also, the graphical representation from Figure 3 shows that in the used treatment system it was obtained the degree of purification (treatment degree) over 75% for three quality indicators (suspended solids, COD and BOD₅) as it was recommended in legislative norms (*i.e.* higher than 70-80%) for all discharges of treated wastewaters in natural aquatic receptor.

In Figure 4 the obtained results and the admissible limitative values, for the analysed quality indicators, specified in the Romania and Senegal legislative regulations are represented. Moreover, the Figure 4 shows that the standard values from Senegal and Romania present some differences. These differences may be due to

different development levels between the two countries, considering both economical and infrastructural points of view for the water-wastewater issues. Also, Romanian legislation regarding the discharge of wastewater in natural emissaries should comply with European directives in the field, which determines the national implementation of restrictive regulations on pollutant (corresponding quality indicator) concentrations in treated wastewater.

Considering the problems that exist in Senegal related to water-wastewater and analysing the data from Figure 4, it can be concluded that the wastewater treated in the experimental installation can be used in some household activities. For example, some of the categories of water uses include the irrigation of green spaces around residence served by small plant, cleaning of housing and auxiliary, washing cars, *etc.*

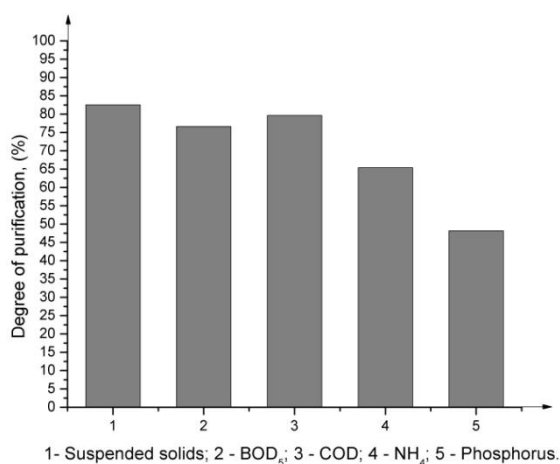


Figure 3. Degree of purification (treatment degree) realized in the experimental installation for the analysed quality indicators.

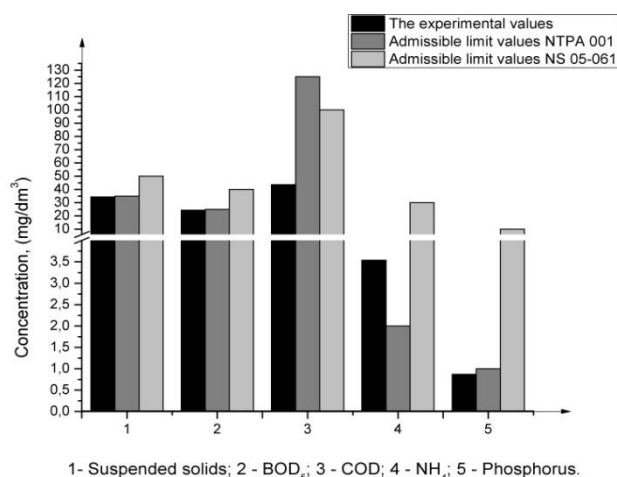


Figure 4. Comparison of experimental results with legislative regulations from Romania and Senegal.

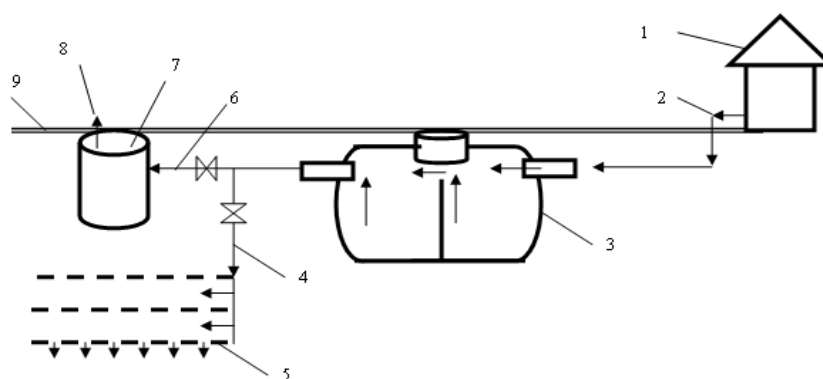


Figure 5. Scheme of the installation for treatment of domestic wastewater.

- 1 - home; 2 - sewerage system; 3 - small wastewater treatment plant; 4 - drainage system for treated wastewater; 5 - infiltration in soil; 6 - drainage system for treated wastewater; 7 - storage tank for the treated wastewater; 8 - utilization of treated wastewater; 9 - the ground limit.

Usually the use of treated wastewater for agriculture requires attention focused to concentration of heavy metals and high concentrations of nitrogen compounds. In this case it can be made the specification that the composition of treated wastewater does not have any concentration or exceeding concentrations of heavy metals because the wastewater derive from household activities. Regarding to the concentrations of nitrogen compounds, the results obtained (Table 1) show that the pollution of soil and groundwater is at an acceptable level considering only the ammonia values in both countries (precaution in use, for Senegal).

From the Figure 5 it can be observed that for a real use the small plant is located underground and this positioning create the possibility of water storage or infiltration into the soil after treatment. Also, Figure 5 shows that the actual utilisation conditions do not create esthetical issues and/or bad odours.

Using treated wastewater (with a composition rich in minerals) for agricultural

purposes has economic advantages in addition to the environment protection, because of limitation the use of chemical fertilizers. Thus, using these types of treated wastewater for irrigation can reduce the use of chemical fertilizers (NPK - nitrogen, phosphorus, and potassium) by 50%, urea by 25% and natural fertilizer by 40% [19]. Even if the small treatment plants treat low wastewater flows, these can provide some complementary waste resource's for household irrigation needs.

Conclusions

The experimental conditions established using a septic compartment in domestic wastewater pre-treatment and SBR compartment as principal treatment stage, have influenced the effluent quality, which found to be corresponding to the legislative standard regulations (from Romania and Senegal).

Comparing the obtained experimental results with those from the legislative regulations

of Romania and Senegal and taking into account the problem of water scarcity in most African countries, it can be considered that the proposal related to the use of treated wastewater in a various household purposes is a solution considering the discrepancies between sources and water requirements.

The small capacity treatment systems, similar with the one presented in this study, can be used in crowded areas where the sewerage infrastructure is missing, the situation in which the sanitation problem can be resolved. In this sense the most relevant example is the capital Dakar, where only 24% of the population is connected to a sewerage treatment plant and therefore the implementation of the small treatment system can be considered a solution to remediate the situation.

The experimental technique used an automated SBR treatment system and this methodology can be adapted to a variable flow of wastewater.

This study did not analyze the wastewater from microbiological point of view. This may be the subject of another study, or a continuation of the present one. A microbiological analysis of wastewater can be guaranteed that its use after treatment does not affect the environment and human health.

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