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LED LIGHTING TECHNOLOGIES FOR DISINFECTION OF THE HUMAN ENVIRONMENT

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Abstract
Currently, the COVID-19 pandemic has highlighted the issue of preventing new environmental pollution. Under these conditions, lighting technology and disinfection technologies open up wide opportunities for the use of ultraviolet radiation. The studies carried out made it possible to establish the possibility of using ultraviolet LEDs to process various media for their disinfection, to develop a methodology and program for calculating ultraviolet LED installations for disinfecting various media, including those infected with COVID-19, to develop the design and parameters of the installation.

Keywords: lighting technology, ultraviolet LEDs, disinfection, installation for disinfection, COVID-19.

INTRODUCTION

During the pandemic, one of the main questions was how to prevent the spread of viruses. But human exposure to the environment increases the risk of new infections that can infect humans; along with humans, more than 60% of such infections come from animals - mainly those living in the wild. Consequently, plans for recovery from the COVID-19 pandemic, and in particular plans to reduce the risk of future epidemics, should focus on the root of the problem, not just the early detection and control of disease outbreaks. Overexploitation of natural resources also increases the risk of outbreaks of infectious diseases like COVID-19 - diseases that are transmitted to humans from animals, the UN said. The current pandemic is a clear example of a threat to human well-being,

It is known that many viruses are transmitted by airborne droplets and through contaminated surfaces. As for the pandemic, all types of its transmission are still unambiguously unknown. It is believed that COVID-19 is predominantly transmitted from person to person through close contact. However, there is some uncertainty as to the relative importance of the different routes of transmission of the SARS-CoV-2 virus that triggered COVID-19 in 2019. A growing body of evidence suggests that once it enters the air, the virus remains viable for a longer period of time and is transmitted over longer distances than previously thought. In addition to close contact with infected people and touching surfaces on which the virus persists,

As evidenced by the results of studies carried out by Ukrainian and Japanese scientists (O. M. Beketov NUUEK under the leadership of Prof. Hovorov P.P., Nichia Corp. TOKUSHIMA in Anan, Tokushima Prefecture, etc.), one of the effective ways of disinfection the human environment is the use of light sources with a certain spectrum of radiation. The experience of using such sources for the disinfection of the environment has shown that its irradiation with lamps in the ultraviolet spectrum with a wavelength of 260-280 nm provides a high level of bactericidal water purification, especially in conditions of a multi-level structure of networks and a multi-stage technology for its disinfection. [5, 6]

The existing sources of UV rays in bactericidal installations are mainly based on the use of gas-discharge mercury-argon or mercury-quartz lamps, in which UV radiation of the bactericidal range is generated during the electric discharge. They are installed in a quartz sleeve at the location closest to the source of pollution. Disinfection occurs by direct exposure to UV rays on microorganisms. Under these conditions, the presence of harmful substances in space leads to the absorption of light radiation, which reduces the effectiveness of disinfection. This requires constant cleaning of the outer surface of the quartz cover from the sediment that accumulates on its walls, and also causes relatively high energy costs. Besides, the design of such germicidal installations allows cleaning only in places that have a very high bacterial contamination. Unfortunately, in such germicidal installations, there is no aftereffect, which is unacceptable. In this regard, installations for disinfecting the environment based on bactericidal lamps are ineffective, although quite attractive in general. Therefore, the search for new and improvement of existing technologies for the disinfection of the environment is an urgent problem of great importance, especially given the state and consequences of the COVID-19 pandemic. In this regard, installations for disinfecting the environment based on bactericidal lamps are ineffective, although quite attractive in general.

EXPOSITION

Analysis of recent research and publications.

Ultraviolet (UV) irradiation technology is widely used. Ultraviolet light can be an insurmountable barrier against all known microorganisms. It is especially effective against microorganisms resistant to chemical agents. In order for the UV equipment to cope with the tasks set, it is necessary to provide the required radiation range and correctly select the power of bactericidal radiation 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/cm^2 should be used. [1] But in practice, the matrix of the medium is so unique that a given dose can be either more than enough or not enough at all. Ways to improve the methods and technical means of disinfection in general should be sought in new methods, providing for the use of more flexible and energy efficient systems. As the analysis shows, high technical and economic indicators provide bactericidal installations based on LED light sources, which, along with improved energy characteristics, also provide the possibility of dispersing bactericidal installations and the possibility of multi-stage disinfection. At the same time, studies of disinfection processes and determination of requirements for germicidal installations based on ultraviolet LED light sources, especially for COVID-19 conditions, have not yet been carried out. This applies to lighting and electrical calculations of germicidal installations based on LED light sources, 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, primarily on COVID-19. The above requires research on the creation of scientific and methodological foundations for calculating germicidal installations based on LED light sources and determining the requirements and parameters of germicidal installations based on ultraviolet LED light sources, which is able to ensure overcoming the consequences of the COVID-19 pandemic. The first experiments on inactivation of COVID-19 viral particles indicated the effectiveness of using LED sources of deep ultraviolet radiation under these conditions, providing inactivation of 99.9% of the proportion of coronavirus. [2]

Methods and technical means of disinfection.

To solve the problem of environmental pollution, a distributed disinfection system based on the use of energy-efficient ultraviolet LED light sources is being considered. This opens up the possibility of locating bactericidal installations at each source of infection, which makes it possible to avoid the re-development of microorganisms, since when organic cells are exposed to various pathogens with ultraviolet radiation of a spectral composition from 200 to 400 nm, cell destruction is observed. Since the purpose of the installation of ultraviolet radiation 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. Analysis of the graphical dependencies shown in Fig. 1 [3, 4, 5], leads to the conclusion that the greatest efficiency of bactericidal installations is provided by light sources with a wavelength of 254 - 258 nm.

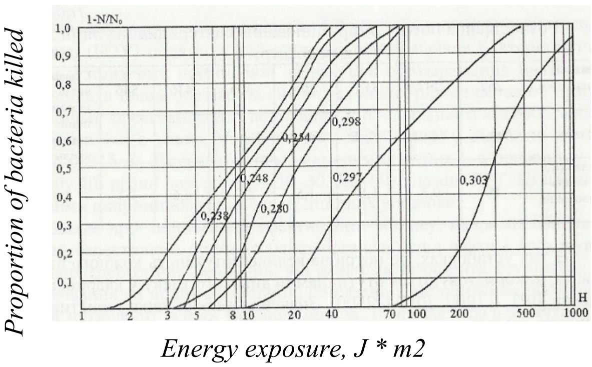

Fig. 1. *Spectrum of effective bactericidal action of radiation*

In the research laboratory of the Nippon Telegraph and Telephone Corporation, under the leadership of Dr. Yoshitaka Tannyasu, LEDs based on aluminum nitride have been created, which allow emitting light in the ultraviolet range with a wavelength of up to 210 nm. Their use is able to provide distributed disinfection of a significant amount of contamination of elements located over a large area. However, the widespread introduction of such light sources in bactericidal installations is constrained by the lack of programs and methods for the lighting design of installations based on them. [6]

Calculation of UV LED light sources.

When calculating disinfecting emitting light installations based on LED light sources, the traditional approach to calculating the light distribution of a single element that shines cannot be applied, and requires calculating the entire area within which the elements that shine are located, taking into account the interaction of these elements in creating a general light distribution and their interactions with the environment. As evidenced by the results of the analysis, the patterns of light distribution of LED light sources are insufficiently studied and have a low accuracy of their description, the calculation of the characteristics of UV light emitters based on them is a rather difficult and unsolved problem.

The studies carried out by the authors [3,4] indicate that the structural model of visualization of the light space created by UV-LED light sources can be realized only for individual LEDs. The lack of technical and methodological support for lighting visualization programs based on LED light sources leads to low efficiency of installations based on them.

Analysis of publications devoted to modeling a light space using LED light sources and descriptions of methods for calculating the light distribution of light sources and lighting devices (LF) based on them [1, 5, 7] showed that mainly publications are devoted to the description of processes in LED light sources for specific conditions.

The bactericidal installation considered by the authors is based on the design of a UV-emitting device, which consists of an n-th number of LEDs, which opens up the possibility of developing a wide variety of design and technical solutions in their design. Therefore, to determine the optimal number of LEDs and their light distribution, taking into account their relative position in the joint venture at the design stage, it becomes necessary to simulate the light distribution of the joint venture and create on its basis a technique for synthesizing installations with specified properties. A detailed method was developed by the authors and presented in [8].

The calculation of the number of irradiators in the design of germicidal installations is acceptable for practice. The calculation of germicidal installations can be carried out using the methods below.

The main parameter of the bactericidal irradiator is the passport value of its performance $\text{Пр}_{0,95}$ $\text{м}^3/\text{ч}$ with bactericidal effectiveness $J_{\text{бк}} = 95\%$ for a sanitary indicative microorganism, the following parameters can be determined:

- Number of irradiators

$$N_{\text{обл.}(0,95)} = V_{\text{п}} 3600 K_{\text{з}} / \text{Пр}_{0,95} \cdot t \text{ , pcs.,} \quad (1)$$

Where Кз = 1.1-1.5 - safety factor; t - exposure time 900 s for open feeds, 3600 s for closed ones.

- The performance of the irradiator at an arbitrary value of the bactericidal efficiency, for example, Jbk = 90%

$$\text{Пр}_{0,9} = \text{Пр}_{0,95}\left[\left(\ln\left(1 - J_{\text{бк}(0,95)} \cdot 10^{-2}\right)/\left(\ln\left(1 - J_{\text{бк}(0,9)} \cdot 10^{-2}\right)\right)\right)\right], \text{ m}^3/\text{h} \quad (2)$$

- Indicator of the efficiency of the irradiator

$$\text{П}_{\text{э.обл}} = \text{Пр}/10^{-3}\text{Р}_{\text{обл}}\text{Ц}_{\text{обл}}, \text{ m}^3/\text{kWth*UAH.,} \quad (3)$$

where $\text{Р}_{\text{обл}}$ – feed power, W; $\text{Ц}_{\text{обл}}$ – irradiator price, UAH

The introduction of a safety factor into the formula allows us to take into account the decrease in the effectiveness of germicidal installations in real operating conditions due to a number of factors affecting the parameters of germicidal lamps. These include:

- Fluctuations in the mains voltage that negatively affect the LEDs and can lead to their failure.
- Reducing the bactericidal flux of lamps during the service life up to 30% of the nominal.
- Influence of the relative humidity of the room air. At a relative humidity of more than 80%, the bactericidal effect of ultraviolet radiation drops by 30% due to the effect of shielding microorganisms with water droplets.
- Dustiness of the lamp surface, which can reduce the flux by up to 10%.

The above data allow, depending on the specific conditions, to select the value of the safety factor in the range of Кз = 1.1 - 1.5 in order to compensate for the listed negative factors. [9]

CONCLUSION

1. The studies carried out made it possible to establish the requirements for ultraviolet disinfection installations that can be applied in the context of the COVID-19 pandemic.

2. For certain conditions and purposes, the proposed energy-efficient disinfection unit based on ultraviolet LED light sources.

3. The developed methodology for calculating the parameters of bactericidal installations allows for a comparative analysis of various designs and various conditions for the use of installations and choose their economically feasible options.

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