International Journal of Basic Sciences and Applied Computing (IJBSAC)
ISSN: 2394-367X (Online), Volume-8 Issue-7, March 2022

Bactericidal Disinfection of Activated Carbon from Aerobic Microorganisms, Yeasts and Molds

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***Abstract:** One of the reasons for non-compliance with the requirements of regulatory documentation of powdered materials, including drugs is microbiological contamination. The search for alternative technical approaches of bactericidal disinfection using modern physical methods is relevant for research. Checking the compliance of activated carbon «Silcarbon», which is used in medicine as a sorbent, showed that the number of fungi (TYMS) exceeds the permissible norms in several times. A number of experimental studies where ultraviolet light, a combination of UV radiation and ozonation were used have been performed to disinfect «Silcarbon» from microbiological contaminants. It is shown that optimal results can be achieved in terms of the content of molds and yeasts: the total amount does not exceed 70 CFU/g using a combination of UV radiation and ozonation. When using pulsed UV lamps with a flux density of 10000-10500 W/m^2, the amount was 30 CFU/g, and for molds fungi 20 CFU/g, which meets the requirements of regulatory documents. In dependance on the method of disinfection use the total amount of microbiological contamination of «Silcarbon» ranges from 50 to 70 CFU/g.*

***Keywords:** Activated Carbon, Uv-Irradiation, Microbiological Purity, Dose of Uv Irradiation.*

I. INTRODUCTION

In pharmaceutical practice, using sorbents toxic substances can be removed from the body, among which the most common and well known is activated carbon "Silcarbon". Analysis of works [1, 2, 3] showed that in some cases drugs do not meet the requirements of the current legislation on microbiological purity [4]. So in work [1] over 1000 samples of non-sterile preparations were analyzed. In about 2% of preparations, fungi and aerobic bacteria were found, the number of which exceeds the permissible limits. In work [2] microbial contamination of 10 non-sterile medicinal preparations, which were delivered to outpatients, were investigated. It was shown that 50% of the tested products were heavily contaminated with Bacillus and Candida. Such contamination of pharmaceuticals by microorganisms, can cause changes in the physicochemical characteristics of drugs. in work [3] It was found that all samples were contaminated with bacteria, most of them with a fungus. If the sorbent does not meet the requirements of regulatory documentation [4, 5] for microbiological purity, the therapeutic effect of such sorbent can cause adverse effects on the human body. Accordingly, to [1] the total number of aerobic bacteria is not more than 1x10^3 CFU/g, the total number of molds and yeasts is not more than 1x10^2 CFU/g.

Respectively with the requirements of regulatory documentation of medicines (sorbents of therapeutic action) is ensured by the principles - Good Manufacturing Practice (GMP) [6]. Disturbance of the technological process of production, storage conditions, including transportation – is the main cause of microbiological contamination. The analysis of the number of works [7, 8] showed that in some cases medicines do not meet the requirements of current regulations in terms of "microbiological purity". Therefore, the search of modern approaches of inactivating drugs from microbiological contamination is an alternative task that scientists have been working on for decades. The infinity of research in this direction is due to the emergence of new viruses and bacteria that are registered around the world. In Europe and most countries in the pharmacology for the production of activated carbon using raw materials of the trademark "Silcarbon". Analysis of a number of batches of activated carbon raw materials at the input control showed that the content of microbiological contaminants does not meet the requirements (Table- I) [4, 5].

Table- I: The Number of Aerobic, Mold and Yeast Fungi in Activated Carbon "Silcarbon"

Microbiological purity	Requirements, CFU/g	Number of microorganisms, CFU/g
TAMC (number of aerobic microorganisms)	1x10^3	corresponds to (650)
TYMC (total number of yeast and mold fungi)	1x10^2	does not match (2700)

The aim of the work is to study the possibility of microbiological purification of activated carbon powder from mold and yeast fungi by UV irradiation. The use of currently existing methods and methods for disinfecting powdered materials makes it possible to fully achieve positive results in the destruction of vegetative and spore-forming forms of microorganisms in the treated object.

Manuscript received on February 19, 2022.
Revised Manuscript received on March 14, 2022.
Manuscript published on March 30, 2022.

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It should be noted that the use of any method is accompanied by the influence of this effect on the structure of chemical compounds, which leads to irreversible changes in chemical properties.

Therefore, research in this aspect of each method of disinfection is a whole complex of scientific research. In particular, it was found that during heat treatment of activated carbon, the organoleptic properties deteriorate; the activity of exposure is slowed down, etc. Methods of disinfection with the use of strong chemical oxidizing agents (ozone and chlorine), as well as radiation methods, when exposed to a given object, can lead to irreversible changes in physicochemical characteristics: the quality of the product is lost and the biological value deteriorates. An effective direction of solving this problem is the use of ultraviolet radiation with a wavelength of 254 nm, which has a strong bactericidal effect and provides inactivation of all types of microorganisms, but the radiation doses differ by several orders of magnitude. UV radiation in comparison with the methods of chemical radiological disinfection at exceeded doses does not impair the biological value of the product [9, 10]. For example, when ultraviolet irradiation of powder materials is processed the thinnest surface layer, which contains various microorganisms. At such irradiation, the basic weight is not exposed and therefore biochemical properties of the product do not change. UV radiation with wavelengths from 205 to 315 nm has a pronounced biocidal effect and produces effective inactivation of microorganisms of various types - bacteria, spores, viruses, micro fungi, etc. Bactericidal disinfection of microorganisms occurs due to photochemical reactions, and the efficiency is determined by the wavelength of ultraviolet radiation (wavelength range 200-400 nm) or the energy of photons. UV radiation is very strongly absorbed by almost all solids - the characteristic ranges of UV photons in solid media range from fractions of a micron to several microns. Therefore, with UV irradiation of a solid particle, only its thinnest surface layer is processed, but the main mass of the substance is not exposed to any effects and, accordingly, does not change its biochemical properties. This is a significant advantage of the method of UV-biocidal treatment compared with other known methods of disinfection [11, 12]. On the other hand, the opacity of solid media for UV radiation in the processing of bulk solids requires efficient mixing of the particles so that the surface of each particle would be available for UV irradiation [10]. The state and environmental parameters of ultraviolet radiation are essential for its life in the inactivation of bacteria, irradiation of surfaces and stimulation of processes [12, 13, 14]. Considering the above stated advantages of physical methods with the use of optical radiation for disinfecting bulk materials with a particle size of several microns, we have proposed a UV radiation technology for the treatment of activated carbon. Processing methods and possible technical solutions are discussed below [15].

II. MATERIALS AND RESEARCH METHODS

In this work, studies were carried out on activated carbon "Silcarbon", made in Germany with a particle size from 1 micron to 0.2 mm. Fig. 1 shows a sample study.

Fig. 1. Activated carbon "Silcarbon"

For UV irradiation, lamps were used whose characteristics are presented in Table- II and Table- III.

Table- II: Characteristics of Ozone-Free Quartz Lamps, Power 80 W

Type of lamp used	P, W	U, V	UV exposure at a distance of 1 m
ZW80D19W	80	120	240-270 **W/cm²**

Table- III: Characteristics of Ozone Quartz Lamps, Power 23 W

Type of lamp used	P, W	U, V	UV exposure at a distance of 1 m
ZW23D15Y	23	40-55	62-69 **W/cm²**

To address the issue of inactivation of microorganisms in activated carbon, a number of studies using UV radiation and different types of lamps of ozone and non-ozone action.

I. UV irradiation of activated carbon on the surface using low-pressure discharge lamps with a maximum radiation at a wavelength of 254 nm.

II. UV irradiation of activated carbon in a cylindrical chamber under the action of free fall, using low-pressure discharge lamps with a maximum radiation at a wavelength of 254 nm

III. UV irradiation of activated carbon in a closed chamber, with the use of low-pressure discharge lamps with a maximum radiation at wavelengths of 185 nm and 254 nm

IV. UV irradiation of activated carbon in a cylindrical chamber under the action of free fall, using pulsed lamps with radiation in the range of 100-300 nm.

III. RESULTS AND DISCUSSION

A. Experiment I

Activate carbon powder with initial characteristics on the content of yeast (CFU/g - $7.2x10^3$) and mold fungi (CFU/g - $1.1x10^3$), was irradiated with doses of UV-C 300-320 J/m^2 and 1000-1100 J/m^2, with using an ozone-free lamp, the parameters of which are presented in the Table- II.

The results of the analysis after irradiation of the powder with a dose of 300-320 J/m^2 for yeast CFU/g - 2600, for mold CFU/g - 800. When irradiated with a dose of 1000-1100 J/m^2 for yeast, respectively, CFU/g - 2200, and for mold CFU/g - 700. The total amount of fungi at a dose of 300-350 J/m^2 is 3500 CFU/g, and at a dose of 1000-1100 J/m^2 - 2950, that is, in the first case they are exceeded 34 times, and in the second - 29 times. The results of the experiment are presented in the Table- IV.

Retrieval Number: 100.1/ijbsac.G0472038722
DOI:10.35940/ijbsac.G0472.038722
Journal Website: www.ijbsac.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table- IV: The Results of Checking the Conformity of Activated Carbon

Indicators	UV dose, J/m^2	Results, CFU/g
Microbiological purity: TYMC	300-350	3500
	1000-1100	2950

The obtained results of inactivation for microorganisms on the surface of activated carbon are unsatisfactory. We have assumed that microbiological contaminants are not only on the surface, and these doses are not sufficient for inactivation. It was decided to look for a more efficient way to use UV radiation.

B. Experiment II

For solving the issue of inactivation of microorganisms, was used a technical approach proposed in [10]. Inactivation of microorganisms under the influence of powerful UV lamps (Table II) occurs in a cylindrical chamber height of 2 m. A sieve is placed above the disinfection chamber, onto which activated carbon is uniformly fed. Activated charcoal is dissolved and under the action of gravity passes through the irradiation chamber.

The particles of activated charcoal when falling in the decontamination chamber are irradiated from all sides with powerful low pressure lamps. The irradiation occurs in the container when packaging. This approach reduces the probability of repeated infection of activated charcoal. Checking 3 batches of activated carbon the number of yeast fungi did not exceed 2100 CFU/g during irradiation, which was 500-600 W/cm^2. Increasing the radiation dose to 2000-2100 W/cm^2 a slightly better result was obtained: the amount was 1200 CFU/g. For mold mushrooms, with appropriate irradiation doses, obtained: 850 CFU/g and 500 CFU/g. The results of experimental studies are presented in the Table- V.

Table- V: The Results Of Checking The Conformity Of Activated Carbon

Indicators	Irradiation, W/cm^2	Results, CFU/g
Microbiological purity: TYMC	2000-2100	1700

The results of the content of microorganisms do not satisfy the requirements of normative documentation [4, 5]. It was assumed that by irradiating only the surface layer, it is impossible to achieve inactivation of microorganisms. They are debris not only on the surface, but also in the thickness of the layer of particles due to the peculiarities of the surface of activated carbon.

C. Experiment III

The effectiveness of bactericidal disinfection of activated coal depends on the following factors: radiation doses, ambient parameters (temperature, humidity), size, surface and amount of agglomerated particles, etc. Based on the indicated factors, further research conducted under the action of a combination of UV radiation and ozonation using raw materials with the following parameters: the number of yeast fungi - 8500 CFU/g, and the number of mold fungi is 1100 CFU/g. For obtaining a combined action of ultraviolet irradiation and ozonation, the UV lamps which are presented in Table- III 3 were used.

A feature of ozone is the ease of its decay with the formation of atomic oxygen - one of the most powerful oxidizing agents. Atomic oxygen destroys bacteria, spores and viruses that are inside the particles of activated carbon. The results of the analysis after irradiating the powder with a dose of 1200-1250 J/m^2 for yeast CFU/g - 40, for mold CFU/g - 30.

The total amount of fungi at a dose of 1200-1250 J/m^2 is 70 CFU/g, which satisfies the requirements [5]. The results of the experiment are presented in the Table- VI. Thus, when exposed to a combination of UV radiation and ozone, the desired results were achieved. But, as is known, ozone, even in low concentrations, causes the oxidative properties of activated carbon, which can affect the effectiveness of exposure to the human body.

Table- VI: The Results of Checking the Conformity of Activated Carbon

Indicators	UV dose, J/m^2	Results, CFU/g
Microbiological purity: TYMC	1200-1250	70

In this regard, it was decided to conduct an experiment using xenon flash tubes, which have a continuous emission spectrum and are characterized by a high radiation density.

D. Experiment IV

The most effective for UV disinfection today are low-pressure mercury discharge lamps [16], but they have low power per unit arc length (1-2 W/cm), which does not allow creating lamps of high unit power with small overall dimensions. For such conditions, it is advisable to use pulsed UV lamps, which are able to provide the necessary dose of UV irradiation for less than 1 sec. To implement the technical solution using pulsed UV lamps in the irradiation chamber (Experiment 2), low-pressure mercury lamps were replaced with pulsed UV lamps. The number of yeast fungi after irradiation with a flux density of 10000-10500 W/cm^2 was 30 CFU/g, and for mold fungi 20 CFU/g, which meets the requirements [1]. The results of the experiment are presented in the Table- VII.

Table- VII: The results of checking the conformity of activated carbon

Indicators	Irradiation, W/cm^2	Results, CFU/g
Microbiological purity: TYMC	10000-10500	50

The obtained results of UV irradiation of activated carbon showed a significant reduction in the overall degree of inactivation by yeast and mold fungi (TYMC) in experiments 1 and 2. When using the combined method, with the use of low-pressure mercury ozone lamps, satisfactory results can be obtained in which the total amount of yeast and mold fungi ranges from 50 CFU/g to 70 CFU/g. The effectiveness of bactericidal disinfection of activated carbon depends on the following factors: radiation dose, surface characteristics, environmental parameters etc. It is recommended to use the ultraviolet method not only in the inactivation of bacteria in medicine, but also in the irradiation of powder materials (milk powder, biomass) and surfaces of various products in the food industry, both in the process of production and storage.

IV. CONCLUSIONS

Thus, with the use of pulsed xenon lamps and low-pressure mercury ozone lamps, satisfactory results can be obtained in which the total amount of yeast and mold fungi ranges from 50 CFU/g to 70 CFU/g.

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