

# NON-CHEMICAL WATER TREATMENT IN UNIFIED LIGHT AND SOUND FIELD AND TESTING ON WASTE WATER DECONTAMINATION

N. M. Lebedev<sup>1</sup>, V. A. Grachev<sup>2</sup>, A. N. Arefieva<sup>1</sup>, O. Y. Lebedev<sup>3</sup>, O. V. Plyamina<sup>2</sup>, V. A. Doilnitsyn<sup>4</sup>, A. A. Akatov<sup>4</sup>, L. V. Leonov<sup>5</sup>, O. N. Rublevskaya<sup>5</sup>, O. A. Lominoga<sup>5</sup>, Y. Gavrilov<sup>6</sup>.

<sup>1</sup>OOO Aleksandra-Plus, Vologda, Russia

<sup>2</sup>Ecology Research Institute, Moscow, Russia

<sup>3</sup>OOO Novotech-EKO, Vologda, Russia

<sup>4</sup>St. Petersburg State Technological Institute (technical university), St. Petersburg, Russia

<sup>5</sup>State Unitary Enterprise 'Vodokanal of St. Petersburg', St. Petersburg, Russia

<sup>6</sup>Vologda State University, Vologda, Russia

**Abstract:** The paper presents the results of testing of a high-performance method for decontaminating sewage, involving combination of ultrasonic and ultraviolet exposure at the final step of water purification aimed at destroying pathogenic microorganisms and thereby preventing the spread of infectious diseases.

A variation of the method was developed and patented by the authors and passed the test at one of the most advanced water facilities in Russia which is the Vodokanal of St. Petersburg. The combined unit was manufactured at OOO Novotech-EKO and installed at the South-West Wastewater Treatment Plant (SWTP) of Vodokanal of St. Petersburg.

The results of the test showed the efficiency of combined ultraviolet and ultrasonic wastewater treatment, both in terms of intensifying disinfection and in terms of the stability of the plant operation by preventing biofouling and salt deposition on the surface of the lamp casings. The latter fact was the basis for the pilot project of improvement of the existing system of UV waste water disinfection at the SWTP.

**KEY WORDS:** SEWAGE, DISINFECTION, ULTRASONIC, ULTRAVIOLET, COMBINED TREATMENT.

Waste water of residential areas usually contains a significant amount of pathogenic microorganisms including agents of serious diseases. Their elimination before discharge into water bodies is an important final stage of water treatment preventing the spread of infectious diseases.

With this end in view, chlorine and ozone treatment technologies are used. They possess limited efficiency and can produce toxic materials in the water under treatment [1]. Besides, more effective and safe ultraviolet treatment is applied [2]. (Sometimes these technologies are combined).

One should note that the efficiency of ultraviolet decontamination decreases in high colour and turbid medium which is characteristic of waste water. What is more, according to the research, pathogenic microflora resistance to ultraviolet has increased 4 times for the recent 15-20 years [3]. Another disadvantage decreasing the efficiency of this process is salt deposition and biofouling of UV lamp casings [4], and as a result it requires regular cleaning the casing surfaces.

Development of powerful ultrasonic sources allowed their possible independent use in water decontamination. Special effects appearing under ultrasonic treatment in liquid media, which are high-speed microstreams > 1 km/s, powerful shock waves > 1 GPa, local heating areas > 1000 K, free radicals [5], being the result of cavitation bubbles collapse are undoubtedly useful for pathogenic flora removal. However, the test showed that if the exposure time is little or the transmitter power is low the number of microorganisms even increases in a number of cases [6, 7]. That is why, ultrasonic treatment is to be applied only in combination with chemical dosing or, for instance, ultraviolet treatment [2].

The joint use of ultrasonic and ultraviolet water treatment is recommended by the authors of this article [8] and is considered the most promising decontamination method due to the combination of positive characteristics of both treatment ways. It has been proved that this combination leads to synergistic increase of decontamination efficiency due to the following ultrasonic effects:

1) crushing suspended particulates inside of which there can be microorganisms [9], as well as crushing microorganisms clusters [10] and breakdown of their cell structure [11, 12] and further accessibility which results in significant increase in microorganism sensitivity to ultraviolet (from this point of view ultrasonic treatment should precede ultraviolet one);

2) intensive water mixing which provides delivery of distant layers to the surface of lamp casings and as a result the whole volume of feed water is treated uniformly;

3) prevention of biofouling and salt deposition on the surface of lamp casings [3, 13] which provides the preserve of original radiation intensity during the whole service life.

The joint use of ultrasonic and ultraviolet water treatment results not only in increase of decontamination efficiency but also in the increase in lamp service life as well as in elimination of work pauses intended for casing cleaning [13]. It also eliminates the need for the use of acid solutions for quartz casing cleaning and etching which allows to diminish servicing costs and contributes to ecological safety. Some papers claim that combined decontamination is preferable economically [2, 3, 6, 13].

In recent years a number of experiments with the use of the mentioned above technology have been conducted [2, 3, 13-16] and showed its high efficiency. Moreover, in Russia OOO Novotech-EKO (Vologda) and ZAO Svarog (Moscow) manufacture equipment for combined (ultraviolet and ultrasonic) water decontamination. The technology developed by OOO Novotech-EKO involves using piezoceramic transducers. The number of equipment units using this technology has made up more than three hundred since 2006. The equipment operates both in Russia and CIS countries.

The UOV-SV-5 unit (Fig. 1), designed and manufactured by OOO Novotech-EKO operates using the technology mentioned above. The unit is a pre-cavitator connected to a decontamination chamber and allows to treat waste water with capacity up to 9 m<sup>3</sup>/h. With maximum waste water flow the unit consumes: in the ultraviolet treatment mode – 0,107 kW·h/m<sup>3</sup>, in the combined treatment mode with all transducers on – 0,196 kW·h/m<sup>3</sup>.



Fig. 1. UOV-SV-5 unit installed in the testing facility

UOV-SV-5 was tested at South-West Wastewater Treatment Plant (SWTP) of Vodokanal of St. Petersburg from October 2015 to December 2016. The unit was placed in the SWTP ultraviolet treatment facility which receives the waste water after primary and complete biological treatment. According to the chemical analysis results, suspended solids made up 5,0-10 mg/dm<sup>3</sup>, and chemical oxygen demand was 20-40 mg/dm<sup>3</sup>. (It should be noted that after the water treatment with the unit these measures did not change significantly).

The water before the ultraviolet treatment was taken from the canal basin with the pump, then it flew through the unit and was discharged back into the canal. The bacteriological analysis of water samples taken at the input and output of the unit was conducted by ZAO Water Research and Control Centre (St. Petersburg). The following factors were controlled: coliphages, total coliforms, E. coli, enterococci, staphylococci.

Table 1. UOV-SV-5 operation modes at different testing stages

Mode	Mode description	Stage		
		I	II	III
US	All ultrasonic transducers (8 pcs) are on (both in the pre-cavitator and in the decontamination chamber).	+		
US-c	Ultrasonic transducers are on only in the pre-cavitator (4 pcs).	+		
US+UV-1	Ultraviolet lamps and ultrasonic transducers are on only in the decontamination chamber (4 pcs).	+		
US+UV-2	Ultraviolet lamps and all ultrasonic transducers are on (8 pcs).	+	+	+
UV-c	Only ultraviolet lamps are on, all ultrasonic transducers are off.	+	+	+

The results of Stage I tests are presented in table 2 where there are either values of logarithmic inactivation factor (LIF) or it is stated that complete cleaning was achieved for these indices. The LIF is calculated as a common logarithm of the living cells concentration ratio in the waste water volume unit before and after its treatment.

Table 2. Stage I test results (flow rate 0,5-0,7 m<sup>3</sup>/h)

Index	Initial values interval	LIF or operation result in the mode				
		US	US-c	US+UV-1	US+UV-2	UV-c

Coliphages	400-1000 PFU/100 cm <sup>3</sup>	0	0	Complete cleaning		
Total coliforms	32000-62000 CFU/100 cm <sup>3</sup>	0	0	1,85	2,78	2,34
E. coli	29000-42000 CFU/100 cm <sup>3</sup>	0	0,23	2,18	4,51	4,62
Enterococci	15000-32000 CFU/100 cm <sup>3</sup>	0	0,32	Complete cleaning		
Staphylococci	45-150 CFU/100 cm <sup>3</sup>	1,65	0	Complete cleaning		

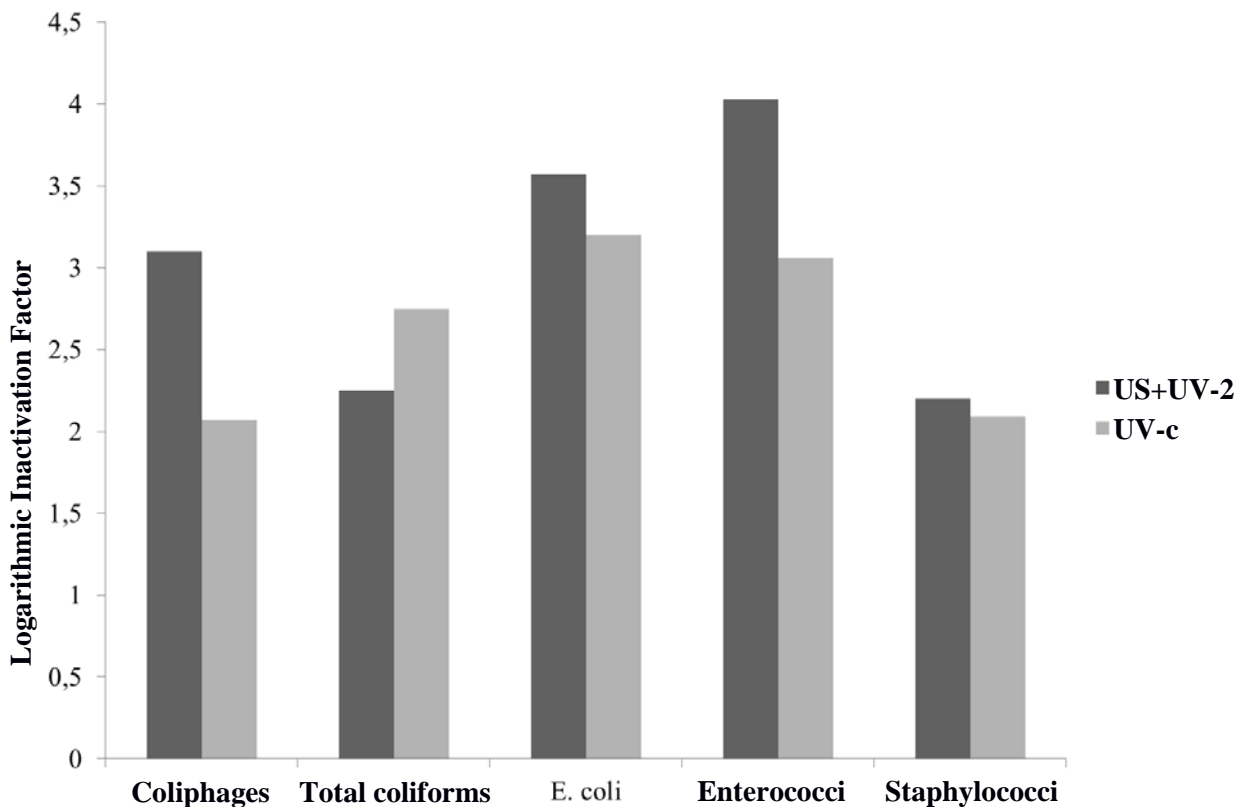
It is obvious that ultrasonic treatment alone does not produce any significant decontaminating effect. Slight intensification of ultraviolet decontamination is noted under the use of ultrasound, and the biggest contribution was made by the pre-cavitator while the ultrasonic transducers in the decontamination chamber even produced some negative effect. Crushing suspended particulates and microorganisms clusters which deprives them from protection from ultraviolet radiation is

likely to be a predominate mechanism. However, the low sewage flow rate through the unit predetermined high efficiency of ultraviolet decontamination on its own and small contribution of the ultrasonic treatment.

That is why at Stage II it was decided not to use pure ultrasonic modes (US, US-c) as well as the mode without the pre-cavitator (UV+US-1) and to increase the flow rate through the unit. The results are presented in Table 3 and Figure 2.

**Table 3.** Stage II test results (flow rate 8-10 m<sup>3</sup>/h)

Index	Initial values interval	LIF or operation result in the mode	
		US+UV-2	UV-c
Coliphages	330-1200 PFU/100 cm <sup>3</sup>	Complete cleaning (> 3,08)	2,07
Total coliforms	30000-83000 CFU/100 cm <sup>3</sup>	2,25	2,75
E. coli	29000-49000 CFU/100 cm <sup>3</sup>	3,57	3,20
Enterococci	4700-25000 CFU/100 cm <sup>3</sup>	4,03	3,06
Staphylococci	140-270 CFU/100 cm <sup>3</sup>	Complete cleaning (>2,14)	2,09



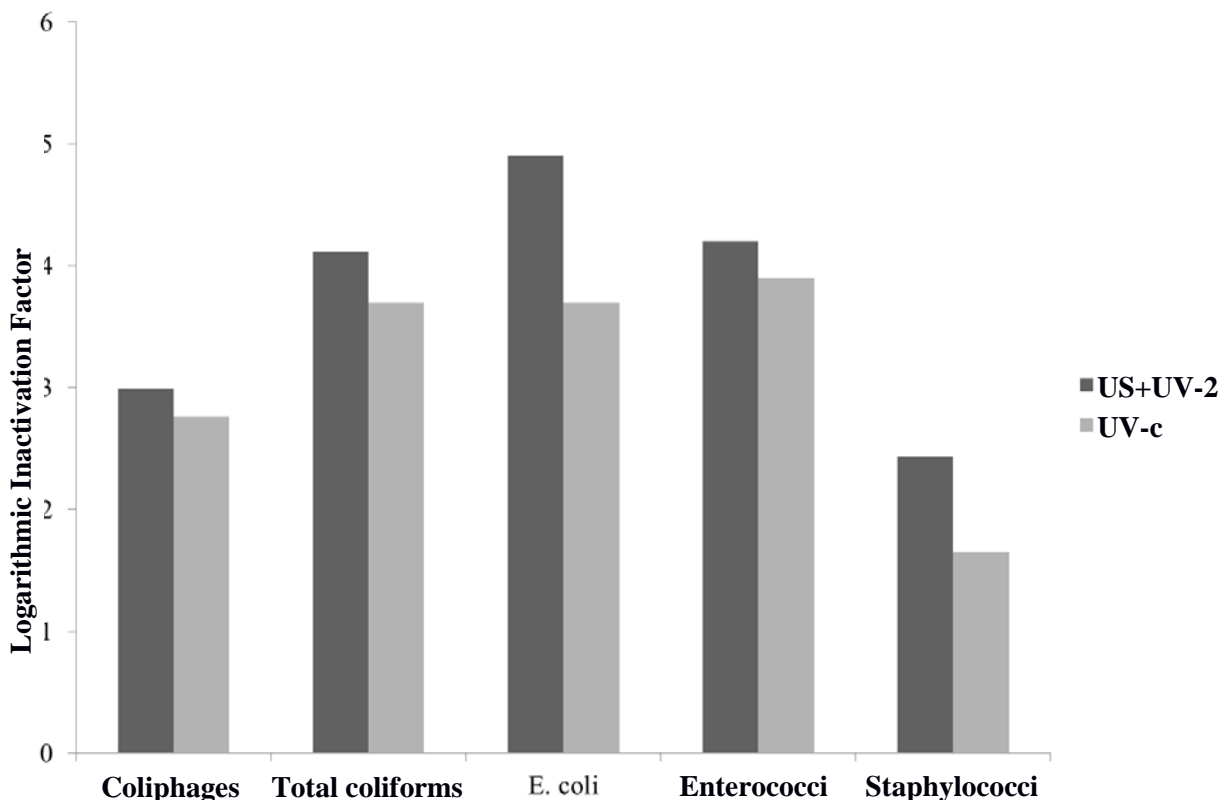
**Fig. 2.** Stage II test results (flow rate 8-10 m<sup>3</sup>/h)

It is obvious that ultrasonic waste water treatment going through the unit significantly (several-fold if absolute values are taken) increases decontaminating effect of ultraviolet radiation almost for all the indices under study while at Stage I ultrasound itself did not demonstrate disinfecting effect.

Stage III focused on ultrasound capability to prevent biofouling and salt deposition on the UV lamp casings. The flow rate was again decreased to 0,5-0,7 m<sup>3</sup>/h, but the water samples were collected after 30-50 days of uninterrupted operation (see Table 4). Thus, the operational stability of the unit was controlled. The flow rate was decreased to ensure the integrity of the test to eliminate any possible washout of deposit and casing contaminants due to high linear flow rate. The results are presented in Table 4 and Figure 3.

**Table 4.** Stage III test results (flow rate 0,5-0,7 m<sup>3</sup>/h)

Index	Initial values interval	LIF or operation result in the mode	
		US+UV-2 (50 days)	UV-c (30 days)
Coliphages	580-970 PFU/100 cm <sup>3</sup>	Complete cleaning (>2,99)	Complete cleaning (>2,76)
Total coliforms	110000-190000 CFU/100 cm <sup>3</sup>	4,11	3,70
E. coli	49000-72000 CFU/100 cm <sup>3</sup>	4,90	3,70
Enterococci	22000-56000 CFU/100 cm <sup>3</sup>	4,20	3,90
Staphylococci	45-270 CFU/100 cm <sup>3</sup>	Complete cleaning (>2,43)	Complete cleaning (>1,65)



**Fig. 3.** Stage III test results (flow rate 0,5-0,7 m<sup>3</sup>/h, long-term uninterrupted operation in the appropriate mode)

The advantages of ultrasonic intensification were confirmed at Stage III too: decontamination efficiency increased a few times for all the microorganisms under study if absolute values are taken into account.

Moreover, the UV lamp casings were visually inspected after the long-term operation in each of the modes and the gravity study of deposition rate was conducted. The second index was measured in the following way: the deposits were removed from the casings by wiping their surface with polyester

rayon fabric. The wiping was done after the determined operation period of the unit in the appropriate mode. Biofouling and salt deposition rate were estimated by the mass difference of the dry fabric before and after the wiping of the UV lamp quartz casings. This difference is proportional to the overall mass of contamination and biofouling products which deposited during the operation of the unit.

The total mass of air-dry deposits on three casings related to 1 m<sup>3</sup> of waste water cleaned in the UV+US-2 mode (all

3 UV lamps and 8 ultrasonic transducers are on) made up 45  $\mu\text{g}/\text{m}^3$ , and in the UV-c mode (only 3 UV lamps are on) – 300  $\mu\text{g}/\text{m}^3$ . Thus, the ultrasonic treatment allowed to decrease the rate of biofouling and saline deposition 6,7 times.

Thus, the test results proved the efficiency of the combined ultraviolet and ultrasonic waste water treatment both from the point of view of decontamination boost and in terms of the unit operational stability by preventing biological slime and salts from depositing on the lamp casing surfaces. The last fact was used as a basis for a pilot project for improving the existing system of UV waste water decontamination at the SWTP. The implementation of combined decontamination technology at the facility of the leading enterprise [17-19] will allow to recommend it for a wider use.

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