BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi
Volumul 63 (67), Numărul 1-2, 2017
Secţia
HIDROTEHNICĂ

MODERN TECHNOLOGIES IN WASTE WATER TREATMENT FLUX FROM WASTE WATER TREATMENT PLANTS

BY

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Received: May 22, 2017
Accepted for publication: June 30, 2017

Abstract. Developing of the water infrastructure through European funding programs has led to a comprehensive process of refurbishment and / or new investment for waste water treatment plants.

Sustainability of wastewater collection, treatment and disposal options in Romania, are discussed in the context of recent large-scale infrastructure investments.

The dynamics of technological changes resulting from the emergence of new waste water treatment solutions superimposed on modifying and improving equipment and facilities, generalization of automation in management processes require strictly necessary technical-economic concept of for sustainable management.

This paper presents a current application for the treatment of waste water for cities with < 100.000 P.E.

The case study analysis is a realization of collective investment by designing and shows the technological line for waste water treatment within this plant, comprising of primary advanced treatment, secondary and advanced tertiary treatment.

With apriorities as to the advanced waste water treatment systems in small and medium sized municipalities of Romania, the selection of the appropriate

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and sustainable level of treatment MUST be based on the recipient's sensitivity considerations and assessment of its ecological status. This can be accomplished through the selection of a good core of DPISR indicators (according to DPSIR framework - Driving forces, Pressure, State, Impact, Response used by the European Environment Agency in its reporting activities) and centred on the flow of data and information from monitoring to reporting (MDIAR chain - The monitoring/data/information/assessment/reporting (MDIAR) chain is the flow of data and information from national monitoring to European reporting).

Keywords: waste water; treatment plants; sustainable technologies.

1. Introduction

The treatment processes are physico-mechanical, chemical and biological. After their application the main products result: the purified water that is discharged into the receiver or that may be recovered (for irrigation or other uses) and respectively the sludges, which are treated and recovered.

The dynamics of the technological changes resulting from the emergence of new treatment solutions, overlapped on the changing and continuous improvement of equipment and facilities, as well as the generalization of automation in the management of technological processes require, as absolutely necessary, the concept of technical-economic sustainable management.

Conceptually, waste water treatment plants are currently a whole. The performance and certain delimitations of the processes, as it has been until now, are no longer possible because the physical, chemical and biological processes succeed themselves and overlap in the same objects.

The waste water treatment technologies (particularly for treatment of substance like N-CBO_5 and P-CBO_5) involve alternation of processes (cyclic) such as aerobic and anoxic/anaerobic for the partial/total removal of these substances. This is achieved by creating distinct areas (reactors) such as de-phosphating, denitrification, nitrification followed by different recirculation ways, depending on the technology. Thus arose treatment after the secondary step - *tertiary treatment* or the biological processes were overlapped on the primary and secondary steps called *primary advanced stage* / *secondary advanced stage.*

At the same time, waste water treatment technologies (in particular, in the biological stage) by fixing the membrane on different types of biomass have appeared. They were conceived modularly, in modules placed over the adopted aeration system. These technologies have the possibility to treat all year long, at maximum efficiency, regardless of the temperature of the waste water.

In the technological schemes within a waste water treatment plant, depending on the operating mode, different types of reactors/ biological tanks, that can be grouped as follows, are used:

1 – continuous reactors (with piston flow, with complete mix, etc.);

2 – discontinuous reactors called sequencing batch reactors (SBR), and in the American literature they are called Batch reactors (SBR).

The processes from the sequencing tanks are identical to those from the continuous tanks, except that the aeration and decantation occur in the same tank. Here the processes take place in stages/sequentially, compared to the classic solution (continuous flow tanks), where the two phases occur simultaneously.

Taking into account the high complexity of situations depending on the existing situation and the future situation, we present a case study, made by our team, on waste water treatment technology by discontinuous process.

2. Waste Water Treatment by Discontinuous Process

2.1. Presentation of the Treatment Stages of the Waste Water in a Sequencing Batch Reactor (SBR)

Stage 1

The reactor is primed and has the necessary biomass to treat a water volume at N_{max};

i) the filling of the biological reactor begins;

ii) during filling (1,...,5 h), depending on the network of the influent waste water network, the alternation of Stages 2 and 3 takes place, respectively of aeration and mixing (triggering aerobic and anoxic biological processes).

If stage 1 take 1 h, then we prefer only aeration to exist during filling (as in stage 2). If the charging of the influent water is small then there may be an alternation of aerobic/anox during charging. The charging mode is given by the influent concentration of dissolved organic substances. Biological treatment is done during charging.

Stage 2

The reactor is filled to the maximum level, and therefore received the entire volume to be treated. The first phase of biological treatment is of aeration. By triggering the aerobic phase the biological aerobic processes (nitrification and oxidation of the carbon nitrogen) start. The blast engines are turned don in this situation (they can function with frequency converters directly proportional with the necessary O_2 imposed by the operator). The decanter, mixer and the sludge evacuation in excess don't work. ($O_2 \geq 2.5$ mg/l).

Stage 3

The ANOXIC stage – At this stage the elimination of nitrogen by denitrification takes place. (O_2 = 0.1,...,0.5 mg/l):

i) the reactor is at the maximum stationary level; turned off aeration; mixer (mixers) work/s;

ii) turned off decanters; the evacuation of active sludge in excess is turned off.

Stage 4

Stage 2 is repeated.

Stage 5

Stage 3 is repeated.

Warning: stages 2 and 3 are repeated until the waste water from the reactor was treated at the level at which it needs to be evacuated from the emissary.

Stage "n"

Must be an aeration stage (idem stage 2).

Stage "n"+1

The stage for decanting and elimination of the treated water

i) the water is at a maximum level; the technological equipment is turned off; aeration is turned off; mixing is turned off;

ii) the decanter is turned off; the evacuation of active sludge in excess is turned off.

iii) the sedimentation of the activated sludge begins - a good activated sludge/viable immediately groups in large flocks forming a "sediment surface" which is clearly separated from the water without any sediment. This surface descends at the same time with the sedimentation.

iv) after 20,...,40 minutes of sedimentation the discharge of the decanted water starts from the top of the reactor. Thus, the sedimentation that continues under the decanter and the decanter discharge of treated waste water are overlapped.

The decanter is a floating ring that has in the middle (inner part) the aspiration of the decanted water. This is done from top to bottom to avoid disturbing the sedimentation. The evacuation may be done by gravity or by pumping. The pump can be set up under the decanter with the aspiration up, or outside the reactor as in the case of the commented project.

The level of the water goes down at the same time with the performance of the sedimentation and the evacuation of the decanted water.

This stage is finalized when the maximum level is reached.

Stage "n"+2

Elimination of active sludge in excess (NAEx.): the mixers are turned on for the homogenisation of the sludge; the pumping station for active sludge in excess in turned on; aeration turned off; decanter turned off at a minimum level. The level is slightly corrected because the eliminated NAEx. is little, compared to the inoculum level.

Stage "n"+3

Time out and waiting for the treatment cycle to start: the reactor is at a maximum level; the aeration is turned on once in a while in order to keep O_2 at values of 0.1,...,1 mg/l; the mixer is turned off; the decanter is turned off; elimination of NAEx turned off (Fig. 1).

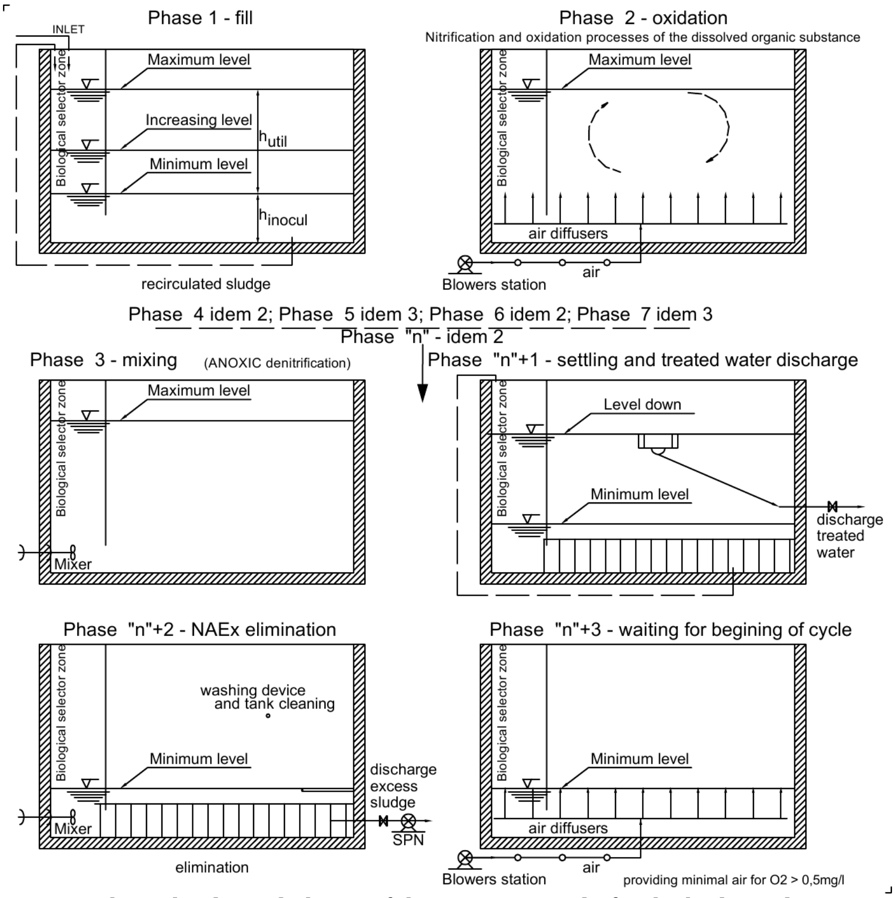

Fig. 1 – The technological phases of the treatment cycle for the biological reactors.

2.2. Case study - Waste Water Treatment Plant of Alexandria City, Teleorman County

a) *General information*

The limits of the analysed objective are:

a_1) uphill: Pumping station for the raw waste water (object that is part of the Treatment Plant);

a_2) downhill: Emissary - Vedea river.

For each stage of the treatment process the possibility of isolation of certain process units in case of emergency is foreseen by creating bypass pipes/canals.

The flow used influent in the Treatment Plant:

$Q_{\text{used or max}}$ = 394.00 l/s;

$Q_{\text{used day average}}$ = 15,638.00 m^3/day;

$Q_{\text{used day max}}$ = 19,613.00 m^3/day.

The influent flows in the Treatment Plant were established for two situations:

i)) during drought times;

ii) during rainy times.

During drought times

The hydraulic sizing was done for:

Primary stage

1 $Q_{\text{use or max}}$ = 0.394 m^3/s;

1 $Q_{\text{day max}}$ = 19,613 m^3/day.

Advanced secondary stage

1 $Q_{\text{day max}}$ = 19,613 m^3/day – hydraulic sizing (including compensations)

1$Q_{\text{day average}}$ = 15,638 m^3/day – sizing of the biological reactor – for loadings (the compensation $Q_{\text{day max}}$ and the allocation of the compensated flow on three lines of biological treatment).

During rainy times

The hydraulic sizing was done for:

Primary stage

The flow consists of :

1 × $Q_{\text{use or max}}$ = 0.394 m^3/s;

Q_{rain} = 1.2 m^3/s.

In this situation in the Treatment Plan may enter maximum 1.6 m^3/s, flows out of which 0.394 m^3/s $Q_{\text{use or max}}$ and maximum 1.2 m^3/s Q_{rain}, flow out of which 0.394 m^3/s will be technologically processed and the rest of 0.8 m^3/s will be discharged by direct by-pass to the emissary.

2 technological lines of 0.394 m^3/s each were created. The pluvial flow will be directed initially toward the tank for the collection of the pluvial flow (the first 15 minutes of rain) and the rest directly towards the evacuation (the trapezoidal canal from the premises).

Advanced secondary stage

Q_c = 1 × $Q_{\text{day max}}$ = 19,613 m^3/day – hydraulic sizing (including compensations)

Q_c = 1 × $Q_{\text{day average}}$ = 15,638 m^3/day – sizing of the biological reactor – for charges (the compensation $Q_{\text{day max}}$ and the allocation of the compensated flow on three lines of biological treatment).

Technological objectives foreseen for the technological line for the treatment for the waste waters (Fig. 2):

– pumping station for waste water (SPAU1 – existing);

– pumping station for pluvial flow (SPAU2 – new);

– rare and compact grills;

– desander and grease separator and blast engine unit;

– measurement of the entry flow and sample collection;

– preparation plants – dosage of the reagents for the precipitation of phosphor;

– retention tank for pluvial flow (BR);

– primary decanters (DP1, DP2);

– overflow room;

– primary decanter with compensation role DP3 (BC1);

– tanks with activated sludge (biological reactors – RB);

– pumping group related to the biological reactors;

– preparation plants – dosage of the reagents for the precipitation of phosphor;

– blast engine unit for (biological reactors SS-RB);

– distribution chamber for the secondary decanters (CD);

– secondary decanter with compensation role DS1;

– secondary decanter with compensation role DS2;

– sample collection point for the treated waste water (CPP);

– discharge system in the emissary and in the discharge.

From the entire technological line the work presents only the stage of biological treatment (secondary advanced) (Klauss *et al.*, 1998; Robescu *et al.*, 2011; Crețu, 2008).

b) Biological Treatment Stage

From the primary decanters, (DP1, DP2) the decanted waste water arrives in the discharge room CD, from where a $Q_{\text{use or max}}$ enters in the compensation tank BC1 and a $Q_{\text{use or max}}$ is evacuated towards the evacuation collecting existing within the unit and is then directed towards the emissary.

From the compensation tank (when the maximum level is reached) one of the 3 biological reactors will be supplied alternately (sequentially). The compensation tank (it compensates the flows because the biological reactors work discontinuously) from where the waste water reaches the sequencing biological reactors, where the biological treatment takes place, is a modified purifying technology with activated sludge.

In the compensation tank, in addition to the volumetric processes for flow compensation, the biological processes also take place, and are mainly anaerobic and fix the structure of the dissolved organic substances to be treated in the biological reactors.

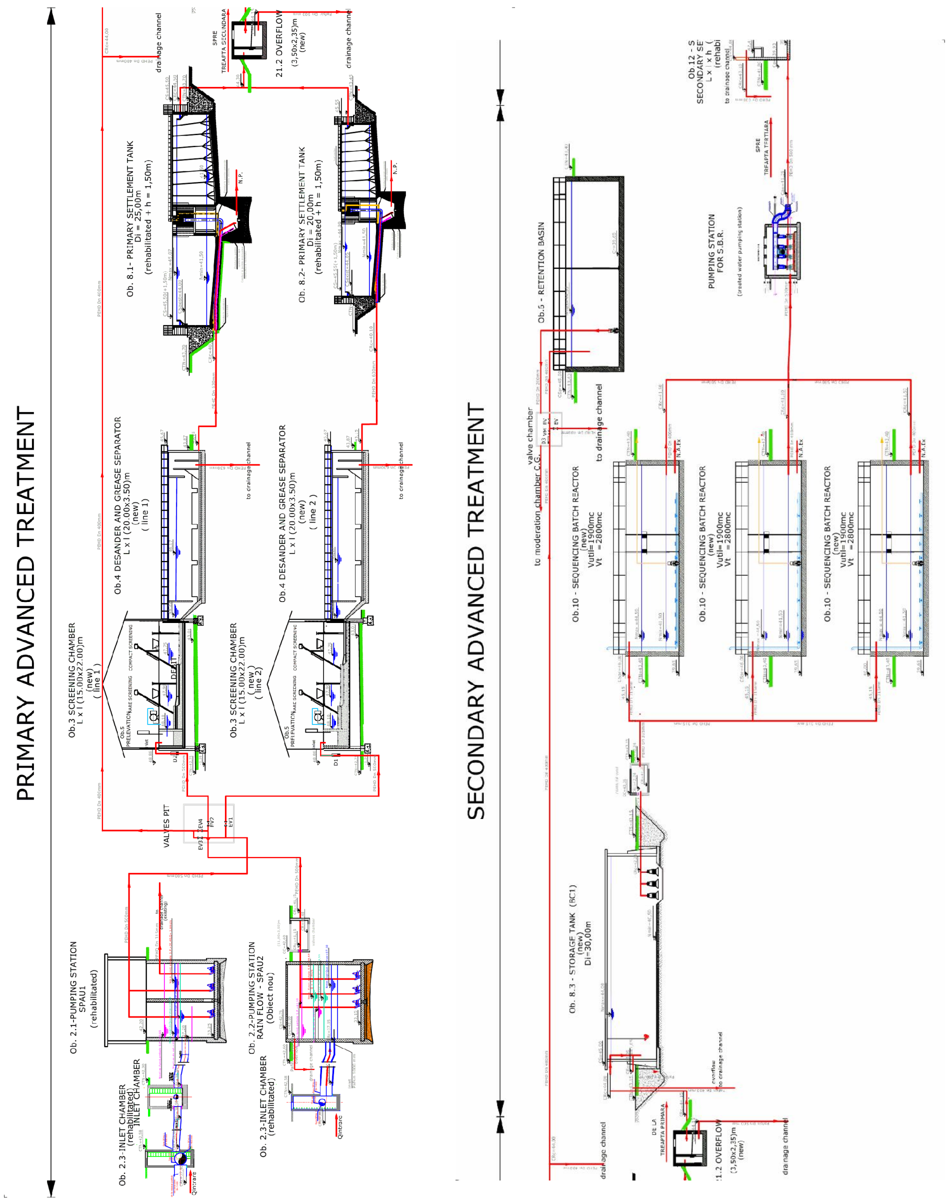

Fig. 2 – Technological line for the treatment for the waste waters.

The biological reactors (RB1, RB2, RB3) have a volume of 2/3 from the total volume of the tank. The water from the compensation tank reaches the biological reactors, where it has multiple cycles of biological treatment, and when the water is considered pure the activated sludge is sedimented and 2/3 of the total volume is discharged and 1/3 of the total volume will be biomass - activated sludge. Wastewater treatment technology with biological reactors is a discontinuous technology with sequencing operation.

A third of the volume of the reactor stays in the tank all the time and is called inoculums level (activated sludge volume).

The duration of an operating cycle of a biological reactor is of 8 hours / cycle water inlet-outlet and the volume of the reactor is of 1900 cubic m..

Thus, after the process of filling a reactor, the aeration processes start (through the diffuser) by turning on the blasts - the process of nitrification and oxidation of carbon.

Once this process is completed, the blasts are turned off and the mixers are turned on, creating an anox process (mixing - denitrification process).

These processes of aeration and then mixing are repeated until the treated waste water reaches the designed parameters.

In the final part the mixers are turned off stop and the sedimentation process (water decanting) takes place.

The evacuation of the treated water is achieved by means of decanters in flotation that remove water from the top up to 1/3 (activated sludge volume) of the total volume of the reactor.

After the biological treatment, the treated waste water can be discharged directly to the emissary. When the temperature of the treated waste water is less than 12 C° the treatment process is extended in order to reduce the amount of organic nitrogen. In this case, the water treated in the biological reactors is of further chemically treated with chlorine based reagents and the role of the secondary sedimentation tank will be of retention.

The water from the secondary decanters, with a role of retention tanks, will also get into the discharge canal and from here, through the canals and pipes, in the discharge mouth - emissary, Vedea River.

Primary settling tank DP3 (BC), with compensation role

The compensation of the uphill flow by the biological reactors is done in a new tank, of reinforced concrete, executed semi-buried, with a diameter of D_i = 30.00 m and with a useful volume of 2,500 m^3.

From the primary decanters part of the decanted water, respectively $1 \times Q_{\text{use or max}} = 0.40$ m^3/s, arrives by gravity in the compensation tank, and $1 \times Q_{\text{use or max}} = 0.40$ m^3/s will be evacuated through the collecting canal existing within the unit, towards the emissary.

The role of this tank is to accomplish the compensation of the flow from $Q_{\text{use day max}}$ = 19,613.00 m^3/day, (at the exit from the discharge room), at the flow $Q_{\text{use day average}}$ = 15,613 m^3/day, at the entry in the biological stage of purification.

Based on the hourly distribution of the influent flow in the biological stage of purification, resulted a compensation volume of 2,500 m^3, for a total of 3 biological reactors, with a number of 3 cycles of 8 hours/day.

The compensation tank is a new construction made of reinforced concrete, of circular shape in plane and with a total depth of the tank of 4.50 m (Figs. 3 *a* and 3 *b*).

The water inlet into the tank is made through a pipe Pafsin Dn 500 mm, the share of the foundation frame of the pipe at the entry into the tank is of CRc = 44.00.

The share of the maximum level of the water in the tank is N_{max} = 44.00, of the minimum level N_{min} = 40.50, resulting an useful depth of 3.50 m.

The submersible electropumps for wastewater were installed in a shaped vessel near the wall of the basin, with sizes of 6.10 × 2.50 and depth of –1.00 m compared to the share of the foundation frame of the tank (CRb = = 40.50).

Also, a submersible mixer was installed in the tank, near its wall.

The functioning of the electropumps is done automatically, correlated with the needs of the technological flow.

The pumps ensure the filling of the biological reactor during the time required to achieve a biological cycle.

On the outer perimeter of the compensation tank a sidewalk of 60cm thickness is provided.

Fig. 3 *a* – Compensation tank.

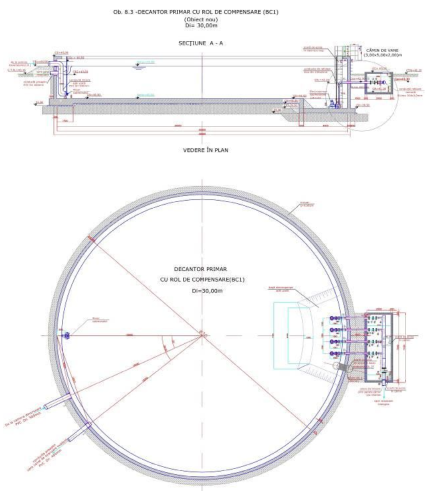

Fig. 3 *b* – Plan view and section BC.

Activated Sludge Tank (Sequencing Batch Reactors)

The functioning of a biological reactor is done as follows (Negulescu, 1978; Tobolcea *et al.*, 2015; ATV-DVWK-A 131E):

– if the reactor is empty and there is water in the compensation tanks, the electrovalve for the access of the water in the reactor is opened;

– the entering water is distributed uniformly in the two tanks of the biological reactor;

– when the water reaches the maximum sensor, the electrovalve is closed and the pump from the compensation tank is turned off;

– after filling in the tank the treatment process begins.

After the biological treatment is completed, the water is decanted in the same reactor and then discharged in the same reactor towards the emissary. When the temperature of the waste water in the bioreactor is low (below 12°C) the process for the elimination of the organic nitrogen through the alternation nitrification – denitrification cannot take place. In this case a prolonged oxidation (through aeration only), after which a part of the organic substances containing nitrogen forms may be reduced in a tertiary stage, by introducing chlorine with the dual purpose: disinfecting and reduction of the organic substance.

The tanks have a reinforced concrete structure and were made on the current location of the activated sludge tank, the technical expertise allowing the use of existing external structure of the basin as lost shuttering for the new structure.

The division of the new structure was made as follows (Figs. 4 *a* and 4 *b*):

– 3 compartments for the biological reactors (RB1, RB2 and RB3), 25.00 × 25.00 m;

– 1 compartment for the retention tank BR, 25.00 × 25.00 m.

Fig. 4 *a* – Biological reactor.

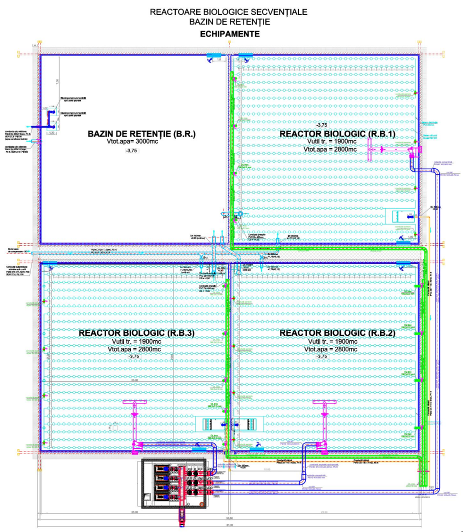

Fig. 4 *b* – Plan view – RB.

From the compensation tank (when the maximum level is reached), one of the three biological reactors will be supplied alternatively (in turn).

The compensation tank (compensates the flows, as the biological reactors work discontinuously), from where the waste water penetrates into the sequential batch reactors, where the biological treatment takes place, a modified purification technology with sludge (Tobolcea *et al.*, 2010; Tobolcea *et al.*, 2013).

The biological reactors (RB1, RB2, RB3) have a useful volume of 2/3 from the total volume of the tank. The water from the compensation tank penetrates into the biological reactors where it bears several cycles of biological treatment, and when the water is considered to be purified, the sludge is deposited and 2/3 of the total volume is discharged with treated water, while 1/3 of the total volume is due to remain as biological biomass - sludge.

The purification technology of waste water with biological reactors is a discontinuous technology with sequential functioning. A third of the reactor's volume remains all the time in the tank and it is named inoculum (volume of the sludge).

The duration of a functioning cycle of a biological reactor lasts minimum 8h/inlet-outlet water cycle, and the useful volume of a reactor is about 1,900 steres.

The surface of the terrain occupied by the RB plant is smaller than the ones with sludge, as a secondary decanter tank is not required

Blast Engine Unit

The building where the blast engine unit related to the biological reactors is an compartment of the technological hall, with sizes of 12.00 × × 10.00 m.

In the chamber of the blast engine (Figs. 5 *a* and 5 *b*) are located the blasts necessary for the biological reactors:

a) number of active units: 3 pc;

b) number of back-up units: 1 pc.

The blast system and the aeration system allow the usage of the back-up capacity of the blasts at higher charges then the designed capacity of the station. (Negulescu, 1978; NP 133-2013; ATV-DVWK-A 131E).

A number of 3 active blasts and a back-up one were foreseen, with a capacity established according to the process calculation of 6,000 Nm^3/h. A complete blast plant was installed in order to supply with air the compartments of the biological reactors. A number of 4 blasts, of rotating piston type, are installed in order to supply with air the aired compartments. One of the blasts is in stand-by.

Fig. 5 *a* – Blower System.

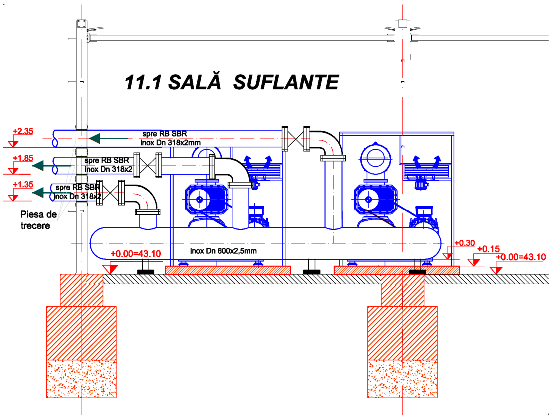

Fig. 5 *b* – Blower System-section.

c) *Secondary Settling Tanks*

Secondary Settling tanks work as reaction tank when the water temperature drops under 10°C. The rest of the time they are empty. Secondary settling tanks (DS1 and DS2) are radial and horizontal type with the diameter D_i = 35.00 m each. Secondary settling tanks work also as compensation volume and Chemical reaction for downstream flow of biological reactor.

3. Conclusions

The particular advantage of biological treatment SBR is that he has great flexibility to adapt to the flow fluctuations and to variaty of pollutant concentration in wastewater, feature of discharges from small amout of people.

Another advantage is the lower cost with 25%,...,40% compared to the systems with active sludge. The sludge production is also much lower and the sludge stabilized can be obtained by discharging the excessive sludge from the primary oversized Settling tanks with a smaller volume, due to the thickening.

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TEHNOLOGII MODERNE ÎN LINIA DE TRATARE A APELOR UZATE DIN CADRUL STAȚIILOR DE EPURARE

(Rezumat)

Dezvoltarea programelor de finanțare a infrastructurii apei a condus la desfăşurarea unui amplu proces de retehnologizare şi/sau investiții noi ale stațiilor de tratare a apelor uzate.

Dezvoltarea durabilă în România cu referire la colectarea apelor uzate, opțiuni de tratare şi eliminare, este discutată în contextul recentelor investiții de infrastructură la scară largă.

Dinamica modificărilor tehnologice rezultată din apariția noilor soluții de tratare a apei uzate, suprapuse pe modificarea şi perfecționarea echipamentelor şi instalațiilor, generalizarea automatizărilor în conducerea proceselor tehnologice impune ca strict necesar conceptul de management tehnico-economic sustenabil.

Această lucrare prezintă o aplicație actuală în domeniul tratării apei uzate pentru investiții < 100 000 PE.

Studiul de caz analizat este o realizare a colectivului prin proiectarea investiției şi prezintă linia tehnologică de tratare a apei uzate din cadrul acestei stații, ce cuprinde treapta de tratare primar avansată, secundar avansată şi respectiv treapta terțiară.

Având în vedere prioritățile pentru sistemele avansate de epurare a apelor uzate în localitățile mici şi mijlocii din România, selectarea nivelului adecvat şi durabil de tratare trebuie să se bazeze pe considerente de sensibilitate ale emisarului şi evaluarea stării sale ecologice. Acest lucru poate fi realizat prin selectarea unui nucleu bun de indicatori DPISR (conform DPSIR-cadru - forțe motrice, presiune, status, impact, răspunsul utilizat de către Agenția Europeană de Mediu în activitățile sale de raportare) şi centrată pe fluxul de date şi informații de la monitorizarea raportării (lanț MDIAR - monitorizarea / date / informații / evaluare / raportare (MDIAR) ce reprezintă fluxul de date şi informații de la monitorizare la nivel național pentru raportarea la nivel european.