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Structural Measures to Improve the Efficiency of Biological Wastewater Treatment Plants

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Preliminary note

The purpose of this paper is to test of certain structural measures to improve the efficiency of the biological wastewater treatment plants by preliminary adding of oxygen to fresh wastewater and rising of the pre-treatment level. The paper compares the possibilities of increasing the oxygen content in wastewater by hydraulic jet, and by straining through a percolator with draught. The comparison is based on results obtained by testing on physical models in laboratory conditions. In both cases, several scenarios were analyzed, with different combinations of structural and hydraulic parameters (number of discharge outlets, outlet size, jet velocity and angle, size of percolator padding, etc.). Based on determined results of dissolved oxygen input (increment of dissolved oxygen concentration), the percolator was selected as the element of higher efficiency and applied on the pilot biological plant for treatment of sanitary wastewater.
Based on determined efficiency of wastewater treatment during the period of two years, interpolation of the percolator as pretreatment of wastewater in biological treatment plants may be assessed as justified and useful solution.

Keywords
Aeration
Biological reactors
Hydraulic jet
Percolator
Treatment
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Ključne riječi
Aeracija
Biološki spremnici
Hidraulički mlaz
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Prokapnik
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Konstruktivne mjere poboljšanja učinkovitosti uređaja za biološko pročišćavanje otpadnih voda

Prethodno priopćenje

Cilj je ovoga rada ispitati određene konstruktivne mjere poboljšanja učinkovitosti uređaja za biološko pročišćavanje otpadnih voda, u smislu osiguranja prethodnog obogaćivanja svježe otpadne vode kisikom i stupnja prethodnog pročišćavanja. U radu je izvršena usporedba mogućnosti obogaćivanja otpadne vode kisikom pomoću hidrauličkog mlaza i procjeđivanjem kroz prokapnik s nategom. Usporedba se bazira na rezultatima dobivenim ispitivanjima na fizikalnim modelima u laboratorijskim uvjetima. U oba slučaja, ispitan je veći broj scenarija s različitim kombinacijama konstruktivnih i hidrauličkih parametara (broj izlijevnih mjesta, veličina izlijevnog mjesta, brzina i kut upada mlaza, veličina ispune prokapnika, visina natege). Na temelju utvrđenih rezultata unosa otopljenog kisika (prirasta koncentracije otopljenog kisika), prokapnik je odabran kao element veće učinkovitosti te je primijenjen na pilot uređaju u funkciji pročišćavanja sanitarnih otpadnih voda.
Na temelju utvrđenih učinkovitosti pročišćavanja otpadne vode tijekom dvogodišnjeg perioda interpolacija prokapnika u funkciji predtretmana otpadnih voda kod bioloških uređaja može se ocijeniti opravdanim i korisnim rješenjem.

1. Introduction

Biological treatment of wastewater in the present time represents an unavoidable segment in the process of active wastewater management. Biological treatment includes, first of all, aerobic processes of decomposition of organic matter in variously shaped biological reactors (conventional bioreactors, lagoons, stabilization pools, constructed wetlands). Accordingly, the essential parameter of successful and efficient operation of biological plants is to provide providing of adequate quantities of dissolved oxygen in biological reactors.

Conventional forms of aeration imply natural processes of photosynthesis and dissolving of oxygen from the atmosphere. However, they do not provide sufficient oxygen for constant maintaining of aerobic conditions in biological reactors. Forced (artificial) aeration contributes to an increase of the oxygen

Symbols/Oznake

Φ	– diameter, mm – promjer
BPK$_5$	– biological oxygen demand in 5 days, mg/L – biološka potrošnja kisika u 5 dana
C_b	– Oxygen concentration in the biological reactor, mgO_2/L – koncentracija kisika u biološkom reaktoru
C_s	– concentration of 100 % oxygen saturation, mgO_2/L – koncentracija kisika 100 %-tne zasićenosti
C_u	– oxygen concentration in the entrance chamber, mgO_2/L – koncentracija kisika u ulaznoj komori
ΔC	– increaseof dissolved oxygen, mgO_2/L – povećanje koncentracije kisika
E	– efficiency of water enriching with oxygen at measured temperature – učinkovitost obogaćivanja vode kisikom pri radnoj temperaturi
E_{20}	– efficiency at water temperature of 20 °C – učinkovitost obogaćivanja vode kisikom pri 20 °C
f	– temperature correction factor – temperaturni korekcijski faktor
H	– height, m – visina
k	– filtration coeficient, m/s – koeficijent filtracije
Q	– flow, m^3/d – protok
T	– temperature, °C – temperatura

content in reactors and constant aerobic conditions, with accelerating and improvement of the treatment process. In conventional wastewater treatment systems, forced aeration is achieved in various ways, such as submerged jets, diffusers, mechanical aeration, etc. Their common property is the need for an external power source, which in turn results in higher costs of construction, operation and maintenance. This aspect is particularly pronounced in small capacity treatment plants, typical for minor rural communities with lower economic potential. Therefore, efforts are made to consider and analyze other possibilities of increasing the oxygen level in wastewater by certain structural measures. In cases where available energy in the form of pressure potential can be used (e.g. in hilly and mountainous areas), certain structural measures may contribute to increasing the oxygen content.

So far, a number of investigations have been carried out trying to determine the efficiency of different hydraulic structures and relevant parameters regarding increase of oxygen content in water systems. The influence of various shapes of sharp-edged spillways on aeration, and the influence of percolation through porous padding (passive aeration pumps) on increasing of oxygen content in water was also investigated [1-2]. Also, numerous results have been published regarding the jet effect on oxygen introduction into water systems [3-8].. In most cases investigation was conducted with clear water due to avoiding possible influence of biological activity [9].

For the purpose of this analysis, experimental tests were carried out in laboratory conditions. Two physical models were established, describing the hydraulic jet and water percolation through porous padding (percolator), and their influence on aeration was discussed. The possibilities of application of the percolator for additional introduction of oxygen into water are discussed in papers [10-11].

In addition to determining the justification of applying the discussed structural measures (hydraulic jet and percolator) as pretreatment or preliminary increasing of oxygen content in fresh wastewater, the intention of physical tests was to find optimum combinations of parameters to achieve maximum level of aeration. Based on the results of physical modeling, the solution that resulted in larger increment of dissolved oxygen concentration was chosen.. The perocolartor with draught was applied on the biological pilot treatment plant treating sanitary wastewater, and its role was monitored as one of the forms of pretreatment in the entire treatment process. In this, the quality of wastewater was analyzed (dissolved oxygen, BOD_5, NH_4, NO_2, NO_3) on the inlet and outlet from the applied structural measure.

2. Physical modeling

Two physical models were built for the purpose of analyzing of the influence of a hydraulic jet and percolator on the oxygen content in biological reactors. The objective of physical modeling was to determine the dependence of the increment of dissolved oxygen content on various values of structural and hydraulic parameters (number of outfalls, size of outfall points, jet velocity and angle, size of percolator padding, draught height, etc.). The intention is to achieve optimum conditions for aeration and wastewater treatment by defining of optimum values of variable structural parameters. For modeling purposes, clear water from public water supply was used. The basic reasons are simplicity of modeling and avoidance of non-uniformity of overloading of water entering the model.

2.1. Physical model of hydraulic jet – description of the model and the measurements

The components of the model are: the entrance chamber, specially shaped outflow element and biological reactor (Figure 1). The range of analyzed discharges was 1.5 to 2.5 L/s. These discharges correspond to the quantity of wastewater for a community size of 1300 – 2100 inhabitants (with assumed specific inflow of wastewater of 100 L/d per household).

In selection of pipe profile sizes, attention was paid to achieving as high jet velocities as possible, with simultaneous reduction of the risk of pipe blocking (as wastewater contains a portion of solid substances). Higher jet velocities result in deeper penetration into the water column of the biological reactor and in higher turbulence. The final effect is higher increment of dissolved oxygen concentration in the biological reactor. Assuming that the first stage of treatment is achieved, which implies clearing up of wastewater, i.e. removal of suspended solids, oils and fats (septic tanks, settling tanks, etc.), the minimum allowed profile of outflow elements is Ø28 mm. Pipes of inner diameter Ø28 and Ø50 mm were chosen.

The objective of measurements was to determine the effect of the hydraulic jet on efficiency of adding oxygen to (waste) water. The purpose of regulation of individual parameters on the outflow element was due to determining the optimum structural form which will result in the highest increment of oxygen in the biological reactor. The parameters that were changed during testing include the number of outflow points, internal diameter of outflow pipes, velocity and the angle of entrance of the hydraulic jet into the biological reactor. Each change was characterized as an individual scenario, and its results were processed separately. The total of 54 different scenarios was analyzed (Table 1). Different values of discharge on the model (within the limits of previously defined values) were achieved by different heights of filling the entrance chamber. The change of height causes a change of the pressure potential, and consequently of velocity and outflow discharge. In relation to discharges and selected sizes of outflow elements, the resulting velocities of the hydraulic jet were within the range of 0,75 to 4,1 m/s. The outflow velocity measuring was based on measuring

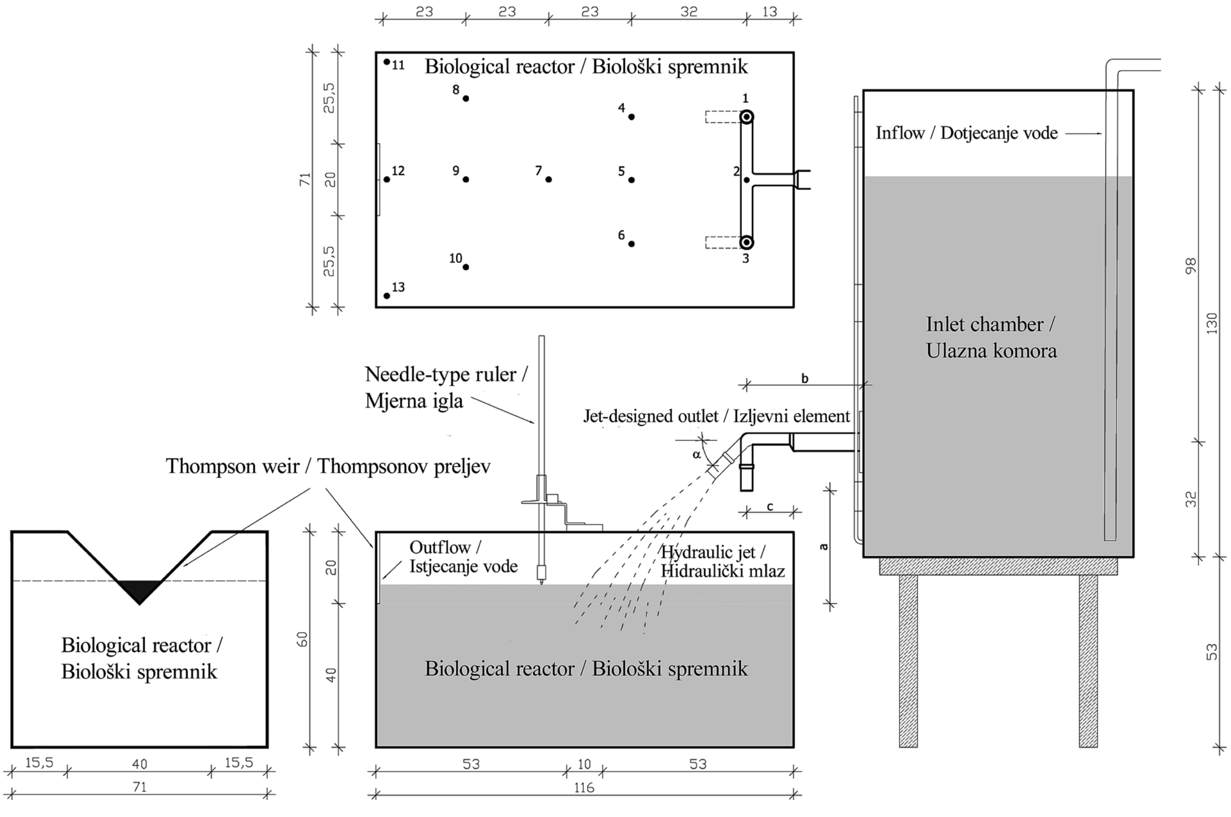

Figure 1. Physical model of hydraulic jet

Slika 1. Shematski prikaz fizikalnog modela hidrauličkog mlaza of discharge, using Thompson's overflow with a gauging needle.

Preliminary measurements of concentrations of dissolved oxygen in the entrance chamber showed negligible variations during the day, with values ranging between 5.50 and 6.75 mg O_2/L.

In relation to the size and shape of the biological reactor, 13 different measuring points were selected (Figure 1), at depths of 5.0 and 30.0 cm. Measuring points are common in all scenarios. In each scenario, measurements were taken four times at each measuring point (including preliminary measurement in the entrance chamber), which reduced the possibility of error. This additionally contributes to the reliability of results.

Table 1. Examined scenarios on physical model of hydraulic jet

Tablica 1. Ispitivani scenariji na fizikalnom modelu hidrauličkog mlaza

Scenario/ Scenario	Number of outfalls / Broj izlijevnih mjesta	Internal diameter of outlet pipes / Unutrašnji promjer izlijevnih cijevi, mm	Jet discharge / Protok mlaza, L/s	Jet angle / Kut upada mlaza, °
1 - 18	2	28	1,5; 2.0; 2.5	90, 75, 60, 45, 30, 15
19 - 36	1	28	1.5; 2.0; 2.5	90, 75, 60, 45, 30, 15
37 - 54	1	50	1.5; 2.0; 2.5	90, 75, 60, 45, 30, 15

2.2. Physical model of percolator with draught – description of model and measurements

The physical model of the percolator with draught consists of the vessel for water preparation, dosing vessel, percolator with draught, and the small basin. The water line diagram is shown in Figure 2. The nominal discharge of the line is 860 L/d (0.01 L/s). At nominal discharge, the percolator is cyclically filled and drained every hour. By estimates it was determined that one volume of water in the preparation vessel allows the cycle of 12 fillings and drainings.

The vessel (tank) where water was prepared for investigation purposes was supplied with water from the public water supply system. The water level in the tank varied during the tests. The minimum volume of water in the tank was 400 l. At the outlet, the vessel was equipped by a stop valve allowing cutting of water supply. Prepared water from the tank then went into the dosage vessel, equipped with a float to ensure equal hydraulic conditions downstream in the percolator. From the dosage vessel, water continued to run into the percolator with draught. The discharge was controlled by the system of fine level regulation. In the dosage vessel, dissolved oxygen concentration was measured before inflow into the percolator.

The percolator was constructed as a cylindrical vessel 0.5 m in diameter and 1.0 m high. The padding material (substrate) selected was gravel of various particle sizes. Hydraulic conditions of percolator operation were controlled by continuous inflow of water on the top of the substrate, and by periodic draining. Continuous inflow at nominal discharge filled the vessel during 1 hour period. When the vessel was filled with water to the level of the top of the draught, within approximately 2 minutes the vessel was drained by approximately 0.7 m, forming an unsaturated condition, which caused stoppage of the draught operation. The described process was repeated periodically each hour. In this case, aeration of water in the percolator was provided in two ways. In addition to aeration by spraying of water over the percolator substrate, causing dissolving of oxygen from the air, dissolving of oxygen also took place during the short period (2 minutes) with increased flow velocities during draining of the percolator.

Water inflow into the percolator, as well as the quantity drained, was measured volumetrically in the small basin into which the percolator was drained. In the basin, outlet concentrations of dissolved oxygen were measured as well.

The purpose of measurements was to determine the effect of the percolator on the efficiency of increasing the oxygen content in (waste) water. Tests were carried out to determine the optimum granulometric composition of the percolator padding and the optimum height of the draught, which will result in the highest increment of oxygen in the biological reactor. Each change of input values was characterized as an individual scenario, and the results were processed separately. A total of 66 scenarios was analyzed (Table 2). The substrate was rinsed before introduction into the percolator in order to remove residual sand and impurities which may block the pores and reduce the efficiency of the percolator.

To reduce possible errors, in each scenario the concentration of dissolved oxygen was measured three times, including preliminary measuring in the dosage vessel.

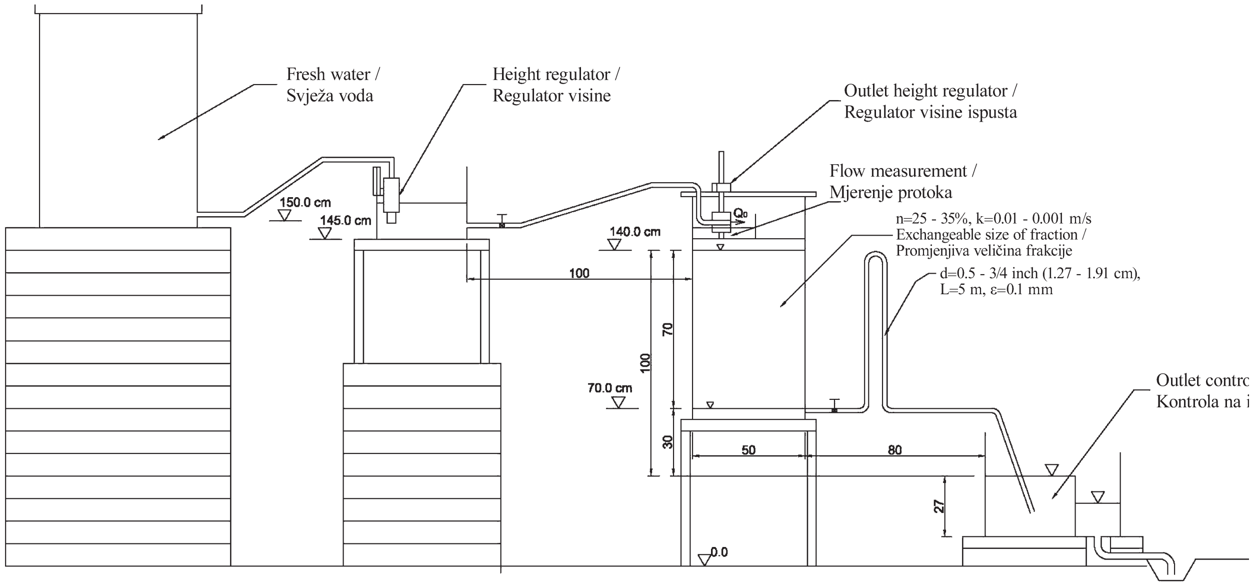

Figure 2. Diagram of physical model of percolator with draught
Slika 2. Shematski prikaz fizikalnog modela prokapnika s nategom

Table2. Examined scenarios on physical model of percolator with draught
Tablica 2. Ispitivani scenariji na fizikalnom modelu prokapnika s nategom

Scenario / Scenario	Granulometric texture of padding / Granulometrijski sastav ispune, mm	Draught height/ Visina natege, m	Discharge/Protok, L/s
1 - 22	G1: 4 - 8	0; 0,3; 0.5; 0.7	0.01; 0.014; 0.018; 0.022
23 - 44	G2: 8 - 16	0; 0.3; 0.5; 0.7	0.01; 0.014; 0.018; 0.022
45 - 66	G3: 16 - 32	0; 0.3; 0.5; 0.7	0.01; 0.014; 0.018; 0.022

Preliminary measuring of dissolved oxygen concentrations in the entrance chamber revealed negligible oscillations during the day, with values ranging from 5.75 to 6.65 mg O_2/L.

2.3. Methodology of determining efficiency of adding oxygen to water

For the purpose of analyses and comparison of discussed structural measures to provide preliminary adding of oxygen to fresh wastewater, their efficiency will be expressed by the equation [12]:

$$E = \frac{C_b - C_u}{C_s - C_u} \tag{1}$$

In the given mathematical formulation, the numerator represents the increment of dissolved oxygen ΔC (mg O_2/L) expressed as the difference between measured concentrations in the biological reactor (C_b) and in the entrance chamber (C_u). The value represented by the denominator describes the initial oxygen deficit expressed as the difference between the concentration of 100 percent oxygen saturation (C_s) and the concentration in the entrance chamber (C_u). The value C_s depends primarily on water temperature and partial pressure of oxygen in the atmosphere. Due to negligible changes of water temperature in the model (the source is the public water supply), the constant value C_s is assumed, read from the tables [13].

As the efficiency of adding oxygen to water is functionally dependent on water temperature and quality of wastewater, these factors should be taken into consideration as well. The dependence of efficiency on water temperature is defined by the following equation [12]:

$$1 - E_{20} = (1 - E)^{1/f}, \quad (2)$$

where E = efficiency of water enriched with oxygen at measured water temperature in the model, and E_{20} = efficiency at water temperature of 20 ºC. The exponent f is defined by the equation:

$$f = 1.0 + 0.02103\,(T - 20) + 8.261 \cdot 10^{-5}\,(T - 20), \quad (3)$$

where parameter T refers to measured water temperature. As mentioned earlier, clear water from water supply network was used for modeling purposes. In this way, major time irregularities of input parameters in the model were avoided, and additionally the influence of water quality on the extent of aeration may be neglected.

Adopting the value E_{20} as the output parameter of the analyses allows simpler comparison of discussed aeration methods or with results obtained in different conditions (different water temperatures, etc.).

3. Pilot plant – percolator witht draught in real conditions

The pilot plant – percolator with draught has been constructed on the left bank of the sewer mains (GOK) in Ivanja Reka. The investigated wastewater was from the main sewer consisting of an average of 1/3 of municipal wastewater and 2/3 of drain water.

The percolator with draught consists of a concrete vessel of circular cross-section, filled with the substrate of particle size 16 – 32 mm (determined on the basis of laboratory tests). The outer diameter of the percolator was ϕ 0.60 m, and the inner diameter was 0.5 m; the height was 1.25 m, and the reception tank is dug into the ground at -0.5 m. The height of the gravel substrate in the percolator is 0.7 m, porosity 0.3-0.35, with filtration coefficient of the gravel padding k=10^{-3} m/s. The volume of the effective part of the biological percolator with draught is 0.137 m^3.

Waterflow from the percolator to the reception tank went through the pipes PELD 20. The height of the draught was 0.3 m.

Testing on the pilot plant was carried out in the period of 2 years. Testing was done with three nominal discharge, as follows: 500, 1000 and 2000 mL/min (0.72 (A), 1.44 (B) and 2.88 m^3/d (C)). Wastewater samples were taken at the entrance into the percolator and in the reception tank. On measuring points, dissolved oxygen was measured in situ at 5 cm below water surface. Wastewater was collected in sterilized glass bottles with glass stoppers and immediately stored in portable refrigerator at a temperature of 4 ºC. After bringing of samples into the laboratory UST and BOD_5 were determined immediately, while determining of NH_4-N was done after thr filtration of the wastewater through a membrane filter (0.45 μm) by

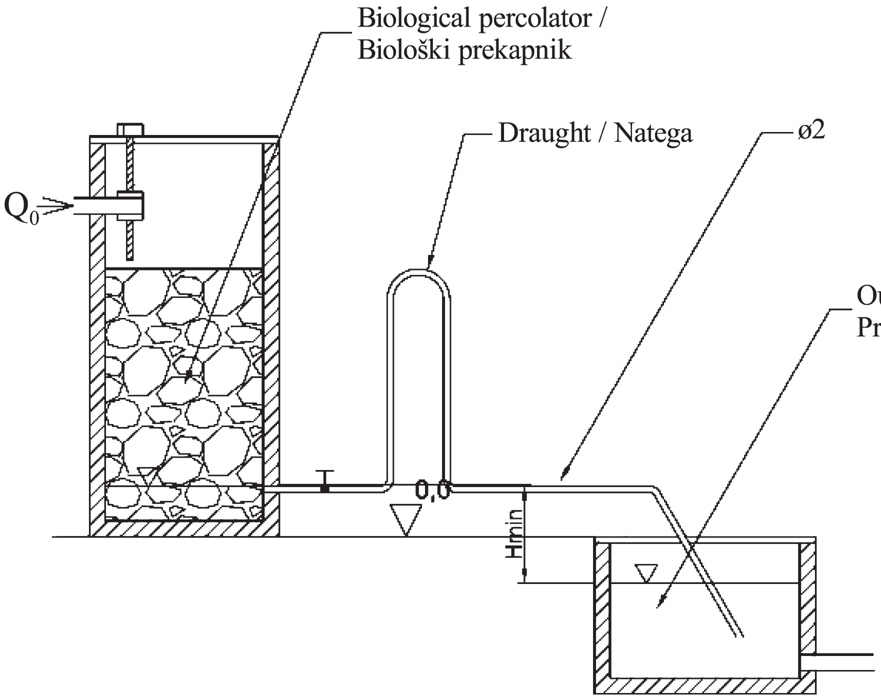

Figure 3. Percolator with draught

Slika 3. Prokapnik s nategom

a spectrophotometer HACH DR 2500 (Salicylate method Hach 8155). The BOD_5 was determined by incubation of diluted samples at 20 °C during 5 days. Concentration of dissolved oxygen was measured by oxymeter WTW Oxi 330i. Efficiency of individual parameters was calculated as percentage of removal of the parameter at the exit in relation to input concentrations of the same parameter.

4. Results and discussion

4.1. Results of physical modeling

4.1.1. Hydraulic jet

The results of measuring refer to measured values of concentrations of dissolved oxygen in the biological reactor. The measurements were used to determine the increment of dissolved oxygen after the action of the hydraulic jet, i.e. the efficiency of water enrichment with oxygen. On the basis of measuring of input and output values of dissolved oxygen concentration, the values E_{20} were calculated, using equations (1), (2) and (3). Water temperature of 12.7 ºC, determined by measuring, did not change during the analyses. In relation to measured value of temperature, the value of concentration of 100 oxygen saturation (C_s) read from the tables is 10.6 mg O_2/L.

The presented considerations refer to the results obtained at measuring point 12 (Figure 1). Results obtained by testing are presented in graphic form in Figure 4, 5 and 6. The tests determined that the structural form of the hydraulic jet has the strongest effect on water aeration in the biological reactor. Namely, such observation was expected, because reduction of the outlet pipe diameter results in an increase of the velocity of the hydraulic jet, which in turn causes stronger turbulence and deeper penetration of the jet in the water column in the biological reactor. This results in longer retention time of newly formed air bubbles in water and finally, in higher efficiency of enrichment of water with oxygen. Also, it has been noticed that the efficiency is dependent on the jet angle. In the given case, the highest efficiency is achieved at the jet angle of 45°, although the tests showed that the influence of the jet angle is not strictly determined, but is also related to the form of the outlet element (number and diameter of nozzles).

In accordance with the above, the best results of aeration of the biological reactor were achieved in the case of single outflow through the nozzle of inner diameter Ø 28 mm and the jet angle of 45° In the scope of the tests, maximum efficiency of enrichment of water with oxygen, E_{20}, at the discharge of 2.5 L/s is 0.62.

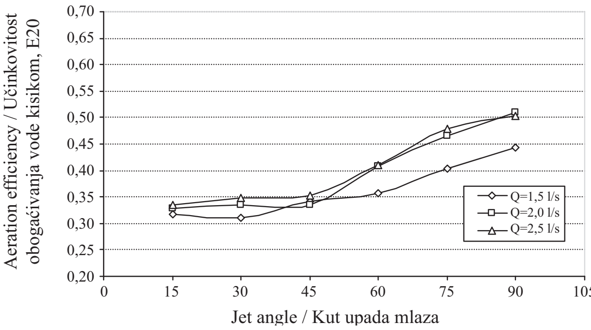

Figure 4. Dependence of the aeration efficiency on the discharge (jet velocity) and the jet angle (a) 2 × Ø28 mm

Slika 4. Ovisnost učinkovitosti prozračivanja o protoku (brzini mlaza) i kutu upada mlaza, (a) 2 × Ø28 mm

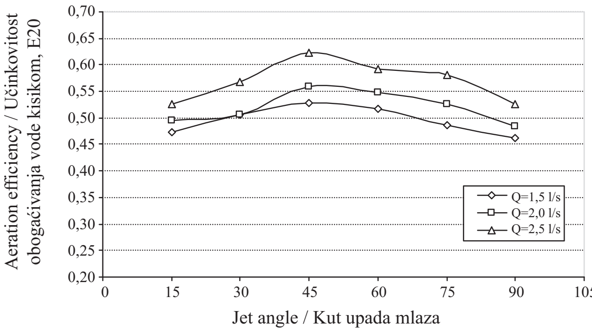

Figure 5. Dependence of the aeration efficiency on the discharge (jet velocity) and the jet angle (b) 1 × Ø28 mm

Slika 5. Ovisnost učinkovitosti prozračivanja o protoku (brzini mlaza) i kutu upada mlaza, (b) 1 × Ø28 mm

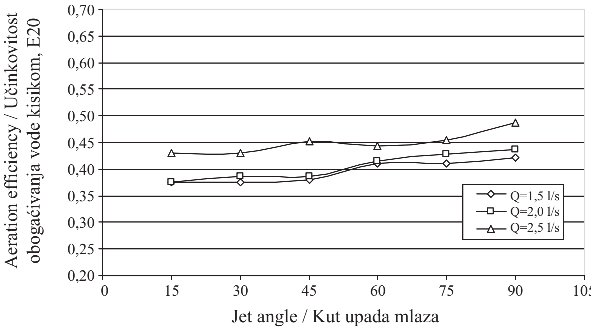

Figure 6. Dependence of the aeration efficiency on the discharge (jet velocity) and the jet angle (a) 1 × Ø50 mm

Slika 6. Ovisnost učinkovitosti prozračivanja o protoku (brzini mlaza) i kutu upada mlaza, (a) 1 × Ø50 mm

4.1.2. Percolator with draught

The results refer to the measured values of dissolved oxygen concentrations in outflow (control) basin. The measurements were used to determine the increment of dissolved oxygen after percolation through porous padding, i.e. to determine the efficiency of the percolator with draught. Based on measured input and output concentrations of dissolved oxygen, the values E_{20} were calculated, using equations (1), (2) and (3), identically as in the previously described case of the hydraulic jet. The water temperature of 11,9 ºC determined by measuring varied negligibly during the analyses (within ±0.1ºC). In relation to the measured temperature value, the value of concentration of 100 percent oxygen saturation (C_s) read from the tables is 10.8 mg O_2/L.

The presented considerations refer to the results obtained in the control vessel (Figure 2). The results obtained by tests are shown in graphic form in Figure 4. The tests show that increasing the particle size of the padding (substrate) improves the efficiency of adding oxygen to water. Thus, on the basis of the results, the highest efficiency of aeration may be noticed using substrate G3, granulometric texture 16-32 mm. The result is in accordance with expectations, because earlier investigations [11, 14] showed that reduced porosity (smaller substrate) results in higher resistance to the air, thus reducing the efficiency of the system. In trying out various scenarios, best results were achieved for smaller draught heights, at H=0 cm and H=30 cm. Also, it may be noticed that different degrees of efficiency are achieved depending on the changes of discharge. In the case of using substrate G3, which gives the best results, medium discharges resulted in higher increment of dissolved oxygen with passage of water through the percolator. Additional advantage of substrate of larger granulometric texture (G3) is reflected in reduced possibility of pore blocking in case of realistic operating conditions with percolation of the wastewater.

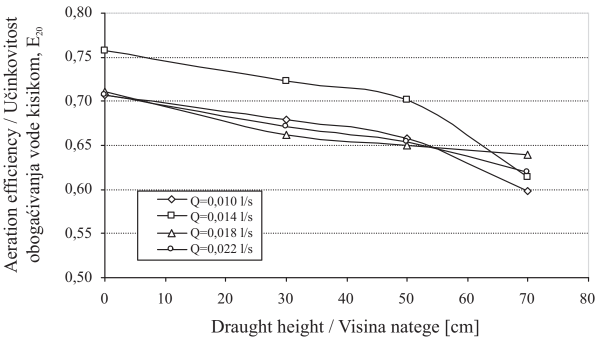

Figure 7. Dependence of the aeration efficiency on the type of the padding (substrate) and the draught height for substrate G1 (4-8 mm)

Slika 7. Ovisnost učinkovitosti prozračivanja o visini natege za ispunu G1 (4-8 mm)

The main oxygen distribution mechanism in the system is diffusion as concequence of partial pressure distribution inside the system. This occurance is notable due to unequal distribution of fresh air inside the substrate (granular media), and also due to the consumption by the microbial acitivitie [15]. Such a system provides for good interaction between the oxygen which tends to go up and the incoming water from the upper side, and the achieved result is maximized in transfer and use of oxygen and decreas of losses [11].

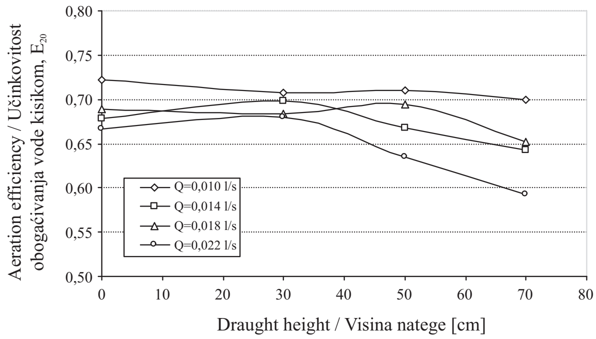

Figure 8. Dependence of the aeration efficiency on the type of the padding (substrate) and the draught height for substrate G2 (8-16 mm)

Slika 8. Ovisnost učinkovitosti prozračivanja o visini natege za ispunu G2 (8-16 mm)

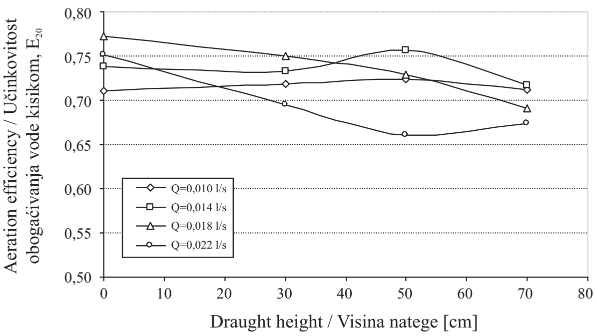

Figure 9. Dependence of the aeration efficiency on the type of the padding (substrate) and the draught height for substrate G3 (16-32)

Slika 9. Ovisnost učinkovitosti prozračivanja o visini natege za ispunu G3 (16-32)

4.2. Pilot plant - percolator with draught in real conditions

Based on analyzed data collected during investigations, it may be concluded that increased flow of wastewater through the percolator is followed by increased concentration of dissolved oxygen in wastewater, both at the entrance and at the exit. The highest concentration of dissolved oxygen was recorded at the discharge C (2.88 m^3/d), amounting to 1.3 mg O_2/L. At the same discharge, the fall of 65 of dissolved oxygen at the exit was recorded. At discharge B the oxygen consumption was highest (71 %).

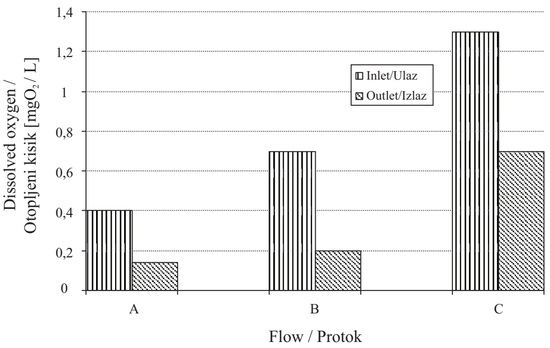

Figure 10. Concentration of dissolved oxygen (mg O_2/L) at entrance and exit of the percolator with draught at discharges A, B and C.

Slika 10. Koncentracija otopljenog kisika (mg O_2/L) na ulazi i izlazu iz prokapnika s nategom pri protocima A, B i C.

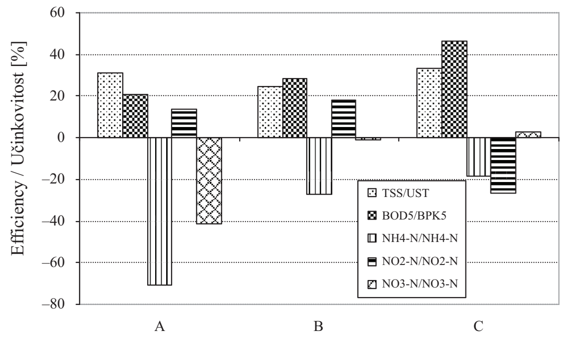

Figure 11. Efficiency of removal of TSS, BPK_5 and NH_4-N in the percolator with draught at discharges A, B and C

Slika 11. Učinkovitost uklanjanja UST, BPK_5 i NH_4-N na prokapniku s nategom pri protocima A, B i C

Passage of wastewater through the percolator with draught resulted, in all investigations, in increased values of NH_4-N, which may be attributed to ammonification of wastewater, as the result of comparatively high percentage of removal of BOD_5 (21 % at discharge A, 29 % t at discharge B and 46 % at discharge C). It is known that decomposition of organic matter containing proteins, or amino-acids, results in generation of NH_4-N originating from the amino group of amino-acids, which is proved by the obtained results on increasing of NH_4-N concentration (Figure 11.). The results indicate the presence of aerobic microbiological decomposition of organic matter in the percolator. Although nitrification is an aerobic process nitrifying bacteria are autotrophic microorganisms with a lower rate of respiration compared to heterotrophic species which decompose organic substrates, and therefore the efficiency of NO_2-N removal was relatively low [14]. At discharge C, the highest concentration of dissolved oxygen in the percolator was ensured, which resulted in high efficiency of removal of BOD_5 (over 40 %) and the nitrification process.

5. Conclusions

On the basis of conducted research on two physical models – hydraulic jet and percolator with draught, it is observed that the use of both structural elements has resulted in an increase of oxygen content in the water.

Better results were achieved with the percolator with draught, and therefore it was implemented as a pretreatment module at the pilot wastewater (biological) treatment plant. The results on the pilot plant (percolator module) have shown satisfying treatment efficiency in organic matter removal (BOD_5) from wastewater of up to 45 %. Regardless of the rather low oxygen concentration recorded at outlet, the structure and hydraulic manipulation inside the percolator enable the sufficient oxygen supply necessary for microbial aerobic processes.

Developed process of nitrification which was also recorded during the investigated period, also confirm that the analyzed structural element – percolator with draught might be considered as adequate pretreatment module for biological treatment plant.

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