Brief information about the project

Name of the project	AP09260629 “Setting of conditions for applying antibacterial coatings on the surfaces of suture and biomedical materials”
Relevance	The scientific project is aimed at developing antibacterial coatings on the surface of surgical suture materials. This is associated with an increased risk of complications due to bacterial contamination, especially during prosthetics and surgical operations. Suture material, like most implants, has a non-detachable surface to which bacteria can attach, forming bacterial biofilms and thereby complicating the course of treatment. Because of such treatments, this is a difficult moral and expensive financial burden for the patient, and in some cases, even fatal. Therefore, an important task in implantology is antibacterial protection of the surface of medical and biological products.
Purpose	Development of physico-chemical conditions for applying antibacterial coatings using the multilayer assembly method on the surface of sutures and biomedical materials (protective fabrics for gowns, bandages) to improve functional properties based on biocompatible, environmentally friendly polysaccharides in the form of nanocoatings containing bioactive agents or silver nanoparticles in multilayers.
Objectives	A way to achieve the project goal through the following logically interconnected sequential tasks: 1. To carry out a scientifically based selection of medical absorbable and non-absorbable surgical sutures and protective materials for medical and biological purposes, to study the influence of temperature, pH of the environment, solvents on the form of their presence in solutions under which modification of their surfaces is expected. 2. Conduct a scientifically based selection of bioactive compounds (natural and synthetic biodegradable polysaccharides) and methods for producing silver nanoparticles. To study the influence of temperature, pH and concentration on the viscosity and electrical conductivity of selected polyelectrolytes (polymer matrices of multilayers) to substantiate the active functional groups of selected bioactive agents for participation in the formation of nanofilms. 3. Establishment of physicochemical conditions to produce nanocoatings based on selected polyelectrolytes (polysaccharides) using the multilayer assembly method, taking into account the influence of temperature, pH of the environment, thickness of bilayers and the nature of the solvent. Study of the physical and chemical characteristics of films: thickness, SEM, IR spectra. Establishment of optimal conditions for methods of applying antibacterial agents and silver nanoparticles to the resulting multilayers and study of physicochemical characteristics: thickness, nature of silver nanoparticles, SEM and IR spectra of the resulting antibacterial coatings. 4. Testing the obtained modified biomedical materials for antibacterial activity. The antimicrobial potential of suture materials obtained by multilayer assembly based on antibacterial

	agents and Ag nanoparticles will be determined against the pathogenic microorganisms Candida albicans, Escherichia coli and Staphylococcus aureus.
Expected and achieved results	**Achieved results:** 1. A scientifically based selection of medical absorbable and non-absorbable surgical sutures, widely used in domestic medicine in Kazakhstan, was carried out. Non-absorbable monofilament threads - polypropylene, synthetic non-absorbable multifilament twisted threads - polyamide, absorbable braided threads - rumacryl, non-absorbable braided threads - rumasan, absorbable natural threads - catgut. Chitosan and sodium carboxymethylcellulose (CMC) were used as polymer matrices for nanofilms. 2. Optimal conditions for obtaining nanocoatings for all types of surgical sutures was developed; the optimal number of bilayers is 10.5 at a temperature of 37 ℃, pH 3 for chitosan and 5 for CMC. For nanocoatings in model samples, the influence of pH and concentration on the thickness of the films and the nature of the solvent were studied. Antibacterial agents were applied by impregnation of films at 37 ℃ for 24 hours. 3. Study of the antibacterial activity of all modified surgical sutures containing chlorhexidine after 24 hours of incubation at 37 ℃ and high humidity (~80%) showed a good zone of inhibition against the museum test strain Staphylococcus epidermidis, Streptococcus pneumoniae, Klebsiella pneumoniae. 4. Physicochemical conditions for obtaining nanocoatings on the surface of medical fabrics was developed. The results of the antimicrobial activity of the obtained medical fabric samples were carried out in vitro against two types of widespread bacteria, Escherichia coli and S. Aureus. The project was successfully implemented, the results were published in the form of an article in Q1 indexed journal, a utility model patent was obtained, and an invention patent was filed. The results were presented at the exhibition in Urumqi Xinjiang University of the People's Republic of China.
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List of publications with links to them	1. Rakhmatullayeva, D., Ospanova, A., Bekissanova, Z., Jumagaziyeva, A., Savdenbekova, B., Seidulayeva, A., & Sailau, A. (2023). Development and characterization of antibacterial coatings on surgical sutures based on sodium carboxymethyl cellulose/chitosan/chlorhexidine. International Journal of Biological Macromolecules, 2023. Vol. 236. P. 124024. Процентиль 91% (Q1). IF=8.2; https://doi.org/10.1016/j.ijbiomac.2023.124024. 2. A.A. Toksanbay, Zh.B. Bekissanova (Kubasheva), D.T. Rakhmatullaeva, B.E. Savdenbekova, A.K. Ospanova, D.Zh. Batyrbayeva, N.F. Uvarov // Preparation of the antibacterial coatings based on natural mineral materials// International Journal of Biology and Chemistry 14, № 1, 184 (2021). https://doi.org/10.26577/ijbch.2021.v14.i1.021
Patents	1. Patent RK No. 6760 for the useful model "Method of obtaining an antibacterial coating on the surface of surgical suture threads "//Ospanova A.K., Rakhmatullaeva D.T. Kubasheva Zh.B., Batyrbayeva D.J., Abdurazakov U. 15.12. 2021, No. 2021/0223.2.

PUBLICATIONS AND PATENTS

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ РЕСПУБЛИКА КАЗАХСТАН

REPUBLIC OF KAZAKHSTAN

ПАТЕНТ
PATENT
№ 6760

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Способ получения антибактериального покрытия на поверхности хирургических шовных нитей
Method for obtaining antibacterial coating on the surface of surgical sutures

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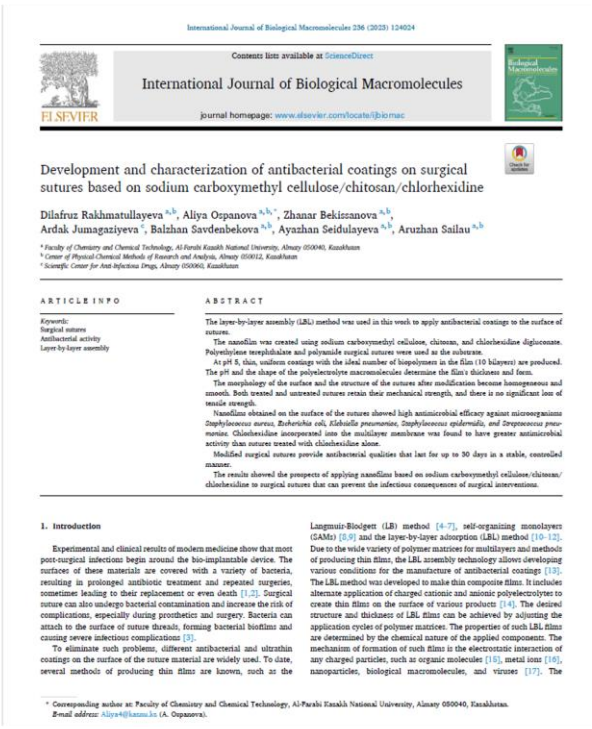

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Development and characterization of antibacterial coatings on surgical sutures based on sodium carboxymethyl cellulose/chitosan/chlorhexidine

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Keywords:
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ABSTRACT

The layer-by-layer assembly (LBL) method was used in this work to apply antibacterial coatings to the surface of sutures.

The nanofilm was created using sodium carboxymethyl cellulose, chitosan, and chlorhexidine digluconate. Polyethylene terephthalate and polyamide surgical sutures were used as the substrate.

At pH 5, thin, uniform coatings with the ideal number of biopolymers in the film (10 bilayers) are produced. The pH and the shape of the polyelectrolyte macromolecules determine the film's thickness and form.

The morphology of the surface and the structure of the sutures after modification become homogeneous and smooth. Both treated and untreated sutures retain their mechanical strength, and there is no significant loss of tensile strength.

Nanofilms obtained on the surface of the sutures showed high antimicrobial efficacy against microorganisms *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Staphylococcus epidermidis, and Streptococcus pneumoniae*. Chlorhexidine incorporated into the multilayer membrane was found to have greater antimicrobial activity than sutures treated with chlorhexidine alone.

Modified surgical sutures provide antibacterial qualities that last for up to 30 days in a stable, controlled manner.

The results showed the prospects of applying nanofilms based on sodium carboxymethyl cellulose/chitosan/chlorhexidine to surgical sutures that can prevent the infectious consequences of surgical interventions.

1. Introduction

Experimental and clinical results of modern medicine show that most post-surgical infections begin around the bio-implantable device. The surfaces of these materials are covered with a variety of bacteria, resulting in prolonged antibiotic treatment and repeated surgeries, sometimes leading to their replacement or even death [1,2]. Surgical suture can also undergo bacterial contamination and increase the risk of complications, especially during prosthetics and surgery. Bacteria can attach to the surface of suture threads, forming bacterial biofilms and causing severe infectious complications [3].

To eliminate such problems, different antibacterial and ultrathin coatings on the surface of the suture material are widely used. To date, several methods of producing thin films are known, such as the Langmuir-Blodgett (LB) method [4–7], self-organizing monolayers (SAMs) [8,9] and the layer-by-layer adsorption (LBL) method [10–12]. Due to the wide variety of polymer matrices for multilayers and methods of producing thin films, the LBL assembly technology allows developing various conditions for the manufacture of antibacterial coatings [13]. The LBL method was developed to make thin composite films. It includes alternate application of charged cationic and anionic polyelectrolytes to create thin films on the surface of various products [14]. The desired structure and thickness of LBL films can be achieved by adjusting the application cycles of polymer matrices. The properties of such LBL films are determined by the chemical nature of the applied components. The mechanism of formation of such films is the electrostatic interaction of any charged particles, such as organic molecules [15], metal ions [16], nanoparticles, biological macromolecules, and viruses [17]. The

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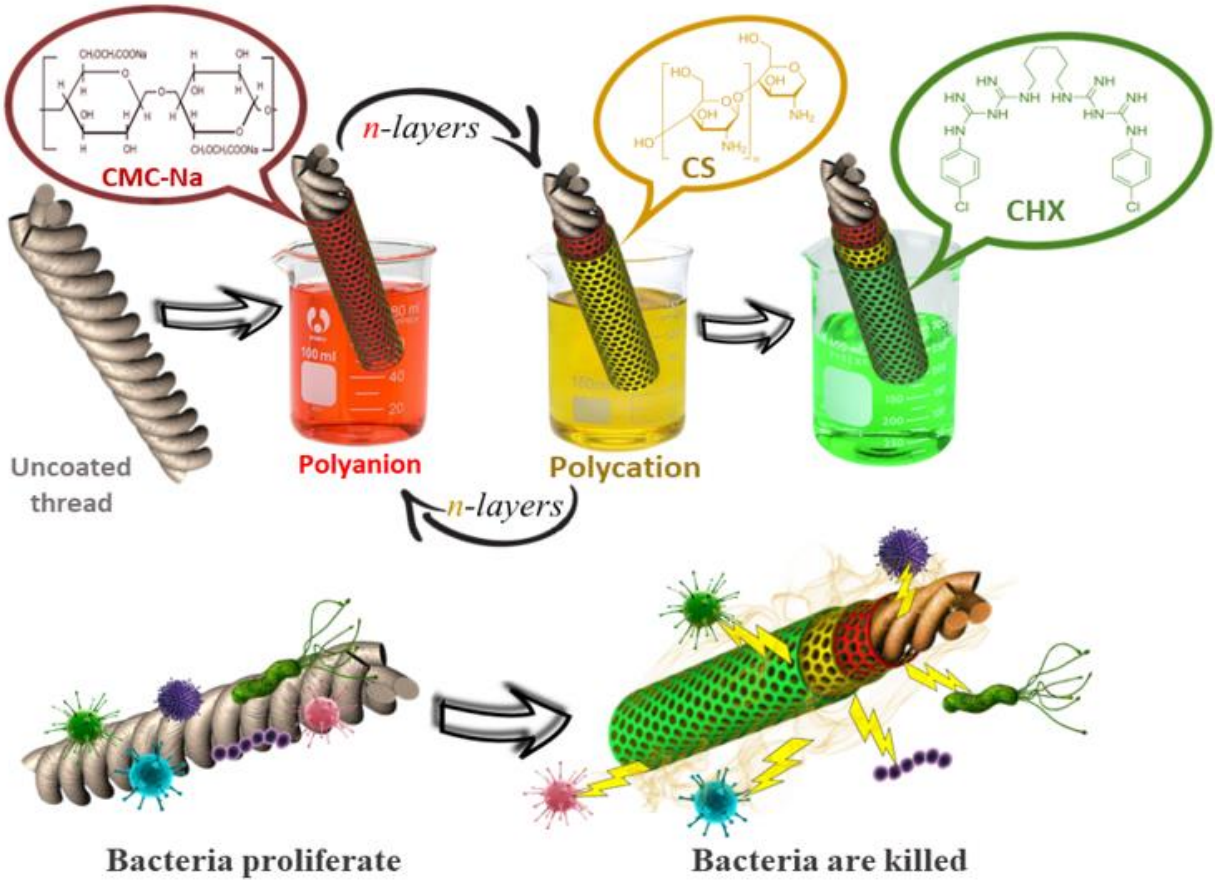
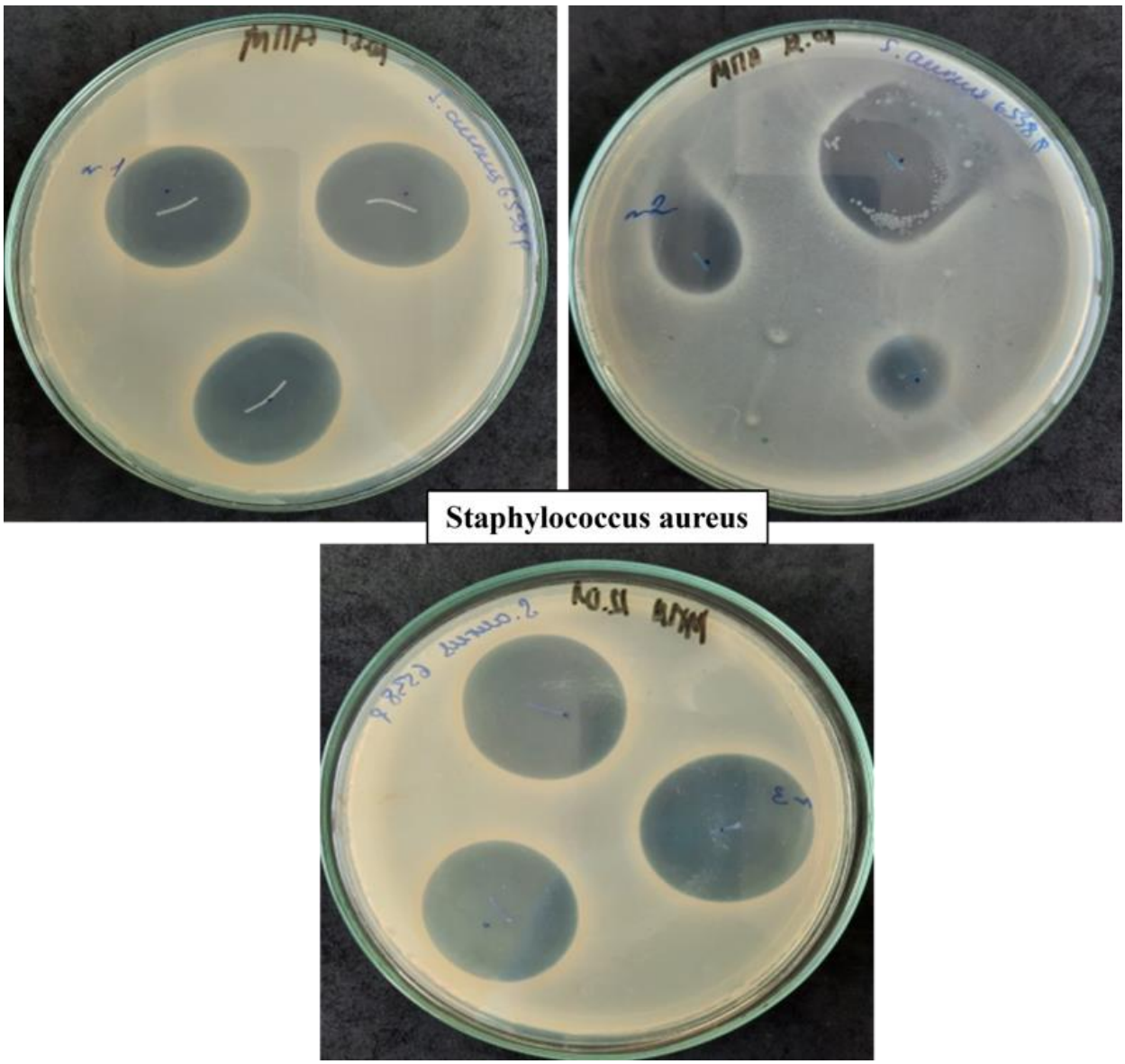


The scheme of obtaining antibacterial coatings

Participation in the exhibition in Urumqi

Conducting an analysis of antibacterial activity



The results of the analysis of antibacterial activity