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

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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.

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 and thereby providing the spread of infectious diseases.

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.
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/dm³, and chemical oxygen demand was 20-40 mg/dm³. (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.

The tests were in three stages. At the first stage (I) the research was focused on different decontamination variants with low sewage flow rate through the unit (0.5-0.7 m³/h). At the second stage (II) the sewage flow rate was high (8-10 m³/h). Finally, the third stage (III) involved studying the intensity of biofouling and salt deposition on the UV lamp casings during long-term operation under the conditions of low sewage flow rate (0.5-0.7 m³/h), as well as evaluation of the biofouling intensity decrease. The stage features are presented in Table 1.

At Stages I and II the water samples were collected in 45 minutes after the unit start in the appropriate mode. Thus, by the time of collecting the UV lamp casings were clean (without any traces of biofouling and salt deposition).

At Stage III the samples were collected after 30-50 days of uninterrupted operation in the appropriate mode.

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

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode description</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>All ultrasonic transducers (8 pcs) are on (both in the pre-cavitator and in the</td>
</tr>
<tr>
<td>US-c</td>
<td>ultrasonic transducers are on only in the pre-cavitator (4 pcs).</td>
</tr>
<tr>
<td>US+UV-1</td>
<td>Ultraviolet lamps and ultrasonic transducers are on only in the decontamination</td>
</tr>
<tr>
<td>US+UV-2</td>
<td>Ultraviolet lamps and all ultrasonic transducers are on (8 pcs).</td>
</tr>
<tr>
<td>UV-c</td>
<td>Only ultraviolet lamps are on, all ultrasonic transducers are off.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stage</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US-c</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US+UV-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US+UV-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV-c</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 m³/h)

<table>
<thead>
<tr>
<th>Index</th>
<th>Initial values interval</th>
<th>LIF or operation result in the mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>US</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 m³/h)

<table>
<thead>
<tr>
<th>Index</th>
<th>Initial values interval</th>
<th>LIF or operation result in the mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>US+UV-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UV-c</td>
</tr>
<tr>
<td>Coliphages</td>
<td>330-1200 PFU/100 cm³</td>
<td>Complete cleaning (&gt; 3,08)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,07</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>30000-83000 CFU/100 cm³</td>
<td>2,25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,75</td>
</tr>
<tr>
<td>E. coli</td>
<td>29000-49000 CFU/100 cm³</td>
<td>3,57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,20</td>
</tr>
<tr>
<td>Enterococci</td>
<td>4700-25000 CFU/100 cm³</td>
<td>4,03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,06</td>
</tr>
<tr>
<td>Staphylococci</td>
<td>140-270 CFU/100 cm³</td>
<td>Complete cleaning (&gt;2,14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,09</td>
</tr>
</tbody>
</table>

Fig. 2. Stage II test results (flow rate 8-10 m³/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 m³/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 m³/h)

<table>
<thead>
<tr>
<th>Index</th>
<th>Initial values interval</th>
<th>US+UV-2 (50 days)</th>
<th>UV-c (30 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coliphages</td>
<td>580-970 PFU/100 cm³</td>
<td>Complete cleaning (&gt;2,99)</td>
<td>Complete cleaning (&gt;2,76)</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>110000-190000 CFU/100 cm³</td>
<td>4,11</td>
<td>3,70</td>
</tr>
<tr>
<td>E. coli</td>
<td>490000-72000 CFU/100 cm³</td>
<td>4,90</td>
<td>3,70</td>
</tr>
<tr>
<td>Enterococci</td>
<td>22000-56000 CFU/100 cm³</td>
<td>4,20</td>
<td>3,90</td>
</tr>
<tr>
<td>Staphylococci</td>
<td>45-270 CFU/100 cm³</td>
<td>Complete cleaning (&gt;2,43)</td>
<td>Complete cleaning (&gt;1,65)</td>
</tr>
</tbody>
</table>

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 m³ of waste water cleaned in the UV+US-2 mode (all
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.

References: