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Silver containing sorbents: Physicochemical and biological properties

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Abstract

New silver containing sorbents, based on mineral carriers, such as alumina and silica systems with a meso- and macro- porous structure, have a higher mechanical resistance and, hydrophilic and hydrophobic chemical composition of the surface. These sorbents are easy to find and relatively inexpensive, compared to their known equivalents. They are furthermore characterised by high specific surface and simple preparation, whilst the addition of silver considerably increases their antiseptic activity. The results of research of the physical, chemical and biological properties of the developed substances, as well as bio-comparability of sorbents with biological tissues, are presented in this paper. The modified material acts simultaneously as the carrier for active substances to the area of therapeutic application and as a sorbent used to remove toxic agents from such areas. This approach led us to modify the sorbent, and prolong the delivery of substances such as silver, as an effective antibacterial and antimycotic agent.

Keywords: Sorbents; Detoxification; Prolongation; Silver

1. Introduction

The increase in the number of industrial environmental disasters and emergencies around the world exposed the world population to high risks of injury and various intestinal infections, over large territories, liable to develop into global catastrophes. According to WHO, each year up to 5 million children around the world die of intestinal infections of various aetiologies.

Toxic agents (microbial cells, their waste, activated ferments, capable of harming the tissue, inflammation mediators, peroxide substances, devitalized tissues ingredients of different structures etc.), enter the body, disturbing its homeostasis and leading to the condition referred to as “endogenous intoxication”, associated with disruption of the functions of detoxification and excretion organs, damage to epithelial sheets and massive tissue damage, organ and tissue ischaemia, exotoxicosis and immuno-suppression [1].

In addition to the conventional therapeutic methods, relying on different drugs for detoxification of the body, sorption methods have also been used. The interest for cerebrifugal sorption methods is unrelenting, since these methods (haemo-, lympho-, plasmo-, liquoro-, entero-, immuno- and application sorption) are all based on extraction of toxic agents from the body, as well as endogenous and exogenous ballast substances, relieving the pressure form organs through natural detoxification of the body (liver, kidneys and the immune system). Scientific research has confirmed the effectiveness of inclusion of sorbents in the therapy and prophylactic treatment in different diseases.

We know that sorption activity is dependent on both the content and the chemical structure of the sorbent surface, as well as on their texture [2,3]. The most commonly encountered sorbents are those based on active carbons, aluminium oxides, silicon and carbon–mineral sorbents [4]. Carbon–mineral sorbents combine the activity of carbons and stability of mineral sorbents, the hydrophilic and hydrophobic nature of their surface, which make them compatible with bio-tissues [3]. Broadly speaking, sorbents come in diverse sizes of specific surfaces, which is measured based on pore size, where the larger the pore, the higher the specific surface of the sorbent.

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According to one classification, porous bodies have the following pore sizes: micropores – the equivalent size of less than 1.5–2 nm; mesopores – the size is between 2 and 50 nm, or up to 100 nm according to other sources; macropores – the equivalent size of 50–100 nm to up to 6500 nm; supermacropores – the equivalent size exceeding 6500 nm. Scientific research indicated a preference for the use of meso- macroporous sorbents in therapy because they are least liable to harm the biotissue, whilst remaining effective in removing medium and highly molecular toxin agents of different types, from biological media.

The requirements for sorbents designated for use in medicine have been defined as follows: they need to be of adequate mechanical and chemical stability, comply with prescribed standardised granulometric and texture parameters, have certain chemical structure, cause as little damage to the biological tissue as possible and do not have a toxic effect on organs and tissue; that they do not absorb proteins and oxygen from the blood and lymph, that they do not disturb the body's mineral balance, that they are selective towards certain class of compounds, that they have optimal absorption capacity, that they remain active in all parts of the gastrointestinal tract and they can be thoroughly and well discharged from it [2,3]. Furthermore, it should to be pointed out that the development of sorption substances ought to be based on competitive, low-energy, resource saving and environmentally friendly manufacturing technologies [5–7].

The research has indicated that sorbent effectiveness can be increased through modification of their surface using biologically active components. One of promising components is silver, offering its therapeutic (antibacterial and virucidal [8–10]) qualities, both in terms of its capacity for releasing into the biological medium, from the sorbent surface, and through contact between its surface and the biological medium. During such exchange, the silver containing sorbent does not act as an active absorbent of toxic agents [11].

From the point of view of possibility of using the above methods in practice, further development and research of silver containing mineral sorbents with meso-macroporous structure is of particular interest, offering high mechanical stability, a hydrophilic/hydrophobic chemical quality of the surface [12,13], as well their enhanced organoleptic qualities. This paper shows the results of research of silver containing sorbent's physical and chemical qualities [14–16] based on mineral carriers, such as aluminium and silicon containing sorbents. These sorbents are easy to find and relatively easily available, compared to their known equivalents (such as Polysorb and Smecta). They are furthermore characterised by high specific surface and simple preparation, whilst the addition of silver considerably increases their antiseptic activity.

2. Materials and methods

2.1. Physical and chemical research

The synthesis of sorbents was based on aluminium oxide carriers with various granulometric composition, such as industrial grade aluminium oxide (gamma Al_2O_3) and thermo-activated aluminium hydroxide (TAGA). In order to obtain hydrophilic/hydrophobic chemical qualities, the surface of aluminium oxide carriers was coated with industrial grade organosilicon polymers (polymethylsiloxanes in the form of molecular solutions and water emulsion). The resulting carrier is a sorbent modified with a complex of Ag/polyvinylpyrrolidone clusters, in particles of 2–5 nm, applied through physical adsorption, as part of thermal processing [17].

Physical and chemical research was conducted using different methods. Granulometric composition was assessed by screen size gradation (0.1–1 mm); the particle size of micronised sorbent (TAGA) was assessed using laser diffractometer (SHIMADZU SALD-2101). Mechanical stability of slightly spherical sorbent specimens was assessed based on losses following mechanical abrasion PIG-2 [3]. The specific surface of sorbent specimens with different granulometric composition was determined based on the BET method, using nitrogen sorption isotherm to determine the size and the volume of pores [18]. The sorbent's weight by volume [19] and powder density were measured using Auto Ruspometer-200. The content of silicon and silver in sorbent was measured based on atomic emission spectrometry with inductively-coupled plasma using Baird (Netherlands) [20] spectrometer.

The distribution of silicon containing polymers in the pore space of aluminium oxides was examined based on the low-temperature nitrogen absorption method (77.4 0 K) using the ASAP-2400 Micromeritics station, whilst the classification of pores based on their size was carried out using the Barrett–Joyner–Halenda method.

The assessment of sorption qualities of the sorbent was carried out based on sorption of blue methylene dye from water solution, which is otherwise used as a marker for medium molecular weight toxic agents. The adsorption was observed at room temperature, with occasional shaking, during 1 hour, where the sorbent–water ratio was 1:10, and where the dye content was measured using spectrophotometry.

2.2. Assessment of sorbent's biological features

Experimental investigation of biological compatibility of modified nanoclusters of Ag/Al/Si containing sorbents was conducted using micronised silver containing sorbent [21,22]. The research was conducted at the Laboratory for Pharmacological Research of the Natural and Biological Compound Department of the FGBNU NIOH [the Federal State Budgetary Scientific Institute of the Novosibirsk Institute of Organic Chemistry] Experiments were conducted on 18 female rats of the Vistar breed, with the mass of 200 ± 2 g. The animals were maintained in accordance with the rules approved by European Convention on the Protection of vertebrate Animals used for Experiments and other Scientific Purposes (Strasbourg, 1986). The groups of animals were randomised, each containing 6 subjects (the animals were marked but kept together): group I – received an intramuscular injection of distilled water (2.5 mL) (the negative control group); group II – received an intramuscular injection of the generic TAGA sorbent, in 2:1 water