DISCRETE-PULSED ENERGY INPUT IN WASTEWATER TREATMENT TECHNOLOGIES

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Wastewater treatment is an important environmental problem of the national economy of any country. Therefore, increasing the efficiency of wastewater treatment through the use of innovative technologies and equipment is becoming relevant. Basically, for the biological treatment of wastewater from organic and biogenic pollution, aerotanks with different aeration systems are used. The aeration and mass transfer of the mixture of waste water and activated sludge accounts for up to 80 % of operating costs. The article deals with the problems of using thermal physics in wastewater treatment by intensifying the mass transfer process and accelerating the biological oxidation reaction. The intensification occurs due to the impact on the treated medium (waste water) of the input energy by the discrete-pulse method. The method is implemented using new heat and mass transfer equipment, namely a rotary-type aerator-oxidizer (AORT). A diagram of a rotary-type aerator-oxidizer and a technological scheme for biological wastewater treatment using this apparatus are presented. A procedure has been developed for determining the volumetric coefficient of oxygen mass transfer from the gas phase to the liquid phase during biological wastewater treatment. A number of studies have been carried out on the dependence of the concentration of oxygen dissolved in water on the number of treatment cycles at: different angular speed of rotation of the rotor unit; different frequencies of flow pulsations; different flow shear rates. It is shown that the maximum concentration of dissolved oxygen is reached in 1–2 passes through the apparatus of the processed mixture. The thermophysical and energy characteristics of the operation of a rotary-type aeration-oxidation plant are determined depending on the frequency of flow pulsations. A comparative assessment of the heat-mass exchange and energy indicators of modern aeration devices used for wastewater treatment with the AORT installation has been carried out and it has been shown that when using the AORT installation, energy costs for aeration are reduced by 20 %.

Keywords: *aerator-oxidizer, biological treatment, flow displacement velocity, pulsation frequency, wastewater*

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1. Introduction

Currently, aeration tanks of various technological and structural solutions, which are equipped with various aeration systems, are used for the biological treatment of wastewater from organic and biogenic pollution. According to expert estimates, 60...80 % of the operating costs of sewage treatment plants fall on aeration and mass transfer of a mixture of wastewater and activated sludge. Hydrodynamic conditions of aeration devices determine the flow of mass transfer processes of oxygen diffusion dissolution, which in its turn affects the speed of biological oxidation reaction.

Taking into account the above, the purpose of the presented work is to study the intensification of the aeration and mass transfer processes at the expense of the new heat and mass exchange equipment, which works on the principle of discrete pulse energy input (DPEI).

The DPEI method was approved in 1984 by the Presidium of the Academy of Sciences of the Ukrainian SSR as an unconventional method of intensification of heat and mass transfer processes in dispersed media and was first proposed in the work (Dolinsky, 1984) as a generalizing method of directed, local and intensive usage of concentrated energy in liquid dispersed media. Its idea is to pre-accumulate (concentrate) energy, which is stationary introduced and arbitrarily distributed in the working volume, in local discrete points of the system and then pulse it to achieve the necessary thermophysical effects. The purpose of DPEI is to intensify the heat and mass exchange and hydrodynamic processes in technological environments, as well as to create the methods for optimizing these processes and ways of managing them.

The application of the DPEI method involves the creation of a large number of working bodies or working elements evenly distributed in a dispersed environment, which transform stationary thermal, mechanical or other types of energy into energetically powerful pulses, discrete in time and space. Shock waves, interfacial turbulence, microcavitation, vortices and penetrating cumulative microstreams, accompanying these phenomena, cause Rayleigh-Taylor or Kelvin-Helmholtz type instabilities on the interfacial surfaces, which leads to intensive crushing of dispersed inclusions, a significant increase in the total surface of phase contact, and an increase in mass and heat transfer processes. Similar effects are often unattainable when using traditional methods of processing dispersed media, even with a much higher level of specific energy consumption.

The DPEI mechanisms were theoretically studied in the works (Dolinsky & Ivanytsky, 1995; Dolinsky & Ivanytskyi, 1996; Dolinsky & Ivanytsky, 1997), technological and engineering additions to this method are presented in studies (Dolinsky, 1996; Dolinsky & Ivanytsky, 2008) and summarized in (Basok et al., 1996; Nakorchevsky, 2002). The DPEI method is implemented in many types of heat and mass exchange equipment, but most often in rotary-pulsation devices of various designs (Dolinsky et al., 2012).

2. Materials and methods

2.1. Experimental installation

To intensify the process of aeration and mass transfer in wastewater treatment technology, a rotary-type aerator-oxidizer (AORT) was created in the Institute of Technical Thermophysics of the National Academy of Sciences, the scheme of which is shown in fig. 1.

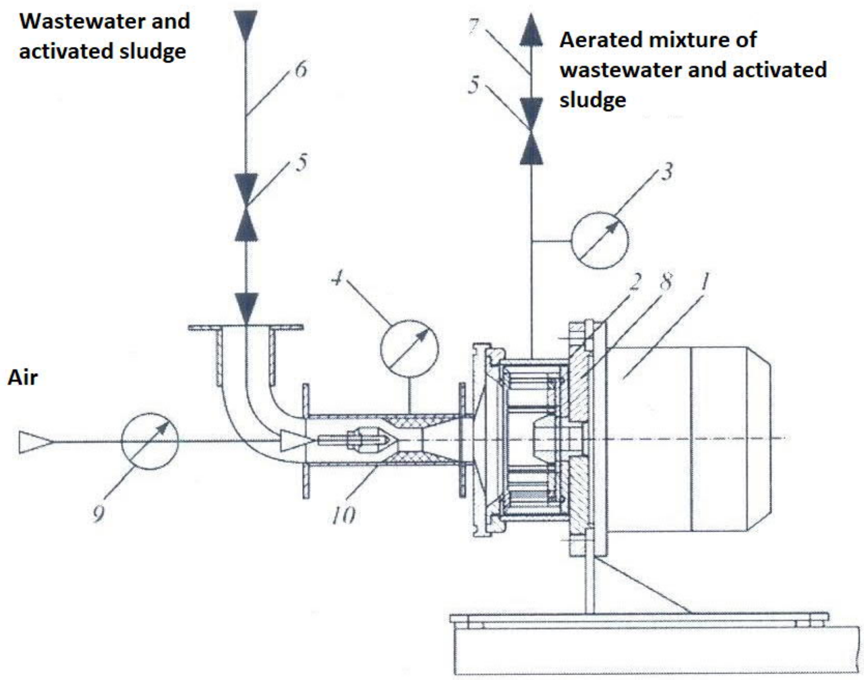

Fig.1. *Scheme of a rotary-type aerator-oxidizer: 1 – electric motor, 2 – rotary-pulsation unit, 3 – manometer for measuring the pressure at the outlet of the RPU, 4 – vacuum meter for measuring the discharge in the inlet pipe, 5 – two-way pipe, 6 – receiving pipeline, 7 – discharge pipeline, 8 – housing of the rotor-pulsation device, 9 – rotameter, 10 – ejector unit*

The rotor-pulsation unit (RPU) of the aerator-oxidizer consists of two rotors connected by screws, which are a single rotor unit (RU), a stator and a centrifugal pump impeller (impeller) (Fig. 2). The rotors have the following design characteristics: the inner radius of the small rotor R_{sr}=56 mm, the large one R_{lr} = 66 mm, the width of the slots a= 3,0 mm, the angle between the slots in the slats is 6^0, the height of the slots h_s = 5 mm, the number of rectangular slots *m* = 60. The gap change range between the rotors and the stator is δ = 0,3…0,5 mm. The structural characteristics of the stator are as follows: the radius of the stator R_{st} = 61 mm, the width of the slots a = 3,0 mm, the height of the slots h_{sl}=5 mm, he number of rectangular slots *m*=60.

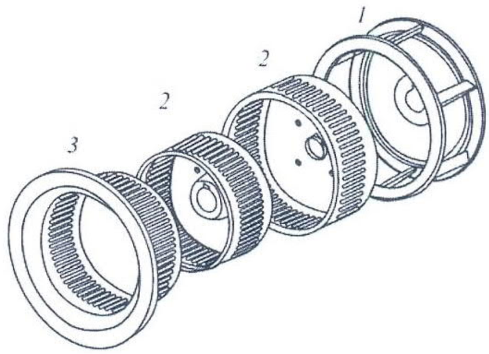

Fig.2. *Working bodies of the rotary-pulsation unit: 1 – centrifugal pump impeller, 2 – rotor, 3 – stator*

The body of the rotor-pulsation apparatus (RPA) is mounted on the flange of the electric motor through the connecting flange. On the free end of the shaft, which has an external thread, a rotary assembly fixed on the shaft with a nut is installed through a key connection. The tightness of the connection between the motor shaft and the RPA housing is ensured by a cuff.

The work of AORT is carried out in the following way. Through the receiving pipeline 6 (Fig. 1), the mixture of wastewater and activated sludge is sent to the RPA.

The impeller of the centrifugal pump, rotating, creates a discharge in the inlet pipe, due to which atmospheric air is supplied to the system. The two-way valve 5 allows you to adjust the air supply. Thus, a water-air mixture is formed, which, passing through the RPU, is exposed to shock waves, interphase turbulence, microcavitation and vortices, which leads to intensive crushing of air bubbles, dispersed inclusions and an increase in the surface area of phase contact. Thanks to this, the rate of mass transfer of oxygen from the gas phase to the liquid phase, its transport by the volume of the liquid phase, and adsorption on the surface of the activated sludge flakes, which are considered a conditionally solid phase, increases.

Next, biological oxidation of organic pollutants by activated sludge microorganisms occurs. The aerated and partially oxidized mixture of wastewater, air bubbles and activated sludge is sent either to recirculation (re-treatment) or to a secondary sedimentation tank through the outlet pipeline 7.

2.2 Method

The scheme of biological wastewater treatment using AORT is presented in fig. 3. Biological treatment of wastewater according to the above-mentioned scheme is carried out as follows. Waste water after mechanical cleaning enters aeration tank 1. Recirculation activated sludge from collector 4 is also fed here. As the aeration tank is filled with a mixture of wastewater and activated sludge, one or more oxidizing aerators are turned on, depending on their performance and the volume of the aeration tank. The devices work for a certain time in recirculation mode, stirring the mixture, saturating it with air oxygen, carrying out the process of mass transfer of the latter to the cells of activated sludge microorganisms and partially oxidizing organic pollution. The mixture processed in this way is then fed into the sump 2, where the final oxidation of organic substances to carbon dioxide and water takes place. The reaction of consumption of organic substances by activated sludge organisms in the presence of oxygen can be described by the equation

$$C_xH_yOz + O_2 \sim CO_2 + H_2O + \Delta W,$$

where $C_xH_yO_z$ - all organic substances of wastewater. After the oxidation process is completed in the sedimentation tank 2, flakes of activated sludge fall into the sediment, and then it is partly recirculated in the aerotank 1, and partly - for disposal. Before being fed into the aeration tank 1, the reverse activated sludge undergoes a regeneration stage (5), which also uses a rotary-type aerator-oxidizer. Thus, after the regenerator, activated sludge, well mixed and saturated with air oxygen, enters the aeration tank 1.

The most important structural element of the aeration tank is the aeration system. Its task is to saturate the treated water with oxygen, maintain activated sludge in a suspended state and ensure constant mixing of wastewater with activated sludge.

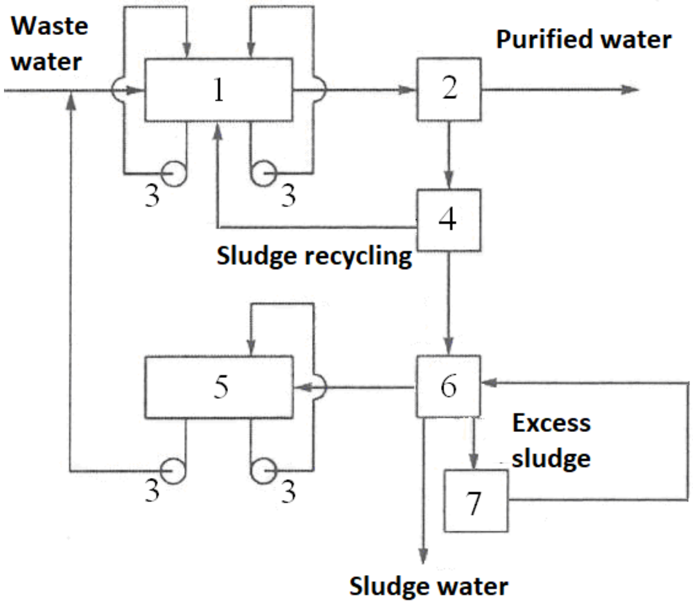

Fig.3. *Scheme of biological wastewater treatment using AORT: 1 – aeration tank, 2 – sedimentation tank, 3 – rotor-type aerator-oxidizer, 4 – collector, 5 – regenerator, 6 – sludge compactor, 7 – sludge platform*

The efficiency of cleaning wastewater from pollution largely depends on the organization of hydraulic and mass exchange processes in the aeration tank. The main factors affecting the choice of the optimal mode of operation of the aeration tank are the hydrodynamic scheme of the flow of streams and the efficiency of the process of saturating the liquid medium with oxygen from the air supplied by the aeration system. The correct selection of the aeration system is one of the ways to achieve high rates of aerobic biological treatment. Until now, the mechanism of joint dissolution and consumption of oxygen, as well as its distribution by the volume of the aerotank, has not been sufficiently studied.

To saturate the wastewater with oxygen, an aeration process is carried out, breaking the air flow into bubbles, which are evenly distributed in the wastewater if possible. From the air bubble, oxygen is absorbed by water, and then transferred to microorganisms (Fig. 4).

Thus, in the course of cleaning, two processes take place - the absorption of oxygen by wastewater and its consumption by microorganisms.

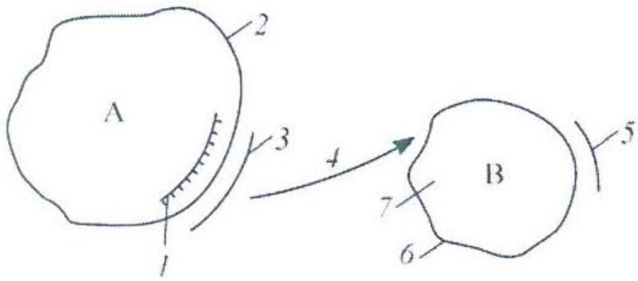

Fig. 4. *Scheme of oxygen transfer from gas bubbles to microorganisms: A – an air bubble, B – a cluster of microorganisms,1 – diffuse boundary layer from the gas side, 2 – interface, 3 – diffuse boundary layer from the liquid side, 4 – transfer of oxygen from gas bubbles to microorganisms, 5 – diffuse boundary layer from the liquid side to microorganisms, 6 – transfer of oxygen inside the cells , 7 – reaction between oxygen molecules and enzymes*

The amount of absorbed oxygen can be calculated using the mass transfer equation

$$M = \beta_v \cdot V \cdot (C_p - C) \qquad (1)$$

where, M – oxygen mass transfer rate, mg/(m^3·h); β_v - volumetric mass transfer coefficient, h $^{-1}$; V – volume of wastewater, m^3; C_p, C - equilibrium oxygen concentration and oxygen concentration in the total mass of liquid, mg/m^3. Based on the mass transfer equation, the amount of absorbed oxygen can be increased by increasing the mass transfer coefficient or the driving force. The most reliable way is to increase the volumetric mass transfer coefficient. It is known that this coefficient is the product of the actual mass transfer coefficient β_l on the specific contact surface of the phases a: $\beta_v = \beta_l \cdot a$. By increasing the intensity of gas flow fragmentation, that is, by reducing the size of gas bubbles and increasing the gas content of the wastewater flow in the facility, it is possible to significantly increase the specific contact surface of the phases and thereby increase the supply of oxygen to the wastewater.

Employees of the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine have developed a methodology for determining the volume coefficient of mass transfer of oxygen from the gas phase to the liquid phase during the biological treatment of wastewater. This technique is based on the fact that the rate of oxygen consumption by microorganisms cannot exceed the rate of its absorption, otherwise the metabolism of the microbial cell deteriorates and the rate of oxidation of pollutants decreases. To calculate the volumetric mass transfer coefficient, it was assumed that the mass transfer rate of oxygen in the diffusion region is equal to the rate of its consumption in the kinetic region. The rate of oxygen consumption is the rate of biological reaction or the specific rate of biological oxidation, which is the amount of total biological oxygen demand (BOD_{total}), i.e. the difference between the BOD of incoming and outgoing wastewater, related to the mass of sludge and the duration of aeration.

The specific rate of biological oxidation is determined by the formula

$$\rho = \frac{L_{en} - L_{ex}}{a_i(1-s)t_{at}} \qquad (2)$$

where L_{en} - BOD_{total} of wastewater supplied to the aeration tank, mg/dm^3; L_{ex} - BOD_{total} of wastewater at the exit from the aeration tank, mg/dm^3; a_i - dose of activated sludge, g/l; s - ash content of activated sludge, t_{at} – aeration period, h.

The rate of oxygen dissolution is the rate of its mass transfer in the diffusion region, which is described by equation (1). Thus, based on the above assumptions that in the established regime, the rate of oxygen dissolution is equal to the rate of its demand, we obtain the equality of equations (1) and (2):

$$M = \beta_v \cdot V \cdot (C_p - C) = \frac{L_{en} - L_{ex}}{a_i(1-s)t_{at}} \qquad (3)$$

The volume mass transfer coefficient is calculated according to the formula

$$\beta_v = \frac{L_{en} - L_{ex}}{a_i(1-s)t_{at} \cdot V \cdot (C_p - C)} \qquad (4)$$

An increase in the volumetric mass transfer coefficient can be achieved by increasing the specific contact surface of the phases, that is, by increasing the intensity of gas flow fragmentation and gas content in wastewater. In practice, when cleaning wastewater using the installation, this is achieved by changing the action of the DPEI mechanisms and the design features of the rotary-pulsation device on the medium being treated. The terms "DPEI mechanisms" and "constructive features of a rotary-type aeration-oxidization installation" mean the possibility of changing the amplitude of pressure pulsations, the frequency of flow pulsations, and the rate of flow shift when the liquid passes through the device. The described changes can occur due to variations in the speed of rotation of the rotor unit, the size of the gaps between the stator and the rotor and the number of slotted holes in them, the number of processing cycles.

At the first stage of research, the dependence of the influence of the frequency of flow pulsations on the absorption of oxygen in drinking water (Table 1) was studied when the frequency of flow pulsations varied from 2.0 to 3.2 kHz and the number of processing cycles from 1 to 3. Analyzing the data in the table. 1, it can be concluded that the most effective oxygen absorption in the AORT installation is in 1 cycle at a pulsation frequency of 2.8 kHz. Under such processing conditions, the content of dissolved oxygen in water reaches 7.9 mg/dm^3. Further studies on the influence of DPEI mechanisms and design features of the apparatus on oxygen absorption were carried out on residential and communal wastewater. Water was poured into the receiving hopper (mini airation tank) of the AORT experimental installation with a volume of 60 l and processed in the recirculation mode for 1-5 cycles. The processing cycle of the specified volume was 40 seconds. Determination of the concentration of dissolved oxygen was carried out by the method of variable oxygen deficiency, in which the medium being analyzed is first degassed, and then aerated with air, the consumption of which is determined in advance. After some intervals, samples were taken to analyze the concentration of dissolved oxygen. Determination of the concentration of dissolved oxygen was carried out using an oximeter EZODO PDO-408 at a constant temperature (26 ^{o}C) and atmospheric pressure.

***Table 1**. The influence of the frequency of flow pulsations on the absorption of oxygen in drinking water*

Pulsation frequency, kHz	O_2 Concentration, mg/dm^3		
	1 processing cycle	2 processing cycles	3 processing cycles
2.0	7.2	7.9	8.0
2.4	7.5	8.0	8.0
2.8	7.9	8.0	8.0
3.2	7.9	8.0	8.0

3. Results and discussion

At the first stage of research, the dependence of the concentration of oxygen dissolved in water on the number of treatment cycles at the angular speed of the RA from 38.2 to 52.52 rpm was studied (Fig. 5).

It was established that when the rotation speed of the RA is increased in the specified range, the number of cycles until the water is saturated with oxygen (7.74 mg/dm^3) decreases by three times. In order to achieve the maximum concentration when processing the environment with a speed of rotation of the RA of 52.52 rpm, one cycle is required, that is, one passage of the medium through the device, and with a speed of 38.2 rpm – 3 cycles.

Thus, it can be concluded that with an increase in the angular speed of rotation of the RA from 38.2 to 52.52 rpm, the maximum concentration of oxygen dissolved in water at a temperature of 26 °C can be reached in a smaller number of cycles, i.e. with a shorter processing time.

When implementing the DPEI method in an oxidizing aerator, one of the main indicators affecting mass transfer is the frequency of flow pulsations, which is the product of the angular velocity of rotation of the RA by the number of slots. Based on this, the dependence of the concentration of oxygen dissolved in the medium on the frequency of flow pulsations was studied in further studies.

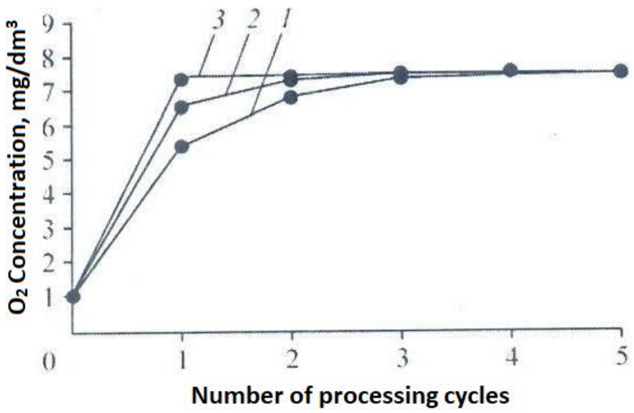

***Fig.5.** Dependence of the concentration of dissolved oxygen on the number of processing cycles at the angular speed of rotation of the RA: 1 – 38.2; 2 – 47.75; 3 – 52.52 rpm; number of slots – 60; the inter-cylinder gap is 150 μm*

During the experiment, the frequency of pulsations varied from 20 to 28 kHz. The results of the research are presented in fig. 6

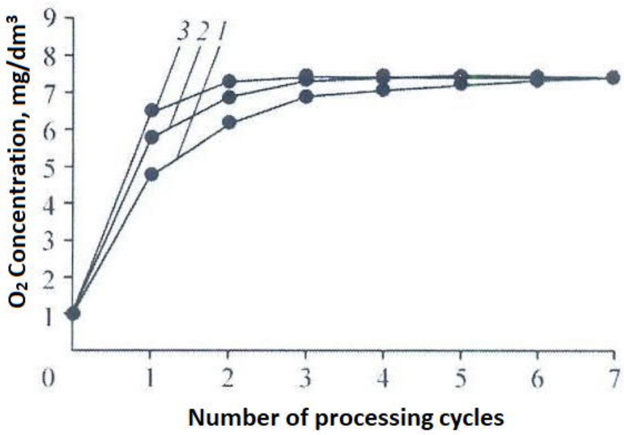

Fig.6. *Dependence of dissolved oxygen concentration on the number of processing cycles at different pulsation frequencies: 1 – 2.0; 2 – 2.4; 3 – 2.8 kHz; n = 47.75 rpm; the inter-cylinder gap is 150 μm*

It can be seen that an increase in the frequency of medium flow pulsations in the AORT allows the process of oxygen dissolution to be intensified. The equilibrium concentration of oxygen when processing the environment with a pulsation frequency of 2.8 kHz is achieved in 2 cycles, at 2.4 kHz – in 3 cycles, at 2.0 kHz – in 5 cycles. The obtained results indicate that increasing the frequency of pulsations of the medium allows creating a developed contact surface between the gas and liquid phases, which has a positive effect on the mass transfer of oxygen, allowing to reduce the duration of its dissolution.

The relationship between the flow rate of the medium in the radial direction of the RPA and the gap between the stator and the rotors is united by the value of the flow shear rate, which takes into account the radius of the rotor and the thickness of the inter-cylinder gap. According to the authors, it can also affect the process of oxygen dissolution. Fig. 7 shows the dependence of the concentration of oxygen dissolved in the medium on the shear rate of the flow at an angular velocity of 47.75 rpm.

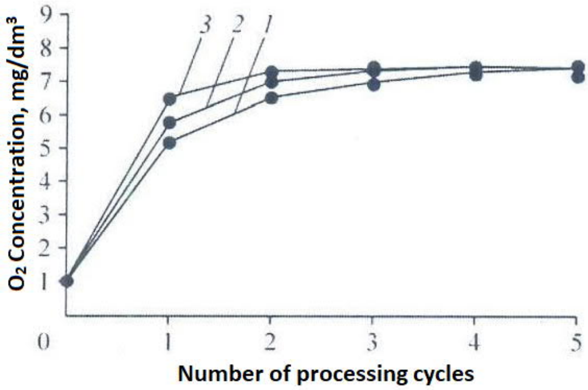

Fig.7. *Dependence of dissolved oxygen concentration on the number of treatment cycles at different flow shear rates: 1 – 57·10^3 c^{-1}; 2 –85,5·10^3 c^{-1}; 3 – 114·10^3 c^{-1}; n = 47,75 rpm; number of slots – 60*

The research results confirm that the change in the speed of the flow shift from 57·10^3 to 114·10^3 c^{-1} allows to reduce the number of medium treatment cycles to reach the equilibrium concentration from 7 to 2. Increasing the flow shift speed to more than 114·10^3 c^{-1} is technically complicated, as it is associated with an increase in angular velocities and a decrease in the gap between the stator and rotors to less than 100 μm.

Thermophysical and energy performance indicators of aeration devices are of great importance in wastewater treatment. The dependence of these indicators on the frequency of flow pulsations during water treatment in AORT is presented in the table. 2. In particular, such indicators were selected as the volumetric oxygen mass transfer coefficient K_v, h^{-1}, oxidizing capacity, kg/(m^3·h), aeration efficiency in relation to oxygen dissolved in the liquid, kgO_2/(kW·h). Table 2. data show that the greatest efficiency is achieved when processing the medium at a pulsation frequency of 2.8 kHz. At the same time, the determined indicators reach their maximum value.

Table 3 shows a comparative assessment of heat and mass exchange and energy indicators of modern aeration devices and AORT installations. These include: Rehau (Germany) and Fortegs (Czech Republic) aerators, perforated, mesh and fabric aerators [Serpokrylov, Smolyanichenko, 2010]. The data in Table 3 indicate that the rotor-type aeration-oxidization plant developed at the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine in terms of heat and mass exchange and energy indicators exceeds the existing plants by 20% (Rehau) to dozens of times (fabric, mesh).

Table 2. *The influence of the frequency of flow pulsations on the absorption of oxygen in drinking water*

Pulsation frequency, kHz	K_V, h^{-1}	Oxidizing ability, kg/h·m^3	Aeration efficiency, kg O_2/(kW·h)
2.0	37.70	4.92	10.9
2.4	40.57	5.71	12.0
2.8	42.00	6.57	13.5
3.2	42.20	6.68	12.7

Table 3. *The influence of the frequency of flow pulsations on the absorption of oxygen in drinking water*

Aerator type	K_V, h^{-1}	Oxidizing ability, kg/h·m^3	Aeration efficiency, kg O_2/(kW·h)
Rehau	34.44	5.67	10.64
Perforated	4.61	0.31	0.61
Mesh	4.24	0.23	0.43
Fortegs	15.41	1.31	2.45
Fabric	3.37	0.01	0.02
AORT	42.0	6.57	13.5

4. Conclusion

The conducted studies allow us to conclude that by using discrete-pulse energy input, controlling its mechanisms and changing the design features of the aerator-oxidizer RPU, it is possible to successfully influence the absorption of oxygen in wastewater. It is also shown that in 1–2 passes through the apparatus of the mixture being processed, the maximum concentration of dissolved oxygen is achieved. Therefore, by pumping the entire volume of the aeration tank through the device, it is possible to saturate the waste water with oxygen as much as possible. The use of AORT for wastewater treatment will allow intensifying the mass transfer at the gas-liquid phase interface and making the content of dissolved oxygen in the treated environment permanently non-deficient, which is one of the most important factors in the intensification of the process of biological wastewater treatment. In addition, energy costs for aeration are at least 20 % less, compared to advanced foreign analogues.

References

1. Basok, B. I.; Gartwig, A. P.; Koba, A. R.; Equipment for obtaining and processing high-viscosity dispersed media. *Industrial heat engineering* **1996**, *1*, 50–56

2. Dolinsky, A. A. The principle of discrete-pulse introduction of energy and energy in technological processes. *Visnik AN URSR* **1984**, *1*, 39–46.

3. Dolinsky, A. A.; Ivanitsky, G. K. Theoretical substantiation of the principle of discrete-pulse input of energy. I. Model of the dynamics of a single vapor bubble. *Industrial Heat Engineering* **1995**, *5* (17), 3–28.

4. Dolinsky, A. A.; Ivanitsky, G. K. Theoretical substantiation of the principle of discrete-pulse input of energy. II. Investigation of the behavior of an ensemble of vapor bubbles. *Industrial Heat Engineering* **1996**, *1* (18), 3–20.

5. Dolinsky, A. A. Using the principle of discrete-pulse energy input to create efficient energy-saving technologies. *Eng.-Phys. journal* **1996**, *6* (69), 35–43.

6. Dolinsky, A. A.; Ivanitsky, G. K. Principles for the development of new energy-resource-saving technologies and equipment based on the methods of discrete-pulse energy input. *Industrial Heat Engineering* **1997**, *4–5* (19), 13–25.

7. Dolinsky, A. A.; Ivanitsky, G. K. *Heat and mass transfer and hydrodynamics in vapor-liquid dispersed media. Thermophysical bases of discrete-pulse input of energy*; Naukova Dumka: Kyiv, 2008.

8. Dolinsky, A. A.; Obodovich, A. N.; Borkhalenko, Yu. A. *The method of discrete-pulse input of energy and its implementation*; Apostrophe: Kharkiv, 2012.

9. Nakorchevsky, A. I.; Basok, B. I.; Ryzhkova, T. S. Hydrodynamics of rotary-pulsation devices. *Eng.-Phys. journal* **2002**, *2* (75), 58–68.

10. Serpokrylov, N. S.; Smolyanichenko, A. S. Reducing the energy consumption of wastewater aeration systems. *Vestnik TGASU* **2010**, *3*, 192–199.

ДИСКРЕТНО-ІМПУЛЬСНЕ ВВЕДЕННЯ ЕНЕРГІЇ В ТЕХНОЛОГІЯХ ОЧИЩЕННЯ СТІЧНИХ ВОД

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Очищення стічних вод є надважливою екологічною проблемою народного господарства будь-якої країни. Тому, підвищення ефективності очищення стічних вод на основі використання інноваційних технологій та обладнання набуває актуальності. Для біологічного очищення стічних вод від органічних та біогенних забруднень, в основному, використовуються аеротенки з різними системами аерації. На проведення аерації та масопереносу суміші стічної води та активного мулу припадає до 80 % експлуатаційних витрат. У статті вирішуються проблеми застосування теплофізики у очищенні стічних вод за рахунок інтенсифікації процесу масопереносу та прискорення реакції біологічного окиснення. Інтенсифікація відбувається внаслідок впливу на оброблюване середовище (стічну воду) енергії, що вводиться дискретно-імпульсним методом. Метод реалізується за допомогою нового тепломасообмінного обладнання, а саме: аератора-окиснювача роторного типу (АОРТ). Представлено схему аератора-окиснювача роторного типу та технологічну схему біологічного очищення стічних вод із застосуванням цього апарату. Розроблено методику визначення об'ємного коефіцієнта масопередачі кисню з газової фази в рідку в ході біологічного очищення стічних вод. Проведено низку досліджень з вивчення залежності концентрації розчиненого у воді кисню від кількості циклів обробки при: різних кутових швидкостях обертання роторного вузла; різних частотах пульсацій потоку; різних швидкостях зсуву потоку. Показано, що за 1–2 проходи через апарат суміші, що обробляється, досягається максимальна концентрація розчиненого кисню. Визначено теплофізичні та енергетичні показники роботи аераційно-окиснювальної установки роторного типу від частоти пульсацій потоку. Проведено порівняльну оцінку тепломассобмінних та енергетичних показників сучасних аераційних пристроїв, що застосовуються для очищення стічних вод з установкою АОРТ та показано, що при використанні установки АОРТ енерговитрати на аерацію зменшуються на 20 %.

Ключові слова: *аератор-окиснювач біологічне очищення, стічні води, частота пульсацій, швидкість зсуву потоку*