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The Influence Of Semiconductor Leds On The Aquatic Environment And The Problems Of Developing Lighting Devices For Fish Industry Based On Them

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ABSTRACT

The paper presents the results of an experimental study of the influence of semiconductor LEDs on the aqueous environment. It has been shown that the use of semiconductor LEDs in fish farming is the preferred source of optical radiation in the development of microorganisms in natural or open bodies of water, in particular, in the growth of functional systems as aquatic plants, fish and their larvae, as well as moderate development of zooplankton, phytoplankton, detritus, which are the natural feed base of fish and their larvae.

KEYWORDS

Semiconductor LED, silicon solar photocell, light wavelength, energy, power, light intensity, light source, water environment, photocurrent, photovoltaic, light scattering, light absorption, light attenuation.

INTRODUCTION

At present, the physical optics of the aquatic environment can be considered sufficiently well studied from both experimental and theoretical points of view [1–8]. The studies have shown that the growth of functional systems of aquatic plants, moderate development of fish and their larvae, bacteria, detritus, benthos depends on the wavelength of light propagating in the aquatic environment.For example, ultraviolet light (λ = 360 ÷ 410 nm) helps to strengthen plants, and blue light (λ = 440 ÷ 450 nm) for its growth, and green light (λ = 500 ÷ 600 nm) practically does not affect the leaves of young plants. Red or infrared rays have λ = 620 ÷ 880 nm, of which λ = 620 ÷ 630 nm are ineffective for plant growth, and with λ> 660 nm are necessary for plant growth and survival [7, 10, 11]. Also, rays with a wavelength λ> 660 nm play an important role in the development and normal growth of zooplankton, phytoplankton, detritus and aquatic plants, which are the natural food base for fish and their larvae [1–6]. Currently, lighting devices using light beams are mainly intended for aquariums and are widely used to ensure the normal development and feeding of fish [2 ÷ 4, 8, 9]. However, the creation and implementation of lighting devices intended for natural or open water bodies, including for the development and moderate growth of zooplankton, phytoplankton, detritus and aquatic plants, is one of the unsolved problems today. This article discusses the results obtained from studies of semiconductor LED lighting devices intended for natural or open water bodies.

RESEARCH METHOD

It should be noted that there are several types of optical radiation sources, including halogen, fluorescent, semiconductor LEDs, incandescent lamps. When creating lighting devices for intended natural or open water bodies, it is necessary to solve the following scientific and technical problems: the choice of an energy-saving source of optical radiation; compatibility of the propagation of light rays with natural light rays in the aquatic environment; the ability of light rays to promote the growth of functional systems of microorganisms in water bodies, in particular fish and fish larvae, their normal development of aquatic plants, bacteria, detritus, benthos, which are a natural food base, and others. Lamps with the same luminous flux were selected as a source of optical radiation for the study, which are shown in Table 1.

Table 1.

Properties and parameters of optical radiation sources [13÷19]

View	Power, W	Light flow, Lm	Light output, Lm/W	Structural strength	The presence of harmful substances in its composition
Incandescent lamp	100	1200	12	very fragile	-
Luminicent	25	1200	48	fragile	mercury
Semiconductor LED	15	1200	80	lasting	-

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The table shows that semiconductor LEDs are economical and efficient in terms of energy consumption and luminous flux, high-strength, safe lighting compared to other types of optical radiation sources.

As mentioned above, light rays with a wavelength λ> 660 nm play an important role in the development and growth of zooplankton, phytoplankton, detritus and aquatic plants, which are the natural food base of fish and their larvae [1–6]. In this connection, the determination of the wavelength of light in the aquatic environment is an important scientific and technical problem in research. Silicon solar cells were used to solve the problem. It is known that the spectral light sensitivity of silicon solar cells corresponds to the wavelength of infrared light λ~660÷880 nm [20, 21, 26÷28]. Figure 1 shows a simplified diagram of the research method.

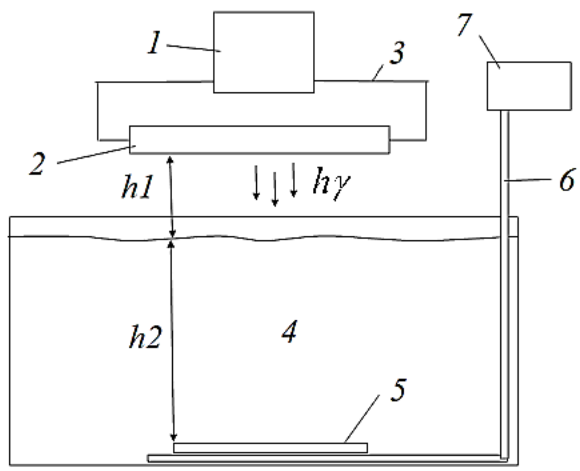

Figure: 1. Simplified scheme of the research method. 1 - illuminator source, 2 - illuminator, 3 - conductor, 4 - aqueous medium, 5 - silicon solar cell, 6 and 7 - solar cell holder and multimeter, h1 - distance from lamp to water surface, h2 - water height.

The studies were carried out in the process of changing the distance between the illuminator and the solar cell in the range h=50÷400 cm. The current and voltage generated in the solar cell were measured with a GDM-8245 multimeter. The experiment was conducted from 18:00 to 04:00 in the morning, and the results were consistent.

FINDINGS AND DISCUSSIONS

Figures 2 and 3 show the dependences of the photocurrent (I) and voltage (U) of the solar cell on h = h1 + h2. In all cases, the photocurrent (I) and voltage (U) were found to decrease exponentially with increasing distance from the illuminator to the solar cell. In a fluorescent lamp, the photocurrent (I)

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and voltage (U) in all cases take almost 10 times lower values than in an incandescent lamp and a semiconductor LED. The dependence of the voltage (U) on the photocurrent (I) on h = h1 + h2 can be conventionally divided into three sections, for example, a-b, b-c and c-d. Here a-b distance h1 = 50 ÷ 100 cm, i.e. distance from the illuminator to the water surface, b-c and c-d are the distances to the water medium, respectively, h2 = 100 ÷ 200 cm and h2 = 200 ÷ 400 cm. For an incandescent lamp, in the section a-b with h1 = 50 ÷ 100 cm (line 1), the photocurrent and voltage drop appear stronger, as compared to a semiconductor LED (line 2). The same is with the fluorescent lamp (line 3). The results can be associated with different distribution of light rays in the air and can be explained as follows.

It is known that the difference in refractive indices (n) of media at the interface between two media leads to a change in the wavelength of the light flux. In our case, light scattering occurs in air and in an aqueous medium. For these two media, we use the following equations [22]: for example, for air,

$$\lambda_1 = \frac{c}{n_1 \nu} \quad (1)$$

and for the aquatic environment,

$$\lambda_2 = \frac{c}{n_2 \nu} \quad (2)$$

Here, n1 and n2 are the refractive indices for air and water, respectively, and c is the speed of light in vacuum.

When a ray of light crosses the border between a vacuum and another medium, or between two different media, the wavelength of the light changes, but the frequency (ν) remains unchanged. Then we get:

$$\frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} \quad \text{or} \quad \lambda_1 n_1 = \lambda_2 n_2 \quad (3)$$

From this equation:

$$\lambda_2 = \frac{n_1 \lambda_1}{n_2} \quad (4)$$

If λ_1 and n_1, n_2 are known, λ_2 can be determined. For example, when n_1~1 and n_2~1,33, for incandescent lamps λ_1~620÷880 nm, we get λ_2~466÷661 nm, and also for a semiconductor white light LED λ_1~1000 nm, we get λ_2~752 nm.

It is known from the literature that water is 770 times denser than air, has a high heat capacity, conducts sound vibrations well and weakens the luminous flux, i.e., light scattering (k), absorption (σ) and attenuation (ε). In this case, the frequency of the light does not change, but the wavelength changes to the short-wave side. According to the literature data, the indicators of scattering and attenuation of light in pure water have, for example, a minimum of k=0.0045 1/m, at λ=400÷500 nm [1, 2, 23, 24]. Accordingly, as the wavelength increases, for example, at λ = 720 nm, the value of k increases by a factor of 274 relative to the minimum value [1, 5].

The calculation shows that in an aqueous medium, the wavelength of light shifts to the short-wavelength side. In this case, there is a significant decrease in photocurrent and voltage in the incandescent lamp in sections b-c and c-d (line 1) than with semiconductor LEDs. However, the luminous flux emitted by semiconductor white light LEDs is close to the spectrum of sunlight and has a wide spectrum [11], and is divided into rays with different wavelengths in the aquatic environment. In our opinion, most of them are exposed to rays with a wavelength $\lambda_2 > 660$ nm. This is sufficient for a silicon based solar cell.

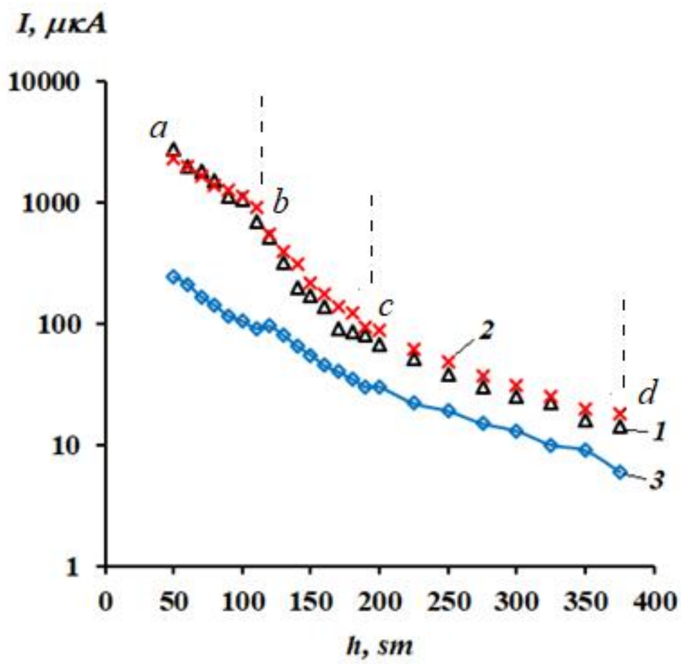

Fig. 2. Dependence of the photocurrent on h. 1-incandescent lamp, 2-semiconductor LED, 3-fluorescent lamp.

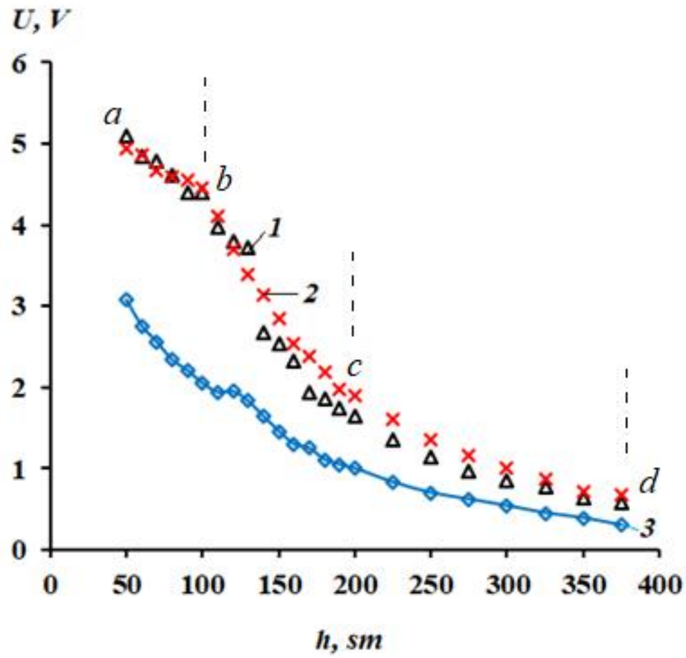

Fig. 3. Photo voltage versus h. 1-incandescent lamp, 2-semiconductor LED, 3-fluorescent lamp.

It can be seen from the results obtained that the use of semiconductor LEDs as applied to incandescent lamps in the design and implementation of lighting devices for natural or open water bodies during the development of microorganisms in water bodies, in particular during the growth of functional systems of fish and their larvae, when the development of bacteria, detritus, benthos is moderate. [1÷9] indicates that semiconductor LEDs are the preferred source of optical radiation.

It should be noted that the design and principle of operation of the proposed lighting device for fish food is based on the destruction of flying insects tending towards the source of optical radiation and using them as a natural food base for fish [25].

CONCLUSION

The lighting device works from late evening from 18:00 to 04:00 in the morning and is applied to the surface of the reservoir. At this time, it was found that the wavelength of light emitted by a semiconductor LED is higher than that of an incandescent lamp. It has also been observed that semiconductor LEDs are more attracted to flying insects than other lighting lamps.

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