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DEVELOPMENT OF OPTICAL OZONE METER AND THERMAL DESTRUCTOR USED IN GASEOUS OXYGEN-OZONE MIXTURE SYSTEM FOR BURN WOUNDS THERAPY

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The paper presents a study of the efficiency of the developed thermal destructor for the decomposition of residual ozone for gaseous oxygen-ozone mixture system for burn wounds therapy. The relevance of the research is due to the need to reduce the ozone concentration in the working space to values not exceeding the maximum permissible concentrations, due to its high toxicity. The destructor is designed as a quartz tube with a nichrome wire heater and a thermostat to maintain a given temperature. The experiments showed that at different oxygen flow rates and ozone concentrations, its complete decomposition is achieved at a temperature of 180 °C. It was found that the maximum heating temperature of 200 °C ensures stable operation of the device and complete elimination of residual ozone. Also, to ensure the safety of personnel during ozone therapy, a special optical meter of the maximum permissible ozone concentration in the room has been developed.

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INTRODUCTION

In cases when microflora is resistant to antiseptic drugs and antibiotics, there is an urgent need to use drugs with a different principle of action. Ozone has not only antiseptic properties but is also capable of stimulating reparative and regenerative processes and attracted attention as such a remedy for the treatment of various wounds [1–3].

Now there are a two ways of local ozone therapy of different wounds. First method includes wound processing with gaseous ozone-oxygen mixtures. Second technology is based on wound irrigation with ozonized saline or distilled water. It was stated that antiseptic action of ozone is not only associated with its oxidative properties, but with different bioregulatory effects, including optimization of oxidative metabolism, stimulating of growth factors activity etc [4, 5].

Treatment of wounds with an oxygen-ozone mixture in a plastic bag is not a novel therapy. The method consists on: a moistened bandage with saline solution or distilled water is applied on an affected skin area. A plastic bag (chamber) is put onto an extremity and the wound irrigation with ozone is performed.

In practical use, the problem of decomposition of residual ozone amounts during therapy is also arises [6]. Ozone is classified as a class I hazardous substance and is extremely toxic – the maximum permissible concentration for the working area is 0.1 mg/m^3, and the average daily concentration for populated areas is 0.03 mg/m^3. In this regard, the issue of developing effective and affordable ozone destructors is relevant. Photochemical, thermal, and catalytic methods of ozone decomposition are possible. Choosing the optimal method is far from a simple task. Photochemical ozone decomposition is advisable to use for selective destruction of ozone. Compared to thermal and catalytic methods of decomposition of residual ozone, the photochemical method is quite expensive due to the complexity of the photolysis technique.

Despite a fairly wide range of industrial catalytic systems, the problem of developing new materials for the decomposition of residual ozone remains relevant, which is due to the expansion of the scope of practical application of ozone technologies [7–9]. Ozone must be decomposed in dry and wet gas flows, in aggressive gaseous environments, and also in exhaust gases containing volatile organic compounds.

To control one of the most important parameters, which is the concentration of generated ozone, original devices have been developed for measuring ozone concentration [10]. The operation of such meters is based on the use of various physical effects. During the development of most of them, the spectrometric method was used. A number of created meters also include a device whose operation is based on the use of the acoustic effect in an ozone environment.

Along with the disinfecting effect, ozone gas is an aggressive oxidant and poses a danger to human health when the maximum permissible concentration (MPC) level is exceeded. To ensure the safety of personnel during sterilization, a special meter of the maximum permissible ozone concentration in the room has been developed.

1. DESIGN OF THE OZONE DESTRUCTOR

The ozone destructor is a quartz tube 300 mm long and 30 mm in diameter. A nichrome wire with a cross-sectional diameter of 1.2 mm, placed inside the tube, was used as a heater. The general appearance (a) and schematic diagram (b) of the ozone destructor are shown in Fig. 1.

To study the effectiveness of the ozone destructor, a series of experiments were conducted. Oxygen from an oxygen concentrator was fed through a flowmeter to an ozone generator. The ozone generator operates on the principle of a dielectric barrier discharge at atmospheric pressure with a high-frequency power supply. Fig. 2

shows the experimental setup for testing the ozone destructor's efficiency.

a

b

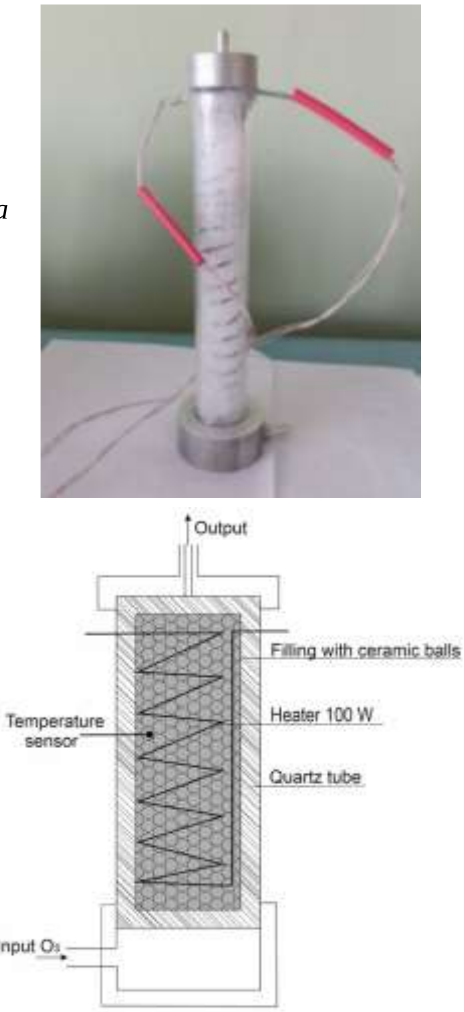

Fig. 1. The main view of the destructor

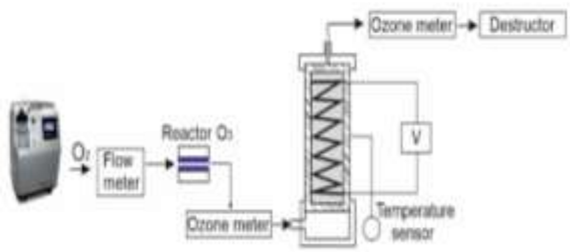

Fig. 2. Experimental setup for testing the ozone destructor's efficiency

A dielectric barrier discharge was generated between two flat metal electrodes (180 x 100 mm) coated with glass enamel (0.2 mm thick). The ozone generator voltage was up to 12 kV, and the frequency was 16 kHz. The oxygen flow rate was set at 0.5, 1, and 3 l/min, while the ozone concentration at the reactor outlet was 50 mg/L. The outlet ozone concentration was measured with M454 DIN ozone meters (USA). The meters were installed downstream of the ozone reactor and destructor. The ozone analyzer, located at the destructor outlet, did not record ozone concentrations in the workspace exceeding the MAC in any of the experiments.

Figs. 3 and 4 show the dependences of ozone decomposition rate on the oxygen flow rate through the ozone reactor. As can be seen from the graphs, the higher the oxygen flow rate, the higher the temperature required for ozone decomposition. Complete ozone decomposition was found to occur at 180 °C, so the ozone decomposition reactor was set to its maximum heating temperature of 200 °C, which was maintained constant by a thermostat.

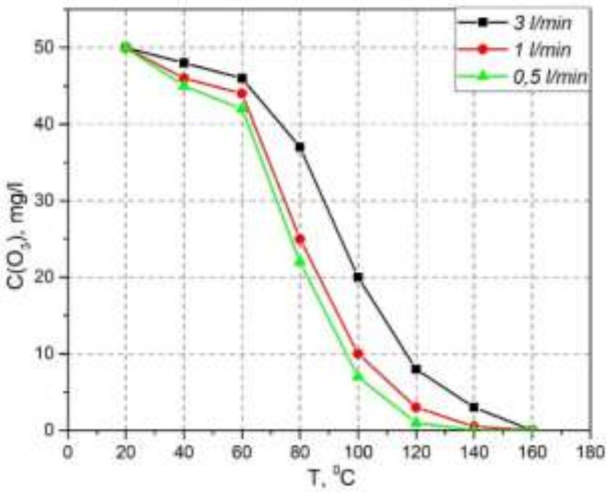

Fig. 3. Ozone decomposition rate depending on oxygen flow rate

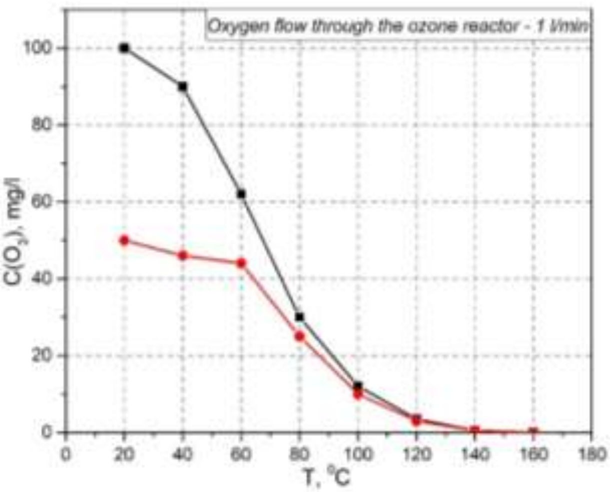

Fig. 4. Ozone decomposition rate depending on ozone concentration

2. OPTICAL OZONE CONCENTRATION METER

The device provides continuous monitoring of the ozone concentration in the working area and gives an alarm signal when the ozone concentration is exceeded in the event of a possible depressurization of the equipment. Such a device uses a semiconductor ozone sensor.

For any application of ozone, especially for medical purposes, the concentration value is decisive. There are several measurement methods: mass spectrometric, optical (by absorbing ultraviolet light when light passes through an ozone medium); by changing the speed of sound from the density of the medium; by changing the voltage of the glow discharge from the composition of the gas.

The simplest method is optical. It is known that ozone is a strong absorber of ultraviolet radiation. In an ozone environment, it actively decomposes into atomic and molecular oxygen and thereby absorbs the energy of ultraviolet radiation from the sun. And, remaining in the upper layers of the atmosphere, it forms a protective ozone layer. This process occurs in the upper layers of the Earth's atmosphere. And this ozone layer is the main protection against active ultraviolet radiation from the sun in the range from 200 to 300 nm. The absorption peak occurs at 250 nm. To build an ozone meter based on this effect, an optical method with ozone absorption in a measuring cell has long been used.

The proposed scheme is quite simple. Previously, either special spectral lamps with mercury vapor or any gas-discharge lamps with mercury filling were used in the ultraviolet source. Spectral lamps are quite rare, and small-sized lamps were enough. But now the latest LEDs in the ozone absorption range of 175 nm have appeared on the market, which completely fits into the ozone absorption zone.

The use of mercury lamps has significantly complicated the measurement method. A mercury lamp for ignition requires either a special pulse converter or a high-frequency field generator. This is not the only drawback. Gas-discharge lamps have a low service life due to cathode degradation and cathode sputtering. And, they do not immediately give a stable light flux. They need a warm-up time to reach a steady state. And the main requirement for the meter is the absorption coefficient in the measurement range. But the lamp extracts the full spectrum of mercury and plus the spectrum of argon, which is always present in these lamps for lighting the arson. An ozone mixture is fed into the working cell for measurement, and only one main mercury line of 256.3 nm is absorbed, and the entire other spectrum passes in the measurement path to the measuring photodiode and, if the photodiode perceived only this line, it would be ideal, but the photodiode perceives the entire spectrum up to the infrared.

Ideally, it is necessary to use either blocking filters from long-wave extraction, or special narrow-band photodetectors. The ideal case is a monochromator, which with a guarantee passes only a given line for measurement. But this is expensive and possible only in special laboratory conditions.

The functional diagram of an optical ozone concentration meter is shown in Fig. 5. The use of a modern differential logarithmic amplifier in the measurement circuit will significantly simplify the solution of many problems. The most important thing is that the temperature drift is completely eliminated.

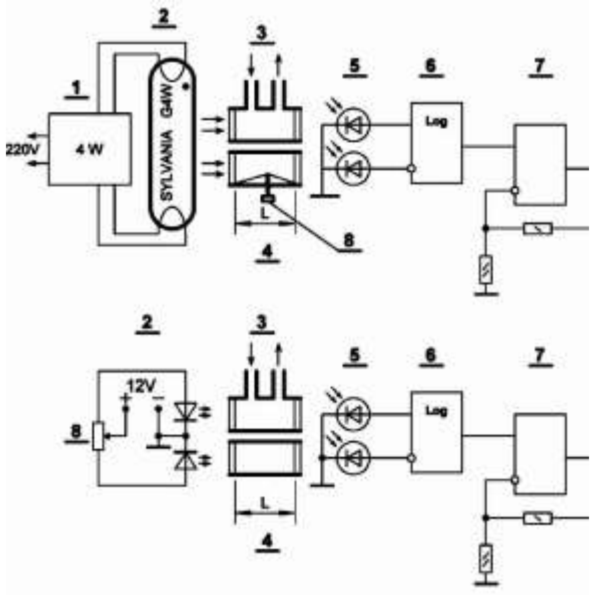

Fig. 5. Functional diagram of an ozone concentration meter: 1 – lamp power supply; 2, 4 – ultraviolet source; 3 – measuring cuvettes; 5 – photodetectors; 6 – logarithmic differential amplifier; 7 – scaling amplifier; 8 – zero setting

Since both measurement signals are fed simultaneously to both differential inputs of the amplifier. The supply of a common-mode signal is more than 60 dB. And the amplifier is also logarithmic, which expands the range of its dynamic measured signal by 6 orders of magnitude. From here it was possible to build a circuit that is capable of measuring the ozone concentration even on photodiodes that perceive the entire mercury spectrum, and the measuring cell absorbs only one mercury line 253.6 nm, thanks to the supply of a common-mode signal.

Now, with the discovery of new LEDs, it has become possible to significantly simplify the circuit and construction of the optical meter. Instead of a light bulb, two LEDs with a balancing resistor are installed and no mains power is required.

CONCLUSIONS

The conducted studies demonstrated the high efficiency of the developed ozone destructor, which consists of a quartz tube with a chromium heater. Experiments have shown that complete ozone decomposition is achieved at a temperature of 180 °C, while maintaining a stable temperature of 200 °C ensures ozone concentrations are reduced to levels below the maximum permissible limits.

These results demonstrate the potential for the developed destructor to be used for gaseous oxygen-ozone mixture system for burn wounds therapy. The proposed solution is technologically simple, cost-effective, and can be recommended for practical implementation in ozone technologies.

The optical ozone meter that provides continuous monitoring of the ozone concentration in the working area have been developed.

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РОЗРОБКА ОПТИЧНОГО ВИМІРЮВАЧА ОЗОНУ ТА ТЕРМОДЕСТРУКТОРА, ЩО ВИКОРИСТОВУЮТЬСЯ В СИСТЕМІ ГАЗОВОЇ КИСНЕВО-ОЗОНОВОЇ СУМІШІ ДЛЯ ТЕРАПІЇ ОПІКОВИХ РАН

А.В. Таран, О.Г. Чечельницький, А.С. Лозіна, А.В. Клосовський, Г.П. Опалева, А.М. Тарасов

Представлено дослідження ефективності розробленого термодеструктора для розкладання залишкового озону для системи на базі дії газоподібної киснево-озонової суміші для терапії опікових ран. Актуальність дослідження зумовлена необхідністю зниження концентрації озону в робочому просторі до значень, що не перевищують гранично допустимі концентрації, через його високу токсичність. Деструктор виконаний у вигляді кварцової трубки з ніхромовим дротяним нагрівачем та термостатом для підтримки заданої температури. Експерименти показали, що при різних швидкостях потоку кисню та концентраціях озону його повне розкладання досягається за температури 180 °С. Було виявлено, що максимальна температура нагрівання 200 °С забезпечує стабільну роботу приладу та повне усунення залишкового озону. Також для забезпечення безпеки персоналу під час озонотерапії розроблено спеціальний оптичний вимірювач гранично допустимої концентрації озону в приміщенні.