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RESEARCH ARTICLE

PROCESS OF DETERMINATION OF SURFACE WATER BY ULTRAVIOLET RADIATIONS

Askar Abdykadyrov[a,b], Sunggat Marxuly[a,*], Ainur Kuttybayeva[a], Vladimir Domrachev[a], Anargul Boranbayeva[a,b], Abdurazak Kasimov[b], Assel Yerzhan[b], Nurbolat Baibolov[a]

[a]Kazakh National Research Technical University named after K. Satbayev
[b]Almaty University of Power Engineering and Telecommunications named after G. Daukeev, Almaty, Kazakhstan
**Corresponding Author Email: askar058@mail.ru*

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ABSTRACT

This scientific research work deals with water disinfection in surface water reservoirs. According to the research, work was carried out to eliminate harmful microorganisms, viruses and microbacteria in the water. According to scientific research work, the electronic circuit of the device for capturing UV rays with a wavelength of 220-240 nm was studied. In the same way, the energy and spectral characteristics of the device, the parameters related to current and power are provided. The design and economic efficiency of the UV radiation device was considered and studied experimentally. In the water production technology, the main sanitary requirements for the organization of UV disinfection of water were considered. In the article , a number of provisions of the main documents of water and sanitary legislation regarding the quality of purified water, hygienic requirements, amount of ultraviolet radiation guaranteeing a given degree of disinfection, ultraviolet installations and their location were shown. At the same time, the scheme of the cleaning process, as well as measures to ensure safe working conditions of the personnel servicing the equipment were considered.

KEYWORDS

Electric Discharge; Ozone; Primary Water; Reservoir; Ozonator; Ozonated Water; Ozone Content; Decontamination.

1. INTRODUCTION

Nowadays, it is very difficult to find a source of clean water, and even if we buy it in a store, we cannot be 100% sure that we are buying high quality water. Therefore, there are now a variety of treatment systems that make tap water suitable for drinking. Water is a source of life for many microorganisms. For example: invisible bacteria and viruses are perfect habitats. They can seriously harm human health. Therefore, drinking water treatment schemes always include a disinfection phase. There are various methods of water disinfection, such as UV light, chlorination, water ozonation, and more. Among them, the most effective method is water disinfection with UV rays. Because ultraviolet light destroys all known viruses and bacteria without changing the chemical composition of water. As for the principle of operation of UV disinfection units, the system consists of a powerful mercury lamp protected by strong quartz glass from which the water enters the reaction chamber.

UV lamp emits light in a small range (wavelength 253 nm). Ultraviolet, even in short contact, stimulates chemical reactions in the nuclei of cells, which leads to the destruction of microorganisms. At the same time, the chemical composition of water remains unchanged compared to chlorination and ozonation methods, which use the strongest oxidizing agents that can form harmful chemical compounds. For maximum effectiveness of UV water disinfection, it is important that the water is as clear and colorless as possible. Iron, manganese, organic complexes, hardness salts, large and small particles, colloids - all these additives have a negative effect on the process of water disinfection by UV sterilizers. They block the flow of ultraviolet radiation, break it by changing the wavelength, adhere to the quartz shell of the emitting element, and basically prevent ultraviolet rays from entering the water. Therefore, in most cases, UV lamps cannot be considered as independent water purification systems, they can be combined with other water purification systems, such as sediment filters, iron water filters, water softener filters, water clarifiers, etc. used with reagents.

Disinfection of water with ultraviolet lamps is widely used not only in domestic systems, but also in municipal water supply and wastewater treatment. This is due to the high efficiency of the method, as well as the safety of people and the environment compared to the traditional method of water chlorination. However, unlike chlorine disinfection, ultraviolet disinfection is not permanent, that is, when storing such water, it should be noted that microflora can reappear in it. State sanitary-epidemiological supervision of drinking water supply systems, as well as during the design, operation and operation of water disinfection units with ultraviolet rays, their operation must be observed during process control.

2. MATERIALS AND METHODS

In this section, literature research was conducted on the process of disinfection of surface waters by means of UV rays. Scientific research work From December 2018 to October 2019, the US Environmental Protection Agency (EPA) "*Test and Evaluation Facility*" presents the effectiveness of pilot-scale plants for UV-C LED water disinfection. The research included collimating beam testing in a pilot-scale project. It is a

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very important test for drinking water, municipal wastewater and wastewater treatment. The test was carried out for the purpose of bacteriophage MS - 2, total coliforms, heterotrophic plaques (HPC), Bacillus globigii and legionella in drinking water and E.coli, Enterococci, total bacilli, HPC and Bacillus globigii in municipal wastewater. The paper presents the results of MS - 2 bacteriophage, total coliforms and HPC in drinking water (Vairamohan et al., 2021).

The creation of a portable semiconductor device for disinfection of water with ultraviolet light, as well as the work of destroying microorganisms in the aqueous environment using UV radiation of a quartz lamp and semiconductor diodes with a wavelength of 365 nm and 275 nm were studied. In experimental studies, it was found that for all sources of radiation, the dependence of the number of microorganisms in the aqueous environment on the time of radiation has a parabolic function. This is due to the fact that in the first stage of irradiation, the protective functions of the cells of microorganisms are turned off, and then disinfection is carried out in proportion to the time of irradiation. Complete disinfection of microorganisms in the aqueous environment was carried out in 5 minutes with a quartz lamp (wavelength 365 nm) and 30 minutes with a UV diode (wavelength 275 nm) (Soldatkin et al., 2022).

Access to sustainably managed clean water is a basic human right. The Sustainable Development Goals (SDGs) of the United Nations have been established to improve water quality and access to clean water. Achieving these goals has become a priority for hundreds of international UN, as well as bilateral and multilateral development agencies. Consumption of untreated or improperly regulated water can lead to adverse health effects, including parasites, diarrhea, chronic malnutrition, and gastrointestinal disease. These effects are magnified in vulnerable populations such as children, the elderly, and the disabled. This research paper describes the development of a prototype device for solar water disinfection (SODIS) (Urquizo et al., 2020).

Lodid-lodate chemical actinometer was synthesized to monitor inactive microorganisms damaged by UV disinfection. The connection between the biodosimeter and the liposome-coated lodide-lodate chemical actinometer was investigated under a low-pressure ultraviolet lamp. A similar dose rate was observed between the chemical actinometer and the bio-dosimeter. The particle sizes of lodide-lodate chemical actinometer coated with liposomes range from 1 to 3 μm. The chemical actinometer was concentrated up to 7-fold by TOC analysis after liposome encapsulation. The results show that liposome-encapsulated lodide - lodate chemical actinometer can be used in UV water disinfection systems. It can be seen that the results of research on low-pressure disinfection using an ultraviolet lamp showed a positive result (Hong and Otaki, 2012).

This scientific research paper presents scientific works on the development of a new camera phone-based UV quantifier for monitoring water insolation and disinfection (SODIS). The UV content consists of a UV indicator dispersed in a polymer matrix based on ethyl cellulose. Demonstrates the use of a camera phone to provide digital measurements of UV exposure. The use of such quantities in conjunction with mobile phone technology is expected to improve SODIS, thereby significantly impacting the supply of clean drinking water in developing regions of the world (Copperwhite et al., 2012). A pilot experiment on preliminary treatment of micro-polluted raw water was conducted. The results showed that the pre-oxidation process can enhance the removal of organic pollutants than the conventional process, such as COD Mn, UV 254, THM and HAA formation potential. Ozone showed better performance than potassium permanganate and sodium hypochlorite. According to pilot experiments, ozone pretreatment has high efficiency in COD Mn and UV 254 removal. The optimum dose of ozone, potassium permanganate and sodium hypochlorite were 0.50, 0.25 and 2.0 mg/l when COD Mn was less than 1.5 mg/l. Ozone treatment dramatically reduced the amount of disinfection by-products. This research work also reports the overall efficiency range of various indices to select the appropriate water treatment process (Wang et al., 2011).

The research work is based on the analysis of the effectiveness of disinfection technologies (chlorine, ozone and ultraviolet radiation) used in ten pools of the Piscilago Girardot - Cundinamarca water park through the physico-chemical and microbiological characteristics of water. This analysis was conducted using two water samples in different seasons (upstream and downstream) at each site with the aim of comparing water characteristics with upstream and downstream users. Similarly, historical data was collected from monthly monitoring of the park from August 2016 to December 2019. Among the main conclusions of the study , it can be noted that all disinfection methods have 100% percent efficiency in terms of microbiological indicators (for example, total coliforms and E. Coli). However, due to its molecular stability, chlorine continues to disinfect after use, for which ozone and UV methods use the least amount of chlorine to ensure residual effects. Similarly, it was found that the efficiency of water treatment in swimming pools depends mainly on the operation of the system. If there is an excess or defect in the use of the disinfection method, this will directly affect the non-compliance of the analyzed parameters provided by the current regulations (Vega and Sanchez, 2021). Similarly, it presents a simple way to design a concentrator multi-junction solar cell module (MJSC) as an energy source for UV-LED water disinfection. Third-generation commercial 1.0 cm 2 InGaP/GaAs/Ge ternary junction solar cells require lenses with solar concentrations greater than 20 to power UV-LED flux modules. Here, excess energy production and solar radiation can be used in low conditions. At least 6 MJSCs must be connected in series to provide 12 V through a DC-DC converter that provides DC to the UV-LED module (Jeco et al., 2020).

It can be cleaned in room air using UV light. For example, during the period of COVID-19, people were in close contact with each other despite the outbreak of the epidemic , taking into account the economic development. The rooms in the hotel were periodically disinfected. In general, ultraviolet (UV) light is an effective method of disinfection and disinfection that is widely used in many application areas. In a scientific research study, the use of UV LEDs against epidemics in a hotel can protect against viral infection while disinfecting rooms (Chen et al., 2022). At the same time, it can be noted that in some foreign research works, the results of aerosol sterilization using pulsed high voltage with different electrode structures are presented (Ueno et al., 2022).

Wavelength of 240 - 280 nm is known to kill the virus as well as inactivate it. In research, size-adjustable mercury-free, UVC light-emitting diode (LED) was considered as one of the virus disinfectants. The results of the work show that:

- can determine radiation power and radiation distance, as well as radiation power density. The radiation dose is determined by the power density and its time;

- due to its high thermal resistance, UVC LED is required for array module design, as well as its low cost and suitable circuit (Cao et al., 2020).

UV-emitting diodes based on AlGaN semiconductors operating in the 210 - 280 nm range have attracted great interest for many important applications, including water purification, air and surface disinfection as preventive measures against SARS COV - 2, decontamination, etc. However, for the above applications, current technology still relies on toxic and ineffective mercury-based UV lamps. Future technologies for water purification and disinfection, driven by the great need for an efficient and mercury-free alternative technology, require the development of UV-C light emitting diodes. To date, the external quantum efficiency (EQE) in AlGaN quantum well (QW) UV–LED heterostructures has been severely limited due to several factors (Hossain et al., 2022). In the same way , it is possible to see the optimized result of $GO/BIVO_4$ nanocomposites for photocatalytic inactivation of Escherichia coli K_{12} (Thomas et al., 2020). A UVA and UVC sensor based on a quartz crystal microbalance was studied during the technological process (Seeneevassen et al., 2022). In the course of the research process, it is worth raising the problem of improving the limitation of holes by monolayer insertion in asymmetric quantum-barrier UVB emitting diodes (Janjua et al., 2014).

LEDs are becoming more and more common in many fields, from ambient lighting to microscope illumination, UV-LED air desalination, and UV water disinfection. Irradiation uniformity is often a key parameter for irradiator design and optimization. For this purpose, many methods and procedures have been proposed to guide the placement of LED sources as well as the design of special lenses. However, there are many applications where it is important to consider other aspects, such as the uniformity of radiation (Cattini et al., 2021). In some research works, it can be observed that deep UV photodetector works based on low-cost solution-processed MoS2 quantum dots have given positive results (Gupta et al., 2022).

Nano - NiO was synthesized by the photocatalyst method and it is used as a photocatalyst along with 355 nm laser radiation in the process of disinfecting water contaminated with Escherichia coli. When the synthesized Nano - NiO material is used as a photocatalyst, the bacterial decomposition rate constant is 0.35 min^{-1} and this rate constant is higher than the bacterial decomposition rate constant of 0.24 min^{-1} for TiO_2 as a photocatalyst at the catalytic concentration and laser pulse energy. From the TEM study, a size of 20 - 40 nm was observed and the absorption study showed a band gap of 3.85 eV. The dependence of the rate of depletion of the number of bacteria in disinfected water on the concentration of Nano-NiO and the energy of the irradiating laser pulse was carried out (Gondal et al., 2011).

The overseas research paper describes the second phase of research and extensive water sampling procedures between the Center for Renewable Energy and the Swire Institute of Marine Science (SWIMS) at HKU to establish safe, chemical-free, PV-powered wastewater treatment. In a region where the demand for clean water is rapidly increasing due to the increase in the use of household appliances, a strategy to use less water is needed. It leads to competition for access to river mouths and depletion of water resources. Decentralized, low-cost and maintenance-free recycling systems are used in urban and rural areas in developed and developing countries. The UV system was compared to the existing SWIMS dechlorination process against various parameters set by local and international irrigation water quality standards and demonstrated that UV delivers high quality water. A comparative study of capital and operating costs of two disinfection systems was conducted (Close et al., 2006). Decomposition of harmful substances in water with a barrier discharge also gives excellent results (Lee et al., 2021).

The modern food industry requires high-quality water treated with UV light at high flow rates. In the study, pilot equipment controlled by a computer program is presented in several stages: treatment of clean air in an underground pipeline, treatment in a pulsating electric current, softening of water in an electromagnetic field and disinfection in ultraviolet (UV) light. High-level water purification is provided in two additional stages: biological nitrification and activated carbon filtration. The main advantage of the proposed method is the avoidance of conventional chemicals by filtration. The entire process with interrelated variables is controlled by a computer, achieving optimal operation (Vaju et al., 2006). Use of pulsed and continuous UV radiation for surface water disinfection. In addition to the use of general surface water disinfection methods, the method of ultraviolet (UV) light disinfection, which is successfully used for water disinfection in world practice, is often used. UV disinfection successfully combines high efficiency and safety (Vasilyak et al., 2008).

The World Health Organization notes the constant deterioration of the sanitary-epidemiological situation in the world due to the emergence of new viruses and mutations of known viruses. In the first half of 2019, deaths from infectious and parasitic diseases almost doubled in Kazakhstan and are now much higher than in Western European countries. Weak control led to a new surge in many infections. The number of people suffering from tuberculosis has increased sharply, and according to this indicator, Kazakhstan has entered the top 100 countries with a high incidence rate. Extreme man-made loads, complete dependence on infrastructure and high population density pose a real threat to human health in a modern city. In such cases, measures to prevent the emergence and spread of infectious diseases, first of all, disinfection, are of particular importance.

The use of ozonators for air disinfection gives good results from the point of view of microbiology. However, the required concentration of ozone is several times higher than the permissible concentration in atmospheric air of 0.03 mg/cm^3. Such concentrations impose additional restrictions on the use of ozone, moreover, excess ozone can lead to the formation of formaldehyde in the environment. Thus, the use of chemical reagents for disinfection leads to an unreasonable increase in the chemical load on the human population.

Show a constant correlation between diseases of the respiratory system, digestion, inflammation of the mucous membrane and the composition of chemical reagents used in the atmosphere. By-products formed during water chlorination, mainly organohalogen compounds, pose a threat to human health in drinking water, and cause great harm to the ecology of water bodies in wastewater. In addition, chlorination and other oxidative disinfection technologies are ineffective against viruses (Butin et al., 1996). Unlike industrial chemical pollutants, disinfectants are directly introduced into the human environment and their use is strictly limited by the standards for the residual composition of disinfectants. In addition to the use of traditional disinfection methods, the method of disinfection with ultraviolet (UV) light, which is successfully used for water disinfection in world practice, is often used.

All available high-pressure germicidal mercury lamps emit lines of wavelength less than 200 nm, which lead to the formation of highly toxic ozone. Low-pressure mercury lamps are generally made of borosilicate glass or special varieties of quartz, which are impervious to short-wave radiation and are well-differentiated from ozone-generating lamps, which prevent ozone production. Recently, considerable progress has been made in the development of a new generation of low-pressure UV lamps in which amalgam is a source of mercury vapor. The main mass of mercury in the combined state (amalgam), and in the free state, one lamp is only 0.03 µg, so the pressure of mercury vapor at temperatures up to 50°C is below the permissible concentration limit and they are not dangerous. These lamps are significantly safer than the fluorescent lamps that are commonly used for lighting. Amalgam lamps have a high efficiency (35 - 40% percent) of converting electrical energy into UV radiation with a wavelength of 254 nm and three times the intensity of UV radiation compared to mercury microcide lamps. They can effectively remove harmful substances from the air. The use of electronic compact ballasts operating at a frequency of 40-50 kHz made it possible to increase the efficiency of the system, extend the service life of the lamp and change the power during its operation.

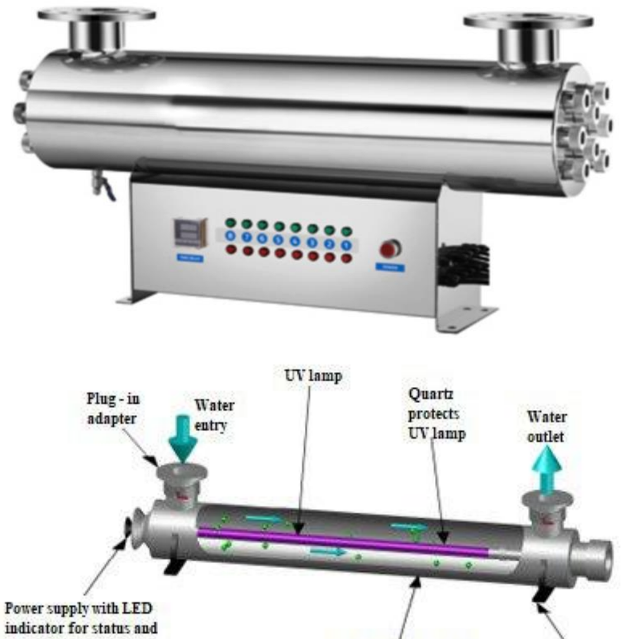
3. Results and Discussion

It successfully combines high efficiency and safety when it comes to UV radiation and surface water disinfection results. Currently, drinking and wastewater chlorination technology is being abandoned all over the world and replaced by UV disinfection technology. In the last few years, this technology has been actively introduced in developed countries such as the USA, Europe and Russia. Wide acceptance of the method depends on a clear understanding of the technology and the rules for its use, as well as on increasing the reliability and efficiency of industrial UV equipment.

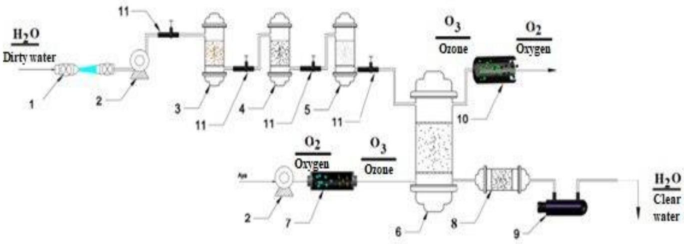
Advantages of surface water disinfection with ultraviolet rays:

- High disinfection efficiency against a wide range of microorganisms resistant to chlorination, such as viruses and protozoan cysts;
- Does not affect the physico-chemical and organoleptic properties of water, there is no risk of overdose;
- By-products are not formed;
- Easy operation of UV units;
- UV devices have low power consumption and do not require additional consumables;
- During the technological process, the compactness of the UV equipment differs.

Taking into account these properties, it is being considered to carry out surface water disinfection works in cooperation with KazNRTU named after K. I. Satbayev and JSC "Kelet". A technological diagram of the device based on the process of water disinfection was compiled according to the general research work (Figure 1).



a) "UUFOV - 20 - KELET" b) ¼ part of the device based on UV light; stainless steel material water by UV light of the decontamination unit general image;



d) technological scheme of the installation based on water disinfection

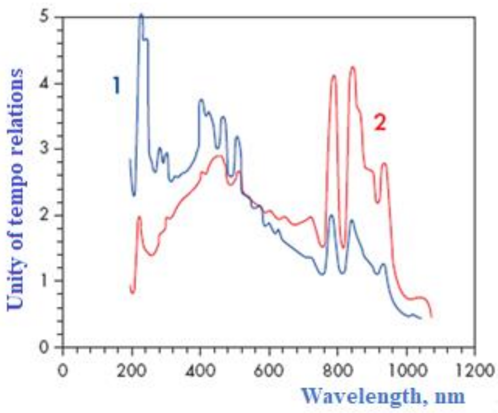
Here. 1) cavitator; 2) water pump; 3) sand filter made of zeolite; 4) activated carbon filter; 5) quartz sand filter; 6) water ozonation chamber; 7) ETRO - 03 ozonator device; 8) membrane filter; 9) "UUFOV - 20 - KELET" water disinfection device made of stainless steel material using UV rays; 10) waste ozone decomposing destructor ; 11) a faucet that regulates water.

Figure 1: A small laboratory device created by representatives of K. I. Satbaev KaNRTU and AO Kelet, designed to increase the quality of water

In general, water disinfection using UV radiation is a universal physical method that is environmentally safe, economical and easy to use. This method has been known for about 100 years, but has been widely used in the last 20 years after the development of powerful, effective UV germicidal lamps in the 1970s. As a source of bactericidal UV radiation during the water disinfection process, mercury vapor electric arc is usually used. The constant increase in environmental safety requirements during scientific work has encouraged the research of alternative sources of UV radiation and the development of technologies for their use. A known source of UV radiation is pulsed discharges in inert gases and their mixtures with halogens (excimer mixtures). In foreign research, equipment using pulsed xenon is currently being developed in various fields of application of lamps , which have a significant proportion of UV rays in their emission spectrum (Figure 2) (Kamrukov et al., 2003). However, the maximum power of the radiation pulse of the xenon lamp is 3 - 10 MW, so the following question arose during the research process:

- There are some differences in disinfection with low and high power ultraviolet radiation;
- Pulse radiation also affects the disinfection process.

during the technological process showed that another additional mechanism can be implemented for microorganisms when the radiation pulse exceeds the threshold power (Wasserrman et al., 2003). Therefore, both disinfection mechanisms and possibilities of pulse systems were considered in the research work (Figure 3).



Here. 6.5 kA/cm ^{2} (1) and 1 kA/cm ^{2} (2) (Perkinelmers Opto - Electronics Corp. (formerly EG&G Corp. Flash Light Technical Bulletins and Catalogs).

Figure 2: Radiation of pulsed xenon lamp at current density spectrum

Impulse UV disinfection mechanisms 205 - 315 nm is always effective in the bactericidal range. It consists of the absorption of ultraviolet photons by DNA and RNA molecules inside the cell. As a result, the microorganism loses its ability to multiply. Depending on the wavelength, the curve of the efficiency of the bactericidal effect of UV radiation corresponds well with the absorption curve of DNA molecules. The maximum of this curve is in the region of 260 nm (Figure 2, curve 1), so the radiation of low-pressure mercury lamps with a wavelength of 254 nm has a high bactericidal efficiency. It is necessary for a tenfold decrease in the number of microorganisms. The amount of UV dose depends on their type and ranges from 2 to 20 mJ/cm² for many bacteria and viruses (Philips, 1983).

The difference between exposure to pulsed radiation and continuous exposure is in the USA and Germany, Russia, Japan, Canada, etc. clearly indicated in research works in countries. The pulsed technology was patented in 1984, and 15 years later, UV photons were proven to be the main contributors to the pulsed beam disinfection process (Jinno et al., 2003). Today, it has been established that pulsed radiation has a bactericidal effect and the mechanism of its action on microorganisms depends on the highest power density of UV radiation. According to the received information, the pulsed beam disinfection mechanism consists of two components (Wekhof et al., 2001):

- effect of bactericidal ultraviolet radiation;
- destruction of the microorganism as a result of its overheating while absorbing all the ultraviolet rays.

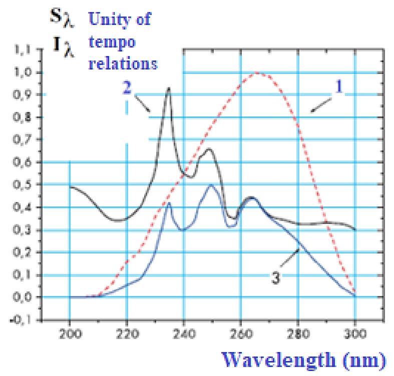


Figure 3: Determination of the bactericidal efficiency of the pulsed xenon lamp

The relative spectral curve of bactericidal effect of S $_{\lambda\ ;\ 2)}$ distribution of radiation energy I $_{\lambda}$ on the spectrum of a pulsed xenon lamp in the range of 200 - 300 nm ; 3) S $_{\lambda}$ I $_{\lambda}$ product - bactericidal efficiency

Disinfection at the maximum power density below the threshold value is determined by UV radiation in the bactericidal range of 205 - 315 nm (Wekhof, 2000). At a high density of pulsed radiation, when the total power density of ultraviolet radiation in the A, B, C (200-400 nm) spectral ranges is higher than the threshold value, the rate of radiation energy transfer exceeds the rate of heat energy discharge. Exposure of the microorganism to the environment and overheating of the microorganism lead to its decomposition (Dunn et al., 1997). It has been proven experimentally that radiation in the visible region of the spectrum does not significantly contribute to the heating of microorganisms. Most bacteria must be heated to a temperature above 130°C to permanently destroy them. An example of such an effect is shown in Figure 4 below (irradiation of A. niger spores with two pulses with the highest UV radiation density of 33 kW/cm²) (Schaefer et al., 2007). Overheating depends on the properties of the environment. For water, the radiation power must be higher, because the heat transfer from microorganism in water is higher than in air. In an experiment on the decomposition of microorganisms on the surface of wax, surface melting was observed - the pulse energy density is so high (McDonald et al., 2002).

In addition to the magnitude of the power peak, it is necessary to provide enough energy to the "target" to heat it. If the radiation pulse is very short, for example, less than 1 μs, then the microorganisms simply do not have time to heat up. In other words, it is necessary to provide both the pulsed radiation power and the absorbed dose of energy sufficient to heat the microorganism to a high temperature. In the course of the experiment, it was found that pulsed heating and destruction of microorganisms can be achieved only by soft ultraviolet radiation from the A and B regions (280-400 nm). This makes it possible to provide disinfection without the use of strong bactericidal ultraviolet radiation (200-280 nm from the C region).

Many years of experience in the use of UV systems have shown that, in addition to the general equipment operating conditions, there are a number of specific requirements for radiation sources. High power, high efficiency, long service life (more than 12 thousand hours) and radiation decay does not exceed 20% at the end of the guaranteed service life. In addition, in the course of the research work, strict requirements were set for the absence of by-products during the use of bactericidal devices and to reduce the risk of mercury vapor contamination of the premises in case of a decrease in the pressure of the lamps. The main factors that determine the effectiveness of ultraviolet radiation sources for bactericidal treatment:

- bactericidal efficiency;
- bactericidal flow lamp;
- the resource and reduction of the bactericidal flow towards the end of the service life of the lamp;
- service life, compactness and cost of the power supply unit;
- safety and productivity of using a bactericidal radiation source.

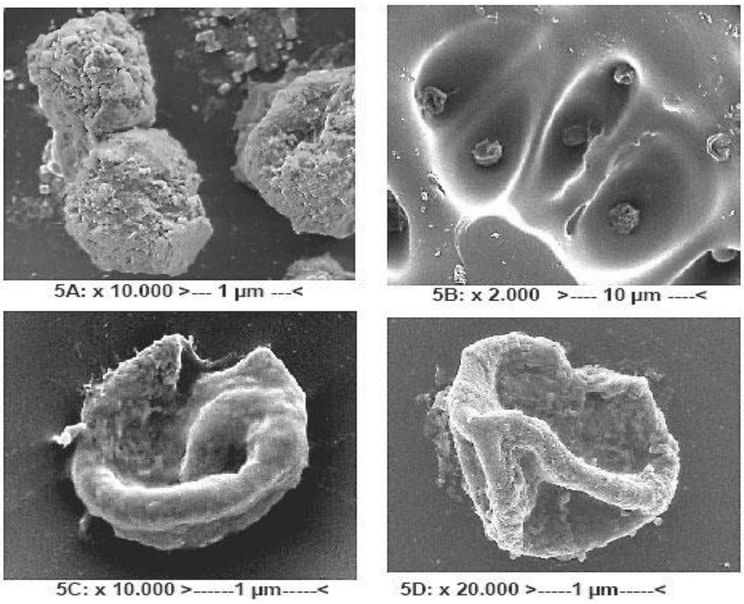
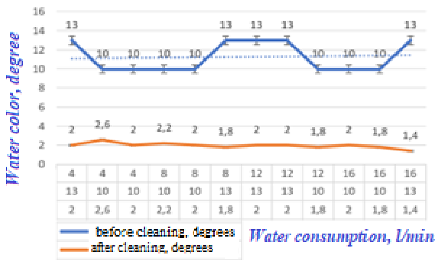


Figure 4: Effect of pulse radiation on A. niger spores (McDonald et al., 2000)

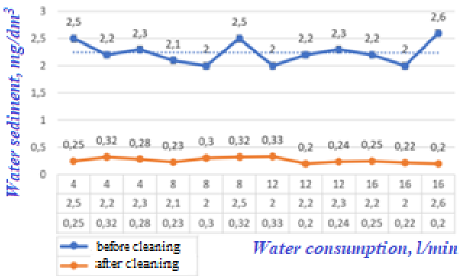
Here: Photographs show scale a - primary spores; (b) Aspergillus niger spores after exposure to 2 UV pulses with a peak power of 33 kW/cm [2.] On the surface of the polyethylene terephthalate substrate, the depressions formed as a result of immersion of heated spores with pulse radiation are visible; (c) A single Aspergillus niger spore after exposure to 2 beam pulses with a peak power of 33 kW/cm [2.] The tip of the spore is torn by a superheated intracellular fluid that escapes from the spore. A crater forms around the spore from the ejected debris; d - spores after exposure to a pulse of radiation with a maximum power of 5 kW/cm [2 5]

Radiation in a fairly small spectral range of 205 - 315 nm has the greatest bactericidal effect. The effectiveness of the radiation source is determined by how close its spectrum is to the maximum bactericidal sensitivity of microorganisms. During the research work, for complete purification of water in accordance with health standards, i.e. radiation affecting harmful substances in water is 16 mJ/cm[2.]

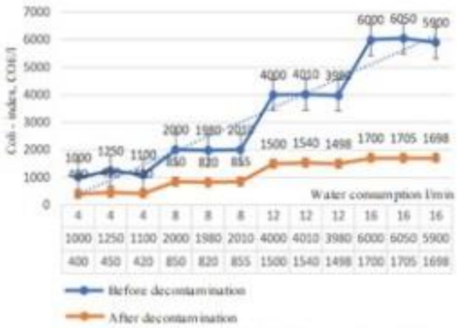
The results of experimental research, that is, the effectiveness of UV rays, can be seen in the following 5 pictures a, b, d, e.



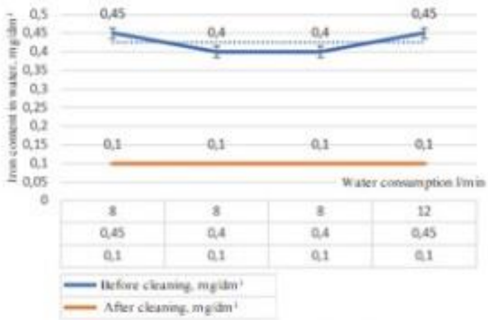
a) The effect of UV radiation on the color of water during the process



b) The effect of UV radiation on the water sediment during the process



d) The effect of UV radiation on the coli index during the process



e) The effect of UV radiation on iron concentration during the process

Figure 5: Laboratory of the process of cleaning and disinfecting water using UV rays results

During research work, with such an active effect of UV radiation, bacteria can be reduced by 5 times or more, and the amount of viruses is reduced by 2-3 times. The average water disinfection time in the chamber is calculated according to the following formula:

$$t = \frac{S \cdot L}{278 \cdot Q} \quad (1)$$

Here:

t - average water disinfection time in the chamber, s;

S - cross-section of the disinfection chamber, cm;

L - length of the disinfection chamber , cm;

Q - water consumption, m^3 /h;

The bactericidal flux of the UV radiation source is estimated by the ratio:

$$F_{l,bk} = \int_{205}^{315} \Phi_e(\lambda) \times S(\lambda)_{к.} x\, d\lambda, Вт \quad (2)$$

where, S (λ)k. - spectral bactericidal efficiency in relative units; Fe (λ) is the spectral density of the radiation flux, W/nm; λ is the wavelength of radiation, nm. Now other quantities and units can be defined with the following expressions.

Bactericidal radiation energy:

$$Wbk = Fl,bk\, xt, J, \quad (3)$$

where t-radiation exposure time, s.

Bactericidal radiation:

$$E_{bk} = \frac{\Phi_{л,бк}}{S}, W/sq.m \quad (4)$$

where S-irradiated surface area, sq. m.

Bactericidal exposure (called dose in photobiology):

$$N_{bk} = \frac{\Phi_{л,бк} \times t}{S} = \frac{w_{бк}}{S}, J/sq.m, \quad (5)$$

Volumetric density of bactericidal energy:

$$E_{4pi,bk} = \frac{W_k}{V}, J/cubic\ m, \quad (6)$$

where, V is the volume of the irradiated air medium, cubic meters.

Microorganisms belong to cumulative photobiological receivers, so the bactericidal efficiency should be proportional to the radiation product over time, that is, it is determined by the dose. However, the non-linear nature of the photobiological receiver limits the possibility of wide variation of irradiance and time values with the same bactericidal efficiency. The ratio of radiation and time can be changed within a 5-10-fold variation within the permissible error.

I_{bk} Quantitative evaluation of the bactericidal effect of removed N_k It is characterized by the ratio of the number of microorganisms to their initial number of N and is estimated as a percentage.

$$I_{bk} = \frac{N_к}{N_н} \times 100\,\% \quad (7)$$

bactericidal efficiency of I_{bk} on the dose of H_{bk} for microorganisms can be expressed using the following equation:

$$I_{bc} = (a \ln N_{bc} + c), \%, \quad (8)$$

it demonstrates the famous Weber-Fechner Law, which establishes a relationship between physical exposure to a biological object and its response. This equation can be transformed into:

$$H_{bk} = exp(\frac{I_{бк} - в}{a}), J/sh.\ M \quad (9)$$

If the required level of bactericidal efficiency is shown, it allows to determine the required value of the dose.

Bactericidal lamps are supplied from the mains voltage 220 V, alternating current frequency 50 Hz. Connecting the lamps to the network is carried out by means of start-up control devices (PRAs) that provide the necessary modes of ignition, burning and normal operation of the lamp and suppress the high-frequency electromagnetic oscillations caused by the lamp, which can adversely affect sensitive electronic devices.

The mercury atom, which is the main radiation element of bactericidal gas-discharge lamps, has a resonant electronic transition with a wavelength of 253.7 nm near the maximum of the bactericidal sensitivity curve. In low-pressure mercury lamps, the efficiency of conversion of electric energy into radiation at a wavelength of 253.7 nm reaches ~ 35-40%, which is more than 90% of the total radiation (McDonald et al., 2000). In combination with a simple ballast design (electromagnetic choke and starter) and a service life of more than 10,000 hours, these low-pressure mercury lamps can be widely used as a source of bactericidal radiation. The linear power of low-pressure mercury lamps does not exceed 0.5 - 1 W/cm, which is not always enough for high-performance equipment. High radiation power and linear power up to 100 W/cm are high pressure mercury lamps. However, the bactericidal efficiency of this type of lamps is 2-3 times lower than that of low-pressure mercury lamps. The share of radiation in the bactericidal wavelength range is 15-17% of the input electricity, and the corresponding bactericidal efficiency is 8-12%. An important drawback of mercury bactericidal lamps, which limited their use, was the high content of free metallic mercury. In low-pressure mercury lamps, the amount of free mercury in one lamp is from 3 to 10 mg, and in high-pressure lamps it is hundreds of milligrams. Since the limit permissible concentration of mercury in atmospheric air is 0.3 μg/m ³ , it is clear that metal mercury lamps pose a significant environmental risk if they are removed.

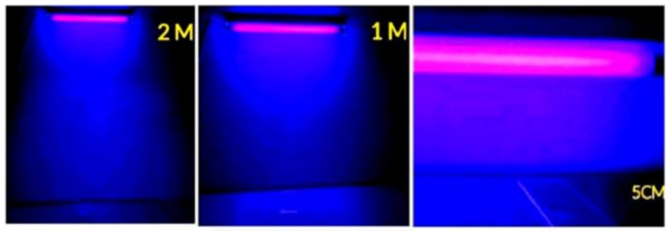


Figure 6: Method of placing the sample under the UV lamp

In this experiment, we tested an LED UV lamp with a power of 9 W. The effectiveness of the lamp will be tested on the simplest microorganisms that live in water. Let's take 4 samples of liquid containing microorganisms and place the first sample five centimeters from the lamp, the second sample one meter from the lamps, and the third two meters from the lamps. The results of research in Urdis can be observed under a microscope. This is what all three models look like before turning on the light. (Picture 7) Turn on the lamp and set the time.

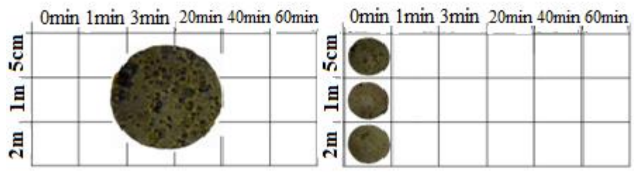


Figure 7: View of the test before turning on the lamp

Let's check the nearest sample after one minute, no special changes are found, but after 3 minutes, we notice that all the microorganisms have been destroyed in the sample five centimeters from the lamp. At the same time, nothing has changed in the average sample. The same after 5, 10 and 15 minutes. After 20 minutes, if we look at the sample at a distance of one meter from the lamp, there is no change, in the average sample, only after 40 minutes, small cells have died, and large ones continue to live. It should be noted that the samples began to dry a little, that is, the thickness of the liquid decreased a little. And in the lower sample, no significant changes were observed within 40 minutes.

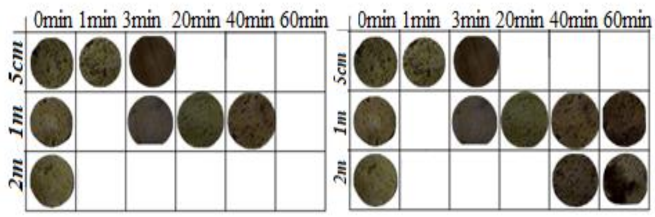


Figure 8: Test results after 1 hour

After one hour of irradiation, it was decided to end the experiment. As you can see (Figure 8), during this time, in the sample at a distance of 1 meter, mostly small microorganisms were destroyed, and in the sample at a distance of 2 meters, everything continues to actively live.

Table 1: Chemical microbiological composition of water disinfected at different distances

Indicators	Normative - sweat not more (MPC)	Initial water composition	UV distance 2 m	UV distance is tight 1 m	UV distance is tight 5 cm
oli is an index in 1dm³ , not more	10000	75	65	49	0
Total microbial count, 1 cm³	< 50	59	57	30	0
Total coliform bacteria, 100 ml	It shouldn't be	1	1.0	1.0	0

As a biological weapon, UV rays attack bacteria from three directions at once. Firstly, the structure of DNA functions is changed, secondly, proteins are destroyed, and thirdly, biomembranes are damaged. It is interesting that in this process, several phases are divided, some cells die, and the surviving cells continue to divide, but the rate of division slows down, some die, only after 2-4 weeks their complete destruction or regeneration of living cells is realized. Thus, we can say that we have a weapon against viruses and bacteria. But, since a person is a living organism, the effect of quartz lamps will also harm him. Although we can protect ourselves from direct UV rays by using glasses, clothing, and special design of lamps, we cannot get rid of ozone. Therefore, when using quartz lamps, there should be no people in the room, and ventilation is required after quartzing. However, progress does not stand still, and over time, bactericidal ultraviolet lamps appeared. The bulbs of such lamps are made of ultraviolet glass, which does not transmit the ozone-forming part of the ultraviolet radiation spectrum.

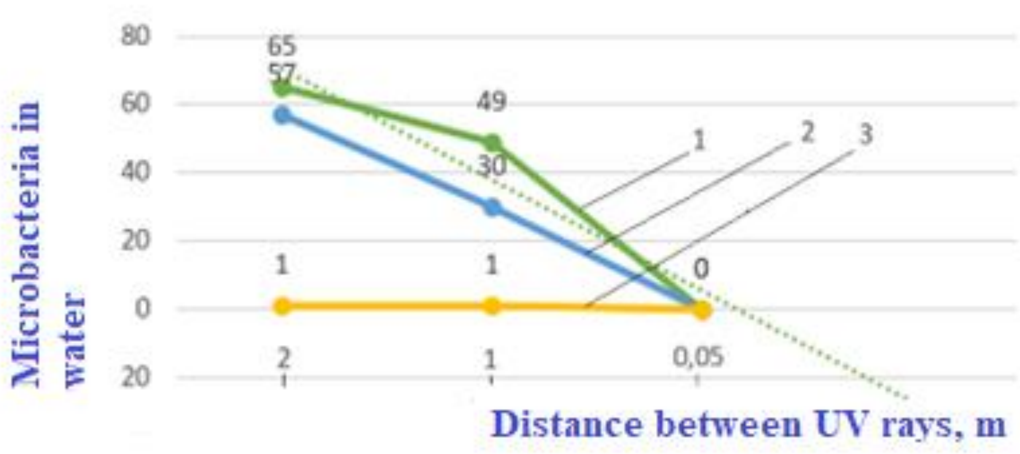


Figure 9: Effect of UV rays on microorganisms in water depending on the distance

Here 1 - Coli - index in 1dm ^{3} , no more , 2 - Total microbial count, 1 cm ^{3} , 3 - total coliform bacteria, 100ml

Table 2: The result of water disinfected and purified by UV rays

The results of the test at a distance of 5 cm							
Indicators	Regulations not more (MPC)	Initial water composition	UV radiation _ 1 min	UV radiation _ 3 min	UV radiation _ 20 min	UV radiation 40 min	UV radiation 60 min
Koli is an index in 1dm³ , not more	10000	75	65	0	0	0	0
Total microbial count, 1 cm³	< 50	59	57	7	0	0	0
Total coliform bacteria, 100ml	It shouldn't be	1	1.0	0	0	0	0
Results of the test at a distance of 1 m							
Indicators	Regulations not more (MPC)	Initial water composition	UV radiation 1 min	UV radiation 3 min	UV radiation 20 min	UV radiation 40 min	UV radiation 60 min
Koli is an index in 1dm³, not more	10000	75	65	59	58	56	56
Total microbial count, 1 cm³	< 50	59	59	59	56	55	55
Total coliform bacteria, 100ml	It shouldn't be	1	1.0	1.0	1.0	1.0	0
Results of the test at a distance of 2 m							
Indicators	Regulations not more (MPC)	Initial water composition	UV radiation _ 1 min	UV radiation _ 3 min	UV radiation _ 20 min	UV radiation 40 min	UV radiation 60 min
Koli is an index in 1dm³, not more	10000	75	59	59	59	58	58
Total microbial count, 1 cm³	< 50	59	59	59	59	58	58
Total coliform bacteria, 100ml	It shouldn't be	1	1.0	1.0	1.0	1.0	1.0

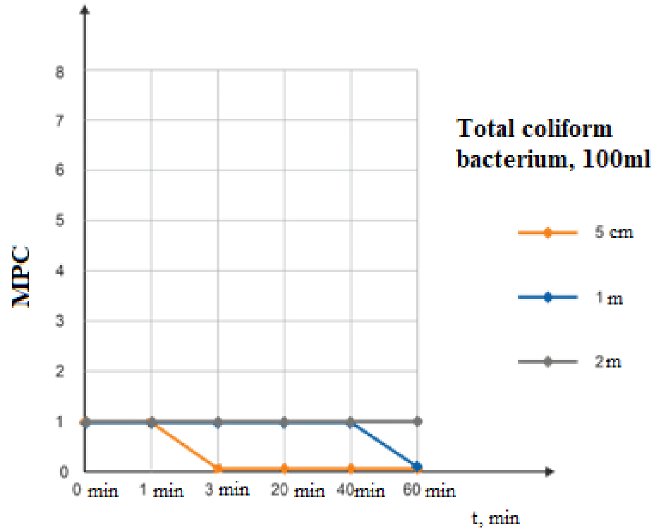


Figure 10: Changes in the amount of total coliform bacteria.

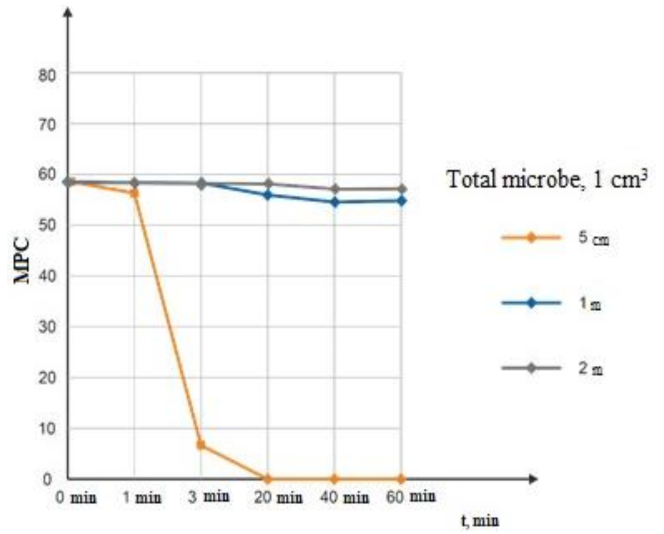


Figure 11: Changes in total microbial counts.

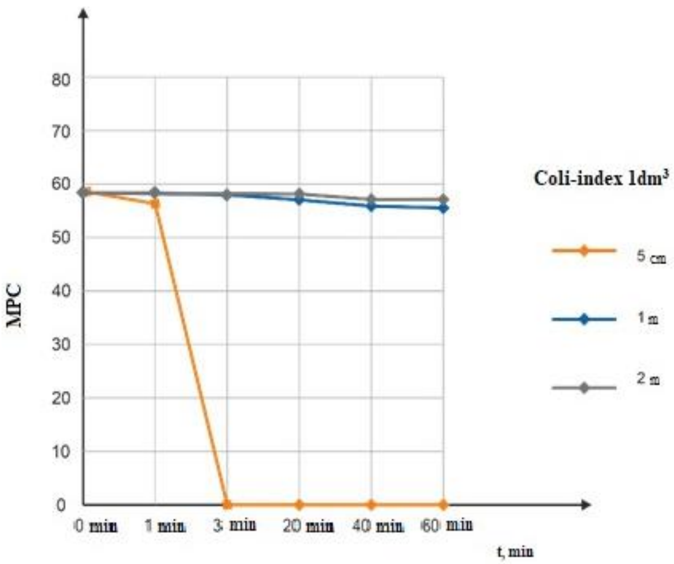


Figure 12: Koli is a change in index size.

Let's discuss the working principle and economic efficiency of the UV LED lamp based on the research experiment. First of all, it should be noted that in this experiment, microorganisms were exposed to radiation compared to bacteria, and their viability is higher than that of bacteria. In addition, they were in a humid environment. On the basis of ultraviolet rays, it passes well through air. Therefore, the lamp is more effective against bacteria and viruses on dry surfaces or in the air.

According to the test results, it can be seen that the lamps are quite effective at close range. From an ecological point of view, a significant advantage of UV disinfection is that in this case only 100% reactive substances are used, so there are no problems related to the recovery of solvents. The curing process is carried out at room temperature, so the coatings can be cured on substrates sensitive to high temperatures. But the most important advantage of this method is the economic factor. The drying process is fast, the operation of the plants is relatively simple, and the operation requires a minimum of space and human resources. The undoubted advantage of this method is the high quality of the final products.

LED UV light sources can provide an arbitrary spectrum of radiation in the bactericidal range and achieve a spectral efficiency higher than low-pressure mercury lamps. Such UV sources have a long service life (10,000 - 50,000 hours), low cost, high reliability and stability of operation in a wide temperature range, and can completely replace mercury lamps in all applications with full environmental safety. LED UV lamps are the most suitable for curing UV radiation, because, unlike mercury and excimer lamps, the technology used in LED emitters makes it possible to create flat lamps half a centimeter thick with a large area of emitting surface (tens and hundreds of square centimeters). This, in turn, makes it possible to create compact and inexpensive sterilization systems.

4. Discussion of Scientific Research Work

Currently, all major disinfection stations are built on such UV lamps only. It should be noted that the world's largest drinking water disinfection station with a consumption of 1.4 million m^3/day was developed and built by NPO LIT manufacturer in St. Petersburg of neighboring Russia. The source of pulsed ultraviolet radiation is pulsed discharges in inert gases and their mixtures with halogens (excimer mixtures). The developed equipment uses pulsed xenon lamps. The main claimed advantage of such lamps is high peak pulse power. It differs from 5 to 10 MW with a pulse duration of several hundred microseconds. Initially, xenon lamps were developed to drive solid-state lasers, and then they began to be used for disinfection. The spectral composition of the radiation depends on the discharge current and the switching circuit of the lamp (Figure 2).

The 200 – 300 nm wavelength range accounts for 25 – 30% of all radiation in the 100 – 1100 nm range and 40% for the entire UV range. Accordingly, the bactericidal efficiency is 10-13% of the total radiation of the lamp (Figure 3, curve 3). The obtained result corresponds to the performance of xenon lamps of type INP - 7/120 and IFP - 8000 (Dunn et al., 1997). Taking into account the transmission costs and heat losses of the lamp, the bactericidal efficiency is ~ 10% of the electricity consumed by the lamp. It should be noted that the wide radiation spectrum of pulsed xenon lamps is more of a disadvantage than an advantage, as its short-wavelength part can lead to the formation of harmful ozone, indirect chemical reactions, and the formation of compounds harmful to humans. To prevent the formation of ozone by short-wave radiation, additional protective films or special varieties of quartz are used. But this significantly increases the cost of the lamps and shortens their service life, because the pulsed thermal stresses increase during the flash (Lagunas-Solar et al., 2006).

The service life of xenon flashing lamps is determined by the number of flashes that the lamp can provide. The higher the pulse energy, the smaller the number of lamp operations, varying from 103 to 108 pulses. The average lamp power is controlled by changing the pulse repetition rate. For equipment from the American company LightStream Technologies, the flash repetition rate at maximum performance is 30 Hz. In the practical use of flashlights, the decrease in UV radiation at the end of their service life is 25-50% (Dunn et al., 1995). Two main electrical circuits are used to operate xenon lamps. In both, pulsed capacitors are used as energy storage devices. Energy is always lost when charging a capacitor. The use of high-power pulsed high-voltage technology significantly increases the size and complexity of the power source for flash lamps and imposes high requirements on electrical safety when working with this equipment (Kamrukov et al., 1993). Thus, pulsed sources of ultraviolet radiation are characterized by high (up to 10 MW) instantaneous power, bactericidal efficiency of about 10%, service life of about 1000 hours and high voltage power supply. High-pressure mercury lamps, such as incandescent xenon lamps, require intensive heat dissipation. This makes their basic apparatus design more complex than equipment based on low-pressure mercury lamps.

5. Conclusion

In conclusion, the following experimental works were performed in this scientific research work:

- LED sources of ultraviolet radiation were analyzed;
- An LED driver with a voltage of 12 V and a current of 720 ma was calculated;
- Maximum radiation with a wavelength of 240 nm;
- A sample of the UV lamp was assembled using the selected components;
- The power of the prototype model was 9 W. The time of stabilization of electrical and energy parameters was 3 minutes and 25 seconds.
- The maximum spectral radiance is equal to $2.88*10^{-3}$ W/nm;
- The power flow of the prototype is 610 mw.

Studies have shown that the developed prototype is an analogue of the LUKT 10 P fluorescent ultraviolet lamp with an energy flow of 0.6 W.

Summarizing the problem of studying the process of disinfection of surface water by UV rays, the advantages and disadvantages of water purification are as follows:

- The advantage is that UV light does not depend on the pH level, water temperature and its chemical composition.
- The disadvantage is the need to take into account the presence of suspended particles in water, as they can absorb pollution and ultraviolet rays. That is, to disinfect such water, it is necessary to use a lot of ultraviolet radiation energy.

During the technological process, UV light and water disinfection is the last stage. Water enters the collection chamber, and from there - through the gravity collector to the discharge point or consumers.

This method of water purification ensures complete disinfection. It completely eliminates the effects of harmful chemicals and various pathogenic bacteria contained in the appropriate quality of wastewater returned to the needs of consumers, surface water reservoirs and drinking water. Unlike other methods, water purification is distinguished by the high quality of purified water and the absence of residual substances in the water. Today, in the process of technological process or in water management, surface water disinfection and cleaning with UV rays would not be better than using it in water reservoirs in the country.

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