LED TECHNOLOGY FOR DRINKING WATER PURIFICATION

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SUMMARY

One of the most important leaving systems for the life support of society are water supply systems. The existing methods of water purification, as well as schemes for its disinfection, which are not able to meet the modern requirements for the quality of drinking water and do not fully meet the requirements of energy efficiency due to the use of ineffective equipment and technologies. The aim of the work is to find effective ways to reduce the effect of harmful organisms in water on humans by disinfecting it using light radiation of a certain intensity and spectrum of radiation. The task of the work is to study the effect of LED ultraviolet light sources on harmful organisms that are in the water, and to determine the radiation spectrum that will have the greatest effect on them. Based on the research results, a mathematical model of the process of radiation exposure to harmful organisms in water has been developed, the scope and conditions for the use of installations have been established. The practical value of the obtained results lies in the possibility of practical application of LED ultraviolet light emitters for the purification of drinking water at any stages of water preparation and various levels of water supply.

INTRODUCTION

One of the urgent problems that affects every inhabitant of our planet and on which the future of mankind depends is to ensure the requirements for the quality of drinking water. According to such world organizations as WHO, UNICEF, UNESCO, United Nations and others, this problem is much larger than we can imagine.

According to the WHO, in 2017, 5.3 billion people used safe water services, which means they have an improved water source that is located where they live, is accessible when needed, and does not contain pollutants. The remaining 2.2 billion people without securely managed water services in 2017 were:

- billion people with basic services, that is, an improved water source that takes less than 30 minutes to access,
- 206 million people with a limited, improved water source that takes more than 30 minutes to access,
- 435 million people receiving water from unprotected wells and natural sources,
- 144 million people withdrawing untreated surface water from lakes, ponds, rivers and streams.

In general, according to WHO, UNICEF, UNESCO and the United Nations:

- 2.21 billion people lack access to safe drinking water (WHO / UNICEF, 2019),
- more than half of the world's population or 4.52 billion people lack access to safe sanitation and hygiene services (WHO / UNICEF, 2019),
- 297,000 children under five die each year due to inadequate sanitation, poor hygiene or unsafe drinking water (WHO / UNICEF, 2019),
- 2 billion people live in water-stressed countries. (UN, 2019). Water scarcity already affects four out of every 10 people (WHO, 2019),
- 80% of wastewater is returned to the ecosystem without treatment (UNESCO, 2017).

Climate change, increasing water scarcity, population growth, demographic change and urbanization already pose challenges to water supply systems. Given the above, it can be assumed that by 2025, half of the world's population will live in areas that will be characterized by a shortage of quality water. Currently, one of the important solutions to the problem is the reuse of wastewater for the recovery of water, nutrients and energy. At present, countries are increasingly using wastewater for irrigation. In developing countries, it accounts for 7% of the total irrigated land area. However, irrigation in them is usually performed incorrectly, this practice can create certain health risks,

The use of water sources for drinking water and irrigation will continue to develop, with a greater emphasis on groundwater and alternative sources, including wastewater. Climate change will lead to greater fluctuations in rainwater harvesting. In order to ensure the availability and quality of water, it is necessary to improve the system of regulation of all water resources.

RESULTS

It should be noted that at the moment in the world there are no technical means for water purification that would meet all the necessary requirements and ensure stable water purification.

For example, in Ukraine, the bulk, namely 2/3 of Ukrainians consume water from rivers, lakes and reservoirs, and 1/3 receive water from underground sources.

The water purification scheme (Fig. 1) at Ukrainian enterprises is traditional and consists of the following main stages:

- dosing of reagents;
- mixing;
- upholding;
- filtration;
- secondary disinfection;
- supply to consumers.

Most enterprises in Ukraine use chlorination to disinfect water, in rare cases ozonation. A typical scheme for the preparation of drinking water is shown in Fig. 2. It should also be noted that the cleaning equipment, in most cases, is in a state of extreme wear and tear and requires urgent reconstruction, which in turn greatly affects the quality of water treatment.

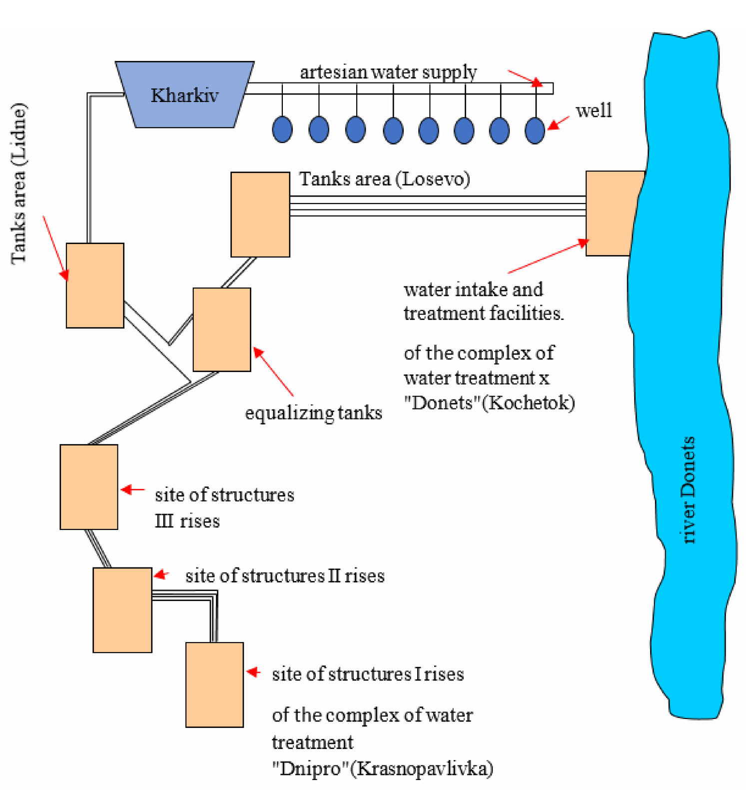

Figure 1. Scheme of water purification in the city of Kharkiv

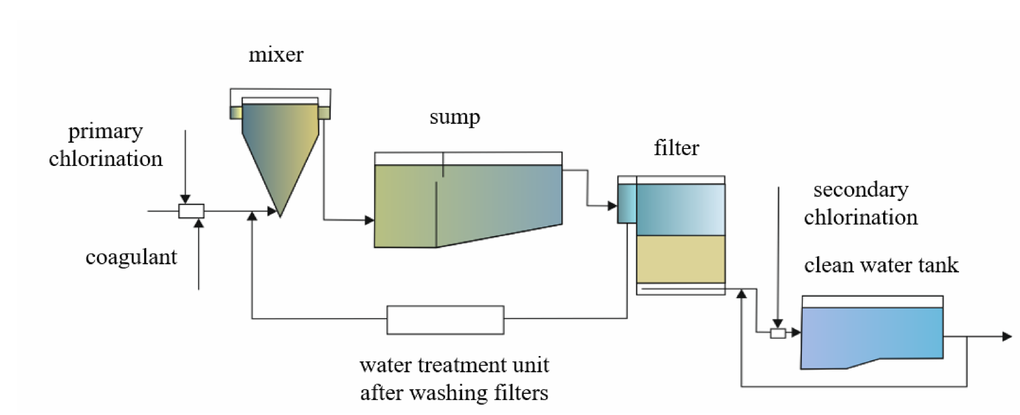

Figure 2. Typical drinking water supply scheme in Ukraine

The main problems at such wastewater treatment plants are:

- the need to reduce the content of dissolved organic matter in water;
- the formation of organochlorine compounds;
- the need to remove various contaminants of anthropogenic origin;
- increasing the efficiency of water disinfection in relation to various groups of microorganisms;
- treatment of flushing water, filters and sediments formed.

Tables 1 and 2 show the characteristics of the quality of drinking water in Kharkiv, obtained using a typical treatment scheme. Similar data were obtained in other cities of Ukraine.[7]

Table 1. Characteristics of drinking water in the city of Kharkiv

Indicators	Unit of measurement	Kharkiv	DSTU 7525: 2014	DSanPiN 2.2.4-171-10	WHO and EU
Coloration	hail.	ten	20	20	15
Turbidity	mg / dm3	0.5	2.5 NOM	0.5 (1.5)	2.0
Hardness	mmol / dm3	6.8	7.0 (10)	1.5-7.0	1.0-2.0
Alkalinity	mmol / dm3	5.2	6.5	0.5-6.5	not the norm.
Oxidizability	mgO / dm3	6.5	2	4	2
Aluminum	mg / dm3	0.12	0.2 (0.5)	0.2 (0.5)	0.2
Iron	mg / dm3	0.3	0.2	0.3	0.2
Sulfates	mg / dm3	185	250 (500)	250 (500)	250
Chlorides	mg / dm3	52	250 (350	250 (350)	250
Nitrates	mg / dm3	1.9	45	45	thirty
Dry residue	mg / dm3	695	1000 (1500)	100-1000	<1000

Table 2 - Characteristics of drinking water in the cities of Ukraine

Indicators	Unit of measurement	Kharkiv	Dnipro	Zapori-zhzhia	Odessa	Mikolaiv	Kiev
Coloration	hail.	ten	20	sixteen	nine	8.0	15.0
Turbidity	mg / dm3	0.5	0.8	0.6	0.3	0.5	0,4
Hardness	mmol / dm3	6.8	4.0	3.6	4.0	3.5	3.5
Alkalinity	mmol / dm3	5.2	3.0	2.6	3.0	3.0	3.0
Oxidizability	mgO / dm3	6.5	9.0	7.5	2.0	7.5	5.0
Aluminum	mg / dm3	0.12	0.17	0.1	0.13	0.12	0.18
Iron	mg / dm3	0.3	0.2	0.2	0.1	0.1	0.15
Sulfates	mg / dm3	185	108)	45	50	185	41
Chlorides	mg / dm3	52	39.9	40	28	51	39
Nitrates	mg / dm3	1.9	2.2	1.0	0.003	0.2	0.3
Dry residue	mg / dm3	695	380	318	311	285	288
Water supply source	Siverskiy Donetsk, Dnipro	Dnipro	Dnipro	Dnister	Ingulets, Pivdeniy Bug	Dnipro, Desna	

Thus, according to most indicators, the quality of drinking water in Ukraine differs significantly from the requirements of the WHO and the EU. On this basis, we can conclude that the methods of water purification that are currently used are ineffective. One alternative solution is the use of ultraviolet radiation for water purification.

To solve the problem of secondary contamination by microorganisms, we are considering a distributed water disinfection system based on the use of energy-efficient ultraviolet LED light sources. This opens up the possibility of placing bactericidal installations after each operation in the water supply systems of cities, which makes it possible to avoid the repeated development of microorganisms, since when organic cells of various bacteria are exposed to ultraviolet radiation of spectral composition from 200 to 400 nm, cell destruction is observed (Fig. 3).

The analysis of the spectrum of bactericidal action of installations (Fig. 4) leads to the conclusion that the greatest efficiency of bactericidal installations is provided by light sources with a wavelength of 205 - 315 nm.

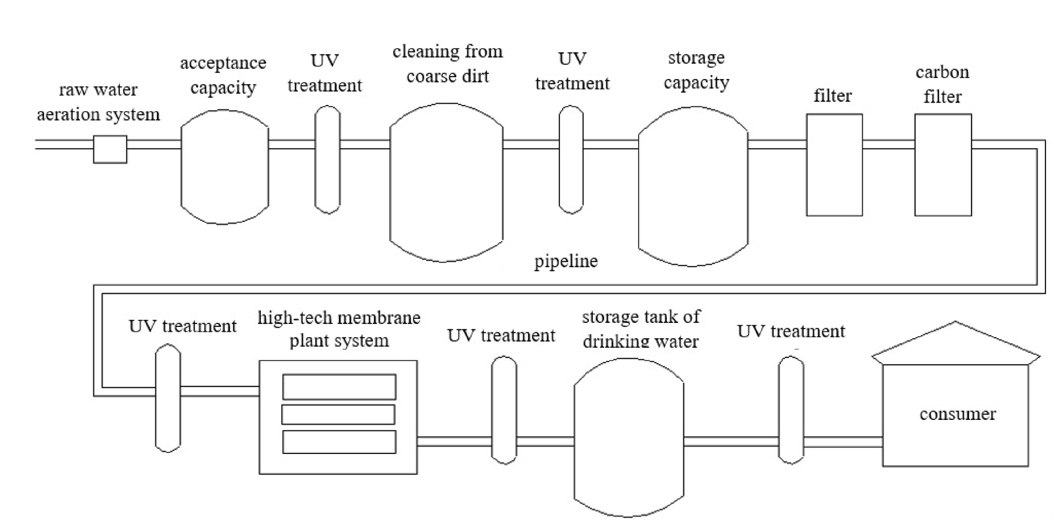

Figure 3. Structure of a water purification system using LED light sources

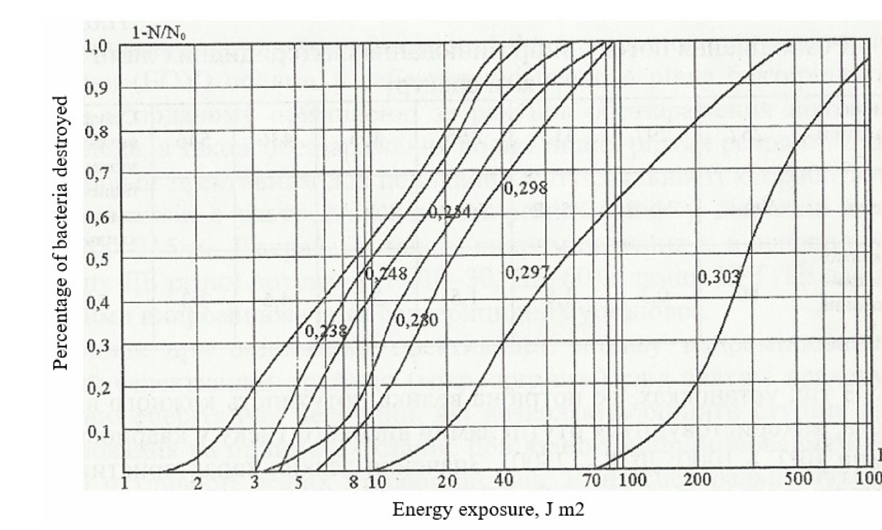

Figure 4. Spectrum of the effectiveness of the bactericidal action of radiation

To identify the general patterns of creating a light space by LED lighting devices, it is necessary, based on the study of the light intensity curves (LSI) of existing LED light sources, to establish the general patterns of their light distribution and, on their basis, to develop mathematical models of the characteristics of LED SPs.

To achieve this goal, the authors have developed a synthesis technique for lighting devices based on the known luminous intensity curve (LSI) of a single LED light source. To form the luminous intensity curve of a device based on LEDs, a model of the form [6] was used: $I'(\lambda)=F(I(\lambda),N,K)=F(I_0,N,2\theta_{0.5},K)$

Modeling of svitolorozpodilu 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 KCC of LED devices with an arbitrary arrangement and orientation relative to a certain center of the LED, as well as for each state of the transmission environment. In fig. 5 shows an algorithm for calculating the parameters and characteristics of lighting devices based on LED light sources.

The calculation result is a graph of light distribution in the plane where the observation points are located. The graph is a luminous intensity curve (LSI) in an arbitrarily chosen plane passing through the axis of the lamp. Under the conditions under consideration, the LSI LEDS is a cubic spline of approximation obtained on the basis of experimental measurements for a single LED. The LSI of the modeled LEDL is calculated in two stages.

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

At the second stage, at the observation points, the luminous intensity from all LEDs of the lamp is calculated. Application of the developed methodology allows calculating the SOC from the LEDL for any conditions of use.

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

distance to calculation points 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. The step is used to calculate the angle between the calculation point and the negative direction of the OZ axis.

The cosine theorem determines the distances to the calculation points and their coordinates. a = - R * cos (г)

In fig. 6 shows the geometric interpretation of obtaining the coordinates of the calculation points as a result of rotation of the calculation point around the center of coordinates.

The task of the angle of inclination of the LED axis to the lamp axis. 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 rays of the axial light intensity of the LED. This is enough to set the direction of the LED axis. Figure 7 shows the geometric interpretation of the obtained coordinates of the points based on the LEDs.

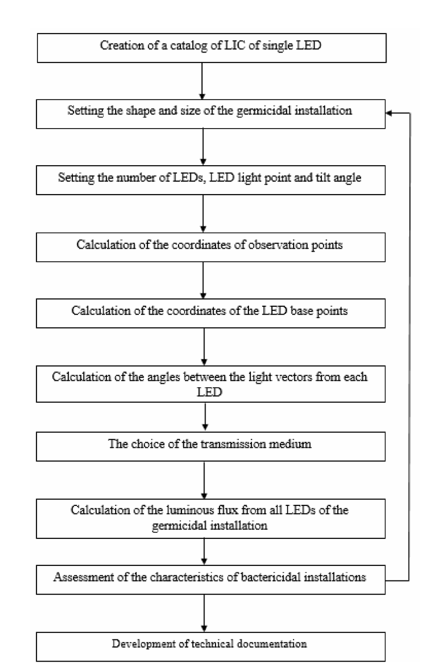

Figure 5. Algorithm for calculating germicidal installations with LED light sources

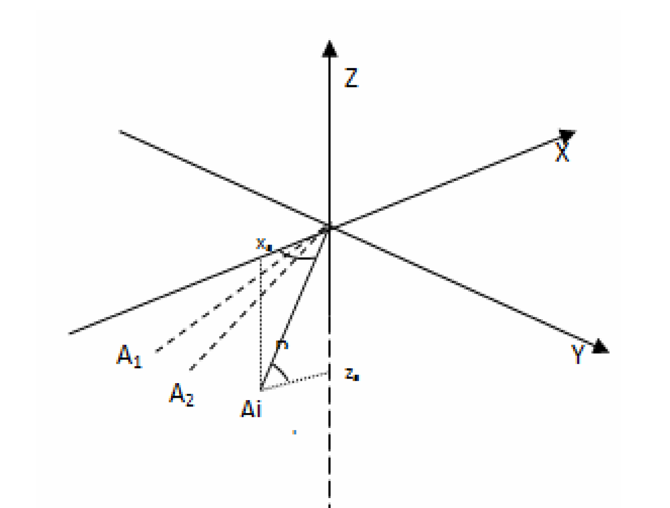

Figure 6. determination of the coordinates of the point of calculation

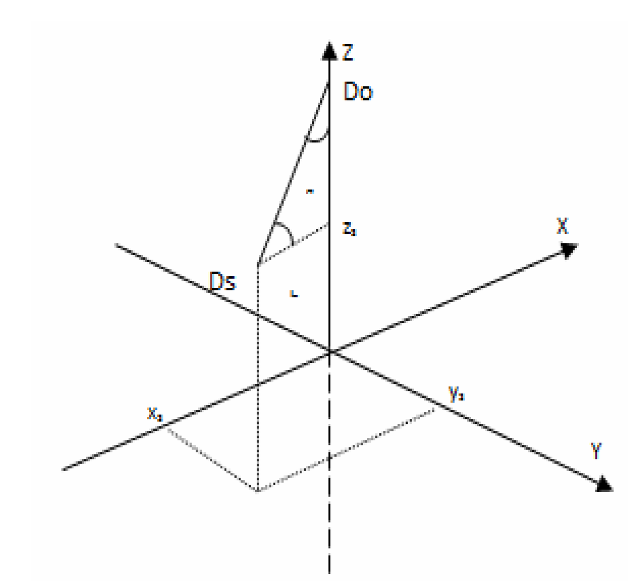

Figure 7. Determining the coordinates of the LED base point

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 are determined for each of the vectors. In fig. 8 shows a geometric interpretation of obtaining the angle between the vectors defining the axis of the LED diode and the vector from the optical center of the LED directed to the observation point (observation vector).

Using the previously found vector lengths and the arcos function, we find the angle. Using the obtained angle between the vector defining the axis of the LED and the vector from the point of the optical center of the LED to the point of observation. After interpolation using the cubic spline approximation function for the selected LED, we calculate the luminous intensity from a specific LED at the selected observation point. Summing up the value of the received luminous intensities from all LEDs of the LEDL, we obtain the luminous intensity at this observation point.

It should be noted that the developed method for finding the angle between the vector specifying the LED axis and the vector from the optical center point of the LED to the observation point does not depend on the methods for calculating the coordinates of observation points and LED base points. Therefore, it can be applied to any arbitrarily chosen 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.

In fig. 9 shows the experimental (-) and calculated (-) LSI at a distance of 1 m from the glow point. The difference between the calculated curves of the real ones does not exceed 10% and is explained by the difference in the parameters of individual LEDs of the SP, as well as their currents and thermal modes.

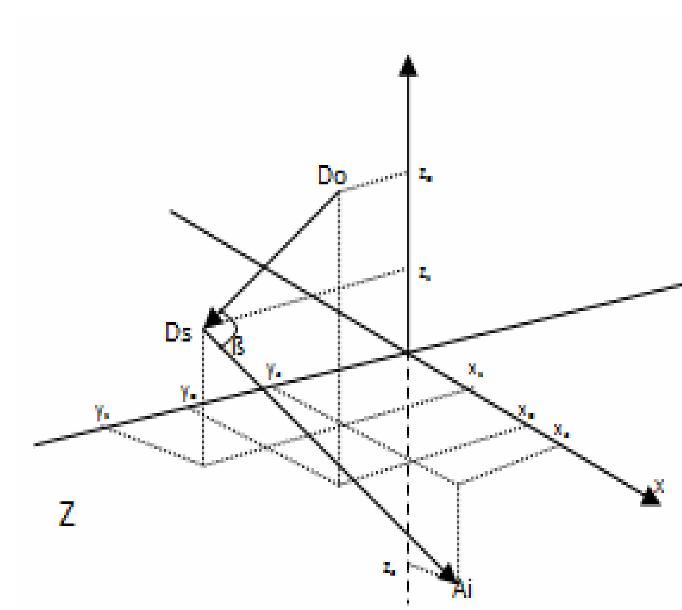

Figure 8. Determination of the angle between the axis of the LED and the calculation vector

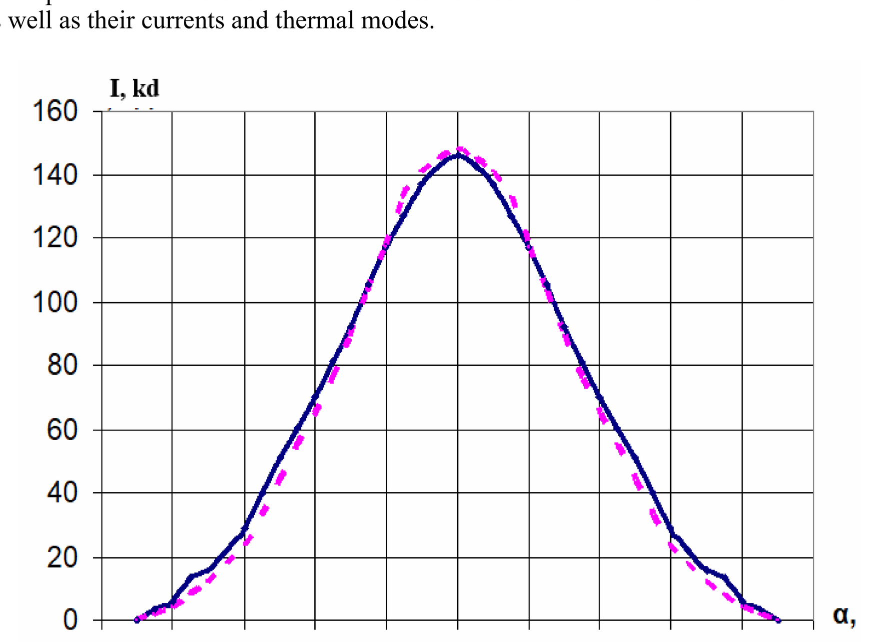

Figure 9. Experimental calculations

CONCLUSIONS

1. The studies carried out allowed to establish the reasons for the deterioration of water quality, and establish requirements for installations for its improvement.
2. The requirements have been determined and the design of an energy-efficient bactericidal installation based on ultraviolet LED light sources for multilevel water disinfection has been developed.
4. By studying the work of the developed bactericidal installation, its certain parameters and modes, ensuring the conditions for its optimal functioning.
5. The developed methodology for modeling the LSI of the LED light fixture based on the known LSI of a single LED and experimentally proved the possibility of its application for the calculation and design of germicidal installations based on ultraviolet LEDs.

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