LIGHTING TECHNOLOGY TO REDUCE THE EFFECTS OF COVID-19

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SUMMARY

Currently, the Covid-19 pandemic has brought to the fore the issues of preventing new contamination of the environment, especially aquatic. Under these conditions, lighting technology and disinfection technologies based on the use of radiation in the ultraviolet range open up wide opportunities. Conducted at the O.M. Beketov National University of Urban Economy in Kharkiv research made it possible to establish the possibility of using ultraviolet LEDs to treat various environments infected with Covid-19, to develop a methodology and a program for calculating ultraviolet LED installations for disinfecting various environments, in particular water infected with Covid-19, to develop the structure and parameters of a prototype installation, as well as the reliability of the main conclusions.

INTRODUCTION

In reality, the problem of environmental quality is one of the most important. It is this problem that concerns all of humanity, since the presence of various kinds of pollution in the environment can lead to a catastrophe, which has become the Covid-19 pandemic today. The pandemic has severely affected the entire environment. It is especially necessary to pay attention to the aquatic environment, since it is not only a source of industrial water, but also drinking water, and the presence of Covid-19 microorganisms in it is unacceptable. The known methods of water purification, as well as systems and schemes for its disinfection are not able to meet all the requirements and guarantee the protection of the population from harmful microorganisms. This is due to the use of ineffective equipment and technologies. Classification-identification of methods for disinfecting water from microorganisms has general approaches to determining its components:

1) chemical
2) physical and chemical or combined;
3) physical - mechanical, electrical, radiation, acoustic, thermal.

General questions on the topic can be determined by the method of action

1) The choice of a method for disinfecting water from microorganisms.
2) Factors affecting the effectiveness of the selected disinfection method.
3) Comparative characteristics of water disinfection methods.
4) Selection and calculation of the optimal parameters of the disinfection system.

Existing bactericidal installations (can be attributed to group 3) are built on the use of ultraviolet gas-discharge mercury-argon or mercury-quartz lamps. The presence of suspended solids in the water and the low light output of the lamps reduce the efficiency of the disinfection process. In addition, the design of the installations allows water purification only in places with very high bacterial contamination.

In this regard, installations for water disinfection based on existing bactericidal lamps are ineffective, although quite attractive in general, and the search for new and improvement of existing technologies for disinfecting drinking water is an important and urgent task. At the same time, it is necessary to determine - water of drinking quality by organoleptic properties, microbiological and chemical composition, complies with the current sanitary norms and rules, and is also safe for human life and health [1-6].

RESEARCH RESULTS

Technology of disinfection with ultraviolet light is widely used, since ultraviolet light can be an insurmountable barrier for many microorganisms, which is especially important during a pandemic. However, in order for the UV equipment to really cope with the tasks set, it is necessary to provide the required radiation range and select its power correctly in order to ensure the required disinfection effect. In particular, for the disinfection of domestic and urban environments, a UV dose of at least 30 mJ / cm2 should be used. But, as practice shows, the external environment is so unique that this dose may be either insufficient or more than necessary. Therefore, to solve these problems, the best option is to find new ways that involve the use of more flexible and energy efficient systems.

The technology of ultraviolet irradiation for the disinfection of drinking and waste water is widely used. When organic cells of various bacteria are exposed to ultraviolet radiation, destruction of microbial cells is observed in the range from 200 to 400 nm. [7] Such opportunities should be used to increase the effective operation of germicidal installations; it is necessary to search for energy efficient light sources operating in the range of 200-400 nm. Since the purpose of these installations is to neutralize bacteria, then only photons with an energy that is capable of breaking the bond of protein molecules by radiation with a wavelength of λ <300nm should have bactericidal properties in them. The study of processes in installations of bactericidal action made it possible to determine the area of their effective action.

In conclusion, after analyzing the graphical dependencies shown in Fig. 1, is that the greatest efficiency of germicidal installations is provided by light sources with a wavelength of 254 - 258 nm. In the research laboratory of the Nippon Telegraph and Telephone Corporation, under the leadership of Dr. Yoshitaka Tannyasu, diodes based on aluminum nitride have been created, which can emit light in the ultraviolet range with a wavelength of 210 nm. Their use is able to provide distributed disinfection of a significant amount of contaminated elements located on a significant plane. Experiments carried out by Japanese scientists have confirmed the possibility of using ultraviolet LED light sources for disinfecting surfaces and environments from Covid-19.[8]

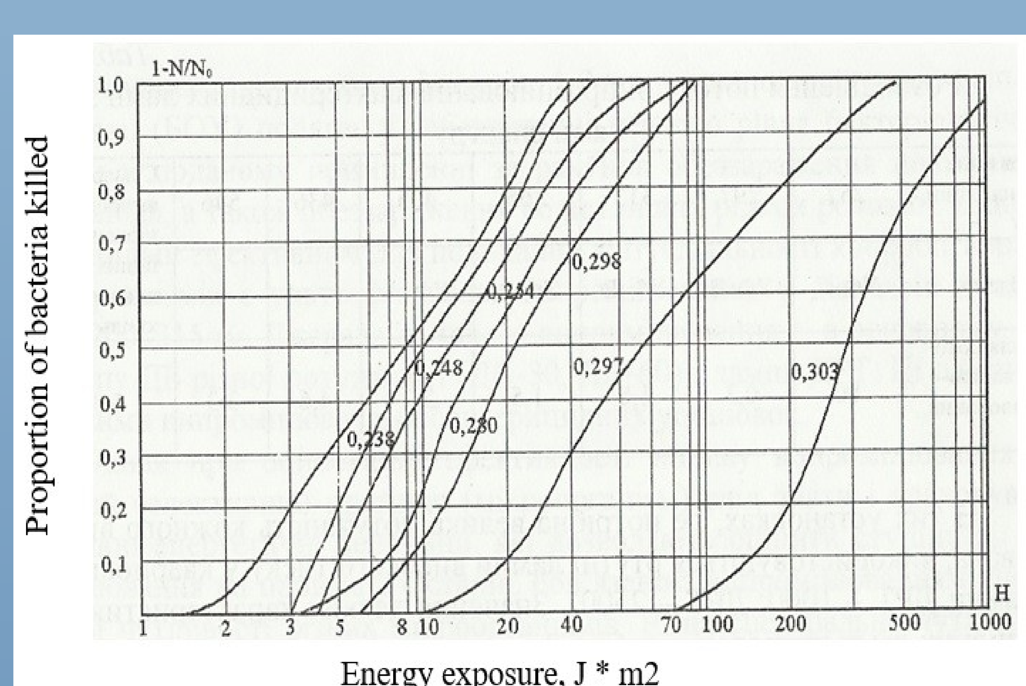

Figure 1. Spectrum of effective bactericidal action of radiation

According to research results, the use of ultraviolet light-emitting diodes in disinfection installations provides inactivation of 99.99% of viral parts in up to 30 seconds. Therefore, the production of lighting devices based on ultraviolet emitting LEDs is an urgent task of global importance.

As the analysis shows, bactericidal installations based on LED light sources provide high technical and economic indicators, which, along with improved energy characteristics, also provide the possibility of dispersing bactericidal installations and the possibility of multi-stage disinfection. But so far there are no lighting and electrical calculations for such systems, which hinders their introduction into existing disinfection systems and determines the low energy and lighting efficiency of such installations and the unrestrained growth of infection.

Therefore, in order to identify the general patterns of creating a light space with LED lighting devices, the authors have developed a technique for synthesizing lighting devices based on the known luminous intensity curve (LIC) of a single LED light source. To form the luminous intensity curve of the device, a model of the form [8] was used:

$$I'(\lambda) = F\,(I(\lambda), N, K) = F\left(I_0, N,\ 2\theta_{0,5}, K\right) \qquad (1)$$

where I '(λ) - light intensity distribution of the joint venture; I (λ) - luminous intensity distribution of one light-emitting diode (LED) N is the number of LEDs in the device; I0 - axial luminous intensity of one LED; 2θ0.5 - angle of illumination of one LED; K is a coefficient that takes into account the distribution of luminous intensity from the optical element of the light device.

Modeling of light distribution LEDs was carried out on the basis of Lambert-type curves using spline approximation, as the most effective description of this process. Finding the desired spline - a function that describes the distribution of the luminous intensity of an LED light source in space, is reduced to solving a system of linear algebraic equations. For this, the Light Power software has been developed, which provides the calculation of the LIC of LED devices with an arbitrary location and orientation relative to a certain center of the LED, as well as for each state of the transmission medium.

In figure 2 shows an algorithm for calculating the parameters and characteristics of lighting devices based on LED light sources.

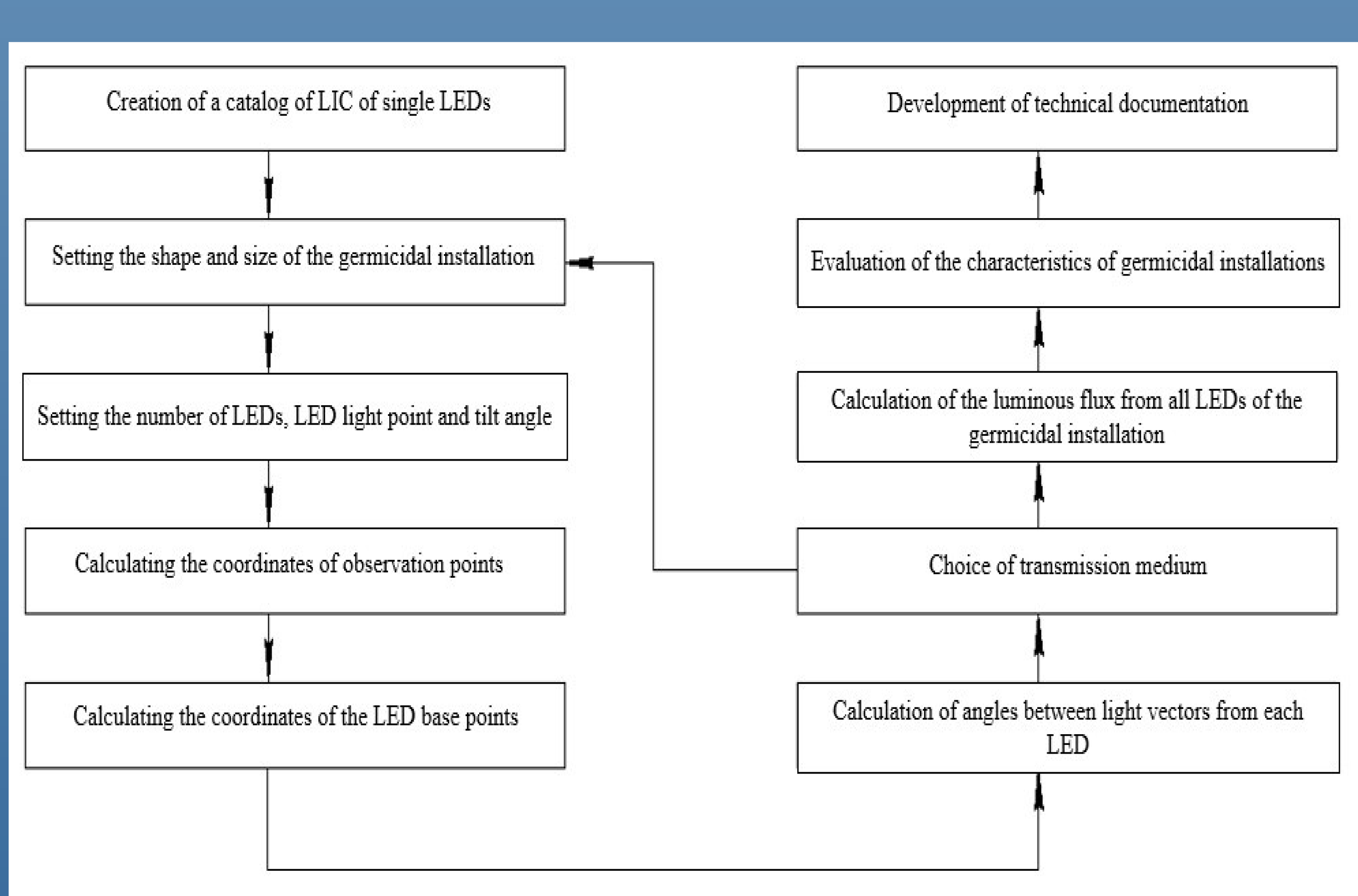

Figure 2. Algorithm for calculating germicidal installations with LED light sources

The result of the calculation is a graph of light distribution in the plane where the observation points are located. The graph is a curve of luminous intensity (LIC) in an arbitrarily chosen plane passing through the axis of the lamp. The magnitude of the luminous intensity in this dependence is the result of the addition of the luminous forces at the observation point, from all the LEDs located in the LED lamp (LL). The angle is defined as the angle between the axis of the lamp and the beam to the observation point. To calculate the luminous intensity, the law of the square of the distance I = E·L2 is used. To calculate the KSS of the SDL, the KSS of single light-emitting diodes (LEDs) are used, which are listed in the passport data. Under the conditions under consideration, the LIS of LEDs is a cubic spline of approximation obtained on the basis of experimental measurements for a single LED. The LIC of the modeled LL is calculated in two stages.

At the first stage, a catalog of LIC of single LEDs of various modifications is created, from which it is supposed to create LL.

At the second stage, at the observation points, the luminous intensity from all LEDs of the lamp is calculated.

The second stage of the task is carried out in accordance with the developed methodology:

calculation of the coordinates of observation points depending on the observation angle for a given step of changing the angle;

calculation of the coordinates of the LED base points for the given LED luminescence points and the angle of inclination of the LED axis to the lamp axis;

calculating the angles between the light vectors from each LED and the vector that defines the axis of the LED.

The application of the developed methodology allows calculating the LIC from the LL for any conditions of use. Calculation of LIC for LL is reduced to the calculation of the luminous intensity at any point of the transmission medium Ai with coordinates (xa, ya, za) in the coordinate system in which the OZ axis coincides with the axis of the lamp. The origin point is the imaginary center of the lamp luminosity, which can be arbitrarily selected in the area of the diode placement plane. The XOY plane is perpendicular to the OZ axis and the OZ axis passing through the zero point. The direction of the OX axis is freely selectable. The algorithm used in the task for calculating observation points Ai of the transmission medium, based on the statement that these points are in the XOZ plane.

To calculate the coordinates of the luminescence points of the transmission medium, an algorithm for calculating the coordinates was used, which consists in finding the coordinates of equidistant points of the transmission medium, when rotating them around the origin of coordinates. In order to use this method, the following values are set [9]:

- the distance to the points of calculation R from the zero point of the coordinate system;

- the step of changing the angle when moving the calculation point around the point of the zero axis OZ. Based on the step, the angle is calculated between the calculation point and the negative direction of the OZ axis.

According to the cosine theorem, the distances to the calculation points and their coordinates are determined:

$$a = -R \cdot \cos(\gamma) \qquad (2)$$

In figure 3 shows the geometric interpretation of obtaining the coordinates of the calculation points as a result of the rotation of the calculation point around the center of coordinates..

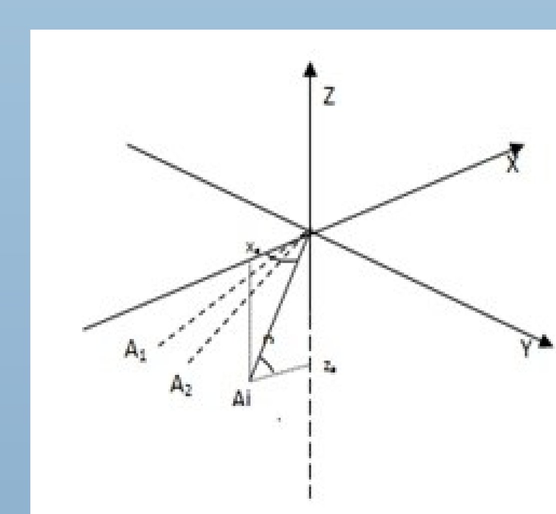

Figure 3. Determination of the coordinates of the calculation points

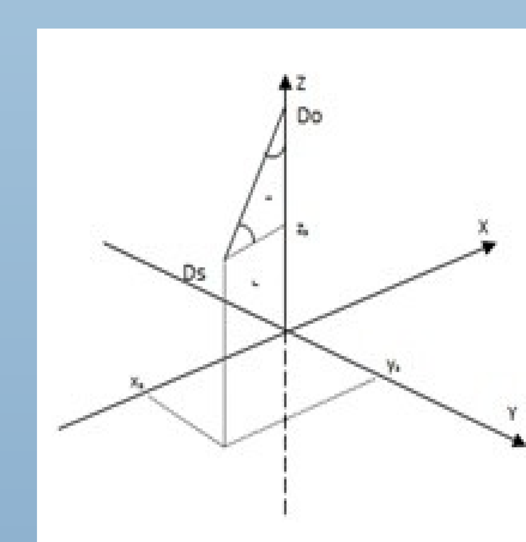

Figure 4. Determining the coordinates of the base point of the LED

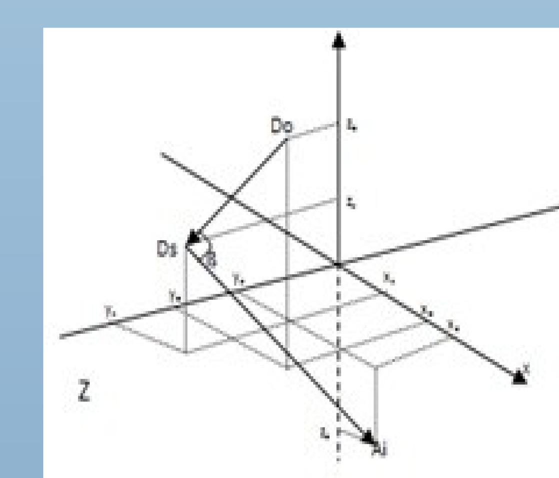

Figure 5. Determination of the angle between the axis of the LED and the calculation vector

The coordinates of two points in space, specified in a specific order, define a single vector. Thus, if you set two points lying on the beam of the axial luminous intensity of the LED. This is enough to set the direction of the LED axis. The end point of the LED vector must be specified as the coordinates of the optical center of the LED. The starting point of the LED vector can be chosen arbitrarily, but it must necessarily belong to the beam of the axial light intensity of the LED. To determine the coordinates of the starting point of the LED vector in specifying the angle between the axes of the LED and the lamp, the angle obtained as a result of drawing the plane through the OZ axis and the point of the optical center of the LED is calculated. From the point of the optical center of the LED, the perpendicular to the OZ axis is restored. hypotenuse, of this triangle, a segment of the geometric ray will protrude from the point of the optical center of the LED to the OZ axis. The angle between the hypotenuse and the OZ axis is set during the design of the lamp and is the angle of inclination of the LED axis to the lamp axis. The starting point of the LED vector, based on this construction, is the point of intersection of the hypotenuse with the OZ axis. Designating the point of the optical center of the LED with coordinates Ds (xs, ys, zs) and using the tangent theorem for a right-angled triangle, we find the size of the leg belonging to the OZ axis in the form:

$$b = a \cdot tg(\gamma) \qquad (3)$$

where a is the length of the leg, which can be found from the coordinates of the optical center point of the LED.

In the XOY plane, the projection of the point of the optical center of the diode has coordinates, respectively, xs and ys. The length of the vector from the optical center to the OZ axis is √ (xs2 + ys2). Thus, leg b is defined as:

$$b = tg(xs^2 + ys^2) \qquad (4)$$

Coordinates of the point of intersection of the hypotenuse with the OZ axis (0, 0, zs + b). Figure 4 shows the geometric interpretation of the obtained coordinates of the points based on the LEDs.

You can set the coordinates of the starting point of the diode vector simply from the geometric image of the lamp. The task uses the calculation of the coordinates of the origin of the diode vector for each diode of the lamp according to the described algorithm, if the coordinates of the point of the optical center of the diode and the angle of inclination of the diode axis to the lamp axis are given.

When specifying the coordinates of the points of the beginning and end of the diode vector from the geometric construction of the lamp, the need for the problem of the angle of inclination of the diode axis to the lamp axis disappears.

To calculate the luminous intensity from the optical center of the LED to the point of calculation, the angle between the vector specifying the axis of the LED and the vector from the point of the optical center of the LED to the point of calculation is recognized.

The angle between vectors in space is found using the concept of scalar multiplication of vectors in accordance with this scalar product of two vectors a (Xa, ya, za) and b (X in, Yb, zv) is the sum of multiplications of the corresponding coordinates of the vectors: ab = xa * Xb + ya * yb + za * zb.

On the other hand, the dot product of these vectors, is the achievement of the lengths of the vectors multiplied by the cosine of the angle between them:

$$ab = |a| \cdot |b| \cdot \cos(\alpha) \qquad (5)$$

To find the angle between the axis of the LED and the vector from the optical center of the LED to the observation point, the start and end points for each of the vectors are determined.

In figure 5 shows a geometric interpretation of obtaining the angle between the vectors defining the axis of the LED and the vector from the optical center of the LED directed to the observation point (observation vector).

The first vector defines the axis of the LED and is assigned to the beam of the axial light intensity of the LED. The vector is drawn from any point lying on the beam of the axial luminous intensity of the Do LED to the optical center of the Ds LED. The second vector is from the point of the optical center of the LED Ds to the observation point Ai.

The coordinates of the points defining both vectors: Ds (xs, ys, zs) - point of the optical center of the LED; Do (xo, yo, zo) - LED base point; Ai (xi, yi, zi) - the point of calculation (the point at which the total luminous intensity from the LEDs located in the lamp is calculated).

The coordinates of the LED vector D (Do, Ds) and the calculation vector A (Ds, Ai) are found using the coordinates of the start and end points of the vector: D (xs - xo, ys - yo, zs - zo) A (xa - xs, ya - ys , za - zs). Having determined the lengths of the vectors, their scalar achievement is calculated: DA = | D | * | A | * Cos (ß).

Using the previously found vector lengths and the arccos function, the required angle is found. Using the obtained angle between the vector specifying the LED axis and the vector from the point of the optical center of the LED to the observation point and interpolating using the cubic spline approximation function for the selected LED, calculates the luminous intensity from a specific LED at the selected observation point. The total value of the received luminous intensities from all LEDs of the SDL provides information about the luminous intensity at a given observation point.

The developed method for finding the angle between the vector, sets the axis of the LED and the vector from the point of the optical center of the LED to the observation point, does not depend on the methods for calculating the coordinates of the observation points and LED base points. Therefore, it can be applied to any arbitrarily selected observation points, LED bases and their location environment, which makes the algorithm suitable for calculating the light distribution from LED systems for bactericidal water disinfection from harmful microorganisms, especially Covid-19.

CONCLUSIONS

1. The studies carried out have confirmed the possibility of using ultraviolet light-emitting diodes to decontaminate the environment from particles of the Covid-19 virus and establish the requirements for germicidal installations in the context of the Covid-19 pandemic.
2. For certain conditions and purposes, the structure of an energy-efficient bactericidal installation based on ultraviolet LED light sources is proposed, which provides a dispersed multi-level disinfection of water.
3. The developed methodology for modeling the LIC of LL based on the well-known LIC of a single LED and substantiated the possibility of its application for the calculation and design of bactericidal installations based on the LEDs.
4. Experimentally developed optimal technological parameters energy efficient germicidal installation based on ultraviolet LED light sources. During the research, it was established that it was necessary to formulate an assessment of the characteristics of bactericidal installations..

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