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Harmful effects on organism induced by light of different wavelength and power

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ABSTRACT

Although a variety of experiments on light exposure stress to animals significantly affect the retina and circulation system, it is still unknown the relationship between the different extent of harmful effect on organism and light with different wavelengths and power. This study is aimed to investigate the changes to microblood vessel and the variations in serum absorption spectrum. LED light of different wavelength and power were used. The results show that power has a relatively larger impact on physiological indexes than wavelength. The extents of these variations are relatively different according to the regression equations. All of these stimulations cause damage to mice physiological conditions, producing some extent of light pollution. The research findings supply the guideline for the effective prevention of the harmful effect on organism by light pollution from the view of science of optical life science.

1. Introduction

Light pollution is a new type of environmental pollution. Excessive light radiation will have harmful effect on human health, traffic, ecological environment. From the last century, the problems on light pollution have been studied from the aspects of economics, environics, bionomic, architecture, and astronomy. In 2004, research on nightglow around Roque de los Muchachos observatory was carried out by Macro Pedani in Spain [1]. He had explained the reason of the night glow in aspect of atomic spectrum with statistical method. A model on urban light pollution with the help of remote sensing technology was build and published on Journal of Environmental Management in 2006 by C.Chalkias in Greece [2]. The influences on economics of global light pollution were firstly proposed by Terrel Gallaway and other scholars in America [3]. All these researches were in terms of macroscopic, but the problem on light pollution can be further studied to cellular and molecular levels from perspective of biophysics. Light-induced damages took effects through affecting the physiological indexes and changing the physiological state. These variations were originated from the gradual changes of microvessels and molecular in microcirculation system. Study on light pollution from microscopic started relatively earlier. As early as 1867, Czemy had focused the sunlight to animal ocular fundus and built the model of light damage on chorioretinal [4]. The clinical manifestation of light-induce damage on retina was found by Verhoef in 1916 [5]. The damage on retinal pigment epithelium by intense light exposure to rats was expressed by Noell in 1965 [6]. Except for the light-induced damage to retina, there were also many researches about light stimulation influences on the content in blood serum, animal stress response and behavioral. These achievements provided a basis for future research on the protection of light pollution problem.

Previous experimental researches using light radiation to animals have shown that light stress causes visual cell damage or even health problems [7–10]. Luminance stimulation of the photoreceptors is known to increase blood flow in microvessels. The elevated blood velocity and the increased vascular diameter have been measured by German scientists in 2010 [11]. The primary aim of microvascular diameter expansion and blood flow regulation is to provide a stable oxygen supply to the neuron tissue and the retina. This is confirmed from the study of brain by Roy and Sherrington [12,13] that an enhanced local blood flow may compensate for the increased oxygen demand in stimulated neural tissue. Bill and Sperber [14] have reported a flicker light-induced retinal blood flow incensement with an experiment in monkeys in 1990. Intense light exposure causes unrecoverable damage and may affect the microcirculation [15–18]. By its action on the photoreceptor cells, light radiation leads to expansion of microblood vessel and accelerates the blood flow.

It was supported by previous studies that the characteristic of blood serum absorption spectrum will change when biological tissue is abnormal [19–21]. With the help of blood serum spectrum analysis, the tissue injury and disease can be effectively studied. The absorption spectrum differences between normal human blood

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serum and serum with high cholesterol and hyperglycemia were described in literature [22,23]. As a result, blood serum absorption spectrum was adopted in this research as it was an important indicator of the variations of physical state when stimulations were imposed. The extent of changes of this parameter reflected the degree of stimulation and damage. In this study, albino mice were used to measure the diameter of their microvascular and the serum absorption spectrum under stimulation of light with different wavelength and power. The aim of the experiments was to define the extents of light pollution to animals and the different damage extent between them.

2. Materials and methods

2.1. Experimental preparations

Male Institute of Cancer Research (ICR) mice weighing approximately 22 g were used. The animals were housed in individual polypropylene cages and fed with commercial pellet rat food and tap water before experiments. The mice were allowed to move freely in cages at room temperature of $26 \pm 2\,^{\circ}C$ with normal light and dark cycle. Before the study, blood 0.5 mm was taken from the mice tails and serum solution was prepared. The absorption spectrum was measured by a UV-3600PC spectrophotometer (Shimadzu Company, Japan) equipped with 1.0 cm quartz cell. After that, mice were randomly divided into 4 groups. All the experiments were carried out in a darkroom. The mice were set on the experimental table with head rigidly fixed using a nontraumatic head holder. About 10 min later, the animals had adapted the experimental conditions and calmed down. The auricle microcirculation microscope images of the mice under normal physiological conditions were recorded. The diameters of the microblood vessel were calculated. These data were accepted as controls.

2.2. Light source selection

The selection of light source was an important step in the experiment. Light emitted diodes of 5 different kinds of wavelength were selected. They were 387.5, 464.7, 512.6, 590.0 and 637.3 nm. White-light LED of 5 different powers was also used. The powers were 0.05, 0.15, 0.50, 1.00 and 2.00 mW. All the parameters of these light sources were measured by optical power meter.

LED light has a relatively wide wavelength band, and its ability in interacting with the biological tissue is strong. The characteristics of these light sources are similar to the light sources widely used in daily life and work. The 5 different wavelengths and powers were chosen to study the influences level of every argument to every dependent variable.

2.3. Experimental system and methods

The main experiments were using LED of 5 wavelengths (1.00 mW) and white-light LED of 5 powers irradiation to the ICR mice and the vitro serum solution. The animals were fixed on the experimental table respectively. The part of the radiation is the mouse receiving eyes but only one eye of each mouse was used. The exposure time is 40 min. The distance between animal eyes and LED light was 5 cm. We used optical fiber to couple the LED light ensuring that the power of the light was not lost. The mice auricle microcirculation images were recorded and calculated. We observed the phenomenon in microvascular change and made comparisons of them in every irradiation condition. The UV–vis spectrum of mice serum solution after the irradiations was measured, too.

The experimental system is shown in Figs. 1 and 2. Fig. 1 shows the system used for recording and calculating the diameter of mice

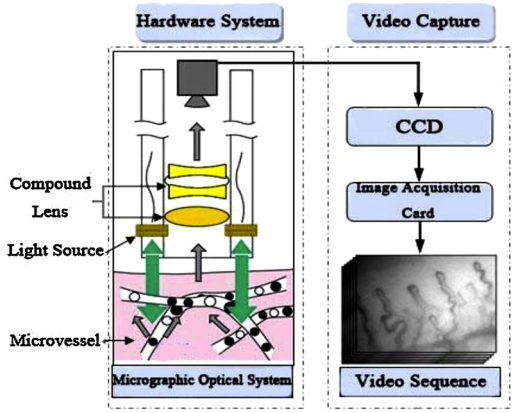

Fig. 1. The microimage system.

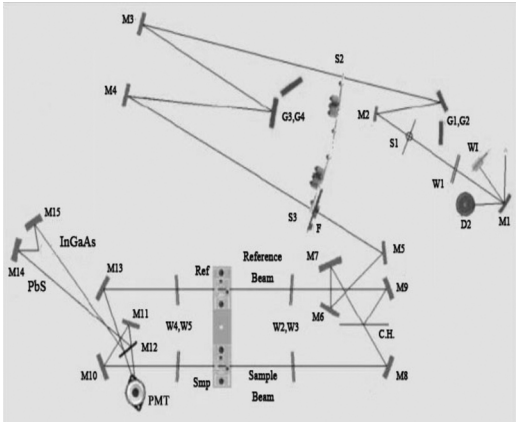

Fig. 2. The optical pathway of UV-3600PC spectrophotometer.

auricle microvessel. The whole system consisted of light sources, optical microscope system (compound lens), real-time monitoring system (microscope, eyepiece, and monitor), image acquisition system (charge coupled device and image acquisition card), and data processing system (computer with software). The light source in Fig. 1 is used as the illumination of the microscope so as we can record the images easily. Fig. 2 is the optical pathway of UV-3600PC spectrophotometer, which is used for measuring the absorption spectrum curves and peaks of mice serum solution. All of the operations were carried out in these experimental systems.

3. Results

3.1. Mice microvascular images

We studied the influences on mice microvascular system under the irradiation of light with different wavelength and power. The microimages of mice auricle microblood vessel under different stimulation conditions were recorded. They were shown in Fig. 3.

The microblood vessel change and the flow variation were observed. Before the LED light radiation to animal eyes, the mouse ear microcirculation was normal and imaged clearly which was shown in Fig. 3a6 and b6. There were many capillaries, blood vessels branches, and less direct vascular. In our experimental conditions, the mouse ear microcirculation changed obviously when they were radiated with LED lights. Leukocytes can be seen rolling adhering to the wall. Mild aggregation of erythrocytes appeared in some microvascular. The gap between blood vessels and surrounding tissue was slightly blurred while the color of perivascular cells became reddish.