Vol. 2, No. 1, 2017

WASTEWATER TREATMENT BY ULTRAVIOLET IRRADIATION TECHNIQUE

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Received: 05.05.2017

Abstract. Devoted to the problem of sewage treatment by ultraviolet radiation. This method can clear the water from microbiological contamination and thereby improve water quality.

Key words: ultraviolet, microorganisms, wastewater treatment.

1. Introduction

The activity of a significant number of chemical industry enterprises is accompanied with the generation of runoff that contains organic pollutants in its composition. These pollutants are the culture media for the rapid development of microorganisms that threaten to pollute the hydrosphere. Therefore, the disinfection stage is necessary in the general wastewater treatment technology.

Natural water is also a medium in which microorganisms can multiply and breed. The rampant development of industrial civilization is followed by massive pollution of soil, rivers and reservoirs by industrially manufactured products. Consequently, surface water preserves the remnants of chemical composition and smells of plants, minerals, organic substances and gases contained in the soil and air. The intensity of microbial growth in water depends on a range of factors and primarily on the presense of microbial nutrient elements in the water content. Natural water always contains a greater or lesser quantity of dissolved organic and mineral substances that may be used by microorganisms in the nutritive process. The state of water sources and systems of main water supply do not guarantee the required water quality which nowadays has reached a dangerous to public health level and continues to deteriorate. Due to the increasing pollution of water supply sources the traditionally used water treatment technologies failed to achieve optimum effect, therefore water supply facilities do not always provide reliable water treatment [1].

Decontamination of water is one of the most important stages of water purification – both in terms of water treatment and wastewater treatment technologies. The topicality of water decontamination is determined by a high degree of danger of causing epidemic and pandemic diseases that are spread by water. One of the most effective methods of water decontamination from microbiological pollution is ultraviolet (UV) irradiation. The decontamination effect of UV irradiation is mainly determined by reactions which result in permanent DNA damages. Beside DNA, ultraviolet also influences the other cell structures, in particular, RNA and cell membranes. Ultraviolet affects namely living cells without affecting the chemical composition of the medium that involves chemical disinfectants [2]. UV irradiation destroys DNA and RNA structure of microorganisms in the case of radiation exposure around 220–280 nm, where a maximum of bactericidal action is equal to a wavelength 260 nm, and the external structure of microorganism affects the efficiency [3]. UV irradiation acts immediately, and simultaneously the irradiation does not add residual bactericidal properties as well as smell and flavour to water. Water treatment by UV irradiation does not lead to the formation of harmful accessory chemical compounds (as opposed to treatment by chemical reagents, including chlorine, chloramine, ozone). Ultraviolet decontamination is highly efficient during all periods of the year, including the floods and, especially, in winter when the efficiency of chlorination is reduced dramatically. Bactericidal installation does not require reagents [4].

The aim of the study was to determine the effect of UV irradiation on the state of the test water and choose the most optimal parameters of the realization of a purification process.

2. Material and methods

The study of ultraviolet effect on decontamination of microorganisms was conducted on the experimental tray-type UV installation that is depicted in Fig. 1.

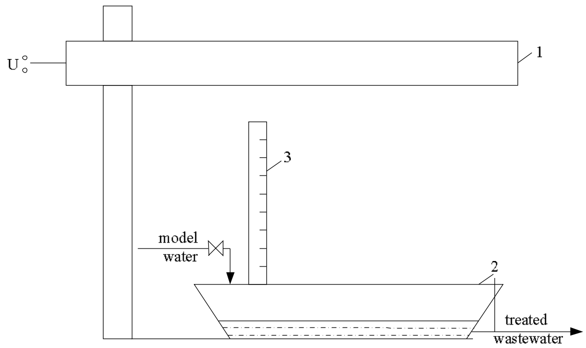

Fig. 1. Installation diagram for the process of water decontamination:
1 – ultraviolet lamp, 2 – liquid tray, 3 – measuring stick.

Ultraviolet radiation is delivered from an ultraviolet lamp 1 Philips TUV 15W/G15 T8 with 15-Watt power, lamp base type G13, wavelength of 253,7 nm. The lamp was mounted above the tray-type container in which there was the test liquid. In the water container the fittings for supplying test liquid and its sampling were mounted.

3. Results and discussion

For the study of water purification from microorganisms different types of monocultures of the genera *Bacillus, Pseudomonas, Sarcina, Diplococcus* were brought to the test medium (distilled water), thus creating infected model water. The experiments were conducted with different duration (from 5 sec to 30 sec) and with different layer thickness of test liquid (from 25mm to 50 mm). In the process of analyzing the samples, the value of a microbial number (MN) was determined. The sampling was conducted before the start of the experiment and after it [5].

The results of the studies are presented in Fig. 2. The studies in the purified water MN with the duration of irradiation 20 sec and layer thickness of 25 mm constitutes 35 CFU/cm^3 for bacteria of the genus Bacillus, 50 CFU/cm^3 for bacteria of the genus Sarcina, 320 CFU/cm^3 for bacteria of the genus Pseudomonas, 260 CFU/cm^3 for bacteria of the genus Diplococcus.

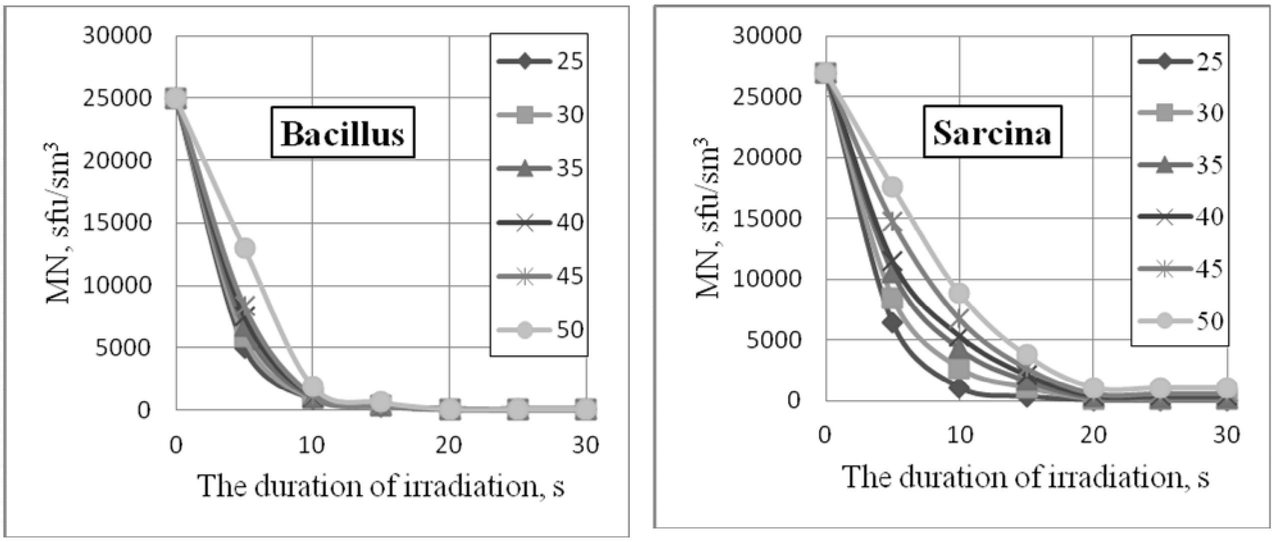

Fig. 2. Kinetics of changes in the number of microbes during the process of UV irradiation against different types of bacteria and for different layer thickness of polluted water (mm).

The best-purified test model water was infected by bacteria of the genus Bacillus. Ultraviolet processing allowed to reduce the level of MN for Bacillus in 714 times, Sarcina in 540 times, Pseudomonas in 56 times and Diplococcus in 76 times. After 20 seconds of irradiation with the layer thickness of 50 mm the purification practically did not take place. Consequently, it is advisable to purify the water with the layer thickness of up to 45 mm and duration of irradiation 20 seconds.

In the purified water MN with the duration of irradiation 20 sec and layer thickness of 45 mm constitutes 51 CFU/cm^3 for bacteria of the genus Bacillus, 605 CFU/cm^3 for bacteria of the genus Sarcina, 560 CFU/cm^3 for bacteria of the genus Pseudomonas, 505 CFU/cm^3 for bacteria of the genus Diplococcus. UV irradiation with these parameters reduced the level of MN for Bacillus in 490 times, Sarcina in 44 times, Pseudomonas in 32 times and Diplococcus in 39 times.

The degree of purification from different types of bacteria is determined by the formula

$$N_p = \frac{P_0 - P_1}{P_0} = 1 - \frac{P_1}{P_0} \qquad (1)$$

where P_1 is the number of microorganisms that are left in the water after UV irradiation, P_0 is the number of microorganisms that were in the water before the start of its irradiation.

The data presented in Fig. 2 was converted in accordance with the dependence (1). The results obtained are presented in Fig. 3.

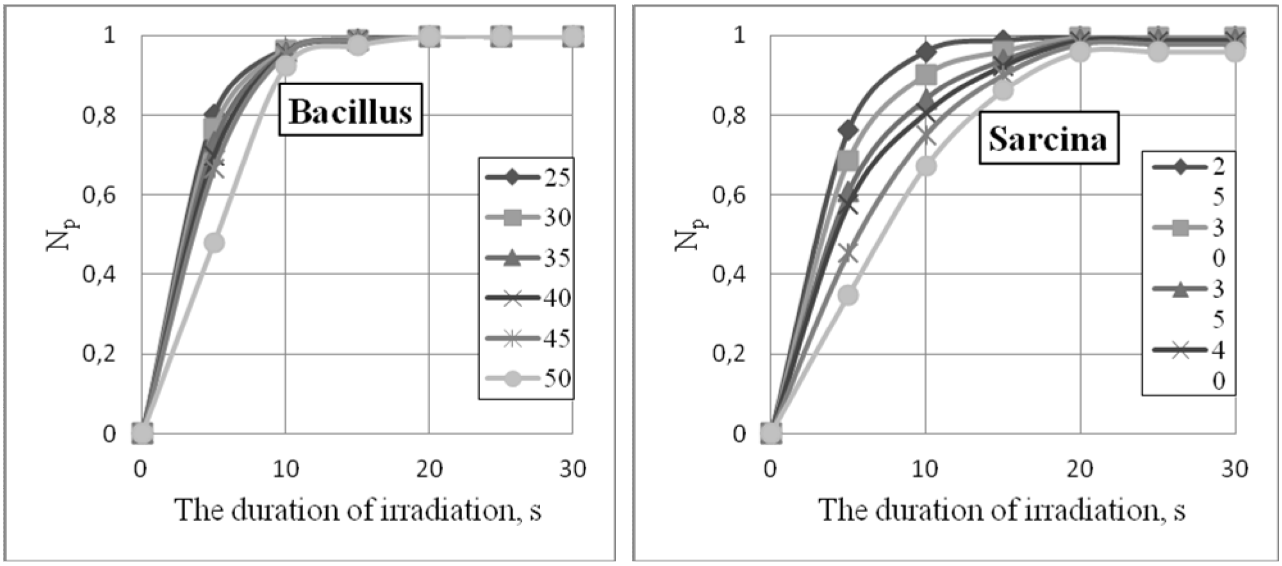

Fig. 3. Kinetics of changes in the degree of purification during the process of UV irradiation against different types of bacteria and for different layer thickness of polluted water (mm)

The studies have shown that the degree of purification for bacteria of the genus Bacillus within the layer of fluid from 25 mm to 50 mm during 20 seconds of irradiation ranges from 0,9986 to 0,99648 respectively. Similarly, for bacteria of the genus Sarcina from 0,9981 to 0,9593, for bacteria of the genus Pseudomonas from 0,9822 to 0,9650, for bacteria of the genus Diplococcus from 0,9870 to 0,9525.

For the evaluation of the number of the absorbed ultraviolet radiation, which was used for inactivation of a particular type of microorganisms, there is required the development of a mathematical model of the process and evaluation of the obtained experimental data on its basis. The equation (1) may be represented in the form

$$\frac{P_1}{P_0} = 1 - N_p \tag{2}$$

The number of microorganisms that remained in the water after UV irradiation is determined by the formula [4]

$$P_1 = P_0 \exp\left(-\frac{Et}{k}\right) \tag{3}$$

where E is the intensity of UV irradiation that was absorbed by the layer of water, mW/cm^2; k is the coefficient that characterizes the resistance of microorganisms to a certain type of UV irradiation; t is the duration of irradiation, c

From the equation (3) we will receive

$$\frac{P_1}{P_0} = \exp\left(-\frac{Et}{k}\right) \tag{4}$$

Having made the logarithm of the both parts of the equation (4) by substituting the resulting value of the formula $\frac{P_1}{P_0}$ from the equation (2), and marking $\frac{E}{k} = \chi$ we will receive

$$ln\left(1 - N_p\right) = \chi t \tag{5}$$

where χ i s the coefficient of the inactivation by UV irradiation (coefficient that characterizes the number of absorbed UV irradiation which was used for the inactivation of a particular type of microorganisms).

As it is seen from the equation (5), there must be a linear dependence between *t* and the complex $ln\left(1 - N_p\right)$. We construct this dependence in order to test this statement by using experimental data. The results of the construction are presented in Fig. 4.

The presented data in Fig.4 indicate that such linear dependence really exists (the minimum value of the correlation coefficient for all linearizations represented in Fig.4 was 0,9508). It provides an opportunity to set the value of the coefficient of inactivation by UV irradiation using the tangent angle of the received linearizations (linear regression coefficient). χ In Fig. 5 the changes of the coefficient of inactivation by UV irradiation for different types of bacteria are presented.

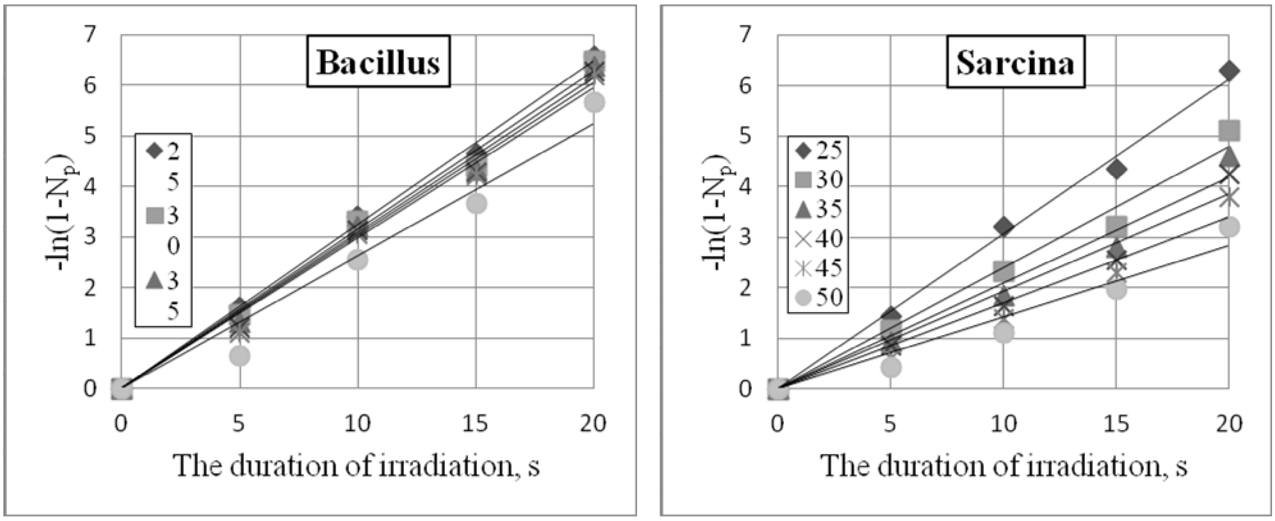

Fig. 4. Dependence $ln\left(1-N_p\right)$ = f(t) for different types of bacteria

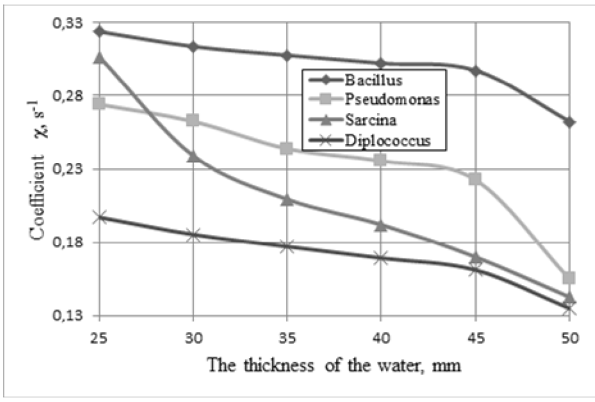

Fig. 5. Dependence of inactivation coefficients by UV irradiation from the water film thickness that is purified for different types of bacteria.

As it is seen from Fig.5, the dependencies of the coefficients of inactivation by UV irradiation from the layer thickness of water which is being purified have different character for different types of bacteria, that is probably connected with the different structure of these bacteria, influence of the external structure of microorganisms on the efficiency of UV irradiation and their different degree of resistance to UV irradiation. The obtained values of the coefficients of inactivation by UV irradiation may be used for calculation of the real processes of wastewater decontamination by UV irradiation.

4. Conclusion

On the basis of analysis of the studies we can conclude that the purification of wastewater by the method of UV irradiation is promising as it has the following advantages in relation to the known oxidative decontamination methods (chlorination, ozonation):

- UV irradiation is lethal for most aquatic bacteria, viruses, spores and protozoa. It destroys the pathogens of such infectious diseases as typhus, cholera, dysentery, viral hepatitis, polio, etc. The use of ultraviolet allows to achieve more efficient decontamination than chlorination, especially against viruses;
- Decontamination by ultraviolet occurs at the expense of photochemical reactions inside of microorganisms, so the change of water characteristics has a much smaller impact on its efficiency than in the case of decontamination by chemical reagents. In particular, the pH and temperature of the water do not affect the impact of ultraviolet radiation on microorganisms;
- in the water treated by ultraviolet radiation there were not detected toxic and mutagenic compounds that cause a negative impact on the biocenose of reservoirs;
- unlike the oxidative technologies, in the case of overdose, the negative effects are absent. This allows to simplify control of the decontamination process and not to conduct tests in order to determine the content of residual concentration of disinfectants in the water;
- decontamination duration by UV irradiation is up to 20 seconds in a flowing mode, therefore, there is no need to create contact containers;
- the maintenance costs for decontamination by UV irradiation are characteristically lower than for chlorination and, moreover, ozonation. This is due to the relatively small cost of electricity (in 3–5 times smaller than for ozonation), the lack of need for expensive reagents: liquid chlorine, sodium hypochlorite or calcium, as well as the lack of need for reagents for dechlorination;

- there is no need to create stockpiles of toxic chlorinecontained reagents that requires special measures for technical and environmental safety. In turn, this increases the reliability of the water supply and sanitation systems in general;
- ultraviolet equipment is compact, requires minimal space, its use is possible within the existing technological processes of wastewater constructions without their interruption, with minimal amounts of construction and installation works.

By the experimental studies, it was determined that it is advisable to purify the water with the layer thickness of up to 45 mm and duration of irradiation 20 seconds by the method of UV irradiation. In our opinion, the most promising application is to use the combined systems of purification which would include purification with the use of multiple methods. This would allow to get rid of the deficiencies inherent to the certain methods, and achieve the guaranteed quality of the purified water.

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