

Brief information about the project

Name of the project	Development of New Drug Delivery Systems for the Treatment of Ocular Diseases Using Mucoadhesive Polymers
Relevance	The relevance of the project lies in the development of ophthalmic drug delivery systems (ODDS) with improved mucoadhesive and/or in situ gel-forming properties. By employing biocompatible hydrophilic polymers and their chemically modified derivatives with enhanced mucoadhesive characteristics, the project offers a promising alternative to conventional pharmaceutical excipients used in ophthalmic drug delivery systems for the treatment of glaucoma and fungal eye infections.
Purpose	The aim of the project is to develop new drug delivery systems for the treatment of ocular diseases using mucoadhesive polymers. These polymers will be obtained by modifying biocompatible materials with various functional groups, which will significantly improve their mucoadhesive properties. The developed delivery systems may be effectively used for the therapy of glaucoma and fungal diseases of the eye.
Objectives	1. Modification of biocompatible polymers with maleimide and/or methacrylate groups to improve mucoadhesive properties and/or the ability for in situ gelation, with the aim of developing effective ophthalmic drug delivery systems (ODDS). The polymers will be characterized using modern physicochemical methods, including NMR, IR and UV spectroscopy, DSC, TGA, and others. 2. Investigation of the in situ gelation process of newly synthesized polymers using various methods. The obtained results will be used in the development of ODDS with optimal characteristics, including viscosity, transparency, and retention on the cornea. 3. Study of the interaction of modified polymers with drug substances used for the treatment of glaucoma (timolol maleate, brimonidine) and fungal infections (fluconazole, ketoconazole). The influence of the degree of polymer modification, environmental conditions, and drug concentration on viscosity, transparency, drug release, and corneal penetration will be investigated. These results are important for the development and evaluation of ODDS prototypes. 4. Development of ODDS prototypes based on synthesized polymers containing drug substances in the form of solutions and films, as well as their characterization by various methods. For solutions and in situ gelling systems, UV spectroscopy, viscometry, and rheology will be used. Films will be studied by optical methods and using a texture analyzer to determine physicochemical parameters.

	5. Investigation of the mucoadhesive properties of the developed ODDS in vitro and in vivo on the cornea of animal eyes. A wash-off method will be used to assess retention on the mucosal surface. For gel-forming systems and films, additional experiments using a Texture Analyser will be carried out, which will provide more comprehensive data for selecting the most effective ODDS. 6. Evaluation of the toxicity of the developed ODDS will include tests on mice and slugs, bovine corneal opacity and permeability (BCOP) tests, as well as experiments on planarians and/or caterpillars to assess irritant effects and safety. In addition, cytotoxicity assays (MTT test) will be conducted to evaluate cell viability and proliferation. 7. Conducting preclinical studies of the developed ODDS for a more in-depth analysis of their effects on the body, determination of therapeutic doses, and possible side effects. Within these studies, the rate of active substance absorption as well as toxicity will be evaluated.
Expected and achieved results	Expected results 1. A literature review on the research topic will be conducted; experimental methods for the chemical modification of various hydrophilic polymers using maleimide and methacrylate functional groups will be developed. 2. A new maleimide-functionalized polymer will be synthesized for the development of effective ophthalmic drug delivery systems with improved mucoadhesive properties. The obtained polymer will be analyzed using various physicochemical methods, such as NMR, IR and UV spectroscopy, differential scanning calorimetry, and others. 3. The influence of various parameters (pH, viscosity, degree of modification, concentration of drug substances, etc.) on the interaction of modified polymers with different pharmaceutical compounds or model substances for the treatment of ocular diseases will be investigated. 4. New maleimide- and/or methacrylate-modified natural polymers will be synthesized for the development of effective ophthalmic drug delivery systems with improved mucoadhesive and/or in situ gel-forming properties. The characteristics of the obtained polymers will be studied using various physicochemical methods, such as NMR, IR and UV spectroscopy, differential scanning calorimetry, etc., to determine their composition, degree of modification, and other properties. 5. The in situ gelation of the obtained new polymers will be studied using viscometry, rheology, and other methods. 6. Prototypes of ophthalmic drug delivery systems based on the synthesized polymers in the form of solutions and films will be obtained and characterized; the release of the drug substance from these systems will also be studied using optical, viscometric, or rheological methods.

7. In vitro mucoadhesive properties will be studied to assess the ability of the obtained ophthalmic drug delivery systems (ODDS), in the form of eye drops and films based on modified polymers, to be retained on the corneal surface using the wash-off method.
8. The retention capability of the developed ODDS based on the obtained mucoadhesive compounds on the cornea of animal eyes will be investigated in vivo.
9. Toxicological studies will be carried out to assess the irritant effect and safety of the developed ODDS prototypes based on modified polymers.
10. Cytotoxicity analysis of the developed ODDS prototypes will be performed using the MTT assay to measure cell viability and verify the safety of the obtained systems.
11. The in vitro antifungal activity of the developed ODDS based on synthesized polymers will be studied to evaluate their efficacy in the treatment of fungal eye diseases.
12. Animal experiments using pharmacological approaches will be conducted. The therapeutic effects and adverse reactions of the developed dosage forms will be determined in order to assess their safety for human use.

Achieved results

1. A literature review on the research topic has been carried out; experimental methods for the chemical modification of various hydrophilic polymers using maleimide and methacrylate functional groups have been developed. The analysis of scientific sources confirmed the high relevance of the selected research area and demonstrated the significant potential of maleimide and methacrylate functional groups in the creation of new generations of polymer systems for biomedical applications. The completed literature review served as a scientific basis for further experimental work and for the development of improved methods for the chemical modification of hydrophilic polymers aimed at obtaining materials with mucoadhesive properties.
2. Poly(vinyl alcohol) was modified with maleimide groups (PVA-Mal) for the development of effective ophthalmic drug delivery systems with improved mucoadhesive properties. The obtained polymer was analyzed using various physicochemical methods, such as NMR, IR and UV spectroscopy, differential scanning calorimetry, and others.
3. The influence of various parameters (pH, viscosity, degree of modification, concentration of drug substances, etc.) on the interaction of modified polymers with pharmaceutical compounds was investigated. The performed studies indicate the high potential of PVA-Mal for application in modern ophthalmic drug delivery systems. Modification with maleimide groups provides

	additional opportunities for regulating the interaction of the polymer with active substances without disturbing the key parameters of their release kinetics. 4. Organosilicate nanoparticles with Schiff bases were synthesized. Their characterization was carried out using modern physicochemical analysis methods. The obtained nanoparticles were found to be non-toxic and to possess antimicrobial properties. These systems may be promising for the development of ODDS with antimicrobial activity.
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Usage	The obtained results have a wide range of potential applications in various fields, including the international scientific community and pharmaceutical companies. The fundamental findings of the study will be particularly relevant to scientists engaged in the development and investigation of new polymers and polymeric materials, as well as to researchers working on innovative solutions in the field of materials science. Manufacturers of pharmaceutical products will also be important users of these data, as the findings may contribute to the creation of new dosage forms and drug delivery systems for active pharmaceutical ingredients.
Priority compared to real-world alternatives	The applied outcomes of the research are of particular value for patients suffering from glaucoma and keratomycosis. These results may lead to the development of effective therapeutic agents that improve patients' quality of life, as well as to the creation of innovative approaches for the treatment of diseases associated with impaired ocular function. Thus, the research may not only deepen scientific knowledge, but also have a significant impact on practical healthcare.
List of publications with links to them	1. Z.E. Kozhantayeva, G.Walton, G.S. Irmukhametova, V.V. Khutoryanskiy, Organosilica nanoparticles functionalised with p-anisaldehyde and p-chlorobenzaldehyde Schiff bases: Synthesis, physicochemical properties, toxicological and antimicrobial evaluation // Biomaterials Advances, Volume 184, 214795, 2026, https://doi.org/10.1016/j.bioadv.2026.214795 2. Rakhman D.M., Kappassuly A., Makhayeva D.N., Kazybayeva D.S., Irmukhametova G.S. Development and study of mucoadhesive hydrogels based on gellan–cysteine complexes // Academic Journal of Physical and Chemical Sciences, Volume 1, Number 357, 2026, pp. 414–427. https://doi.org/10.32014/2026.2518-1483.429 (in Kazakh)
Patents	-