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Editors: ***Dr Slavko Arsovski,*** full professor
Faculty of Engineering, Kragujevac
Dr Miodrag Lazic, full professor
Faculty of Engineering, Kragujevac
Dr Miladin Stefanovic, associate professor
Faculty of Engineering, Kragujevac

Technical Editor: ***Snezana Nestic***
Faculty of Engineering, Kragujevac

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Vanja Sustersic[1)]
Dusan Gordic[1)]
Slobodan Savic[1)]
Jasna Glisovic[1)]

1) Faculty of Engineering, University of Kragujevac, Serbia{vanjas, gordic,ssavic, jaca}@kg.ac.rs

BIOLOGICAL FILTRATION IN WASTEWATER TREATMENT

Abstract: *Disturbances of ecosystem, caused by the discharge of untreated wastewater, have grown over time to such an extent that the treatment imposed as a necessity. During the wastewater treatment, the mechanical, biological, and if necessary, chemical purification is carried out.*
The biological treatment i.e., biological filtration of wastewater is described in the paper. The biofiltration process and operation of the biofilter are described in detail in the paper as well as calculation of thetricklingbiofilter and its 3D model.
Keywords:*Biological filtration, wastewater, biofilters, trickling filter*

1.INTRODUCTION

Modern man is increasingly occupied by environmental issues, but information about her condition and the changes are not always easily available. In particular, there is not enough discussion about whether and what each of us as an individual or interest group can do to stop or slow some negative impacts on the environment. Environmental influences on attitudes and personality of individual is inevitable.Only healthy and ecologically educated environment can enable the healthy survival of future generations.

A technological development in the world accompanied with a constant increase in population has led to increased needs and consumption of water. One of the most important issues today is the quality of water and its availability. The current state of water in Serbia is the result of lack of investment, lack of concern about this resource and lack of understanding of its importance.

It is necessary to build 434 urban systems capacity of over 2,000 population equivalent (PE) in Serbia. The facilities for treatment of wastewater are built only in 26 cities in our country.When the analysis in relation to the number of residents whose homes are connected to the sewage system is performed, the situation in this area is even more disturbing, because in relation to the total population, less than 10% Serbian population is covered by the sewerage system with the wastewater treatment [1].

2.WASTEWATER TREATMENT

Wastewatersrepresent thesetof complex compounds, and often it is possible to determine the toxicity of the complex wastewater only with biological tests of toxicity and thus determine the manner and extent of purification. In this way, a large savings are achieved in the design phase and during operation of treatment systems.

The most common methods of wastewater treatment are:

- Mechanical pre-treatment,
- Physico-chemical treatment and
- Biological treatment.

Procedures that are based on the removal of impurities from the water (the difference in specific weight, shape, weight, etc.) are called mechanical treatment,and theiroperating principle is based on the action of physical forces (gravity, pressure, etc.).These procedures are the basis of the so-called pre-treatment and primary treatment process as well as individual stages of the secondary and tertiary processes of the wastewater treatment.

Physico-chemical methods of water treatment include coagulation and flocculation, flotation, adsorption, ion exchange, aeration and similar methods.

Biological wastewater treatment involves removal of dissolved organic matter and not depositing colloidal particles. In the system of waste water, the biological treatment is carried out as a secondary treatment, after mechanical or primary treatment. Biological treatment can also occur as an independent process [2].

Today, in Serbia, 80% of the population is not connected to the sewage system that includes a wastewater treatment plant (WWTP). 11% of Serbia's population is connected to the biological treatment of wastewater, 0.1% is connected to mechanical treatment, while 4.5% of population still waiting for the construction of biological purifiers. 2.5% of population is in anticipation of the construction of mechanical purifiers. Serbia has 37 central plants for wastewater treatment, but only 12% of municipal wastewater is treated [3].

2.1 Biological processes

The biological processes of water treatment can be carried out as aerobic and anaerobic, with the help of aerobic or anaerobic microorganisms. There is a difference in the way of biological oxidation of organic material.

Aerobic processes are used for treatment of water with small and medium concentrations of organic matter and anaerobic for water with high organic load. Aerobic processes are far more represented in wastewater treatment.

Aerobic processes can take place in two ways:

- with suspended microflora (with activated sludge), and
- with immobilized microflora on an inert carrier(biological filtration).

During aerobic biological treatment is necessary to provide a sufficient amount of oxygen (to achieve a large contact surface water-air).

Lagoons and shallow pools have a large surface area, thus providing oxygen intake. In the pools with activated sludge, the oxygen intake is carried out by blowing air or by mixing usingmechanical aerators, thereby increasing the contact surface.

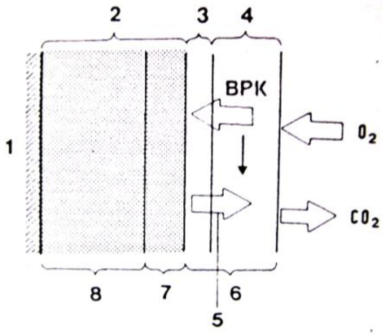
The large area of contact in biofilter is provided through the filter's filling across which the wastewater interflow, and a supply of oxygen is achieved by draftor blowing air [4].

2.2The process of biofiltration

In the biofiltration process,the organisms are placed on the filter medium, where the organic substances that they treated are brought, while in the activated sludge process, the organisms are brought to the organic matter in polluted water.In both cases, for the successful functions, it is necessary to ensure the aerobic condition in the life cycle of bacteria, as well as the required amount of organic matter that serves as food for these bacteria that perform its decomposition.

The biomembrane is formed on the filter's filling of the biofilter, consisting mainly of bacteria and fungi that feed on the organic matter in polluted water brought to the filters.Various microorganisms are also present in the biomembrane. During warm weather, sunlight allows the growth of algae on the surface of the filter's filling. The graphic display of the biological process in the biofilter is presented in Figure 1.

The amount of oxygen dissolved in the liquid is filled from the ambient air by absorption, and with the air in the cavities of the filter. The biomembrane, although very thin, is still anaerobic in the inner area. Therefore, regardless of the fact that the biological filtration is called aerobic process, it is essentially an optional process that includes the effect both aerobic, and anaerobic micro-organisms.



1 - Filter media; 2 - Biomembrane, 3 - Fixed water membrane, 4 - Mobile water membrane; 5 - Final products; 6 - Water membrane; 7 - Aerobic zone, 8 - Anaerobic zone

Figure 1 -The flow of the biological process in biofilter

2.3 Biological filters

Thebiofilter's filling consists of coarse-grained material or specially profiled plastic, a certain height (Figure 2).Wastewater is evenly distributed along the upper surface of filter's filling, and from thereinterflows downthrough the grains of the filling,under the influence of gravity, while the air flows freely through the free spaces in the filling.Depending on the hydraulic and organic loads, there are following types:

- The low loaded filters, which can be a favorable solution for smaller installations, have thedegree of elimination of $BOD_5$of about 95% in a single stage, with almost complete nitrification and the sludge stabilization;
- Heavily loaded filters, where the organic matters in the sludge are not stabilized, have the degree of elimination of BOD_5between 75 - 90% in a single stage, and to maintain sufficient water velocity in filter's filling,the recirculation of water is applied;
- Towers 5 - 20 m tallare used for the partial purification of organically highly loaded industrial wastewater, as the first stage in a multistep purification plant.

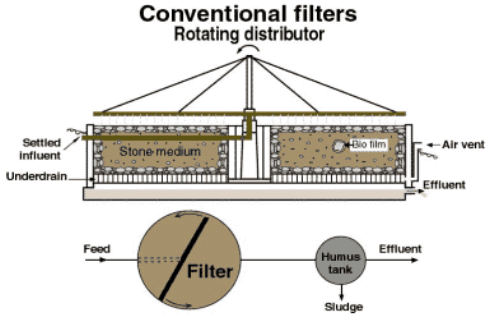


Figure 2 - Schematic representation of the biological filter

2.4 Problems of exploitation

Operation and exploitation of the biofilter, especially with gravel or gravel's fill are related to two main issues - the quality of the filtrate and the occurrence of unpleasant odors.Both problems are caused by the size of the organic load, the presence of industrial wastewaters and operation of the filter at low temperatures. Middle lowering effect of BOD of high-efficiency single-stage biofilter is approximately 85%. Therefore, in order to obtain a filtrate with output BOD valueof 30 mg/l, influent does not need to have a BOD more than 200 mg/l, which corresponds to the faecal waters.If there is the industrial water in urban polluted waters, it is necessary to predict the two-stage filtration system.

During the low-temperatures, the reduction of BOD drops significantly, so it is desirable to cover objects ofbiofilters with special overlays.

Due to the anaerobic processes taking place on the surface of the filter's filling, the final products of metabolism spread odors, especially in autumn and spring, when because of the changes in air temperature, its circulation through the body of the biofilter is reduced. In this respect, a special problem is industrially polluted water, especially from the food industry, when there is an overload of biological pollution and the emergence of strong odors.One way of dealing with this problem is artificial ventilation, but it normally increases exploitation costs.

The situation regarding the odor is much more favorable in biological towers. This is explained above all, with better aeration and a more balanced distribution of contaminated water at the surface of the plastic filling. Nothing less of a problem in these facilities is side effects during freezing temperatures.

3.MATHEMATICAL MODEL OF BIOLOGICAL FILTER

The biological filter, also called the trickling filter, is the oldest method of biofiltration (first carried out in England in 1893.).Trickling filters are often applied as an alternative, in case of small flow of waste water with activated sludge processes because of lower operating cost and simple operation - but they have a lower efficiency of the removal of pollution.Tricklingfilter consists of a carrier layer, which makes the filling of the filter, and which has high permeability. A thin layer of immobilized cells of microorganisms-biological film is formed on the carrier surface.Aeration is provided with the natural draft.

3.1 Calculation of the biological filter

As an illustration,the calculation of the biological filter is carried out forthe municipality Raca, which has 12,960PE (according to the census from 2002) i.e. 11,475 PE (according to the census from 2011), which corresponds to the selected technology. The calculation is done in the software Mathcad, while the 3D model is createdin the software CatiaV5R20.The biological filter with plastic filling (thickness 8 m) is chosen to the towen's wastewater treatment with characteristics given in Table 1.

Table 1 - Initial data for calculation

The average annual flow of household'swastewater Q	*8,164 m^3/d*
The flow of industrial wastewater	*3,500 m^3/d*
Total BOD_5 influent water from household	*240 mg/l*
BOD_5 influent water from households and industry	*520 mg/l*
The final $BOD_5$of the influent	*≤ 24 mg/l*
The value k at 26 °C and D = 6m [4]	*0.27 $(l/s)^{0,5}/m^2$*
Summer temperature (operating)	*20°C*
Winter temperature (operating)	*10°C*
The constant n	*0.5*

Eckenfelder's (1963) and Germain's(1966) formulas are used for the design of the biological filter with plastic fillings. Eckenfelder's equation is an exponential formula that describes the removal of the organic load as a reaction of pseudo-first-order, and Germain proposed the following reaction of the first order for the removal of organic pollutants in a biological filter with plastic fillings which, in essence, is a simplified form of the Eckenfelder's equation [5]:

$$S_e / S_i = \exp\left[-k_{20} D / q^n\right]$$

whereterms in the equation are:
S_e - soluble BOD_5 effluent, (mg/l)
S_i -soluble BOD_5 influent,(mg/l)
k_{20}-constant of the treatment correspond-ding to the filter's thickness at 20 °C,
D - filling thickness, (m)

q - input volumetric flow,
n- empirical constant dependent on the type of filter's filling.

Step 1. First, the value of the coefficient *k* which corresponds to the treatment at 20 °C, for a filling's thickness of 6 m is calculated:

$$k_{20@6} = k_{26@6} \cdot 1.035^{T-26} = 0.22\ (l/s)^{0,5}/m$$

Step 2. Then, the correction of value of constant *k*for the filling's thickness of 8 m is performed, using the equation:

$$k_2 = k_1 (D_1 / D_2)^x = 0.201\ (l/s)^{0,5}/m^2$$

Step 3. The total flow (Q) in summer is equal to the sum of the urban wastewater's flow and industrial waste water's flow:

$$Q = (8164 + 3500)\ m^3/d = 135\ l/s$$

Step 4. The filter's area, A, at the filling's thickness of 8m in the summer is calculated by the following formula:

$$S_e / S_i = \exp[-k_{20} D / q^n]$$

$$A = Q \cdot [-(\ln S_0 / S_i)/k_{20}/D_2]^{1/n}$$

$$A = 135 \cdot [-(\ln 24/520)/0.201 \cdot 8]^{1/0,5} = \\ = 493.936\ m^2$$

Step 5. Calculation of the area ofbiological filter with filling's thickness of 8 m during the summer at a temperature of 10 °C, corresponding to the standards prescribed for effluent is done by calculating the k_{10} for filling's thickness of 6 meters:

$$k_{10@6} = 0{,}27\ (l/s)^{0.5}/m^2 \cdot 1.035^{10-26} = \\ = 0.156\ (l/s)^{0,5}/m^2,$$

then the correction of k_{10}values for filling's thickness of 8 m is done:

$$k_{10@8} = 0.156\ (l/s)^{0.5}/m^2 \cdot (6/8)^{0,3} = \\ = 0.143\ (l/s)^{0.5}/m^2$$

The flowQ is:

$$Q = 94.491\ l/s,$$

arequired area, A, for filling of 8 m:

$$A = 94.491[-(\ln 24/240)/(0.143 \cdot 8)]^2 = \\ = 383.68\ m^2$$

Step 6. Required projected volume is controlled by summer conditions. Since the required area for the summer period is larger, the required projected area is 493.936 m^2.

Step 7. Total hydraulic load q_t:
a) For the summer period is:

$$q_t = \frac{Q}{A} = \frac{11664\ m^3/d}{493{,}936\ m^2} = \\ = 23.614\ m^3/(m^2 \cdot d),$$

b) For the winter period:

$$q_t = 16.528\ m^3/(m^2 \cdot d)$$

Step 8. Organic load of BOD has value:
a) For the summer period:

$$V = 8\ m \cdot 493.936\ m^2 = 3951\ m^3$$

$$BPK = \frac{11664 m^3/d \cdot 520\ g/m^3}{3951\ m^3 \cdot 1000\ g/kg} = \\ = 1.535\ kg/(m^3 \cdot d),$$

b) For the winter:

$$BPK = \frac{8164\ m^3/d \cdot 240\ g/m^3}{3951\ m^3 \cdot 1000\ g/kg} = \\ = 0.496\ kg/(m^3 \cdot d).$$

Step 9.Reqiureddosing speed (*cm/position*) of atrickling filter's hand can be approximately determined by multiplying the BOD load in kg/m^3 with a correction factor of 0.30.

Dosing rate is:
a) For the summer:

$$DR = 1.535 \cdot 0.3 = 0.46 cm/hod.$$

Using two hands in a rotary distributor α = 2, the rotational speed is obtained:

$$n = \frac{0{,}00044 \cdot q_t}{\alpha \cdot (DR)} = 0.011\ o/\min,$$

b) For the winter:

$$DR = 0.496 \cdot 0.3 = 0.419\ cm/hod$$

$$q_t = 16.528\ m^3/\left(m^2 \cdot d\right)$$

$$n = \frac{0.00044 \cdot q_t}{\alpha \cdot (DR)} = 0.024\ o/\min .$$

Figure 3 shows the 3D model of the biological filter designedin software CatiaV5R20.

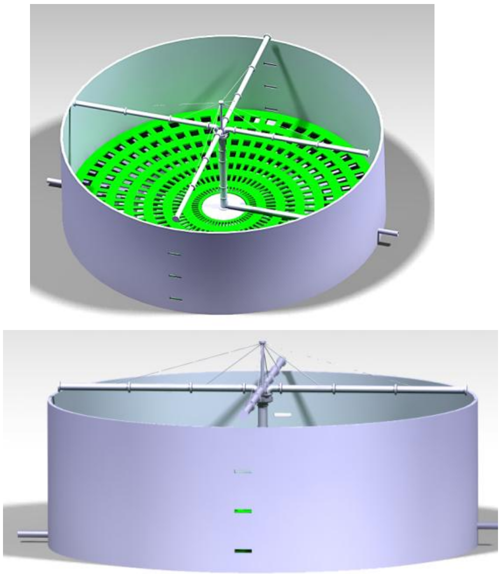


Figure 3 - 3D model of the biological filter

5. CONCLUSION

In addition to reducing the amount of water available today, the world is in danger of long-term pollution of existing reserves. Every year, Mediterranean countries are the final destination of about 120,000 t of mineral oil, 12,000 t of phenol, 60,000 tons of detergent, 100 tons of mercury, 3,800 t of lead, 2,400 t of chrome, 21,000 t of zinc, 320,000 t of phosphorus, which is simply poured into the river, sea and other water surface. All these substances are very slowly diluted with clean water from nearby streams and sea.The solids, in contrast, require an extremely long period of time for decomposition in the water - from a few weeks for the paper packaging, up to several hundreds of years for plastics.

Since the biological filtering is the procedure that is mainly used for smaller settlements'swater purification and pre-treatment of certain industrial wastewater, this is the right technology that should be used where the central wastewater treatment plant (WWTP) is profitable from techno-economical aspect, because the purification of small villages'swastewater isthe hardest solvable problem, especially bearing in mind that data shows that this is by far the largest group of polluters in the country.

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