Decontamination of aeration station wastewater using ultraviolet radiation

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1 Introduction

Since the 80s of the 20th century, water treatment and wastewater treatment based on the technology of ultraviolet (or electromagnetic radiation) radiation began to develop. Currently, more than 1,500 municipalities in North America are using UV technology to treat wastewater [1-3]. For example, a large ultraviolet radiation station with a production capacity of 1 million m$^3$ per day was launched in Calgary, Canada [4-6]. In the next 10 years, 25% of wastewater in the USA is planned to be disinfected using ultraviolet radiation technology. Currently, disinfection of wastewater using ultraviolet radiation is widely used in the People's Republic of China and South Korea. The method of disinfection of wastewater with ultraviolet radiation is also used in a number of treatment facilities of the Russian state. One of such complex methods is the so-called "Lazur" technology, that is, simultaneous disinfection of wastewater using ultrasound and ultraviolet radiation. Based on this method, the current density of ultraviolet rays is not less than 40 mDj/cm$^2$ and the wavelength is 253.7 nm and 185 nm, and at the same time, the density of ultrasound current is 2 W/cm$^2$ and acoustic vibrations by affecting and neutralizing wastewater [7,8]. This method was patented in Russia in 1996. In 1997, the "Lazur M" series bactericidal device was successfully tested. The basis of this device is the sudden change in the pressure and temperature of the wastewater sent for disinfection, and the pathogenic microflora in the wastewater will be completely destroyed.
Ultraviolet radiation is one of the most modern physical methods at present. This method is also called bactericidal filtration or reagentless method\(^{[9-12]}\). In Uzbekistan, it has not yet been well established to neutralize the wastewater of enterprises and organizations, communal facilities at wastewater treatment plants. Nowadays, when developing the project of wastewater treatment stations with the help of ultraviolet radiation, it is necessary to take into account the dynamics of microflora growth in water. Taking this into account, the minimum dose of ultraviolet radiation is projected to be 40 mDj/cm\(^2\) in economically developed countries and 70–100 mDj/cm\(^2\) for all other planned stations\(^{[13-15]}\).

Technical specifications of modern bactericidal UF lamps used in the disinfection of wastewater with ultraviolet radiation are given below:

- Wavelength: 205–315 nm;
- Neutralization efficiency: 98%;
- UF lamp life: 9000 hours;
- Decontamination time: 4–5 hours.

When wastewater is treated with ultraviolet radiation, the microorganisms in the wastewater—bacteria and viruses—absorb ultraviolet rays, break them down, and lead to inevitable death. But ultraviolet rays can only kill bacteria and parasites in wastewater, heavy metal ions, pesticides and many other impurities, but can break down chlorine compounds\(^{[16, 17]}\).

Currently, the water coming out of the sewage treatment plant (Uzbekistan) is neutralized with the help of liquid chlorine compound. The treated water is discharged into open water bodies. There, these waters can produce toxic-toxic chlorinated organic compounds and cause deterioration of the environment.

### 2 Materials and methods

In the tank laboratory of the aeration station, scientific research works on the disinfection of wastewater with the help of ultraviolet radiation were carried out at the laboratory stand. Studies were conducted at the laboratory stand on the dependence of wastewater consumption, speed, chemical and biochemical oxygen demand indicators on the effect of UV radiation. Water consumption was measured using a stopwatch and control of the intensity of UV radiation was carried out using a special sensor. Determining the coli-index and coli-titer of water was carried out according to the methodological instructions given in the following literature.

### 3 Results

The results of studies on the dependence of water consumption and speed on the influence of UV radiation are presented in Table 1 and Figure 1.

**Table 1.** Dependence of water consumption and rate of UV disinfection of wastewater.

<table>
<thead>
<tr>
<th>#</th>
<th>Water consumption, cm(^3)/s</th>
<th>Coli-index</th>
<th>Coli-titer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1100</td>
<td>1200</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>850</td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>950</td>
<td>950</td>
<td>111</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>800</td>
<td>105</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>2000</td>
<td>56</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
<td>2600</td>
<td>53</td>
</tr>
<tr>
<td>7</td>
<td>1100</td>
<td>2900</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>1600</td>
<td>3000</td>
<td>43</td>
</tr>
<tr>
<td>9</td>
<td>1800</td>
<td>3500</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>2000</td>
<td>4200</td>
<td>38</td>
</tr>
</tbody>
</table>
Waste water consumption, cm³/s

Fig. 1. Studies on the dependence of water consumption on the coli-index of wastewater during UV disinfection of wastewater (samples 1, 2).

As can be seen from Table 1 and Figure 1, with the increase in water consumption, the number of bacteria (coli-index) in the treated wastewater also increases, and after reaching a certain peak, the coli-index decreases again. In our opinion, this phenomenon may be related to the nature of the bacteria in the wastewater. As can be seen from the graph, the optimal water consumption should be around 100–300.

The graph (Figure 2) reveals a clear correlation between the intensity of UV radiation and the reduction in bacterial counts during the wastewater treatment process. As the intensity of UV radiation increases, there is a noticeable decrease in the number of bacteria present. This observation underscores the efficacy of UV radiation as a disinfection method in wastewater treatment.

Fig. 2. Dependence of the intensity of UV radiation on the number of bacteria (coli-index) in the wastewater (samples 1, 2) during wastewater disinfection.

The relationship between UV intensity and bacterial reduction suggests that higher levels of UV radiation contribute to a more effective sterilization or disinfection process. UV radiation is known for its ability to disrupt the DNA and RNA of microorganisms, including bacteria.
inhibiting their ability to replicate and causing their inactivation. The graph's downward trend signifies the positive impact of increased UV intensity on the overall microbial load within the wastewater.

This finding is significant in the context of wastewater treatment practices, as it highlights the potential for UV radiation to serve as a reliable method for disinfection, promoting the removal of harmful bacteria and pathogens. Such insights contribute to the optimization of wastewater treatment protocols, ensuring the production of treated water that meets stringent quality and safety standards. The graph's trend may also inform decisions related to the design and operation of wastewater treatment facilities, emphasizing the role of UV radiation in achieving efficient microbial control.

As can be seen from the graph, it was observed that the number of bacteria decreases with the increase in the intensity of UV radiation during wastewater treatment. Figure 3 presents a comprehensive analysis of studies focusing on the time-dependent impact of UV radiation on the disinfection process of wastewater from the aeration station. The graph provides valuable insights, revealing that the effectiveness of UV disinfection reaches an optimal level within a specific time range.

Disinfection time of wastewater using ultraviolet rays

Fig. 3.

Studies on the dependence of UV radiation exposure time of aeration station wastewater neutralization (samples 1, 2, 3, 4)

The observed trend indicates that the disinfection efficiency increases as the exposure time to UV radiation is extended. However, a notable finding from the graph is the existence of an optimum exposure duration, falling between 3 to 8 seconds, where the maximum disinfection efficacy is achieved. Beyond this optimal range, there seems to be a diminishing return on the disinfection efficiency, suggesting that prolonged exposure may not yield substantial additional benefits.

This information is pivotal for wastewater treatment protocols, as it helps determine the ideal duration for UV radiation exposure to achieve the desired microbial inactivation. The identified range of 3-8 seconds serves as a practical guideline for optimizing UV disinfection processes in the aeration station. Balancing the need for effective disinfection with considerations of energy efficiency and operational feasibility, wastewater treatment facilities can tailor their UV exposure durations based on this empirically derived optimal range.

These findings contribute significantly to the field of water treatment, enabling more.
Precise and efficient disinfection strategies that can be applied to enhance the overall quality of treated wastewater discharged from aeration stations. Studies on the dependence of the indicator of chemical and biochemical oxygen demand of treated wastewater on the effect of UV radiation are presented in Figures 4 and 5 below. It should be noted that the higher the chemical and biochemical oxygen demand of wastewater, the slower the process of artificial water purification and neutralization in aerotank devices.

Fig. 4. Studies on the dependence of the indicator of chemical and biochemical oxygen demand of purified wastewater on the effect of UV radiation (samples 1, 2, 3).

Fig. 5. Studies on the dependence of the indicator of chemical and biochemical oxygen demand of purified wastewater on the effect of UV radiation (samples 1, 2, 3).
Indeed, the conducted studies, as indicated in Figure 3, establish a clear connection between the disinfection process using UV radiation and the chemical and biochemical indicators of wastewater. The observed optimal exposure duration of 3-8 seconds for UV radiation correlates with specific chemical and biochemical characteristics of the wastewater, highlighting the interdependence of these factors in the disinfection efficacy (Figure 5).

The relationship between UV disinfection and wastewater quality indicators underscores the importance of considering the composition of wastewater in designing effective treatment processes. Chemical and biochemical parameters such as organic content, microbial load, and other contaminants play a crucial role in determining the optimal conditions for UV radiation to achieve maximum disinfection.

This correlation has practical implications for wastewater treatment plants. Understanding how UV radiation interacts with the chemical and biochemical components of wastewater allows for the development of tailored disinfection strategies. By considering these indicators, treatment facilities can optimize UV exposure durations and intensities, ensuring not only effective disinfection but also efficient utilization of resources.

Moreover, this insight contributes to the broader understanding of the complex dynamics involved in wastewater treatment processes. It reinforces the idea that successful disinfection strategies should be designed with a holistic view of the wastewater composition, taking into account its chemical and biochemical characteristics for a comprehensive and effective treatment approach.

How the bacteria count -coli index changes after the primary radial clarifier, after the aerotank device and after the last secondary radial clarifier and after disinfection in the technological process of aeration station wastewater treatment. Studies were carried out.

In the technological process of wastewater treatment, research conducted on the samples taken after step-by-step treatment facilities showed that the number of bacteria (coli-index) in the wastewater was decreasing (Figure 6).

Fig. 6. Samples taken after the step-by-step treatment facilities in the technological process of wastewater treatment.

The improved technological process and scheme of decontamination of wastewater of the aeration station is presented (Figure 7).

Fig. 7. Improved technological process and scheme of SAS wastewater decontamination.
4 Discussion

Wastewater from the aeration station is sent to the grate (2) and sieves (3) by means of centrifugal pumps (1), passing through them, and passing through the wastewater separator (4) to bring the wastewater coming in different batches to the same concentration. After that, the wastewater is cooled in the primary radial clarifier (5) and flows into the aerotank device (6). In the aerotank device, wastewater is treated, that is, wastewater is cleaned using air flow and active water. After that, the wastewater is disinfected from disease-causing bacteria using a UV radiation device (7), and the wastewater is purified in a secondary radial clarifier (8).

Wastewater is disinfected with the help of the last second-stage UV radiation device (9), and the neutralized wastewater is discharged into open water bodies after the final disinfection, i.e., the ultrasonic device.

Below (Table 2), we will consider the advantages of the process of decontamination of wastewater using UV radiation compared to traditional methods and indicators of economic efficiency (comparative cost ratio for the process of decontamination of 1 m$^3$ of wastewater using chlorine, sodium hypochlorite and UV radiation).

<table>
<thead>
<tr>
<th>Costs</th>
<th>Disposal methods</th>
<th>Chlorination</th>
<th>Treatment with sodium hypochlorite</th>
<th>Exposure to UV radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration</td>
<td>Concentration</td>
<td>Processing power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1563.4·ηηη · lg(P/P0)</td>
<td>85 · 0.3 · 2500 lg3 · 1000</td>
<td>1563.4 · 0.7 · 0.9 = 853W</td>
<td></td>
</tr>
</tbody>
</table>

The power of the lamp working in bactericidal current for 5000 hours is $N_p = 250$ W.

Let's calculate the bactericidal current $F_b$, W:

$$q \cdot \alpha \cdot k \cdot lg\left(\frac{P}{P_0}\right) = \frac{85 \cdot 0.3 \cdot 2500 \cdot lg^3}{1563.4 \cdot \eta \cdot \eta_0} \cdot \frac{1563.4 \cdot 0.7 \cdot 0.9}{1563.4 \cdot 0.75 \cdot 0.9} = 853W$$
\[ n = \frac{F_b}{F_c} = \frac{853}{250} = 3.41 = 4 \]

\[ S = \frac{N_b}{q} = \frac{250}{85} = 2.94 \]

5 Conclusions

The analysis of the literature showed that the disinfection of drinking water and waste water without reagents (UV radiation, UT and high voltage currents) in a complex way from pathogens - pathogenic bacteria and viruses is more economical than chemical methods (chlorination, ozonation, etc.). It was found to be effective, cheap and simple in terms of construction. As a result of decontamination of wastewater using chemical methods, it was found that toxic chlorine organic compounds are formed in the neutralized wastewater, which causes damage to the ecology of the environment. In practice, it has been proven that it is possible to use combined methods such as UV+UT, UV+high-voltage currents and UV+UT+YUKT for decontamination of wastewater using UV radiation. The general conclusions showed that UV radiation technology devices are distinguished by their simplicity of operation and maintenance. The technologies for decontamination of wastewater using UV radiation, UT and YUKT have not yet been introduced in wastewater decontamination stations located in our republic. For the first time, a technological scheme for decontamination of wastewater in this way was proposed for decontamination of wastewater from an aeration station. An improved technology of wastewater disinfection using UV rays was developed and optimal parameters of the process were established. If we make a general conclusion, it was found that the disinfection of wastewater using ultraviolet radiation requires less capital than the chlorination method, and the operating costs are economically reduced by 5 times. This is because 3-5 times less electricity is consumed compared to ozonation technology. Also, it was found that wastewater can be neutralized under the influence of UV radiation at treatment aeration stations in our republic.

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