ENGLISH
LANGUAGE

SLOVAK RESEARCH
AND DEVELOPMENT
AGENCY

MINISTRY
OF EDUCATION, RESEARCH,
DEVELOPMENT AND YOUTH
OF THE SLOVAK REPUBLIC

EXCELLENCE IN SCIENCE

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FOREWORD

Dear friends,

we feel honoured to invite you to read the ninth publication The Excellence in Science by which the Agency presents the implementation of projects achieving outstanding level. The publication should meet the needs of everybody who is interested in finding more information on research support in Slovakia.

The publication informs about the implementation and results of several years lasting work of Slovak experts on projects from 2020 up to 2024 in the basic and applied research of natural, technical medical, agricultural, social sciences and humanities. Of course, the publication and its content cannot compete with the electronic sources of latest information that are much faster and updated. However, it definitely has certain positives, it enabled us to sum up all the activities conducted by project teams and co-operating institutions within a scientific community in Slovakia. As we have already published the nine publication, we believe it can clearly present the progress achieved in particular fields of science in which the projects presented in this publication ware implemented.

Since its establishment the Slovak Research and Development Agency has been a significant part of the state aid for basic and applied research and development in Slovakia. We are very pleased by the fact you can hardly find anyone from research and development that does not know the name of our Agency. However, it remains our goal to improve every year and support more projects that end up at an excellent level of solution.

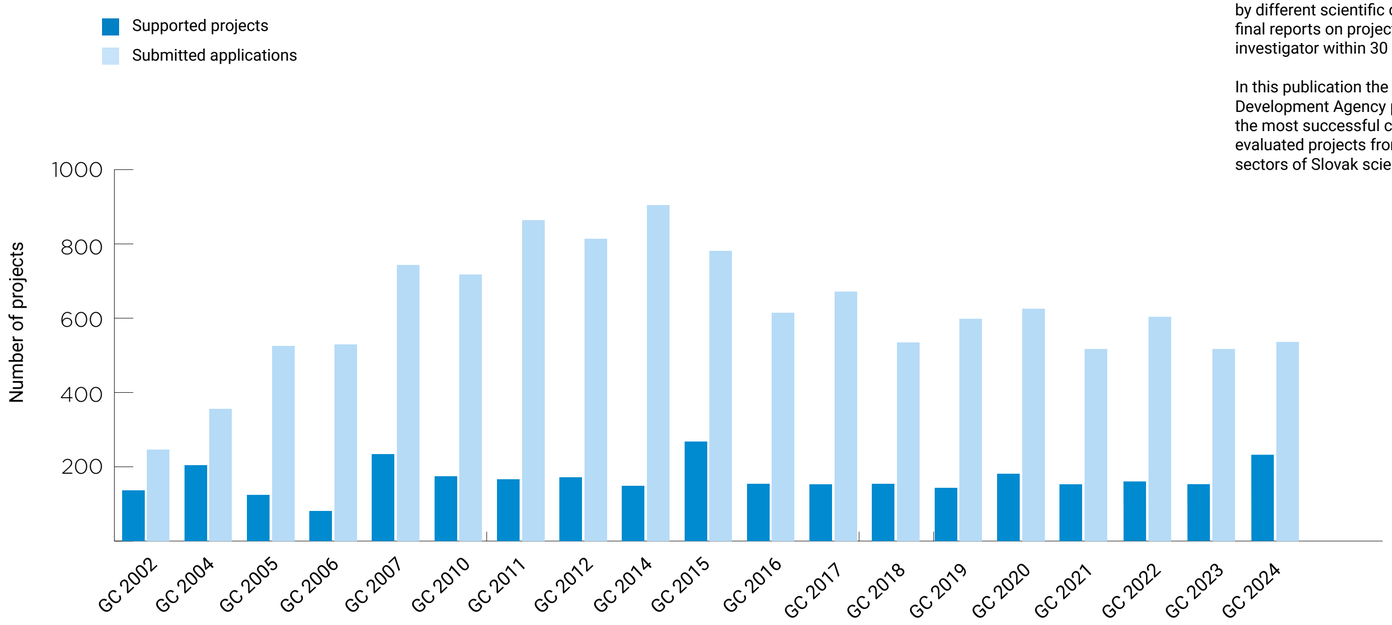
Finally, our deepest thank you belongs to all solvers of the projects presented in the publication as well as to those who contributed to the preparation of the ninth publication of the research projects with excellent level 2025.

JUDr. Stanislav Mydlo
Director

Dr. Ing. Robert Mistrík
Chairperson

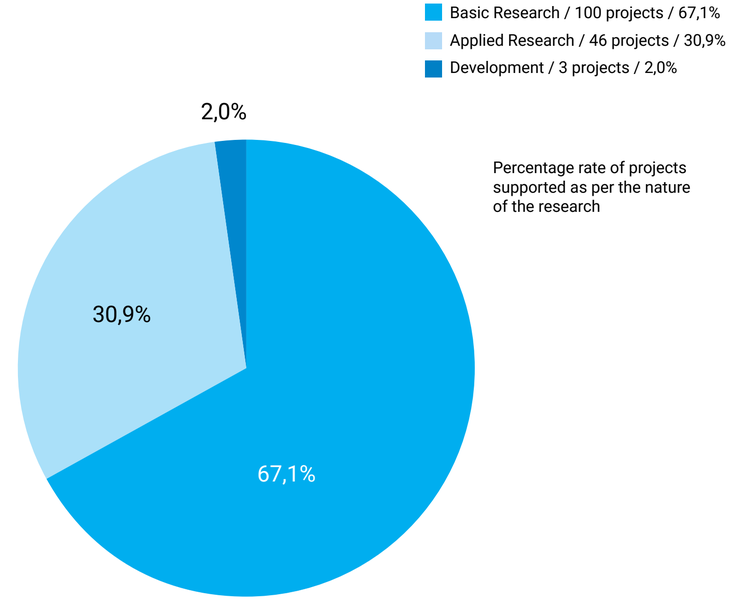
ÚVOD

Summary of applications submitted and supported projects in the general calls in the years 2002 – 2024



The projects presented in this publication have been submitted within the general call to the Slovak Research and Development Agency marked GC 2019. General Call GC 2019 had no limitations on the substantive focus of the projects. Specific focus, objectives and contents of the research and development were determined by the applicants themselves. Applications could be submitted by legal entities as well as natural persons – entrepreneurs without limitation as per sector of research and development. 606 applications for funding were received and registered as part of the general call GC 2019, in order to resolve research and development projects and 149 applications were supported. Start of the project solution was 1. 7. 2020. Latest date of completion of project solutions was 30. 6. 2024. In 2024 subsequently completed projects were evaluated by different scientific councils on the basis of the final reports on projects submitted by the principal investigator within 30 days of the end of solution.

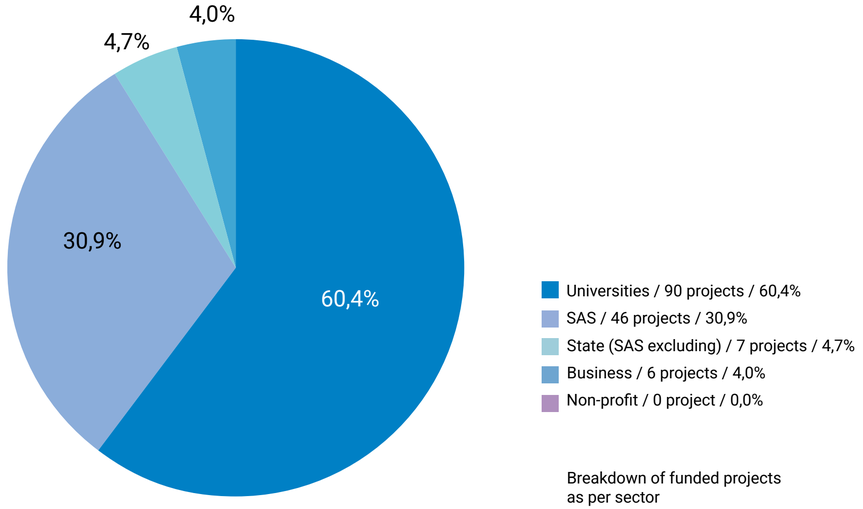
In this publication the Slovak Research and Development Agency presents the selection of the most successful completed and subsequently evaluated projects from the general call GC 2019 in all sectors of Slovak science and technology.



Percentage rate of projects supported as per the nature of the research

Department of Science and Technology	Registered applications	Financed projects	Success Rate (%)
Natural sciences	125	36	28.8%
Technical sciences	191	44	23.0%
Medical sciences	58	14	24.1%
Agricultural sciences	83	19	22.9%
Social sciences	96	24	25.0%
Humanities	39	12	30.8%
Total	592	149	

Success rate of applications supported by GC 2019 as per scientific departments.



Breakdown of funded projects as per sector

NATURAL SCIENCES

Preparation of new antibiotics and antitumor agents by manipulations of secondary metabolite genes and synthetic biology methods

Principal investigator
RNDr. Kormanec Ján, DrSc.
Applicant organisation
Slovak Academy of Sciences, Institute of Molecular Biology
Participating organisations
Biomedical Research Center - Cancer Research Institute
Slovak Academy of Sciences, Institute of Chemistry
Term of solution
07/2020 - 06/2024
Budget from agency
200 000 €
Project ID
APVV-19-0009

Research Subject

The project reflected on the acute threat of the increase in multidrug-resistant bacteria and tumors, which is currently one of the most serious problems facing modern medicine. Clinical practice is faced with the need to introduce new effective antibiotics and antitumor agents. The standard approach by which many substances used in clinical practice were discovered in the past is currently limited. Modern molecular biology techniques, including gene manipulation and synthetic biology, offer new opportunities for the discovery of new biologically active compounds. Bacteria of the genus Streptomyces are dominant producers of secondary metabolites with a wide spectrum of biological activities. Genes for these metabolites are grouped into so-called biosynthetic gene clusters (BGCs). Analyses of streptomycete genomes revealed the vast potential of BGCs ranging from 18 to 54 per genome. However, only a small fraction of these secondary metabolites is produced under laboratory conditions. The remaining “silent” BGCs represent new metabolites waiting to be "awakened." The aim of the project was to prepare and characterize new effective antibiotics and antitumor agents by manipulating secondary metabolite genes and synthetic biology methods.

Aim of the Research

Characterization of the Streptomyces lavendulae CCM 3239 genome, in addition to the BGC for the antibiotic auricin, identified 30 BGCs for new secondary metabolites that were silent under laboratory conditions. The first goal of the project was the activation of these BGCs by integrating strong promoters upstream of the genes, followed by characterization of the activated secondary metabolites. The second goal was the cloning of these BGCs and their integration into the genomes of heterologous host strains and the characterization of the production of new biologically active substances. The third goal was the investigation of the unique biosynthesis of auricin and the preparation of its new intermediates by genetic manipulations, followed by characterization of their antibiotic and antitumor properties. The fourth goal was the application of synthetic biology for the characterization of the auricin biosynthesis, as well as for the generation of new biologically active substances using a combination of the biosynthetic genes of auricin and other polyketide antibiotics.

Achieved Results

We prepared a new system for inserting a strong kasOp* promoter into the genome of streptomycetes, which we verified in S. lavendulae CCM 3239. In the case of inserting kasOp* into two positions of BGC2, we demonstrated the induction of new substances active against yeast, streverten A2 and X. We optimized the cloning of BGCs for their heterologous expression. By cloning BGC26 under the control of kasOp*, we demonstrated the production of the pyrrolidine antibiotic anisomycin in the heterologous S. coelicolor M1146 strain. We characterized the production of secondary metabolites in several mutants of the auricin BGC. In the case of a mutant in lacking the sa48 gene, we characterized the auricin intermediate SA48B, which was more stable and active than auricin. In addition, it showed high cytotoxicity against many human tumor cell lines, and especially against human leukemia cells. We characterized its mechanism of action in inducing apoptosis accompanied by a cell cycle arrest at the G2/M phase. We prepared a new synthetic biology system based on monocistronic units (kasOp*-gene-terminator), allowing their sequential incorporation into synthetic BGCs, which we successfully verified using the biosynthetic genes for the antibiotic landomycin and the antitumor agent mithramycin.

Benefits for Practise

A new system for inserting a strong promoter into the genome of streptomycetes will enable the activation of BGCs for new biologically active substances and their use in clinical practice. Characterization of the auricin intermediate SA48B demonstrated its high cytotoxicity against many human tumor cell lines, and especially against leukemic cells, which is a promising prerequisite for its use in the treatment of leukemia. The new synthetic biology system will enable its use in the biosynthesis of new and modified compounds with potentially new biological properties. The achieved results aroused interest in the Irish biotechnology company Nemysis to cooperate in the overproduction of a specific protease E40 suitable for the treatment of celiac disease in streptomycetes, which resulted in a jointly approved world patent WO2023285135.

Fig. 1 / Activation of BGC2 in S. lavendualae CCM 3239. A Scheme of BGC2 in the wild-type and in two mutant strains. Detection of strevertenes in strains by TLC biochromatography with a yeast (A) and HPLC (B).
Fig. 2 / Heterologous production of anisomycins in S. coelicolor M1146 after integration of the plasmid pOri6-ani3. A Scheme of pOri6-ani3. B HPLC detection of activated metabolites.
Fig. 3 / Production of novel auricin intermediates in S. lavendualae CCM 3239 after sa48 deletion. A Scheme of auricin BGC. B HPLC detection of the auricin intermediate SA48A in S. lavendualae Dsa48 and its conversion to SA48B. As a control, S. lavendualae CCM 3239 was analyzed.
Fig. 4 / A Schemes of the integration plasmids pOri6-lanABCtFDLEr, pOri12-lanM, and pOri12-lanMV, which contain an artificial BGC containing kasOp*-gene-fdT transcriptional units from the landomycin biosynthetic genes. B HPLC analysis of the S. coelicolor M1146 with pOri6 and the indicated integrated plasmids.

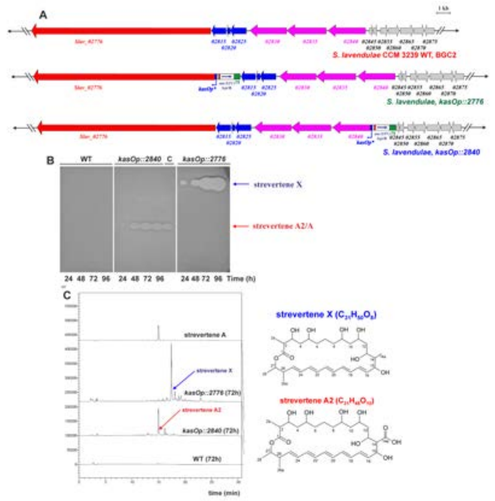


Fig. 1

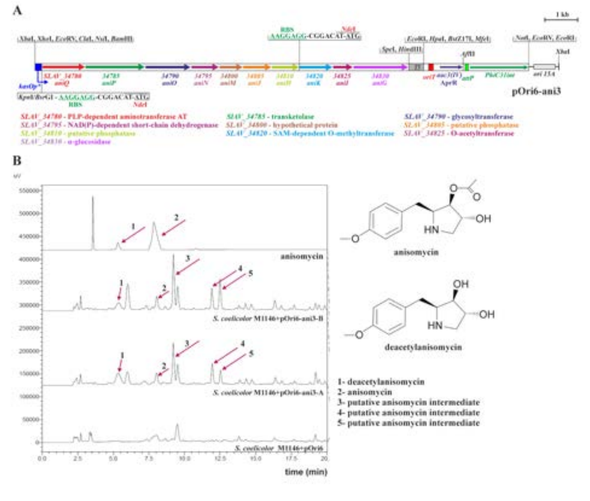


Fig. 2

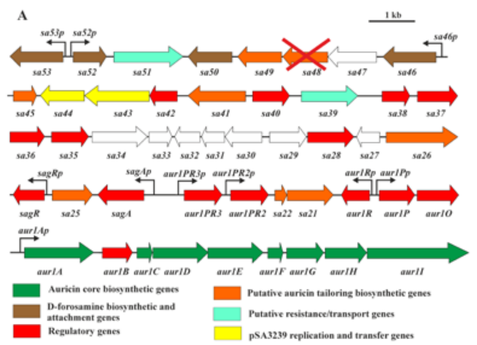


Fig. 3

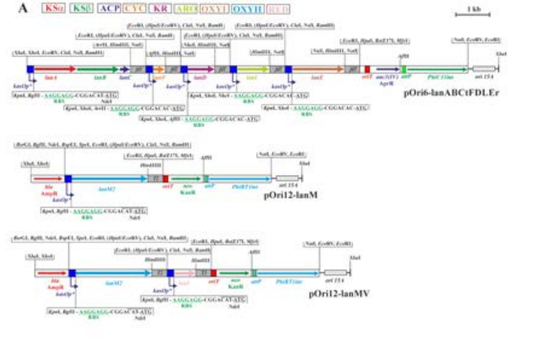


Fig. 4

Redox active metal complexes exhibiting dual anticancer and antibacterial activity

Principal investigator
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Applicant organisation
Slovak University of Technology in Bratislava
- Faculty of Chemical and Food Technology
Term of solution
07/2020 - 06/2024
Budget from agency
220 000 €
Project ID
APVV-19-0024

Research Subject

Coordination compounds with metal ions represent attractive alternatives to small organic molecules in cancer therapy, due to the many advantages of transition metal complexes with a wide range of coordination numbers and geometries, as well as high structural diversity. Compared to organic compounds, metal complexes offer excellent possibilities for tuning their properties by modifying their ligands. In addition, many metal complexes are known to disrupt cancer cell homeostasis and induce excessive production of reactive oxygen species (ROS). A modern approach to the preparation of new biologically active metal complexes is the combination of redox-active ligands with promising antioxidant or therapeutic effects with selected transition-metal ions. This can lead to the synthesis of new compounds showing altered properties of the biologically active ligand because of the effect of the central atom introduced into the complex. Therefore, special attention has been focused on the charge transfer on such molecules and on the stability of their different redox states. The research subject of the project was mainly focused on finding the relationship between the unique physicochemical properties of coordination compounds with multifunctional anticancer and antibacterial effects and processes associated with charge transfer.

Aim of the Research

The project focused on newly prepared redox-active coordination compounds bearing biologically active structures, mainly from the family of heterocyclic thiosemicarbazones, excellent transition metal chelators. In our project, we focused on various new ligand hybrids and their metal complexes using analytical and spectroscopic techniques of X-ray diffraction, UV-vis-NIR spectroscopy, pH-potentiometry, EPR and NMR spectroscopy, electrochemistry, spectroelectrochemistry and quantum-chemical calculations, including modern docking studies. Within the project, five main classes of metal complexes with confirmed biological activity were selected: water-soluble copper complexes of quinoline-carboxaldehyde thiosemicarbazones; copper complexes with redox-active thiosemicarbazones with a morpholine group; new triapine derivatives and their metal complexes; coordination compounds with hexaazamacrocycles showing catalytic and reactive oxygen species (ROS) generating activity. Detailed information on the mode of action of the studied samples was obtained by spectroelectrochemistry and EPR spectroscopy combined with the spin trap technique.

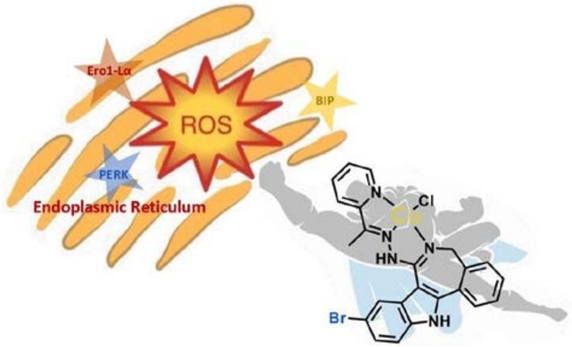
Achieved Results

The redox processes of many newly synthesized metal ion complexes and their free ligands and precursors as potential biologically active substances were elucidated using EPR spectroscopy and unique in situ EPR/UV-vis-NIR spectroelectrochemistry. Quantum chemical calculations significantly assisted in the design of reaction mechanisms of oxidation and reduction of selected compounds. The complex subsequent reactions of electrically charged forms of the investigated substances in the field of anticancer and antibacterial drugs were identified. Significant anticancer properties of newly prepared thiosemicarbazone (TSC) derivatives were demonstrated, We also confirmed the ability of the investigated ligands to bind iron, while the resulting iron complexes exhibited the ability to form reactive oxygen species. In view of the above results on copper(II) complexes with isomeric hybrid ligands based on morpholine-thiosemicarbazone with good cytotoxicity in cancer cells. The molecular target responsible for this activity was shown to be tubulin. It was possible to find a relationship between the type of metal ion in the complex and its stoichiometry and antiproliferative activity, associated with inhibition of microtubule polymerization in cells. This significantly helped to interpret the mechanism of action of such substances.

Benefits for Practise

The project has the character of basic research, the results of which were published in more than 45 scientific articles registered in the Web of Science (WOS, Core Collection), mainly in periodicals with a high impact factor. The published works have already recorded a significant citation response in WOS. The results of the work were also promoted at major international scientific conferences. Understanding the mechanism of action of newly prepared coordination compounds and their ligands under investigation has the potential to be used in practice for the preparation of multifunctional drugs with anticancer and antibacterial effects.

Fig. 1 / Example of a newly prepared copper complex showing significant generation of reactive oxygen species (ROS).
Fig. 2 / Illustration of the X-ray structure of the investigated nickel complex dimer and theoretical spin density calculation of its electrochemically generated mono-cation.
Fig. 3 / Illustration of the results of molecular docking calculations of the copper(II) complex with thiosemicarbazone. (a) Docked co-crystallized ligand with colchicine. (b) Predicted interactions with amino acid units (dashed lines).
Fig. 4 / (a) Optical spectrum of a water-soluble thiocarbazone ligand (black line), which can bind ferrous cations by forming the corresponding metallocomplex (blue line). (b) Results from the EPR spin trapping technique confirming the formation of ROS.



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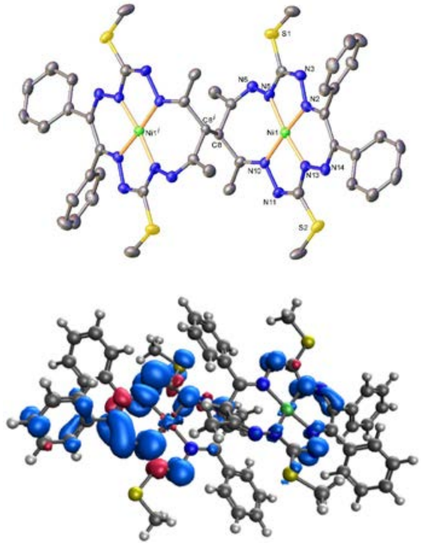
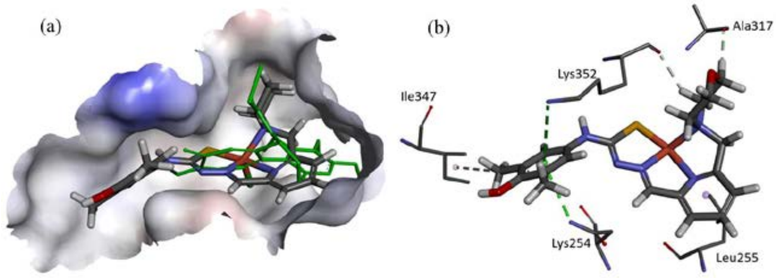


Fig. 2



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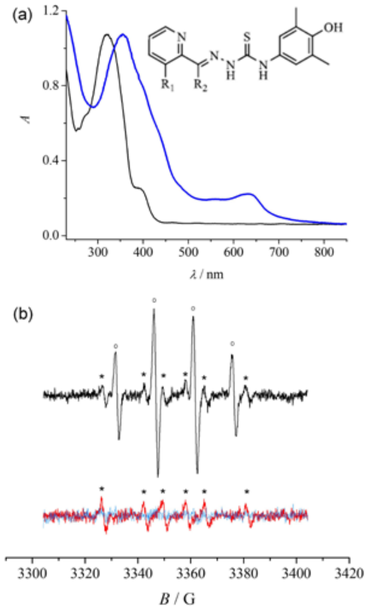

Fig. 4

Petrological-geochronological record of riftogenesis and crust-mantle recycling in the Western Carpathians orogenic wedge

Principal investigator
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Applicant organisation
Comenius University Bratislava - Faculty of Natural Sciences
Participating organisation
Matej Bel University in Banska Bystrica - Faculty of Natural Sciences
Term of solution
07/2020 - 12/2023
Budget from agency
209 332 €
Project ID
APVV-19-0065

Research Subject

Orogenic areas, such as the Western Carpathians, are the result of complewx tectonic events. The investigated rock complexes provided petrological-geochemical and geochronological constraints on their peri-Gondwanan origin and evolution. Riftogenesis is a process of thinning to break-up of continental or oceanic crust in the lithosphere extension regime above ascending hot asthenosphere. The near surface features are rift grabens, valleys, as well as sea and ocean basins of various width, and characteristic magmatism/volcanism, or sedimentation. Rift-related complexes bring the information about material migration between the crust and mantle, or between the Earth core and mantle e.g., according to occurrences of critical metals. The project was focused on specific groups of rocks and their minerals as indicators of the paleo-riftogenic and paleo-oceanic zones in the Western Carpathians from the Late Proterozoic (at ca. 550 Ma) up to the Mesozoic-Cenozoic boundary (at ca. 60 Ma), when the riftogenesis continued with the opening of the main Tethyan paleo-oceans on the Earth.

Aim of the Research

The project goal was the reconstruction of evolutionary models of Tethyan riftogenic zones of the Western Carpathians and their correlation with the neighbouring Austro-Alpine segment, but also with the ophiolites of the Central Dinarides in Bosnia and Herzegovina. The investigation methods included the field study, mineralogical-petrological and geochemical analytical methods to constrain paleotectonic environment and the crust-mantle sources of the material recycling, thermodynamic modelling the lithospheric P-T conditions, isotopic geochronology to constrain the ages of rocks and minerals, and for the evolutionary periodicity models of the continental and oceanic riftogenic zones.

Achieved Results

The Western Carpathians basement complexes record a long-term history during Proterozoic and Paleozoic periods. Desciphering the evolutionary stages contributed to clear the geological processes, which accompanied the gradual breakdown of the northern Godwana margin (Fig. 1). The newly formed crust evolved in the active Gondwana margin during the Prototethyan-Cenerian and Paleotethyan-Variscan subduction-accretion processes accompanied by a massive material transfer from the upper mantle to the crust. The relict of a Prototethyan backarc basin at the northern Gondwana margin is the lower-crustal layered amphibolite complex of the Tatric and Veporic basement of Cambrian to Ordovician age with characteristic mantle rocks and Ni-Co-Cu mineralization. We declare the existence of the Devonian Paleotethyan oceanic crust, the remnants of which occur in Pernek complex of the Little Carpathian Tatric basement, but also in Rakovec-Klátov complex of the Gemeric basement (Fig. 1). Analogous Devonian ophiolitic Sieggraben complex was detected in the Austro-Alpine basement. The closure of these oceanic basins and the subduction metamorphism were dated on metamorphic minerals at ca. 400, or 350 Ma, respectively. The subsequent Gondwana (Africa) and Laurentia (Europe) collision assembled the new megacontinent Pangea in Permian. The Pangea breakdown is registerd by the Permian-Triassic riftogenic complexes. For example, A-type granites in Velence Hills, Hungary, in Gemeric and Veporic zones, or Hronic volcanics and lamprophyres of the Tatric basement, all dated Permian. Continental riftogenesis of Meliaticum was dated at ca. 248 Ma on zircon from calc-alkaline rhyolites. Lu-Hf isotopic garnet age vice versa dated the basin closure and subduction of Meliatic oceanic crust at 155 Ma (Upper Jurassic) and the transformation of basalts to blue-schists within the NW Neotethys branch (Fig. 2, 3). Isotopic dating first constrained Triassic-Jurassic ages of Neotethyan Vardar ophiolites in Dinarides of Bosnia and Herzegovina (Fig. 4, 5).

Benefits for Practise

The project data can be further used in basic and applied geological investigation and exploration, as well as in national parks. Project yielded possibility to develop a software for elaboration of multi-dates in mineralogical, petrological, and geochemical databases, with the connection to free world databases such as Min-Dat. The investigation of Proterozoic gabbros and granites in southern Egypt (Aswan region) revealed that these rocks and their minerals are enriched in critical metals (REE, Au, Cu, Mo) with a deposit perspective. The ophiolitic dunites of the investigated part of Dinarides in Bosnia and Herzegovina are rich in chromite ores as a source of Cr.

Fig. 1 / New concept of Paleozoic evolution of the W. Carpathians basement based on geochemistry and isotopic dating.
Fig. 2 / Palinspastic (A) and evolutionary schemes in cross-sections (B, C) of the Meliatic (Bôrka) and Fatric (Klape) nappes in the Western Carpathians.
Fig. 3 / Elemental map of Mn in garnet from electron microanalyzer. Trace element and chondrite-nomalized rare earth element diagrams constrain oceanic (POD-4) and continental (HAC-1) Meliatic basalts. An age of 152-154 Ma (Late Jurassic) of subduction metamorphism of Meliaticum was determined by Lu-Hf isochron from garnet, glaucophane, and rutile. Thermodynamic modelling of basalt transformation to blue-schist by Perple_X software gave T 490-520°C and P 1.55-1.72 GPa at the subduction depth of ca. 50 km.
Fig. 4 / Correlation study of Meliaticum with Triassic-Jurassic Neotethys in Dinarides of Bosnia and Herzegovina.
Fig. 5 / New geodynamic model of the Dinaridic Neotethys based on geochemistry and isotopic dating.

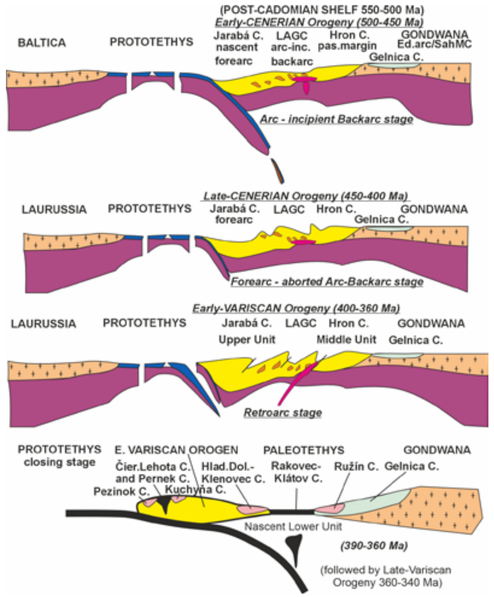

Fig. 1

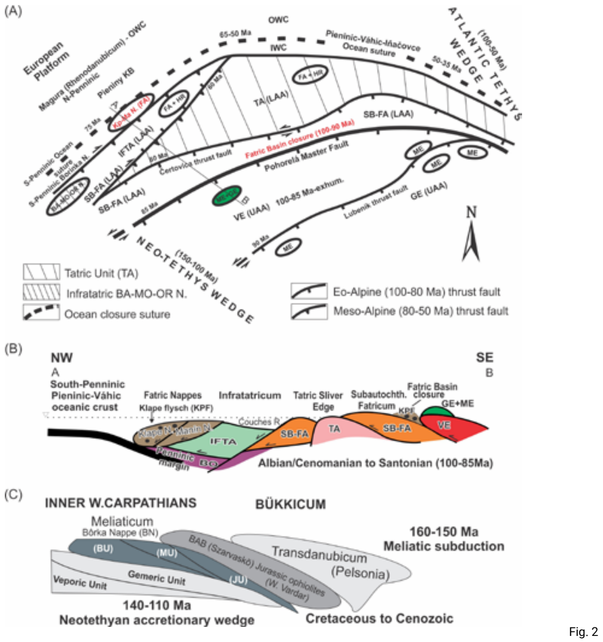

Fig. 2

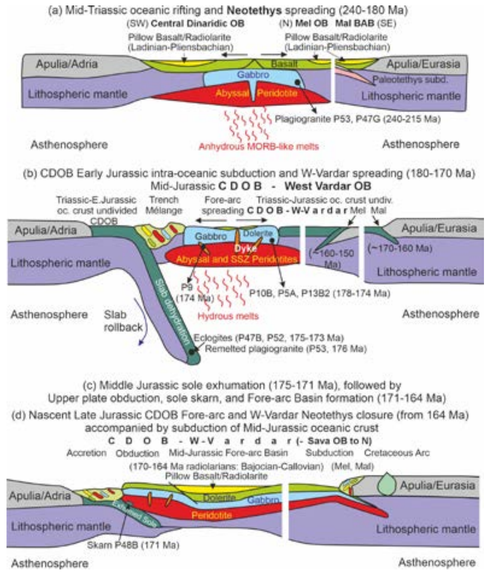

Fig. 5

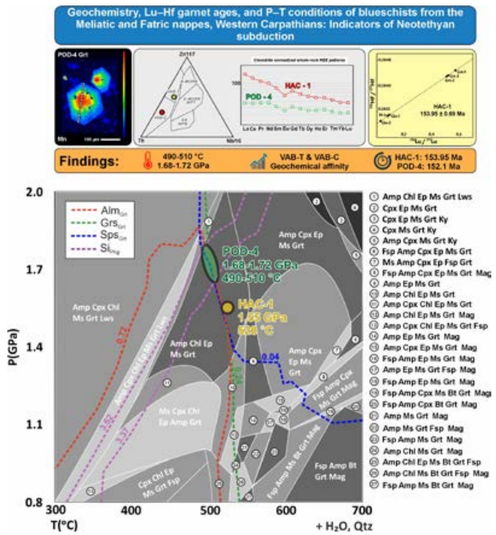

Fig. 3

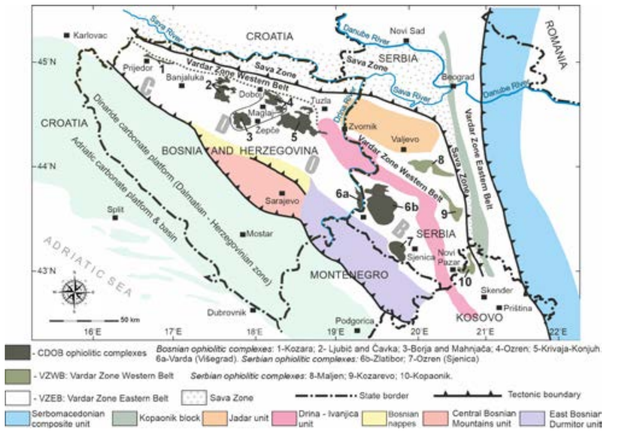

Fig. 4

Exploring yeast biodiversity for uncovering novel mechanisms of telomere maintenance of eukaryotic chromosomes

Principal investigator
prof. RNDr. Tomáška Ľubomír, DrSc.
Applicant organisation
Comenius University Bratislava - Faculty of Natural Sciences
Term of solution
07/2020 - 06/2024
Budget from agency
220 000 €
Project ID
APVV-19-0068

Research Subject

The DNA ends of linear chromosomes (telomeres) are essential DNA-protein complexes involved in protecting the genome integrity. Dysfunction of telomeres can result in various types of cellular pathologies, including carcinogenesis. Although several molecular mechanisms involved in telomere maintenance have been described, a number of fundamental problems still remain unexplained. The project was dedicated to answering questions arising from the evolutionary divergence of telomeric sequences and the mechanisms of their maintenance in ascomycete fungi. Specifically, we have asked: What is the repertoire of solutions to the crisis that occurs immediately after the loss of telomeric sequences in different yeast species? How do telomeric repeat sequences co-evolve with DNA-binding proteins that ensure their functions? How is the telomere crisis communicated between the nucleus and other organelles of the eukaryotic cell?

Aim of the Research

Taking advantage of the biodiversity of ascomycetous yeast and the unprecedented sequence variability of their telomeric repeats, the project had the following objectives: (1) to identify novel mechanisms involved in the cellular response to the loss of telomeric sequences and (2) to uncover shared sequence and/or structural features and their co-evolution with telomere-binding proteins. Although the planned research was focused on telomeres in a specific phylogenetic group of organisms, the goal was to obtain results of general importance for (i) answering questions regarding the mechanisms and genomic changes involved in the response to intracellular stress, (ii) identifying principles for optimizing the interaction between DNA and specific DNA-binding proteins, and (iii) revealing trends in the evolution of eukaryotic genomes.

Achieved Results

Within the context of the planned research goals, we (1) performed a systematic analysis of telomeric repeats of yeast nuclear chromosomes and described possible modes of their co-evolution with other components of telomere maintenance machinery; (2) identified the first poly-(ADP-ribose) polymerase in ascomycete yeast and identified its major substrates, as well as its role in telomere maintenance in the yeast Yarrowia lipolytica; (3) prepared a collection of mutants enabling the analysis of alternative mechanisms of telomere maintenance in Yarrowia lipolytica cells lacking functional telomerase; (4) performed a comparative biochemical analysis of the DNA-binding properties of yeast telomere-binding proteins; (5) developed an experimental strategy for reprogramming yeast telomerase and used it to study the evolutionary mechanisms of co-evolution of telomeric repeats and telomere-binding proteins; (6) employed the auxin degron system to perform a systematic study of the mechanisms of telomere maintenance in Saccharomyces cerevisiae; (7) prepared a database containing more than 20,000 post-translational modifications of mitochondrial proteins of the yeast Saccharomyces cerevisiae; (8) prepared an educational primer explaining the importance of the so-called "humanization" of yeast for biomedical research.

Benefits for Practise

The project results illustrate the importance of using the biodiversity of ascomycete fungi to gain a comprehensive view of general phenomena related to the eukaryotic cell. Using our experimental strategy, we were able to identify the unique molecular tools for telomere maintenance and DNA-binding protein properties that are not present in conventional model organisms. This has not only heuristic, but also potentially technological significance. An example is the identification of the first yeast poly-(ADP-ribose) polymerase (PARP). PARP inhibitors are used in the chemotherapy of some human oncological diseases, so yeast can now become a tool for screening of new types of anti-PARP drugs. Several results of the project represent the basis for new research directions in our laboratory. In addition to scientific results, the project also had educational benefits, which include: (1) seven doctoral dissertation projects related to the project's objectives, four of which were already successfully defended; (2) nearly 25 defended diploma theses in the study programs of genetics and biochemistry; (3) presentation of results in master's courses led by the members of the team; and (4) a series of popularization activities in print and audiovisual media.

Fig. 1 / Telomeric sequences can form different types of structures (Tomáška et al. (2020). DNA Repair 94: 102901). Image credit: Prof. Jack Griffith (University of North Carolina, Chapel Hill, USA).
Fig. 2 / Telomeric repeats in ascomycete yeast show a high degree of divergence, which is accompanied by co-evolution with telomere-binding proteins (Červenák et al. (2021). Genome Biology & Evolution 13: evaa268.
Fig. 3 / A collection of strains in which genes encoding telomere-associated proteins of the yeast S. cerevisiaeare tagged with an auxin degron allows monitoring the immediate consequences of their absence on the state of telomeres (Petrík et al. (2024). Yeast 41: 499-512).
Fig. 4 / A database of all known post-translational modifications of mitochondrial proteins of the yeast S. cerevisiae allows their rapid search and represents a platform for their functional analysis (http://compbio.fmph.uniba.sk/y-mtptm/; Brejová et al. (2023). Genetics 224: iyad087.

Fig. 1

Fig. 2

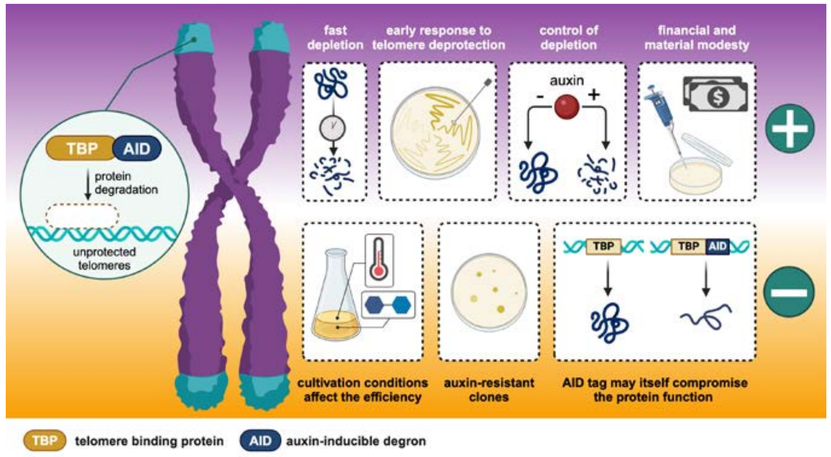

Fig. 3

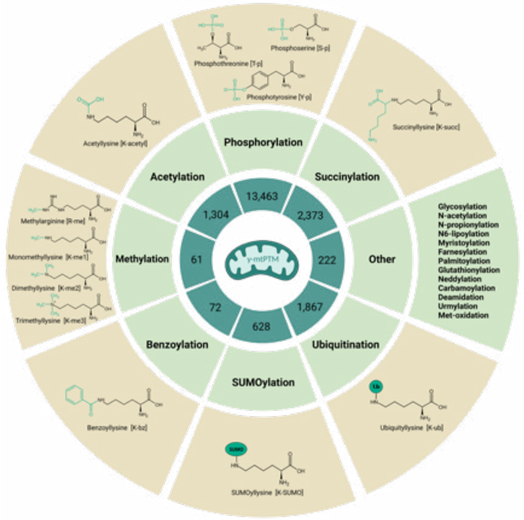

Fig. 4

The relationship between color and polarization in comets: clues to understanding microphysical properties of cometary dust and mechanisms of its ejection

Principal investigator
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Applicant organisation
Astronomical Institute
Term of solution
07/2020 - 06/2024
Budget from agency
130 000 €
Project ID
APVV-19-0072

Research Subject

The project was focused on the investigation of physical properties of dust particles in cometary atmospheres, with special emphasis on rapid changes in the color index and the degree of linear polarization. Most comets had previously been observed only sporadically, with large time gaps between observations, which made it difficult to detect short-term variability. This project aimed to address these inconsistencies. The analysis included both new observations and archived data to study the rates of change in color index and polarization in different parts of the coma and tail. These measurements were used to explore correlations between optical changes and the microphysical characteristics of cometary dust, such as composition, structure, and size distribution. In addition, possible links between these rapid variations and other cometary properties like orbital dynamics, ice composition, and thermal behavior were examined. The study is contributed to a deeper understanding of the mechanisms behind rapid changes in cometary activity and significantly advanced our knowledge of short-term evolutionary processes in comets.

Aim of the Research

The project was aimed at investigating the physical properties of cometary dust through the systematic analysis of short-term variations in color index and linear polarization in the atmospheres of at least ten comets. The study analyzed both new and archival data to estimate the frequency of these phenomena and their correlation with the microphysical properties of dust particles. Additionally, the project investigated potential links between rapid changes in dust characteristics and other cometary parameters, such as orbital motion, ice composition, and thermal emission.The results helped to address discrepancies in previous observations and contributed to a better understanding of short-term processes in cometary evolution.

Achieved Results

The project produced unique results in basic research by employing a comprehensive approach to study the physical, optical, and chemical properties of selected comets. Through a combination of diverse methods, including quasi-simultaneous photo-spectro-polarimetric observations with both large and small telescopes, we gathered high-quality, long-term data.This approach facilitated a deep understanding of cometary evolution across wide temporal and spatial scales, enabling us to not only obtain the physical parameters of the comets but also uncover how these parameters evolve in response to the cometary activity. Our efforts led to the identification of rapid changes in the color index and polarization over time, along with variations linked to heliocentric distance. These fluctuations highlighted changes in the composition and size of dust particles, providing priceless insights into the underlying mechanisms driving cometary activity. Through qualitative and quantitative analysis, supported by advanced simulations, we revealed significant correlations between changes in color, polarization, and cometary dust properties. Methods developed during this research, based on simultaneous numerical modeling of brightness, color, and polarization distributions in cometary comae, enabled precise estimates of dust particles' physical, chemical, and dynamical properties, including composition, size distribution, and velocities. For active asteroids, this modeling also yielded critical parameters such as color, dust ejection velocities, masses, along with estimations of the onset time of activity. Our modified geometric model enabled the analysis of morphological structures in the comae of active objects, identifying active regions on the surfaces of cometary nuclei and asteroids. These results emphasize the importance of quasi-simultaneous research and continuous monitoring, marking a significant step in understanding short-term active processes in comets.

Benefits for Practise

The project is of a fundamental research nature, resulting in 32 original papers published in high-impact scientific journals. The published results represent a significant contribution to the field of small body physics in the Solar System, achieved through a comprehensive approach to studying the physical, optical, and chemical properties of selected comets. The results of the project were not only widely presented and discussed at a number of international conferences, but also served as the foundation for organizing a unique international workshop "Active small bodies in the Solar System over a wide range of heliocentric distances."

Fig. 1 / Comet 67P/Churyumov-Gerasimenko observed with the 6-m BTA telescope using the r-sdss filter on November 8, 2015. (a) Raw image, (b) Image after applying the rotational gradient technique with jets modeled geometrically, and (c) Nucleus image indicating the potential jet origin region.
Fig. 2 / Spatial distribution maps of color and polarization in comet C/2014 B1 (Schwartz), observed at a record heliocentric distance of 9 AU from the Sun. This resukts is obtained for the first time for such distant objects.
Fig. 3 / Six examples of the agglomerated debris particles (top) and color slope of Comet 29P/Schwassmann–Wachmann 1 (bottom) in 2018 as a function of phase angle.
Fig. 4 / Workshop "Active small bodies in the Solar System over a wide range of heliocentric distances", September 5-8, 2023, Stará Lesná, Slovakia

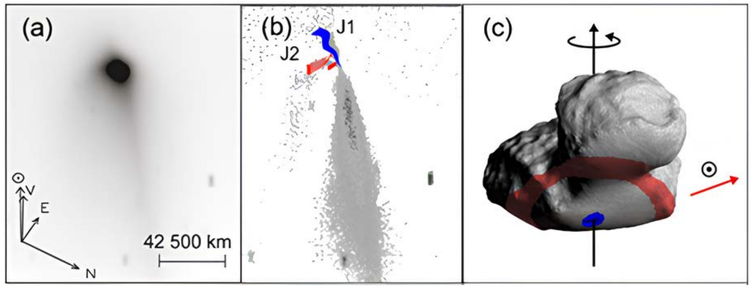

Fig. 1

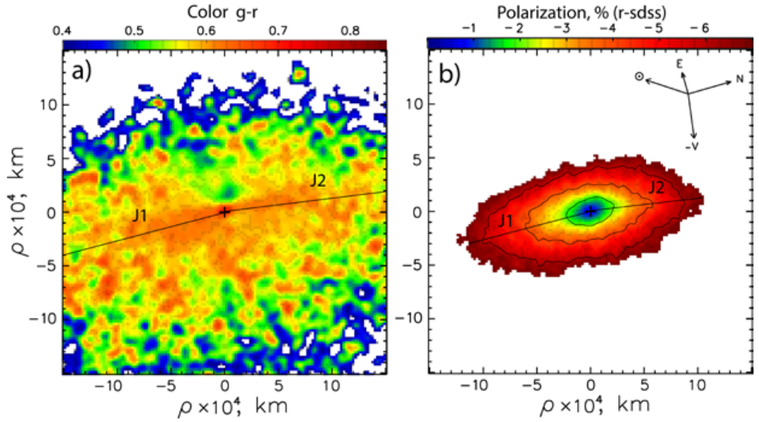

Fig. 2

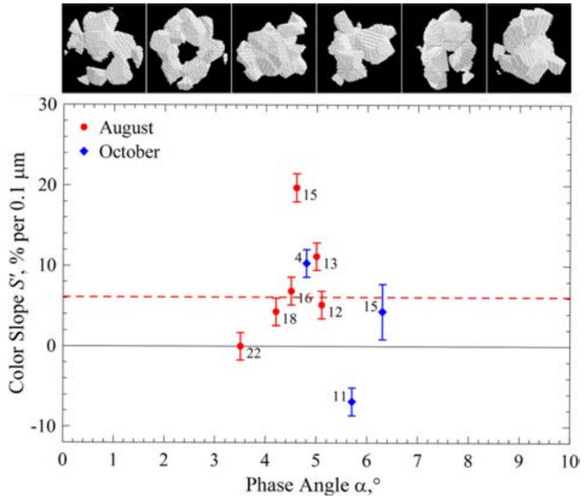

Fig. 3

Fig. 4

Soil microbiota in natural forest ecosystems: its response to changing biotic and abiotic factors of habitat

Principal investigator
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Participating organisations
National Forest Centre
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Term of solution
07/2020 - 06/2024
Budget from agency
120 000 €
Project ID
APVV-19-0142

Research Subject

The project focused on the community of soil microorganisms (including nematodes) mainly in natural forest ecosystems in relation to abiotic and biotic environmental factors. The relationships were studied in locations with different parent rocks, altitude, and latitude and longitude. In addition to data from new plots, results were synthesised using also data obtained during previous projects in various locations within and outside Slovakia.

Aim of the Research

The aim of the project was to analyse and evaluate the response of the community of soil microorganisms and nematodes to abiotic and biotic environmental factors of their habitat in natural forest ecosystems at different levels - stand level, regional and global level, and to find out whether the pattern of this response to these factors varies at different levels.

Achieved Results

At the stand level, we performed a detailed study of the effect of the stand structure and herb layer on soil properties, microbiota and nematodes in the Poloniny, Poľana and Záhorie regions. Although we found a response of some microbial characteristics (especially in the A-horizon) to changing stand characteristics in natural beech stands, this effect was much weaker than the effect of soil physico-chemical properties. The absence of a significant effect indicates that stand structure indicators such as stand stock, homogeneity coefficient, relative abundance of developmental stages etc. have only limited ability to predict soil and microbial characteristics in the upper horizons of the soil. This does not necessarily mean that the stand structure does not influence the observed soil properties, but possibly the used indicators do not adequately reflect this influence.

In the case of sandy soils, the structurally differentiated pine stand resulting from the application of close-to-nature management seems to be a very important factor in increasing the humus content of the soil, its better water retention and, consequently, also more favourable conditions for soil nematodes and microorganisms. In contrast, stands with the conventional age-class management, which were not differentiated in age, tree diameter and height, were characterised by lower humus content and more unfavourable conditions for soil microorganisms and nematodes. Three species, namely Bunonema ditvelseni, Plectus infundibulifer and Metaporcelaimus labiatus, were identified at this site as new species in Slovakia.

At the level of a smaller region (Slovakia), we observed high variability in soil and microbial characteristics at both stand and regional levels, with a surprising increase in variability with soil depth. The amount of soil organic matter was significantly influenced by parent rock and altitude. Soil properties (especially C and N content) contributed most to the variability of microbial characteristics within a given region; the influence of vegetation was less pronounced (< 30% of the total variability), while microbial characteristics were most influenced by the herb layer – its cover, richness and diversity.

Within a broader region and at the global level, climatic variables and stand stock did not show significant effects on soil organic matter content; a significant association was found with parent material. We found that the general trend of soil properties changing with elevation may vary across latitudes, with slope gradient playing an important role, particularly in extreme climates. Regarding the response of soil microorganisms, regardless of whether the sites are located in cooler (e.g. northern Canada) or warmer conditions (Apennine Peninsula), soil micro-organisms in natural forest ecosystems respond to soil properties most strongly, in particular C and N content.

Benefits for Practise

The project focused primarily on basic research tasks. The obtained results will contribute to the extension of knowledge in the field of soil microbiology, soil geography, carbon sequestration, soil conservation, forest ecology, as well as in other related disciplines. The project generated a large amount of empirical data on soil properties, which can be used in modelling processes related to nutrient cycling in forest soils and ecosystems. The knowledge on the effect of tree species as well as stand structure on soil properties can be used in practice in silviculture and management planning, the information on the variability of soil properties in forest typology, and the knowledge on nematodes in forest conservation. T

Fig. 1 / The research was performed primarily in the natural beech forests
Fig. 2 / Soil properties and soil microbial communities were evaluated not only in the top soil horizon but also in the deeper mineral horizons
Fig. 3/ Location of sampling sites in the natural beech forest (natural reservation Havešová)
Fig. 4/ Positions of localities in primeval beech forests in the Central, South-East and South Europe, were soil sampling was done
Fig. 5/ Metaporcelaimus labiatus – a nematode species new for Slovakia

Fig. 1

Fig. 2

Fig. 5

Fig. 3

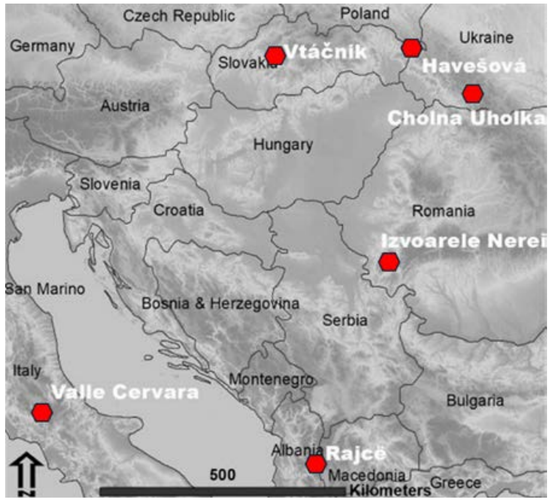

Fig. 4

Embedded graphs – colorings and structure

Principal investigator
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Participating organisation
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Term of solution
07/2020 - 06/2024
Budget from agency
150 000 €
Project ID
APVV-19-0153

Research Subject

The project was focused on research of embedded graphs (which include planar graphs, polyhedral graphs or crossing-free representation of graphs in orientable surfaces) in two important areas: the chromatic and the structural properties. For the former area, the attention has been paid on the study of various graph colorings and labelings, with the concentration on finding the exact values or estimates of corresponding chromatic invariants; within the latter area, we studied local properties (concerning mainly the small configurations of graph elements) as well as large-scale structure (the existence of long cycles and particular spanning subgraphs).

Aim of the Research

In the research of colorings and labelings, the following goals were planned to be achieved:
- obtaining exact values of the achromatic number of Hamming graphs whose Cartesian factors have specific orders
- improving the bounds on chromatic invariants related to edge colorings defined by specific structure of the subgraphs induced by particular color classes or bichromatic subgraphs
- developing polynomial algorithm for deciding the 3-colorability of claw-free graphs with additionally forbidden subgraphs
- continuing the study of various facial colorings of plane or embedded graphs tending to find improved estimates or exact values for related chromatic parameters
- exploring various types of colorings characterized by constant color degrees of graph elements, with the aim to obtain bounds on related chromatic numbers and an information on specified colorability of graphs formed by graph operations
- obtaining new results on the vertex interval colorability or the unique-maximum colorability (with respect to vertex neighborhoods) of graphs
- extending particular concepts of facial colorings of plane graphs to graphs with a given rotation system
- obtaining a basic estimate for the analogue of the 1-2-3 conjecture concerning edge labelings which induce a proper vertex and a proper face coloring in a plane graph
- characterizing families of trees and planar graphs which attain extremal values of the local antimagic chromatic number
- exploring, for directed graphs, variants of labelings of arcs which define two particular induced vertex colorings (summing the labels of ingoing and outgoing edges of a vertex separately)
- investigating the generalization of the concept of face irregular labelings for graphs with a given collection of edge-covering subgraphs and determining the involved labeling invariants

In the research of the structure of graphs, the following goals were proposed:
- describing the types of light edges in embedded graphs with a prescribed girth
- bringing new results on the existence of unavoidable sets of small cycles in families of planar graphs of minimum degree 5 or minimum edge-weight at least 9, or polyhedral essentially 4-connected graphs
- finding analogues of dual versions of Kotzig theorem or the light path theorem for face chains without a self-touch
- improving the upper bound on the weight of light edges in the family of hypohamiltonian planar graphs
- obtaining new results (concerning constructions, connectivity properties, local structure) on nonhamiltonian graphs which lead to a hamiltonian graph after an arbitrary edge contraction
- extending known results on specific spanning subgraphs (k-trestles, k-walks, cacti) in planar graphs to k-planar graphs

Achieved Results

Among the most important results of this project, we mention
- complete information on exact values of the achromatic number for Hamming graphs with one factor having 6 vertices
- characterization of k-regular graphs with strong chromatic index 2k-1 (and the resulting construction of a counterexample to the 30-year-old open hypothesis by Faudree et al.)
- exact specification of types of light edges and light 3-stars in planar or embedded graphs with minimum degree at least 2 and prescribed girth
- initiation of research on a new class of so-called perihamiltonian graphs
- obtaining the best lower bound for the length of the longest cycle in essentially 4-connected planar triangulations

Benefits for Practise

The obtained results find wide applications in various areas:. in the operation of mobile communication networks, solving scheduling problems, software optimization, the structure of interconnections between wireless routers, surface modeling in CAD, and the design of nanostructures.

Fig. 1 / Voltage graph embedded into nonorientable surface of genus 9 (pic2.jpg)
Fig. 2 / An example of essentially 5-connected polyhedron, whose 4-cycles contain a vertex of large degree (pic1.jpg)
Fig. 3 / The unique strong edge 5-coloring of Petersen graph with derived coloring of its vertices (pic3.png)

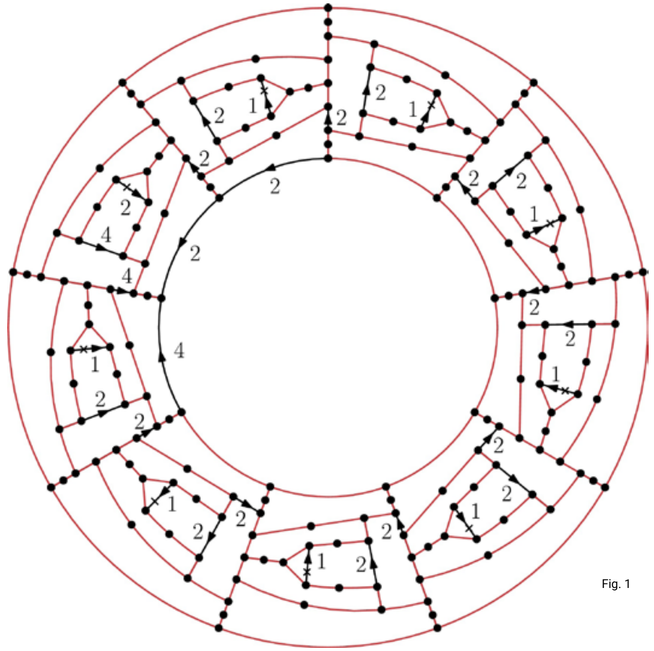

Fig. 1

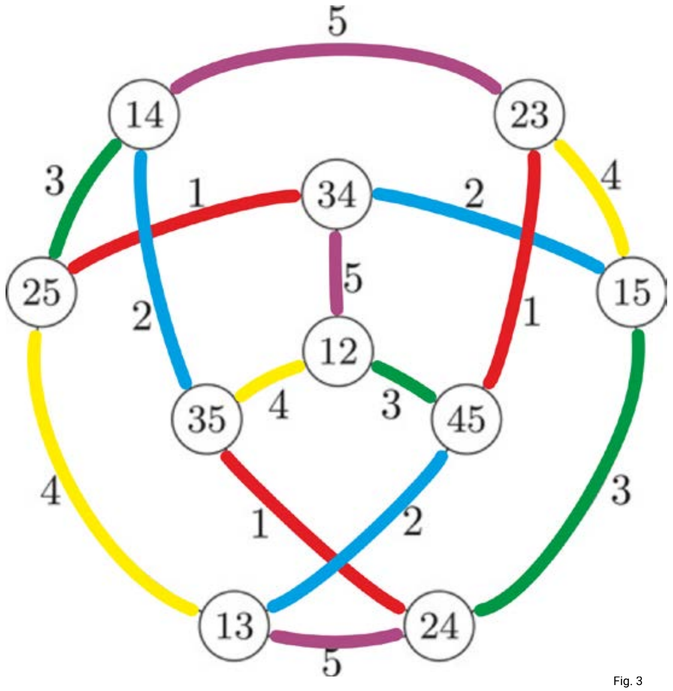

Fig. 3

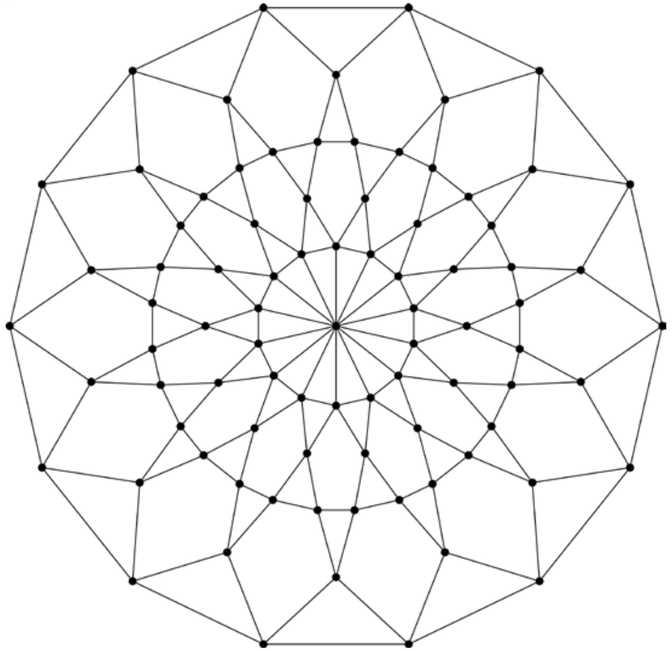

Fig. 2

Study of biological effects of H2S/NO/selenium products and molecular mechanisms of their actions

Principal investigator
RNDr. Ondriaš Karol, DrSc.
Applicant organisation
Biomedical Research Center - Institute for Clinical and Translational Research
Participating organisations
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Comenius University Bratislava - Faculty of Pharmacy
Term of solution
07/2020 - 06/2024
Budget from agency
160 000 €
Project ID
APVV-19-0154

Research Subject

The subject was basic research on the study of biophysical interactions of hydrogen sulphide (H_2S), selenium and their derivatives with biological thiols, glutathione and cysteine in the context of applying the results in application studies that could lead to their use in medicine.

Aim of the Research

Since H_2S, selenium and their derivatives affect many processes in the body where glutathione and cysteine are present, the aim of the project was to contribute to the explanation of their biological effects. That is, to study the biophysical properties of the interaction products of H_2S and selenium with biological thiols, glutathione and with cysteine at different levels of system complexity. The following effects of the interaction products of H_2S and selenite with thiols were studied: 1.) Antioxidant radical quenching properties. 2.) Release nitric oxide from NO-donors. 3.) Cleave hydroperoxides. 4.) To damage plasmid DNA in-vitro. 5.) To modulate the tone of isolated arteries from the rat. 6.) To influence the hemodynamic parameters of the rat.

Achieved Results

The results were published in nine scientific papers, which had an impact factor ranging from 3.7 to 6.3 and were in the Q1 - Q2 category. We found that the products of the interaction of H_2S and selenium derivatives with thiols have prominent and multiple biophysical and biological effects.

1.) Antioxidant radical quenching properties;
We found that the products of the interaction of H2S and selenite with thiols have catalytic radical eliminating properties. Thus, the products may contribute to the understanding of the involvement of H_2S and selenite in the regulation of antioxidant stress. H_2S significantly potentiated the antioxidant properties of Acanthopanax senticosus (Siberian ginseng) root extract.
2.) Release nitric oxide from NO-donors;
The interaction products of selenium derivatives with thiols released nitric oxide from S-nitrosoglutathione.
3.) Cleave hydroperoxides;
H_2S and selenium derivatives cleaved the model hydroperoxides.
4.) To damage plasmid DNA in-vitro:
The glutathione/selenite mixture produced radicals and cleaved plasmid DNA. The aqueous extract and its two components inhibited the cleavage of plasmid DNA when the damage was induced by polysulfides.
5.) Modulate the tone of isolated arteries from rat:
Selenite/glutathione products reduced the tone of isolated mesenteric artery from rat.
6.) To influence hemodynamic parameters of rat.
Glutathione/selenite products affected several hemodynamic parameters including lowering blood pressure of rats. Root extract from Acanthopanax senticosus and phthalic acid selenoic anhydride modulated the hemodynamic parameters of rat.

In the methodological part, we developed two methods.
In the first method, we used EPR spertrometry to measure the influence of the interaction products of selenite with glutathione and the H_2Se donor on the cleavage of model hydroperoxides in the absence and presence of DMSO. We have developed a method to use KO2 as a superoxide radical source and vEPR spectrometry to measure it.
In the in-vivo method, we have refined a procedure to obtain 35 parameters from the arterial pulse wave of the rat. We studied the hypothesis that the cardiovascular system can be characterized just from the detailed arterial pulse waveform. Therefore, we developed a procedure to measure the anacrotic (AnN) and dicrotic (DiN) notch on the pulse wave in the carotid artery (aorta carotis communis) of the rat.

Benefits for Practise

There is no practical application of the project results at this stage of basic research. However, the results indicate the direction in which applied research should go, using the findings of the above mentioned basic research. It will be necessary to identify a single product or products of the interaction of H2S and selenium with biological thiols that have the catalytic properties to eliminate radicals, liberate nitric oxide from NO-donors, cleave lipid hydroperoxides, damage DNA, inhibit DNA damage, relax blood vessels and lower blood pressure.

The results of application studies may lead to products that can be used in medical practice.

Fig. 1 / Catalytic properties of the glutathione/selenite mixture:
Radical reduction of cPTIO (100 µM) by glutathione/selenite mixture (10,000/3 µM, red) and after addition of 5 x cPTIO (100 µM).
Fig. 2 / Time dependence of rat arterial pulse wave parameters. Parameter "Anacr. N. delay" has di-gital properties depending on systolic pressure.
Fig. 3. / Plasmid DNA (ncDNA) damage in-vitro with increasing concentration of thiols (homosysteine-HCys, glutathione-GSH, cysteine-Cys) in the presence of selenite (10 µM, SeO32-).

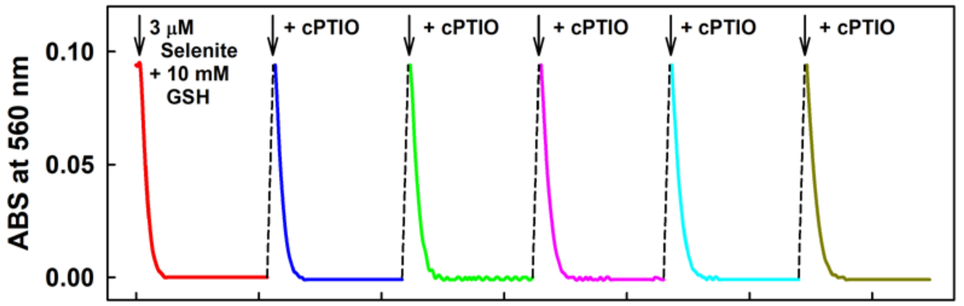

Fig. 1

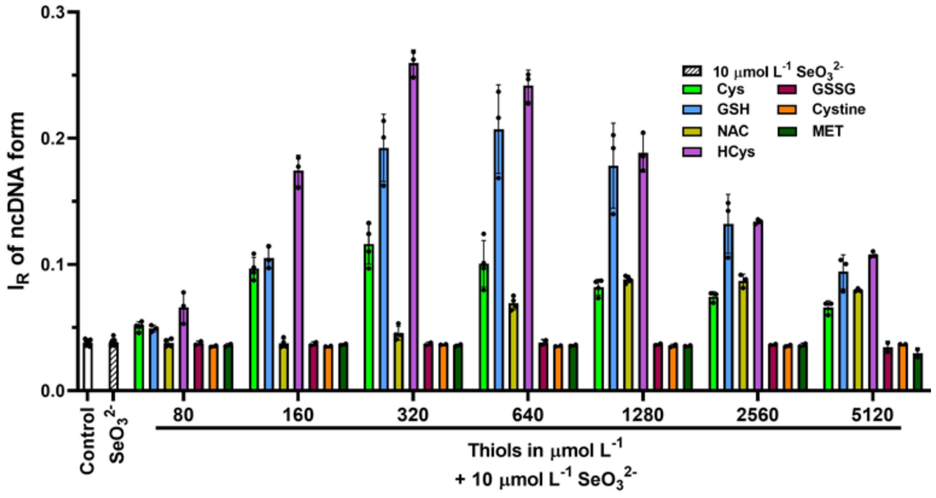

Fig. 3

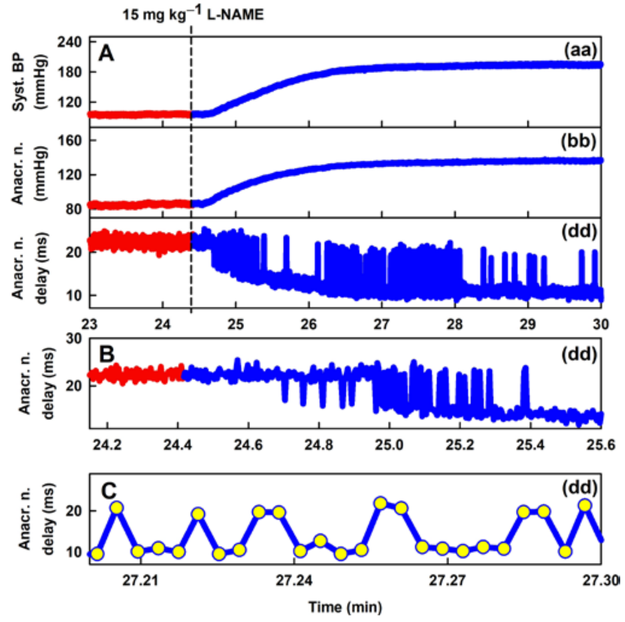

Fig. 2

Neurotransmitter-mediated regulation of postnatal neurogenesis in the rat olfactory system under physiological and pathological conditions

Principal investigator
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Applicant organisation
Biomedical Research Center
Participating organisation
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Term of solution
07/2020 - 06/2024
Budget from agency
120 000 €
Project ID
APVV-19-0279

Research Subject

The generation of new neurons in adulthood, postnatal neurogenesis, plays a key role in the adaptive and regenerative processes of the brain, and recent research suggests that its alteration may be linked to the development of some neurodegenerative and psychiatric diseases. The regulatory mechanisms of postnatal neurogenesis in the olfactory neurogenic area of the mammalian brain - the subventricular zone (SVZ) and rostral migratory stream (RMS) are still not fully understood. The project was focused on investigation of neurogenesis regulation in the SVZ-RMS via neurotransmitters nitric oxide (NO) and serotonin in intact rats and in the rat model of depression. We also focused on identifying the neural circuits in which neurons located in the RMS are involved. The subject of our research was also the analysis of integral components of the SVZ microenvironment.

Aim of the Research

The main goals of the project included mapping the possible neuronal circuits of NO-producing neurons localized in the rat RMS and obtaining new morphological data on these neurons, as well as mapping the morphological picture of the mutual arrangement of nitrergic neurons and blood vessels in the SVZ-RMS. The association between decreased serotonin levels due to depression and reduced neurogenesis has been demonstrated only in the hippocampus. Therefore, our further experiments were aimed to investigate the link between depression, altered serotonin regulation and neurogenic processes in the olfactory neurogenic area. Another goal was to map serotoninergic innervation of the SVZ-RMS and characterize the phenotype of cells expressing serotonin receptors (5-HT receptors) in these structures, as well as to map the expression of BDNF and its receptors (TrkB, p75NTR) in the SVZ-RMS.

Achieved Results

We obtained original results on the regulatory mechanisms of postnatal neurogenesis in the rat olfactory neurogenic region – the SVZ and RMS. Morphological evidence for the connection of NO- and secretagogin-producing neurons of the RMS with the striatum suggests the existence of neuronal circuits that may be invovled in the regulation of neurogenesis. The close anatomical relationship found between nitrergic neurons and specifically arranged blood vessels of the RMS indicates that nitrergic neurons of the RMS belong to perivascular interneurons. These findings contribute to the understanding of the functional significance of nitrergic neurons in the RMS. We obtained data about the serotonergic innervation of the SVZ-RMS in control rats and rats with induced depression. We determined the phenotype of cells producing the neurotrophin BDNF and the phenotypes of cells expressing serotonin and BDNF receptors in the SVZ-RMS. Monitoring cell proliferation and migration revealed a significant decrease in neurogenesis in the SVZ-RMS in rats with induced depression. Analysis of individual SVZ-RMS cell types revealed that type A and B cells express the gene for telomerase reverse transcriptase (TERT), which is related to the regulation of proliferation. The results of analyzes showed that during postnatal development, the expression of TERT in B-cells is diminished, which reduces the neurogenic activity of stem cells.

Beyond the planned activities, during the pandemic period, we organized remote olfactory testing in patients with persistent olfactory dysfunction after COVID-19 throughout Slovakia. Based on the results of olfactory tests allowing objectification of olfactory dysfunction, patients were referred to participating ENT doctors. A total of 1,025 patients requested olfactory testing. Quantitative olfactory dysfunction, anosmia or hyposmia, was confirmed in 82.6% of participants. More than 50% of normosmic subjects showed qualitative olfactory dysfunction, parosmia and/or phantosmia. The results of the smell testing have been published.

Benefits for Practise

During the project, we gained original knowledge about the regulation of postnatal neurogenesis, which may be useful in developing new therapeutic strategies aimed at neuronal replacement after various injuries or in the treatment of neurodegenerative diseases.

Olfactory testing of patients after infection with the SARS-CoV-2 virus has highlighted the importance of psychophysical olfactory testing for objectifying olfactory dysfunctions, as well as its suitability for remote use during the pandemic. In addition, the testing has drawn the attention of experts to the importance of olfactory examination in clinical practice, which is rarely used in Slovakia.

Fig. 1 / Schematic drawing of stereotactic application of the retrograde fluorescent tracer Fluoro-Gold into the striatum of adult rat.
Fig. 2 / Double immunofluorescent labeling showing NO-producing neurons (green) in the RMS labelled with the retrograde tracer Fluoro-Gold (red) (indicated by arrows). Cell nuclei labeled with DAPI (blue) (A – D). Scale bars (A, B, C) 50 µm, (D) 25 µm.
Fig. 3 / Explant from the RMS with chains of migrating neuroblasts cultured in vitro. The explant is from a rat model of depression. Scale bar, 100 µm.
Fig. 4 / Percentage of normosmics, hyposmics and anosmics according to the smell test, OMT (Odorized Markers Test). 82.6% of participants had quantitative olfactory dysfunction, hyposmia (partial loss of smell) – 37.6% or anosmia (complete loss of smell) – 45.0% (Martončíková et al., 2023).
Fig. 5 / Qualitative olfactory dysfunctions, parosmia and phantosmia in normosmics. 54% of normosmics had parosmia and/or phantosmia (Martončíková et al., 2023).

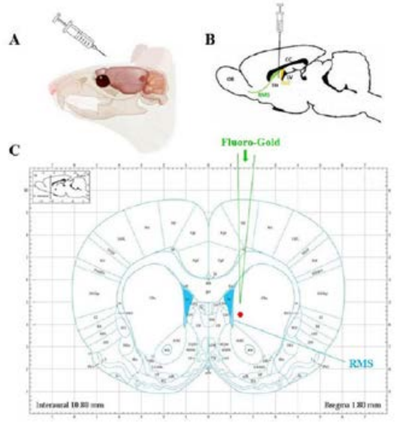

Fig. 1

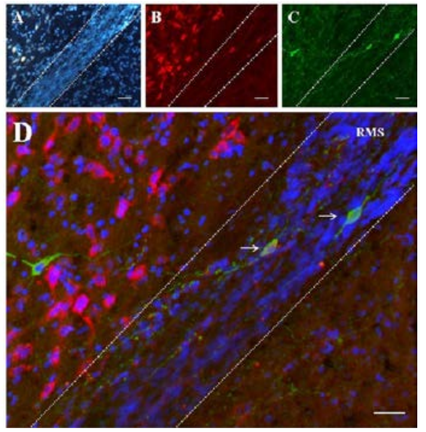

Fig. 2

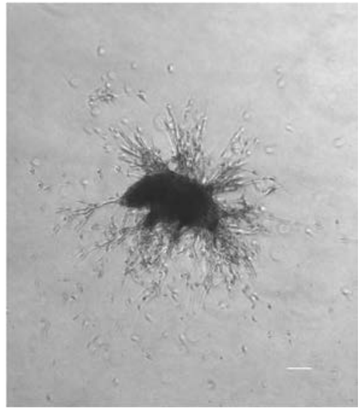

Fig. 3

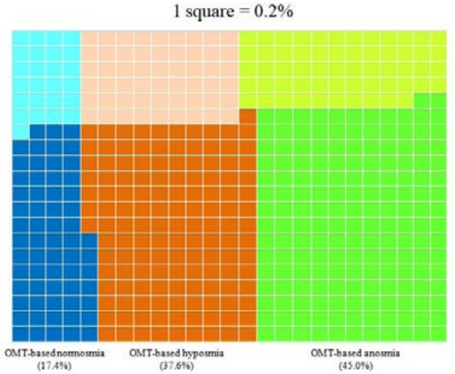

Fig. 4

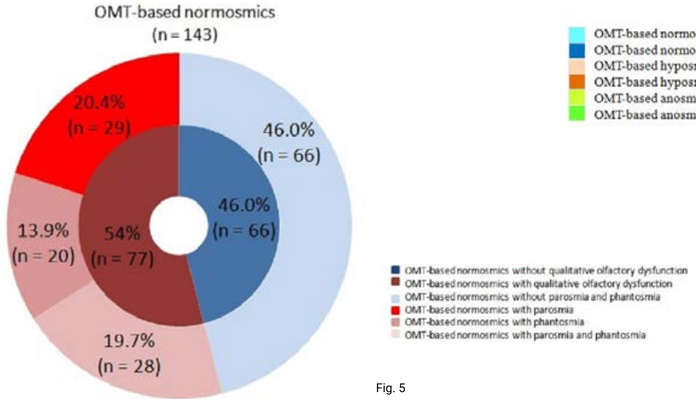

Fig. 5

Is HIF-1α a master regulator of DNA repiar capacity and chemotherapy response in testicular germ cell tumors?

Principal investigator
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Applicant organisation
Biomedical Research Center - Cancer Research Institute
Term of solution
07/2020 - 12/2023
Budget from agency
190 000 €
Project ID
APVV-19-0286

Research Subject

Treatment resistance is a persistent problem in clinical oncology. Cancer cells respond to therapy mainly by repairing damaged DNA and metabolism change. However, the causes of the unfavorable response are unclear. In a model of testicular carcinomas (TGCT) with unique sensitivity to the DNA-damaging agent cisplatin (CDDP), we tested the hypothesis that the HIF/miR-218-5p/phosphatase regulatory axis controls the efficiency of DNA repair and thus the success of treatment. Hypoxia may be crucial in the genetic and epigenetic control of DNA repair of treatment-induced damage. Our hypothesis is based on the observation of increased expression of miR-218-5p in resistant TGCT cell lines, which results from hypoxia-induced transcriptional upregulation by HIF1a. Subsequently, high expression of miR-218-5p posttranscriptionally reduces the expression of target phosphatases PPP2R2A/PPP2R5A, thereby maintaining repair proteins (including ATM) in a phosphorylated, i.e. active state, increasing the efficiency of DNA repair and the development of resistance.

Aim of the Research

Using molecular, cell biology and biochemistry methods we aimed to compare the expression of components of the studied regulatory axis between resistant and sensitive TGCT cell lines. We focused on confirming the transcriptional control of miR-218-5p by HIF1a and the subsequent posttranscriptional control of phosphatases by this miRNA. By functional analysis, we aimed to verify whether such regulation affects the level of ATM phosphorylation and thereby the increased DNA repair activity in resistant cells.

Achieved Results

Our results showed that the HIF/miR-218/phosphatase axis associates with the degree of resistance of TGCT cells and modulates their response to CDDP. Comparison of TGCT cell lines showed significantly higher expression of HIF1a, miR-218 and its host genes SLIT2/3 in resistant cell lines and expression of both phosphatases significantly reduced. Using siRNA inhibitors of miR-218 and HIF1a, we confirmed both phosphatases posttranscriptionally regulated by miR-218, which, together with SLIT2/3 (with HRE element in the promoter), is under the control of HIF1a. The negligible methylation of the phosphatase promoters indicated the exclusive downregulation by miR-218. We also confirmed selected DNA repair genes to be under hypoxia control. The functional involvement of the regulatory axis in the CDDP response was evaluated by comparison of double-stranded DNA breaks and the amount of phosphorylated vs. unphosphorylated form of ATM, a key activator of DNA repair. The increased phosphorylated ATM in resistant TGCTs suggests the validity of our hypothesis that HIF1α-induced expression of miR-218 downregulates phosphatases that insufficiently dephosphorylate ATM, thereby prolonging the activation and capacity of DNA repair leading to chemoresistance. Activation of the HIF/miR-218/PP2A-PPP2R5A axis compromises homologous recombination, increases the efficiency of nucleotide excision repair, thereby progressing chemoresistance with a prediction of a worse prognosis for TGCT patients. Components of the HIF/miR-218/phosphatase axis potentially provide new biomarkers of resistance and predictors of the success of CDDP treatment.

Benefits for Practise

The knowledge about HIF/miR-218/PP2A-PPP2R5A axis brings new potential biomarkers that can more accurately characterize the histological subtype of TGCT, better stratify patients, and detect the development of chemoresistance in a timely manner. Mitigation of side effects of ineffective toxic treatment and its replacement with more effective one are the main benefits for the patient. New biomarkers can also be proficient for better treatment monitoring. Revealing the role of the HIF/miR-218/PP2A-PPP2R5A axis in chemoresistance opens up new possibilities for therapeutic targeting, potential development of new therapeutics or treatment regimens. The results of the project contribute to the knowledge of the molecular background of TGCT malignancy and the understanding of cellular regulatory connections, supporting the importance of epigenetic regulation in cancer diseases and their treatment. Understanding the differences between resistant vs. sensitive phenotypes opens up new treatment options not only for TGCT but also for other solid malignancies, where treatment with CDDP is often the first choice.

Fig. 1 / The HIF/miR-218-5p/PPP2R2A-PPP2R5A regulatory axis is involved in controlling cellular response to cisplatin (CDDP)-based therapy.
Fig. 2 / Significantly increased basal expression of miR-218-5p in resistant TGCT cell lines identified by miRNA microarrays and RT-qPCR analysis.
Fig. 3 / The HIF/miR-218-5p/PPP2R2A-PPP2R5A regulatory axis offers novel biomarkers for personalized resistant patients management.
Fig. 4 / The research team.

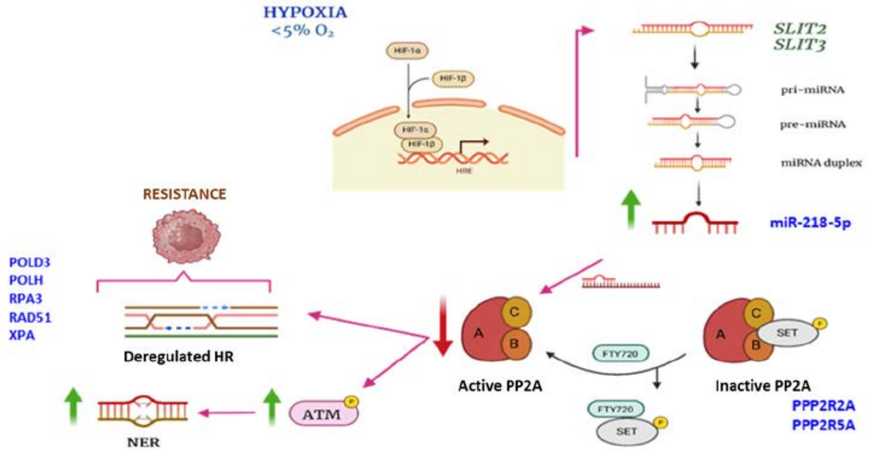

Fig. 1

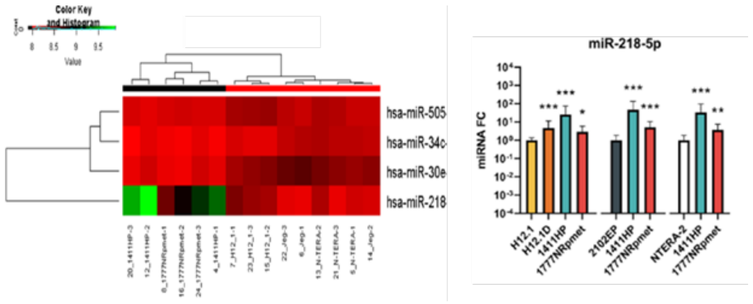

Fig. 2

Fig. 4

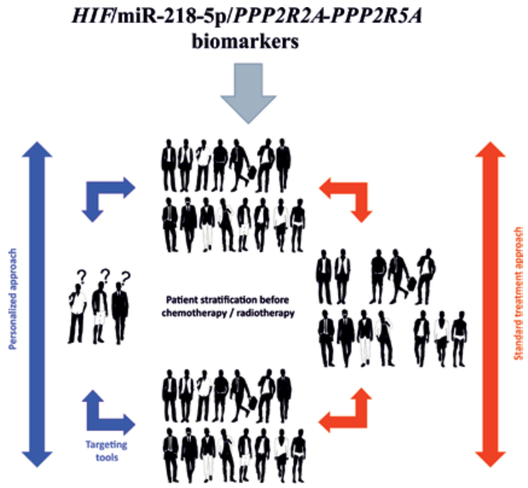

Fig. 3

Robust Spin Waves for Future Magnonic Applications

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Institute of Electrical Engineering
Participating organisation
Comenius University Bratislava - Faculty of Mathematics Physics and Informatics
Term of solution
07/2020 - 06/2024
Budget from agency
196 000 €
Project ID
APVV-19-0311

Research Subject

Spin waves are bosonic elementary excitations in magnetically ordered systems. Spin waves are considered a new generation of information carriers. It is due to their unique properties, namely low energy dissipation, possible manipulation at nano-scale (short wavelength as compared to EM waves), or reconfigurability due to the switching of magnetic states. Spin waves are also proposed for the realization of non-boolean computing components or could be used to mediate interaction and synchronize neuromorphic computing elements based on spin torque nano-oscilators. In order to use spin waves, one has to learn to control them precisely.

Aim of the Research

The main goal of the project was to study robust spin waves for future magnonic applications. By robust spin waves, we mean defect-immune waves propagating in unidirectional nanochannels. The project was divided into four work packages (WPs) with different focuses: WP1 focused on the research of unidirectional spin waves in topological magnonic crystals. WP2 focused on unidirectional spin waves in bilayer or bichannel systems. WP3 focused on theoretical and experimental methods needed to realize reprogrammable artificial spin ice, and WP4 focused on the application of the acquired knowledge in a specific functional magnetic component, such as a diode or a circulator.

Achieved Results

We achieved several important results related to the project objectives. During the project implementation, we made the most significant progress in the work on WP1, WP3, and WP4. The results obtained during the work on WP2 were not satisfactory in terms of reproducibility and experimental control, therefore, the greatest emphasis was placed on the other WPs. When solving WP1, we realized most of the objectives. Specifically, we demonstrated theoretically and experimentally several methods for controlling the chirality of the magnetization of one unit cell of a magnonic crystal (Fig. 1) and theoretically demonstrated the topological properties of unidirectional spin waves in such crystals (Fig. 2). We developed a method for producing a magnonic crystal with high dipolar coupling between individual cells in the ground state (Fig. 3). These results allow us to continue experimental research into the dynamics of spin waves in this type of magnonic crystals. During the work on WP2, we demonstrated and investigated interesting properties of spin wave propagation in double-layer systems. Special attention was paid to non-reciprocal couplings. We further investigated the possibilities of experimental realization of this type of structure. We found that simultaneous control of the exchange parameters of the DMI anisotropy is difficult, and the sample-to-sample deviations are large. While working on this goal, we improved the sensitivity of the ferromagnetic resonance measurement setup and integrated a rotary stage, which was also used to study the properties of magnonic crystals in WP1. Within WP3, we developed theoretical models that describe the control of the magnetization state taking into account the magnetization dynamics (Fig. 4). This and also with the experience from WP1, will allow us to fabricate artificial spin ice with controllable magnetization in the future. We further improved experimental techniques for characterizing magnetic structures, such as the vortex-core tip for magnetic force microscopy (Fig. 5). In relation to WP4, we have made a significant contribution to the description of non-reciprocal spin wave propagation and used it as a building block of magnonics: diodes or circulators. We have also shown that hybrid systems can be used to overcome the skyrmion Hall effect undesirable in the context of racetrack applications and are suitable for transporting skyrmions along a straight path using electric current pulses. In total, 15 publications related to the project have already been published in international journals. The project findings open avenues for several research topics with high impact potential.

Benefits for Practise

The project results are not currently directly applied in industry. The project was focused on basic research, so the use of the results will be to apply the knowledge gained by this project for further research. One of the important outputs of the project is a unique sample of a magnonic crystal made of tightly coupled magnetic elements. Such a crystal will serve for further research in magnonics with an impact on other areas of physics.

Fig. 1 / (top) Schematic of magnetic nanoelements that are switched by a magnetic tip. (middle) Magnetic force microscopy image of the switching procedure. (bottom) Corresponding numerical simulation.
Fig. 2 / (left) Band structure of spin waves in a finite-width topological magnonic crystal. (right) Clockwise propagation of the topological edge state.
Fig. 3 / Crystal images taken (a) by scanning electron microscopy and (b) by magnetic force microscopy show a regular magnetic arrangement.
Fig. 4 / (Left) Scheme of the symmetry of the magnetic field of a ferromagnetic disk at its edge. (Right) An inhomogeneous local magnetic field generated by the magnetic force microscopy tip breaks the symmetry between the lower and upper edges of the disk, thus allowing control of chirality.
Fig. 5 / Comparison of scans measured with a commercial low magnetic moment tip (a), a commercial super sharp tip (b), and a vortex-core tip without (c) and with a fixation cavity (d).

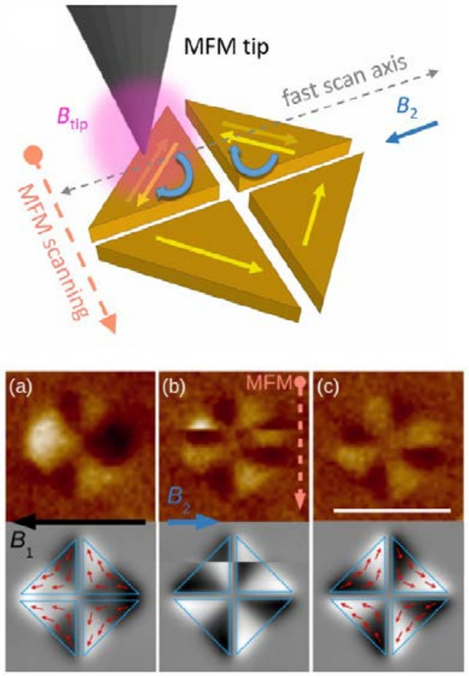

Fig. 1

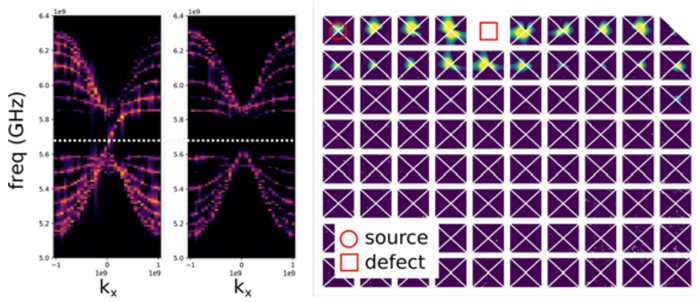

Fig. 2

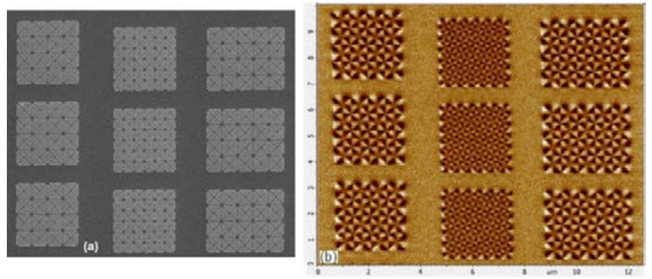

Fig. 3

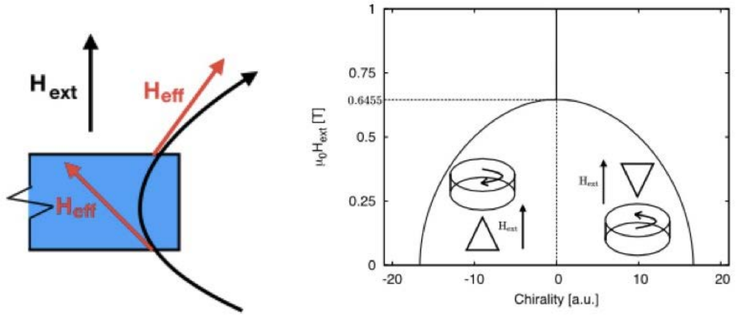

Fig. 4

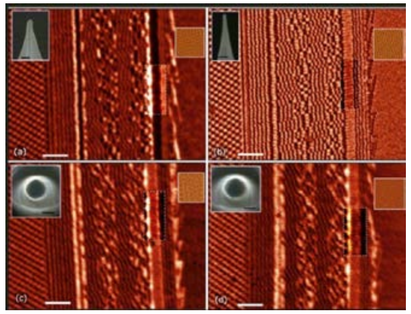

Fig. 5

Development of bioimmunotherapeutics inspired by viral tricks: TREATing despite the TRICKs

Principal investigator
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Biomedical Research Center - Institute of Virology
Participating organisation
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Term of solution
07/2020 - 06/2024
Budget from agency
140 000 €
Project ID
APVV-19-0376

Research Subject

Immunotherapy represents a leading field of modern biomedical research. Our goal is to push its boundaries by redirecting immune modulation through virus-inspired mechanisms. Our long-term objective is to study the molecules through which cytomegalovirus suppresses the immune response and to apply the acquired knowledge in the development of novel biotherapeutics for the treatment of viral and autoimmune diseases. In our research, we focus on important viral glycoproteins that manipulate immune responses, aiming to understand the underlying mechanisms of their action.

The project integrates a multidisciplinary approach combining molecular and cell biology, crystallography, immuno-virological in vitro assays, and computational in silico drug design based on known crystal structures. Building on preliminary data, a skilled team, and strong external collaborations, the project could succeed in long-term vision to develop innovative therapeutics applicable to both antiviral and cancer immunotherapy.

Aim of the Research

Within the project, we investigate two key glycoproteins of human cytomegalovirus (HCMV UL141 and UL144) that modulate NK and T cell responses. The aim is to evaluate or inhibit their function using in vitro biological testing on both normal and tumor settings in parallel with computational in silico methods. Identifying factors that regulate the expression of receptors (e.g., TRAIL-R2, CD160) and ligands (e.g., TIGIT, DNAM-1) on the cell surface will enable a deeper understanding of the role these viral proteins play in immune responses and how these pathways can be targeted for therapeutic intervention. The long-term objective is to generate a detailed characterization of their molecular architecture and function, providing a molecular-level foundation for the rational design of bioimmunotherapeutics, which will be subjected to experimental validation.

Achieved Results

The project brought new insights into the molecular mechanisms of the immune response induced by HCMV, which resulted to the fulfillment of planed goals. We succeeded to characterize the native and fusion complex of CD160 with endogenous (HVEM) and viral ligands (UL144) and determine their tertiary structure, flexibility of unoccupied binding sites, thereby revealing their possible cell surface recognition mechanism. Furthermore, we managed to determine the effect of PTM on binding to immunoreceptors, where we determined binding kinetics and the specific glycans that affect this binding. We obtained a lot of valuable results when studying the interaction of viral UL141 with anti-TIGIT, while we proved that UL141 mimics this binding site thus disrupts CD155 signaling on NK cells, while this binding is equimolar.

In the development of new computational methods for protein interaction analysis, we successfully applied the connection of RIN methodologies (NDA, CSV), amino acid fragmentation methods by segmentation (FMO-PIEDA), and molecular dynamics simulation of UL141-TRAIL-R2 complex as well as for other model systems. By combining modeling, synthesis, and biological testing, we succeeded to identify new iminoglycan-based substances that block TRAIL-R2 binding. The results correlated well between tested methods both in silico and in vitro, while maintaining non-cytotoxic properties. Using empirical and quantum-mechanical methods of molecular modeling and targeted mutational and surface plasmon resonance (SPR) analysis, we determined binding site of the de novo antagonist on UL141 surface and described paired interactions and kinetics.

Benefits for Practise

Although project focuses on basic research, the project's outcomes have translational potential. Viral immune evasion proteins offer tools to suppress pathological immune responses and contribute to novel immunotherapeutic strategies in cancer and autoimmunity. The project resulted in 12 peer-reviewed articles in Current Contents Connect-indexed journals (with cumulative IF 55), several already cited during the project. Findings were presented at international conferences. The project also supported the education of young scientists, with two master's and two doctoral theses defended.

Fig. 1A / Crystals of viral glycoproteins in complex with the endogenous ligand patterns and electron density map.
Fig. 1B / Screening of compounds 1–21 by TMB-ELISA for their ability to block and yellow indicate positive antagonistic hits.
Fig. 1C / Overall cytotoxicity assessment of compounds 1–21 on human fibrol Compounds reducing cell viability below 40% were considered cytotoxic (exam
Fig. 1D / Binding kinetics results from SPR. Affinity constants and compound s graph.
Fig. 1E / Superposition of QM/MM-optimized UL141/compound 14 (grey) and based mutational analysis revealed compound 18 binds to Trp235 and Asp23
Fig. 1F / Structure of compound 18 docked into UL141. Preferred binding sites of QM/MM-optimized UL141/compound 18 with TRAIL-R2 (orange).

Fig. 1A Kryštalizácia a röntgenová štruktúrna analýza

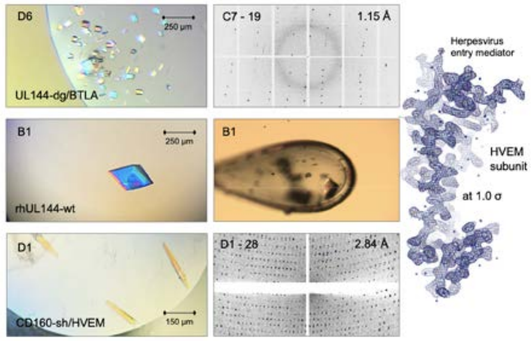


Fig. 1B ELISA-TMB skríning

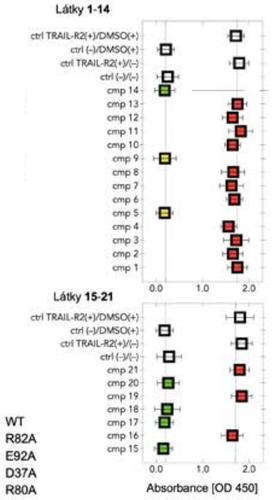


Fig. 1C Zhodnotenie cytotoxických účinkov

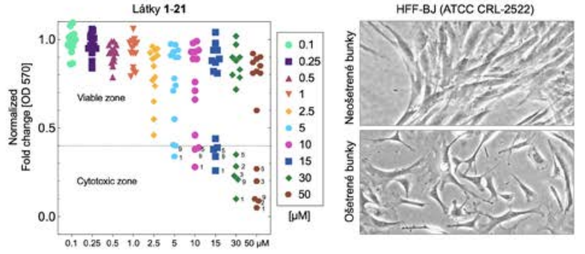


Fig. 1D Analýza väzby a kinetiky pomocou SPR

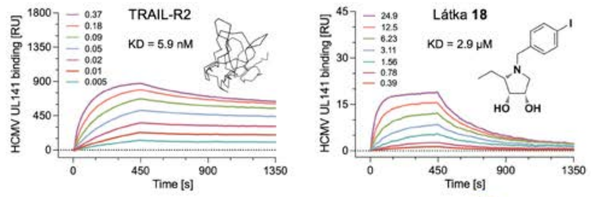


Fig. 1E Superpozícia UL141 s antagonistom a mutačná analýza

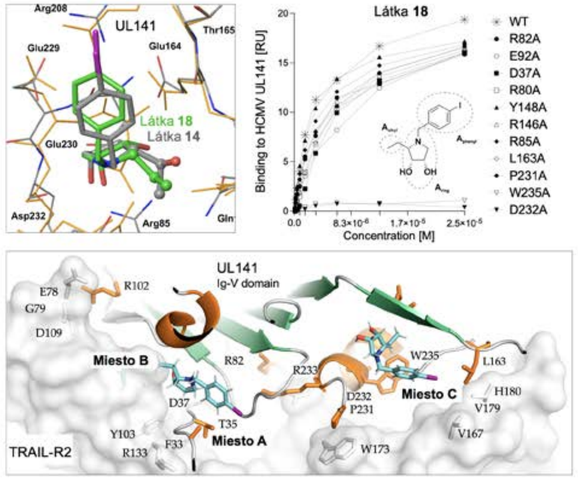
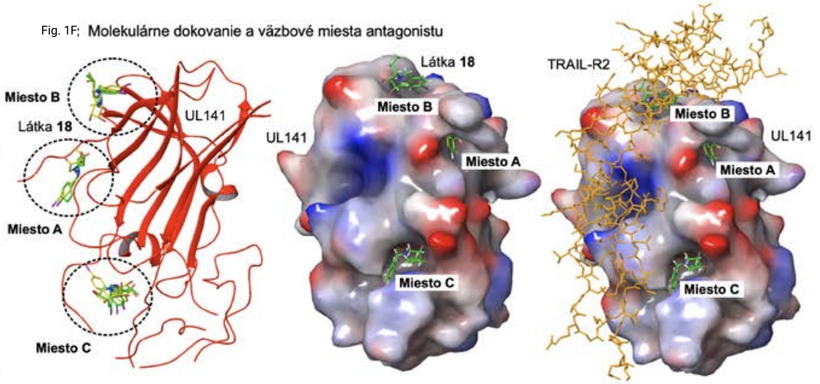


Fig. 1F; Molekulárne dokovanie a väzbové miesta antagonistu



Ion and electron processes for advanced spectrometric methods

Principal investigator
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Applicant organisation
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Term of solution
07/2020 - 06/2024
Budget from agency
210 000 €
Project ID
APVV-19-0386

Research Subject

The project focused on the research of electron and ion induced molecular processes, occurring in interstellar space, planetary atmospheres, electrical discharges, plasma, nanotechnologies based on electron and ion beam etching or deposition, various analytical methods, and even in agricultural applications. To study these processes, the Electron and Plasma Physics Laboratories (EPPL) at Comenius University in Bratislava employs advanced spectrometric techniques - emission spectroscopy (ES), mass spectrometry (MS), and ion mobility spectrometry (IMS).

Aim of the Research

The aim of the research was to combine experimental and theoretical methods to study electron-induced ionization, excitation, dissociation of molecules, electron attachment to molecules, and ion-molecule reactions. The outcomes of the research provided insights into the kinetics of processes (cross sections, rate constants) and the dynamics and thermochemistry of reactions (analysis of products and threshold energies for their formation), related to:
- electron-molecule reactions in the atmospheres of small celestial bodies, studied using ES,
- the role of low-energy electrons in nanotechnologies, studied via MS,
- the development of advanced spectrometric applications using IMS and IMS-MS,
- diagnostics of atmospheric electron sources and discharges using advanced spectrometric methods.

Achieved Results

The unique combination of EPPL's experiments focused on the study of elementary processes (Fig. 1) and their quantum-chemical interpretations, led to a range of original results.

We were the first to identify the detailed composition of the spectral bands of the most significant transition of O_2+ with electron-induced fluorescence. Based on calculations performed by colleagues from the Department of Physical and Theoretical Chemistry at the FNS CU, it is possible to determine the absolute cross sections for individual vibronic transitions in the O_2+ ion, experimentally indistinguishable. Following significant modernization of the experiment, emission cross sections for any process and energy can be extracted from the 2D spectral maps (Fig. 2, nitrogen emission), while previously published data are known only for a few individual points, which greatly facilitates the use of these results in further research.

We demonstrated the significant role of low-energy electrons in technological plasmas and their nanotechnological applications through MS measurements of dissociative ionization (oxazolines, phthalates) and dissociative electron attachment (DEA) to molecules and clusters (organometallics, halogenated hydrocarbons, silanes). Our DEA measurements on clusters are unique and the first of their kind; thanks to high energy resolution and theoretical calculations, we identified several ion-molecule channels leading to cluster formation (Fig. 3).

The detection and decomposition of various molecular isomers and conformers (phthalates, thiophenes, chlorinated hydrocarbons) was studied using IMS-MS. Combining with theory, we can determine the selectivity of protonation on different isomers and identify specific molecular decomposition reaction channels via atmospheric pressure chemical ionization (APCI). The variability of the IMS experiment also lies in the modification of the composition of reagent ions in the discharge (NH_3, CCl_4 dopants), and the subsequent application to molecules capable of charge retention at lower energies than in standard APCI (detection of plant hormones, Fig. 4).

As part of applied research, we developed various types of plasma sources and studied the physicochemical changes stimulated by their effect on water; activation through increased concentrations of hydrogen peroxide, nitrites, nitrates, conductivity, ORP changes, drop in pH. Its use in reducing Escherichia coli bacteria confirms the great potential of this technology as an alternative to conventional chemical methods (Fig. 5).

Benefits for Practise

The significance of the achieved results is reflected in the number of high-quality publications in peer-reviewed journals ranked in Q1 and Q2 categories, as well as in the citations these works have received. The diverse objectives of EPPL's fundamental research have led to outcomes applicable in astrochemistry (spectroscopic data of relevant molecules), the nanotechnology industry (electron and ion–molecule reactions of precursors), analytical chemistry (detection and decomposition of substances in the environment, as well as in the food, pharmaceutical, and agricultural industries).

Fig. 1 / Scheme of the electron and ion processes studied with the EPPL group at Comenius University in Bratislava.
Fig. 2 / The calibrated 2D emission spectral map of nitrogen, the absolute emission cross sections can be extracted.
Fig. 3 / The -CO and/or -NO ligand losses from the molecular dimer $[Co(CO)_3NO]_2$- measurements with the MS experiment vs CBS-QB3 reaction energies of (neutral)+[ion]- product pairs (with violet for M- accounted in the pair, with red for the typical DEA fragment, and with wine for rearrangement products like $[Co(CO)_4]$-).
Fig. 4 / IMS using corona discharge ion source with dopants used for measurement of three auxin plant hormones including indole-3-acetic acid (IAA), indole-3-propionic acid (IPA), and indole-3-butyric acid (IBA).
Fig. 5 / The effect of plasma-activated water generated on the reduction of Escherichia coli bacteria.

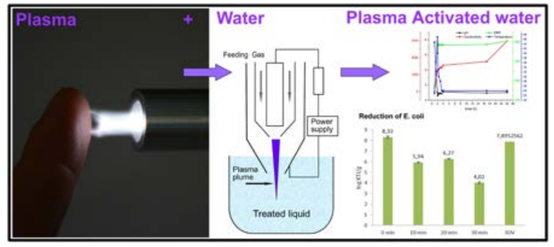


Fig. 5

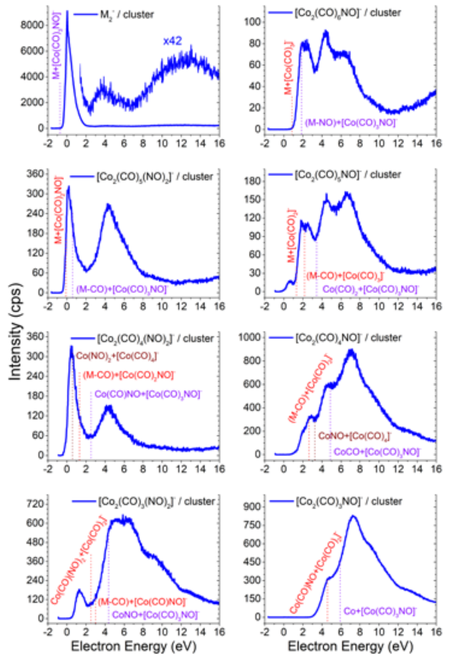


Fig. 3

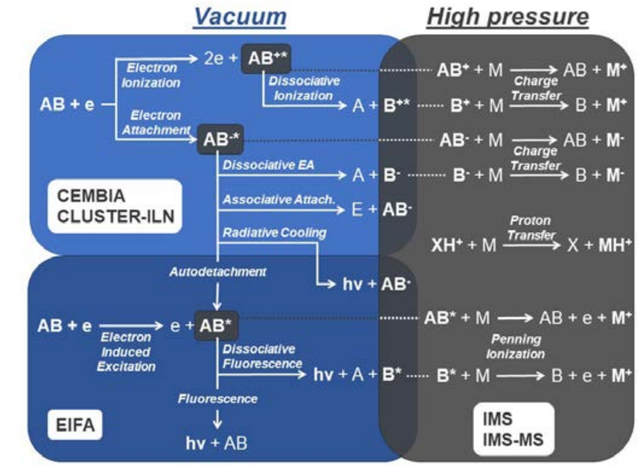


Fig. 1

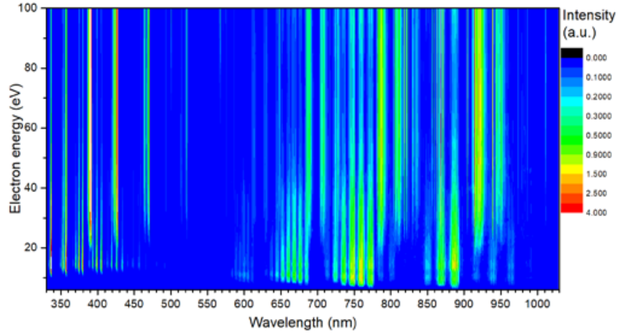


Fig. 2

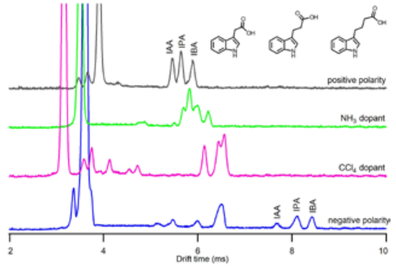


Fig. 4

Semiconductor Narrow Bandgap Ternary Chalcogenides

Principal investigator
RNDr. Sýkora Milan, PhD., MBA
Applicant organisation
Comenius University Bratislava - Faculty of Natural Sciences
Term of solution
07/2020 - 06/2024
Budget from agency
200 000 €
Project ID
APVV-19-0410

Research Subject

Perovskites are crystalline solids with the chemical composition ABX_3, where A, B are cations and X is an anion. A subset of these materials called organohalide perovskites (HPs) (Fig. 1a), in which A is an organic cation such as CH_3NH_3+, B is Pb^{2+}, and X is I^-, Br^-, or Cl^-, has generated tremendous interest in the past decade due to the record performance of solar cells using these materials as the optically active component. Despite their great potential, HPs are not yet widely commercialized mainly due to their low thermal and chemical stability, as well as the toxicity of the key component, lead. Structurally related chalcogenide perovskites (CPs) (Fig. 1b), in which A and B are cations such as Ba^{2+} and Zr^{4+}, respectively, and X is S^{2-} or Se^{2-}, have been proposed as a possible alternative based on theoretical studies. These studies suggested that CPs should have optical properties similar to HPs, better thermal and chemical stability, and can be possible prepared without the use of toxic elements. However, most of these predictions have not yet been confirmed experimentally, mainly due to the difficulty of preparing these materials using published procedures, requiring high reaction temperatures (>1000 °C) and times (weeks), incompatible with the fabrication of optoelectronic devices and often producing impure materials of low quality.

Aim of the Research

The key objectives of the project were: (1) Using systematic computational studies, identify nontoxic chemical compositions of CPs with highest practical potential; (2) Develop new synthetic procedures for the preparation of CPs that will produce materials of high quality, under conditions suitable for the preparation of photovoltaic and other optoelectronic devices; (3) Experimentally verify the theoretically predicted properties of CPs important for practical applications, such as optical properties, thermal and chemical stability, and the feasibility of their preparation in a form usable in optoelectronics.

Achieved Results

The key results of the project include: (1) First theoretical analyses of CP at the level of Ab-initio Molecular Dynamics, which identified $BaZrS_3$ and mixed compositions such as $BaZrS_xSe_{3-x}$ (x = 1 to 3) as the CPs with the most suitable properties for use in photovoltaics, and also quantitatively showed how and why the optical properties and crystal structure of CPs vary with temperature and the size of the comprising ions. (2) Development of new chemical approach for the preparation of CPs, allowing the first time their preparation at temperatures below 600 °C and with reaction times hours to minutes, from a wide range of starting materials, by using innovative reducing agents such as boron sulfides (Fig. 2). Preparation of a series of CPs: $BaZrS_3$, $SrZrS_3$, $BaHfS_3$, $SrHfS_3$ using the new method, in the form of powders, pellets and thin films (Fig. 3a, b). (3) New method for the preparation of nanocrystalline $BaZrS_3$ CP, without toxic reagents, at temperatures below 350°C (Fig. 3c). (4) New synthetic procedure for the preparation of CPs with mixed compositions. (5) Detailed experimental analyses of the prepared CPs, quantitatively confirming that CP are thermally and chemically much more stable than HPs (Fig. 4). The results of the project are summarized in 33 publications, one monograph, one Slovak and one international patent application. Of these, 5 publications are in the Nature Index category and one publication was highlighted as a journal cover page study. The results of the project have been presented in 24 presentations at international scientific conferences.

Benefits for Practise

The results of our theoretical analyses reveal not only which CPs have significant practical potential but also how the properties of these materials can be tuned by changes in chemical composition and temperature, which is critical for the design and optimization of new CP materials. With significantly reduced reaction temperatures and times, the new CP preparation methods developed in the project allow for the first time integration of CP into solar cells and other optoelectronic devices using conventional commercial approaches. Our experimental studies have confirmed that the nontoxic materials prepared by the new methods are chemically and thermally more stable than the intensely studied HPs. The methods and materials developed in the project have already attracted commercial interest in form of patent licensing agreement and collaborative development of CP optoelectronic devices.

Fig. 1 / (a) Crystal structure of (a) organo-halide perovskite (HP) $CH_3NH_3PbI_3$ and (b) chalcogenide perovskite (CP) $BaZrS_3$. Relative sizes of ions are shown in scale.
Fig. 2 / Top: Scheme of the synthetic procedure for the preparation of CP from various starting materials by sulfurization with boron sulfides. The symbols A, B shown in italic represent metal cations, letter B in the standard font represents boron. Bottom: Energy diagram showing relative enthalpies of sulfurization in the absence and presence of boron.
Fig. 3 / (a) Powder X-ray diffraction patterns (blue) of CPs prepared from the corresponding ABO_3 oxides and literature reference patterns (orange). Green curves represent the temperature programs used in the preparation of the materials. (b) Diffraction pattern of a $BaZrS_3$ thin film prepared by the method in Fig. 2. (c) Microscopy image of a $BaZrS_3$ nanocrystal with a size of ~5x10 nanometers.
Fig. 4 / Thermal phase and chemical stability map of selected HPs and CPs

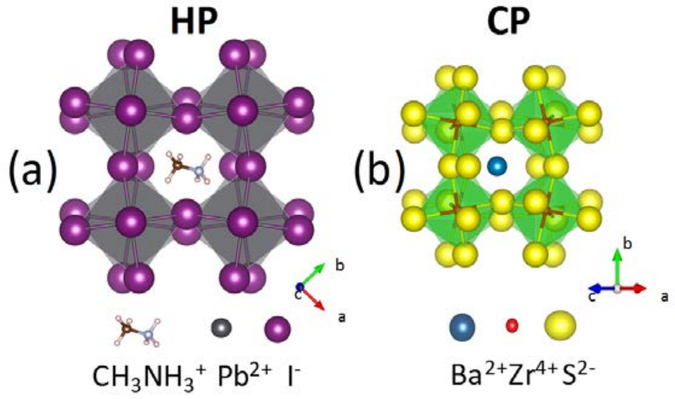


Fig. 1

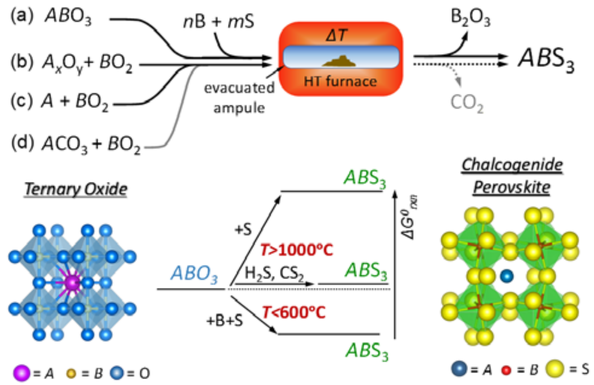
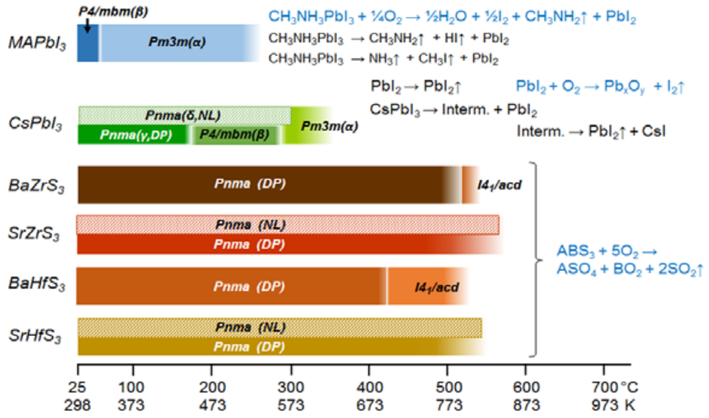


Fig. 2



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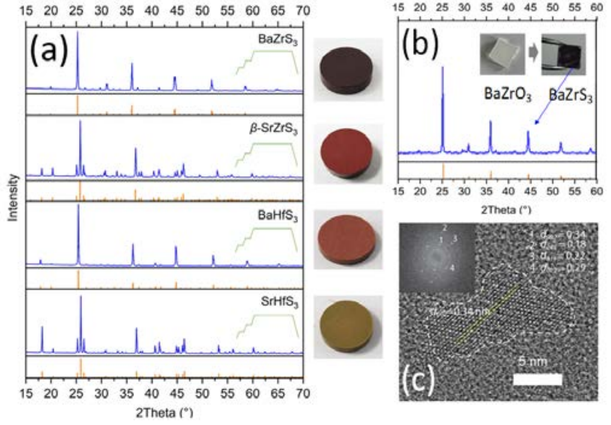

Fig. 3

Hybrid Low Dimensional Layered Materials with new Functionalities

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Participating organisation
Institute of Physics, Slovak Academy of Sciences
Term of solution
07/2020 - 12/2023
Budget from agency
220 000 €
Project ID
APVV-19-0465

Research Subject

Project focuses on the preparation of new types of 2D inorganic MXene materials and preparation of new types of perovskite quantum dots (PQDs), materials of 0D type. From prepared MXenes of different types and modified PQDs innovative bilayers will be prepared. Their arrangement - monolayer of PQDs on monolayer of MXene on solid substrate and complex characterization of their formation and structural, optical and electronic properties, measurement of photoluminescence in dependence of MXene and PQDs particles parameters will provide new knowledge, which can be used in the application of these new materials in optoelectronics.

Aim of the Research

The project aims to address the most current research challenges in the field of 2D materials - MXenes and perovskite quantum dots (PQDs) and their incorporation into innovative perovskite photovoltaic and optoelectronic structures. In addition to gaining new knowledge about properties and processes, the project is expected to contribute to the preparation of new structures based on PQDs and MXene particles with modified composition.

Achieved Results

PSCs were fabricated on ITO-coated glass substrates measuring 19.2 × 19.0 mm with a sheet resistance of ≈7 Ωsq-1 (Fig. 1). We observed an increase in perovskite grains on the MXene-modified SnO2 layer for all concentrations used. No detailed mechanism has been proposed yet to explain the beneficial effect of electron transport layer (ETL)-modified MXene on the perovskite grain size. Modification of the SnO2 layer with 0.1 wt. % MXene resulted in an increased perovskite grain size, as confirmed by SEM analysis (Fig. 2). In particular, the average perovskite grain size reaches 492 nm compared to 475 nm on the pure SnO2 layer (Fig. 2). The increased size of perovskite grains on the MXene-modified SnO2 ETL compared to the pure SnO2 ETL was confirmed. During annealing, an increasing number of grains was observed using in situ GIWAXS. These results are interpreted using a nucleation and growth model. The increased power conversion efficiency from 17.4% to 18.3% (Fig. 3) of the methylammonium lead iodide perovskite solar cell after modification of the SnO2 ETL with 0.1 wt.% MXene type Ti3C2Tx is the result of two contributions (i) the increased electrical conductivity of the modified ETL and (ii) the improved crystallinity and larger size of the perovskite grains compared to the perovskite layer grown on the pure SnO2 ETL, which reduces the total boundary area and charge recombination at defect states (traps) that typically form at the grain boundaries.

Benefits for Practise

New insights in the field of solar cell preparation that can contribute to stable and efficient solar cells.

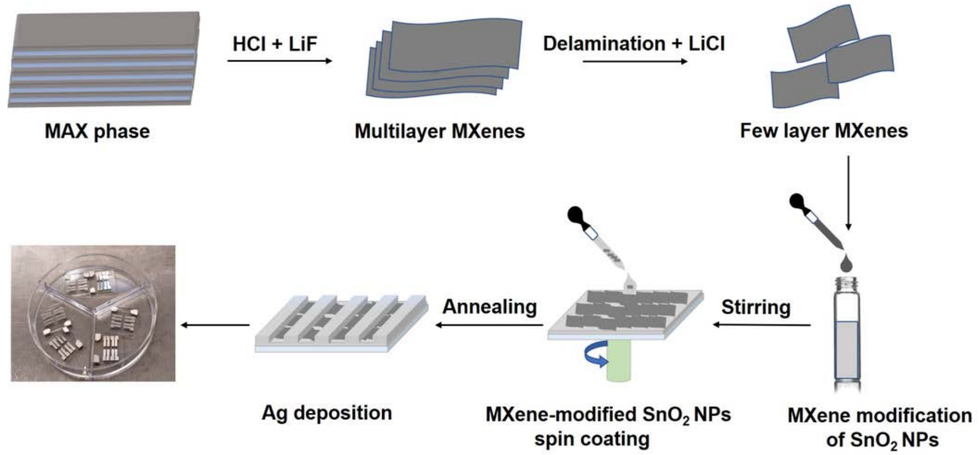

Fig. 1

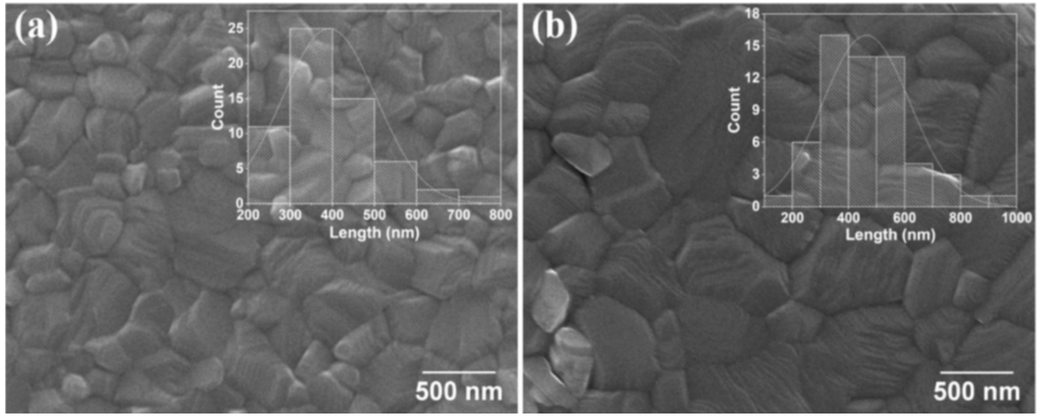

Fig. 2

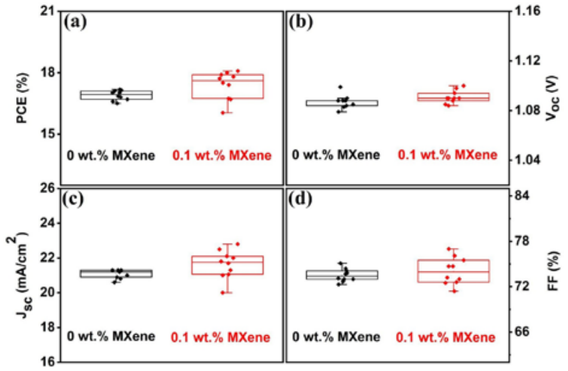

Fig. 3

Fig. 1 / Scheme of PSC preparation and layer characterization.
Fig. 2 / SEM images of the MAPI layer on the (a) 0 wt.% and (b) 0.1 wt.% MXene-modified SnO2 layer.
Fig. 3 / Statistics of the photovoltaic parameters of the devices with the 0 wt% and 0.1 wt% MXene-modified SnO2 ETLs.

Bionanocomposites based on organic polycations and layered silicates

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07/2020 - 06/2024
Budget from agency
220 000 €
Project ID
APVV-19-0487

Research Subject

Preparation and complex characterization of composite materials consisting of layered silicates from smectite group and commercially available cationic and non-ionic polymers and new synthesized copolymers.

Aim of the Research

To prepare nanocomposites with interesting biocompatible properties based on montmorillonites (Mnt) and poly(2-oxazolines) (POx). To follow the effect of various factors on the properties of prepared materials by experimental and computational DFT methods. To investigate in vitro cytotoxicity of synthetised copolymers and their intercalates with Mnt. To study modified smectites due to their possible applications as adsorbents of dangerous compounds and as fillers to selected polymers.

Achieved Results

Two series of the samples were prepared by intercalation of cationic poly(ethylenimine) (PEI) and non-ionic poly(2-methyl-2-oxazoline) (PMeOx). Different charge of polymers affected the extent of their intercalation into Mnt. While PEI was intercalated only up to the cation exchange capacity (CEC) of Mnt, for PMeOx the value of intercalation was the over CEC. Ab initio DFT method showed that both polymers are anchored onto the basal surface of Mnt through moderate to weak hydrogen bonds. The calculated intercalation energies correlated well with the strength of the H-bonds and confirmed the high stability of both hybrid materials. The models based on other smectites (beidellite, saponite, hectorite) and PMeOx were prepared the effect of smectite on the mechanical properties of the polymers was studied. Water dispersions of the samples consisting of the same concentration of Mnt and different concentration of PMeOx, poly(2-ethyl-2-oxazoline) (PEtOx) and poly(2-propyl-2-oxazoline) (PPrOx) were prepared. Based on adsorption isotherms the highest adsorption ability was found for PMeOx, lower values were achieved for PEtOx and PPrOx. PDDA polycation was used for the preparation of multicomponent films by “layer by layer” (LBL) method. Fluorescent spectroscopy was applied for the characterization of the films fotoactivity and determination of the effectivity of the energy transfer. Due to the LBL method more than 90% of the resonance energy transfer between dyes was reached.

Copolymers based on poly(2-ethyl-2-oxazoline-co-ethyloene imine)s (PEtOx-co-PEI) of different composition were prepared in living cationic polymerization and partial hydrolysis and tested toward in vitro cytotoxicity using MTT cell proliferation assay on mice 3T3 fibroblasts. The copolymer with 22 mol% of PEI units was biocompatible up to the concentration of 20 mg/mL and the copolymer with 55 mol% PEI can be considered as non-toxic up to 5 mg/mL. Modification of Mnt with cationic copolymers improved their biocompatibility. With increasing loading of copolymers in Mnt up to 500 mg/g, in vitro cytotoxic effect of Mnt was completely diminished. Mnt modified with PEtOx-co-PEI with different content of PEI were used for the study of the adsorption and decontamination of organophosphate paraoxon as potent parasympathomimetic agent with strong neurotoxic effects.

Hydrolytic decomposition of paraoxon in the presence of Mnt modified with PEtOx-co-PEI was compared with decomposition of paraoxon in the presence of non-modified Mnt. Non-modified Mnt was able to adsorb paraoxon but without further decomposition. In the case of PEtOx-co-PEI modified Mnt, PEI units participated on the basic hydrolysis and simultaneous sorption and decomposition of paraoxon were observed. Nanocomposites consisting of natural rubber and nanofillers based on Mnt modified with PEtOx and PEtOx-co-PEI polymers were prepared. The presence of nanofillers has a significant effect on the tensile strength and elongation at break, which are higher for carbon black-containing materials compared to carbon black-free composites. At the same time, PEtOx has proven to be a suitable modifier for modification of Mnt as an additive to increase the strength of rubber compounds, for example, in some tire parts.

Benefits for Practise

The results of the project showed great potential of the polymers from the POx group for the modification of Mnt. POx is suitable for the application in vivo and in vitro. According to the study on the decontamination of paraoxon, montmorillonites modified with POx are non-toxic materials suitable for health and environment protection. PEtOx is also proper polymer for the surface modification of Mnt as additives for tyre threads exhibiting optimal balance between fuel consumption and driving properties of the cars.

Fig. 1 / Preparation and characterization methods of the composite materials based on montmorillonite and selected polyoxazolines.
Fig. 2 / Thermogravimetric curves (A) and XRD patterns (B) of PMeOx-Mnt samples prepared with different amount of polymer.
Fig. 3 / Improvement of in vitro biocompatibility of Mnt after modification with PEtOx-co-PEI with 22 mol% using various copolymer loadings.

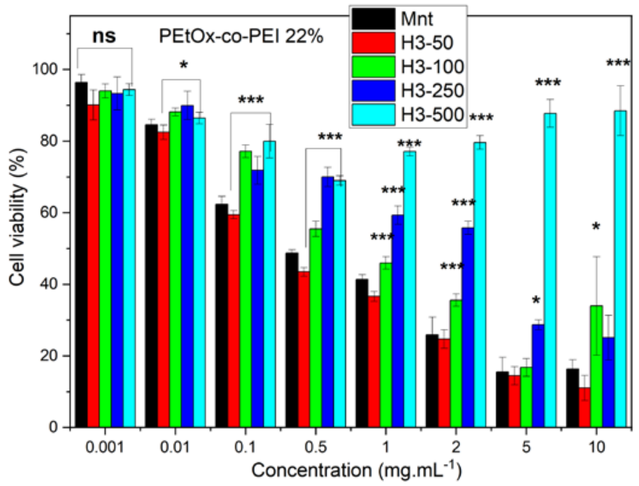

Fig. 3

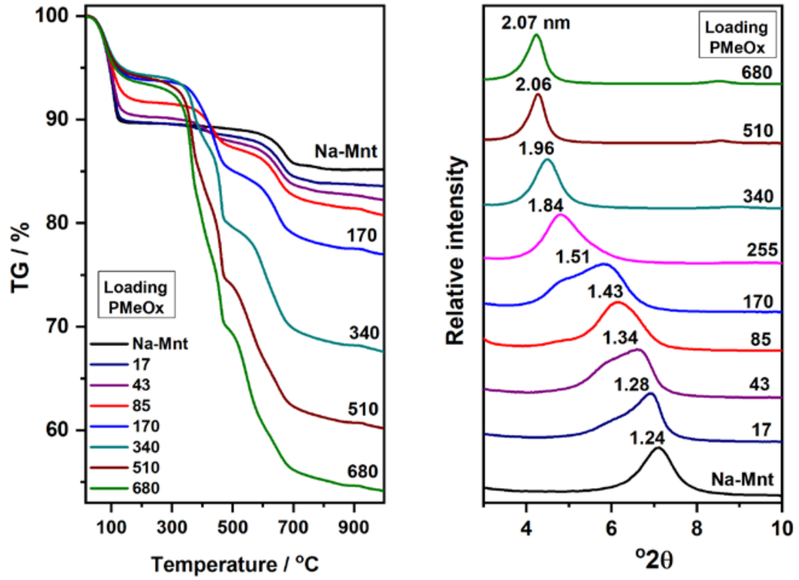

Fig. 2

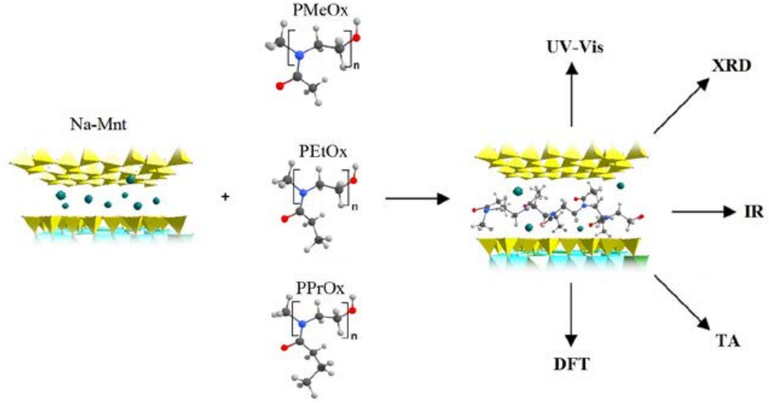

Fig. 1

Development of tools for advanced analysis and prediction of parameters of EPR, NMR and pNMR spectra of complex systems containing heavy elements

Principal investigator
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Term of solution
07/2020 - 06/2024
Budget from agency
150 000 €
Project ID
APVV-19-0516

Research Subject

The project is devoted to the development of new quantum-chemical tools for the investigation of spectroscopic properties of compounds containing heavy elements.
The presence of heavy elements demanded the inclusion of relativistic effects. The use of Density Functional Theory allows the application of developed methods to moderately large systems containing more than 100 atoms.

Aim of the Research

The main goals of the grant proposal can be briefly formulated as follows:
1) Development and implementation of new quantum-chemical methods for accurate calculation of paramagnetic NMR shifts for heavy-element compounds with low-lying exited states. That would require further development of the methodology based on four-component and two-component TDDFT approaches for calculation of properties of excited states.
2) Development and implementation of new quantum-chemical methods for interpretation of EPR, NMR and pNMR parameters.
3) Application of the developed approaches for systems of real chemical interest (including transition metal complexes)

Achieved Results

1)The exact two-component (X2C) TDDFT represents a computationally efficient alternative to the more accurate but more expensive four-component TDDFT. To improve the accuracy of the X2C TDDFT, we have developed and implemented a simple way to take into account the picture change (PC) effects for the two-electron terms.
We have investigated the formal and numerical aspects of collinear and noncollinear density functionals in the context of relativistic two-component methods and proposed a screening procedure that allows to efficiently treat small magnetization points that would otherwise be problematic.
We have implemented the GIAO approach for relativistic four-component calculations of EPR g-tensors based on the Dirac-Coulomb Hamiltonian with a restricted magnetically balanced basis.

2) To analyze the spectroscopic properties of complex systems containing heavy elements, the concept of relativistic spin-orbit electronegativity was introduced, which is associated with the interatomic distances between heavy and light elements and the spin-orbital correction for NMR shielding.
To investigate the quadratic spin-orbit effects on the EPR g-tensor of heavy element compounds, we implemented an analysis of the contributions of molecular orbitals based on the third-order perturbation theory.
Two theoretical approaches were developed to distinguish the “through space” and “through bond” contributions to indirect NMR spin-spin interactions in complex systems.
A by-product of our work on the analysis of spin-spin interaction pathways was an approach to evaluate the effect of pi-orbitals on the transfer of spin polarization.
We used a new approach to study the role of pi-orbitals for various aspects of the spin-spin interaction constants and the hyperfine structure constants.

3) The first applications of the developed methods are mentioned in the previous point. Among other applications, we would like to mention the following works.
In collaboration with the University of St Andrews, UK, we investigated the NMR parameters in transition metal phosphine and selenoether complexes of peri-substituted acenaphthenes. The presence of heavy elements such as Ag, Pd, Pt and Hg required consideration of relativistic effects.
The calculation of J(Hg-P) and J(Hg-Se) requires the use of four-component relativistic methods. This was a challenging task, since some of the complexes contain 112 atoms, including two Hg and several other heavy elements. We were pleased to see that the current efficiency of our ReSpect code was in line with this challenge.
We also worked on the calculation of X-ray absorption spectra near the L- and M-edges using a relativistic four-component time-dependent DFT approach (4c-DR-TDDFT). The calibration of the method allowed us to reproduce the experimental L2,3-edge X-ray absorption spectra of [RuCl2(DMSO)2(Im)2] and [WCl4(PMePh2)2] and to split the broad bands into separate lines, which allows for an interpretation based on ligand field theory and double point groups.
The results of our work were published in international CC journals with an impact factor from 2.7 to 16.4, which indicates the high quality of scientific work within the APVV-19-0516 project. In conclusion, we state that all project objectives were fully met.

Benefits for Practise

The developed computational tools can assist research in different areas of chemistry including drug design, development of new materials, treatment of nuclear waste etc.

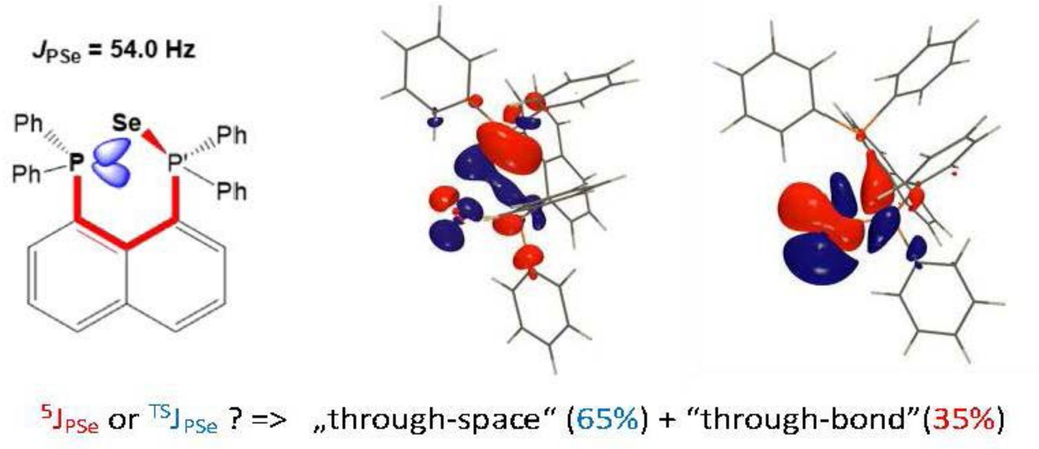

Fig. 1 / NMR indirect spin-spin couplings contain invaluable information for structure determination especially in solution when other techniques such as X-Ray are not available. However, this information cannot be extracted without understanding the structure-property relation in system under study. Computational approaches that allow the visualisation of individual transmission pathways and estimation of their relative weight have been proposed. The approaches are applicable to large systems with complex interaction of the nuclear magnetic moments. Moreover, a general picture of the transmission pathways in a complex system can be further refined by the contributions from individual molecular orbitals or their pairs related to any particular fragment of the structure. [Olga L. Malkina, Jean-Cyrille Hierso and Vladimir G. Malkin, J. Am. Chem. Soc. 2022, 144, 10768–10784]

Fig. 1

TECHNICAL SCIENCES

Advanced materials with eutectic microstructure for high temperature and functional applications

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Term of solution
07/2020 - 06/2024
Budget from agency
247 580 €
Project ID
APVV-19-0010

Research Subject

Ceramic materials with eutectic microstructure have technological and commercial potential due to their high-temperature properties and their role as optically active materials applicable in photonic applications and energy-efficient lighting sources. In most cases, such materials are prepared by controlled solidification of melts, which requires expensive and technologically demanding experimental equipment and high energy costs. The subject of the current project was the development and optimization of alternative methods for the preparation of such materials at significantly lower temperatures, with the aim of reducing the energy demands and environmental impact of their production.

Aim of the Research

The objective of the project is the preparation of ceramic materials with a eutectic microstructure (i.e., a microstructure containing two or more crystalline phases percolating at the submicron level) in RE_2O_3–Al_2O_3–(ZrO_2) systems, where RE = Y, Yb, La..., potentially doped with optically active rare earth elements (Er, Eu, Ce), exhibiting exceptional high-temperature mechanical properties (resistance to high-temperature deformation) and luminescence across a broad range of the electromagnetic spectrum. The alternative preparation methods developed within the project—such as controlled crystallization of glass frits of the desired composition, or the preparation of precursor powders with eutectic composition using chemical methods followed by sintering under increased pressure (hot pressing, SPS)—reduce the energy demands of producing these materials and thus open the door to broader commercial use.

Achieved Results

Alternative preparation methods for ceramic composites in the Al_2O_3–Y_2O_3 and Al_2O_3–ZrO_2–Y_2O_3 systems were developed and optimized. These methods require significantly lower temperatures and shorter preparation times compared to the previously established melt-solidification techniques for these materials. The SPS (Spark Plasma Sintering) method allows the preparation of a wide range of qualitatively distinct microstructures under precisely defined conditions (Fig. 1, 2).

For the prepared materials, relationships were defined between their chemical composition, preparation conditions, and physical properties. Special attention was given to mechanical properties at room temperature (hardness, fracture toughness) and resistance to high-temperature deformation (creep) at temperatures up to 1450 °C. The prepared materials achieved Vickers hardness values around 17 GPa and fracture toughness values around 4.5 MPa·$m^{0.5}$. The addition of ZrO_2 improved the resistance to high-temperature deformation.

Materials with eutectic microstructure doped with optically active rare earth elements—especially Er, Yb, and Nb—were also prepared and optimized. In the latter case, the method of direct melt solidification was also optimized at the partner institution UNIZA for the preparation of such materials. Intense red luminescence was confirmed in Er-doped materials, and its intensity could be enhanced via charge compensation using lithium ions. Materials co-doped with Li and Er exhibited intense red or green luminescence through up-conversion of infrared excitation radiation (Fig. 3). The ratio of red to green luminescence could be modified by adjusting the type and amount of dopants.

Benefits for Practise

The prepared materials are particularly useful due to their outstanding mechanical properties (hardness, fracture toughness, resistance to high-temperature deformation) and their high chemical and thermal resistance (resistance to oxidation at high temperatures). These advantages result from the strong phase interface bonding, making the materials suitable for high-temperature applications (e.g., gas turbine blades, aircraft engine components, spacecraft parts, and more).

Currently, there are no other materials available that can be used long-term in strongly oxidizing environments at temperatures above 1650 °C. A prime example is the eutectic ceramic composite material Al_2O_3–ZrO_2–Y_2O_3, with a maximum operating temperature of approximately 1650 °C—substantially higher than that of current nickel-based superalloys (1050–1100 °C), oxide ceramics (≈1400 °C), or nitride ceramics (1350 °C).

Other potential applications for eutectic ceramic materials include optical devices or new types of fluorescent materials for LED lighting.

Fig. 1 / SEM microstructure of samples produced from partially calcined powders subjected to heat treatment at 1000˚C for (A) 3 h, and (B) 5 h. Note different magnification of images.
Fig. 2 / EBSD band contrast map of a selected area of samples produced from partially calcined powders
Fig. 3 / Photoluminescent up-conversion spectra of crystallized samples measured at an excitation wavelength of 980 nm.

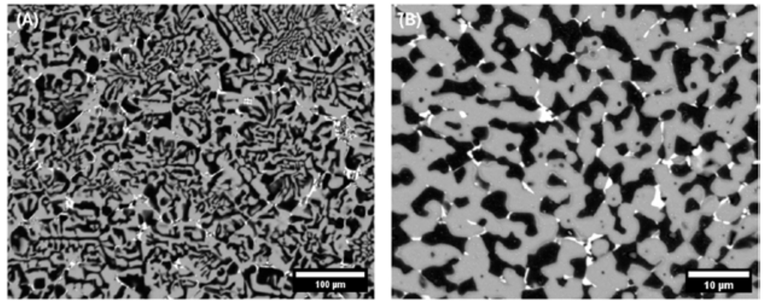

Fig. 1

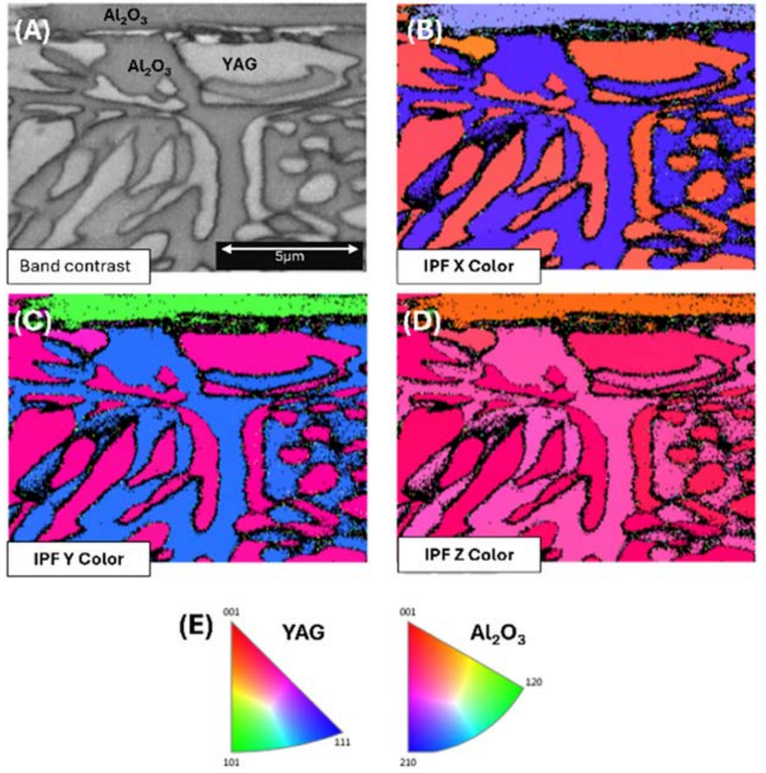

Fig. 2

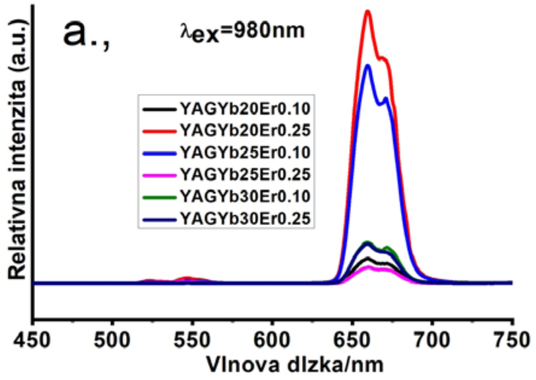

Fig. 3

Elastomer composite and blended materials with addtives from renewable resources

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Participating organisations
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Term of solution
07/2020 - 06/2023
Budget from agency
250 000 €
Project ID
APVV-19-0091

Research Subject

The project was focused on research and development of new materials prepared by application of untraditional components originating from renewable resources and magnetic active or hybrid fillers into elastomer compounds as well as development of new vulcanization systems for rubber materials.

Aim of the Research

The goal of the research was to clarify the application possibilities of biopolymer materials as additives in rubber compounds. The attention was aimed at searching of efficient ways of surface modifications of biopolymers and elastomer matrices with the view to improve their mutual compatibility. Application of magnetic active fillers into rubber compounds results in the fabrication of ferrite rubber composites with the effect of magnetic and electromagnetic radiation shielding.

Achieved Results

In the case of composites with the ability to shield electromagnetic radiation the research was focused on the application of magnetic soft ferrites, manganese-zinc and nickel-zinc ferrite into rubber compounds. The results revealed that composites filled with ferrites are able to efficiently shield electromagnetic radiation by absorption mechanisms, so that the radiation could be efficiently absorbed by the shield and not emitted back to the surrounding. To modify physical-mechanical as well as shielding properties, ferrites were combined with carbon based fillers (carbon black, carbon nanofibres, carbon nanotubes, graphite and graphene). Their combination led to the enhancement of physical-mechanical properties of composites, but to the modification of shielding properties, too. Then, the mutual combinations of both ferrites were tested. The results demonstrated that by combination of ferrites it is possible to modify the absoprtion shielding ability in targeted manner. The combination of ferrites with carbon based fillers resulted in the improvement of physical-mechanical as well as shielding properties. When considering the rubber materials with incorporated biopolymer additives, the research was focused mainly on the application of calcium lignosulfonate. First, lignosulfonate was incorporated into different rubbers. It was demonstrated that due ti its polarity, biopolymer filler has a higher compatibility with polar rubbers. For cross-linking of rubber matrices, not only sulfur curing systems, but also peroxide curing systems were used. The achieved results pointed to the fact that not only sulfur, but also peroxide curing systems can be efficiently used for cross-linking of rubber compounds filled with calcium lignosulfonate. The combination of biopolymer filler with reinforcing fillers (carbon black) resulted in the improvement of physical-mechanical and application properties of the materials. As calcium lignosulfonate acts as inactive filler, the aim was to investigate the possibilites to modify the biopolymer component to improve the adhesion and compatibility on the phase interface filler - rubber. A very easy way to do it is to use some plasticizers. The results demonstrated that application of plasticizers resulted in higher distribution and dispersion of the biopolymer filler and to the enhancement of adhesion between the rubber and the filler. This led to the improvement of physical-mechanical properties of composite systems. Within the frame of the project, the fabrication conditions of composite materials in lab-scale, semi-industrial and industrial conditions were optimalized.

Benefits for Practise

Composite materials based on rubber matrices and magnetically active fillers represent a new generation of special materials with high added value for applications in various areas of human activity, especially in the form of sensors and elastic materials with shielding effects of magnetic and electromagnetic fields. The application of elastomer magnetic composites in the form of shielding materials will simultaneously enable the reduction of electromagnetic smog emissions, which will significantly contribute to the protection of the functionality of electronic devices, the environment and the protection of human health, as well as the health of living organisms. The use of biopolymers from renewable raw materials as components of elastomer compounds will lead to an improvement in the ecological and economic aspect, especially in terms of reducing the cost of final products and the use of secondary raw materials. At the same time, this will have a positive effect on reducing the carbon footprint with a direct positive impact on the Earth's climate conditions.

Fig. 1 / Frequency dependences of return loss RL for composites filled with manganese-zinc ferrite, nickel-zinc ferrite and their combinations
Fig. 2 / Influence of plasticizers on tensile strentgh of elastomer composite materials
Tab. 1/ Electromagnetic absorption parameters of composites filled with manganese-zinc ferrite, nickel-zinc ferrite and their combinations (RLmin - minimum value of return loss at a matching frequency fm, fm - matching frequency, df (MHz) – 10dB, – 20dB - frequency bandwidth for return loss – 10 dB, resp. – 20 dB

Vzorka	RL_{min} (dB)	f_m (MHz)	Δf (MHz) -10 dB	Δf (MHz) -20 dB
Mn300	-58	2660	2500	740
Mn200Ni100	-49	3980	3600	1160
Mn150Ni150	-63	3250	3800	1130
Mn100Ni200	-69	4140	3800	1530
Ni300	-62	5260	3750	2090

Tab. 1

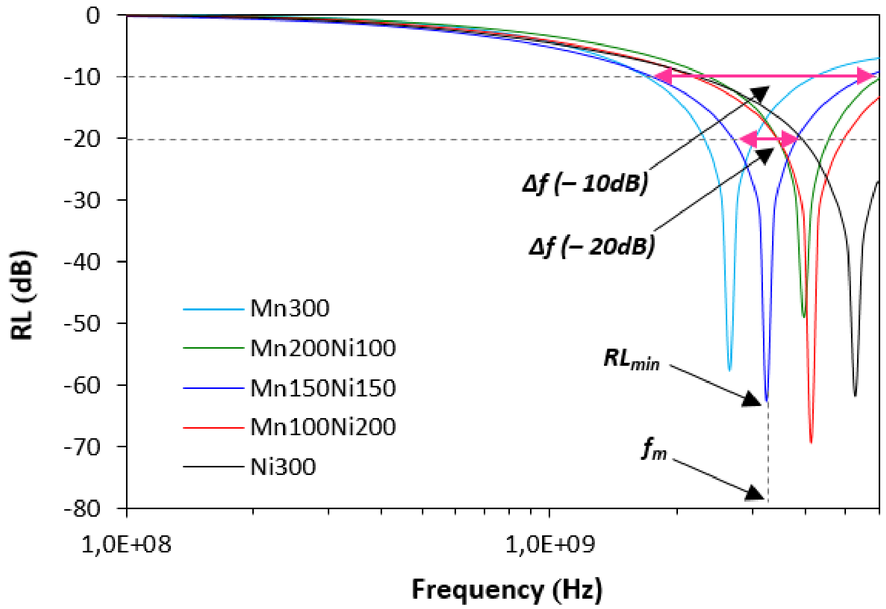

Fig. 1

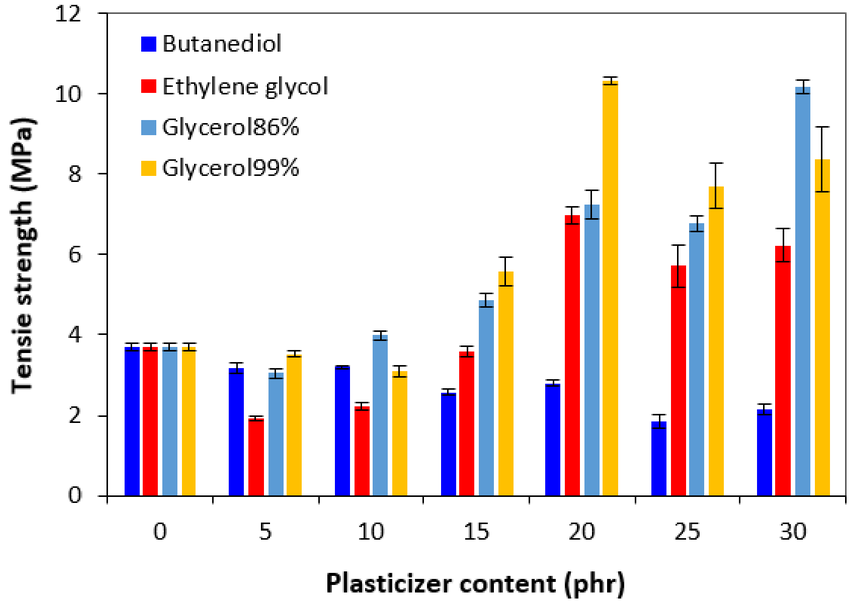

Fig. 2

Innovations in analytical systems for sustainable and safety environment

Principal investigator
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Applicant organisation
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– Faculty of Chemical and Food Technology
Participating organisation
State Geological Institute of Dionýz Štúr
Term of solution
07/2020 - 06/2024
Budget from agency
210 310 €
Project ID
APVV-19-0149

Research Subject

The project was dedicated to the development and innovation of ecological, rapid and efficient analytical methods for monitoring toxic organic substances such as pesticides, pharmaceuticals and nitroaromatic compounds at ultra-trace concentrations. The presence of environmental endocrine disruptors represents a key marker for monitoring the impact on the human organism. To achieve low limits of determination in environmental samples, the project focused on the combination of advanced ecological extraction and microextraction techniques, sample preparation and determination of analytes by chromatographic methods using appropriate detection, predominantly methods of mass spectrometry.

Aim of the Research

The project aim was to develop new rapid, robust, efficient and environmentally friendly analytical methods using extraction/microextraction for monitoring organic substances from the group of pesticides in water samples and to develop rapid microextraction methods for the preparation of geological and forensic samples from the environment (contaminated soil, post-blast residues) with subsequent chromatographic separation and detection by mass spectrometry. The development of optimized procedures for the combination of instrumental extraction methods with purification and pre-concentration procedures with minimizing the volume of organic solvents used for monitoring pesticide residues in solid samples was planned, as well as the validation of the developed GC, GC-MS(/MS) and LC-MS/MS methods.

Achieved Results

Solving the project the innovations in analytical systems for selected groups of toxic environmental contaminants as well as for the simultaneous determination of multiple groups of contaminants, which brings significant benefits in terms of analysis speed for laboratory throughput, price and environmental aspects were presented. Several multianalyte and "multifamily" analytical methods were proposed. Method arrangements in which optimal validation parameters were achieved without the need for extraction of analytes with direct analysis of groundwater samples are significant. For complicated matrices such as sediments, methods with an optimized sample preparation step for simultaneous extraction and purification of the extract in one step were introduced. Solvent-free procedures were developed as well as procedures with minimizing the volume of extraction solvents to the level of units of microliters. Single-drop microextraction and microextraction with a sorbent filled in a microsyringe were used to isolate nitro compounds and pesticides from forensic and environmental samples. Methods for the analysis of sediments and surface water samples to monitor contaminants from the group of pesticides and fungicides (fipronil, organotin substances) will be used for the purposes of monitoring studies. Methods for the simultaneous determination of pesticides, pharmaceuticals and perfluorinated substances by LC-MS/MS have been developed for the monitoring of contaminants in accordance with the Water Directive and the Environmental Quality Standards. Matrix effects bring fundamental problems in environmental analysis. The solution to this issue has resulted in published studies that evaluate matrix effects and bring solutions to minimize and eliminate these effects. Innovative methods have been developed for advanced inspection of the degradation of contaminant components in environmental water purification applications, such as industrial water. The issue of remediation of contaminated water using the electrocoagulation technique with the possibility of valorization of the resulting sludge for reuse was addressed.

Benefits for Practise

The project was a basic research project and the results obtained by its solution contribute to the development of environmental chemistry, analytical chemistry and bring fundamental results for the field of watercourse protection. The methods are useful in the monitoring of environmental contaminants, in the issue of synergistic valorization of industrial water and in forensic investigation. The results were published in the form of 18 publications registered in WOS and 89 other contributions or abstracts. The international scientific conference ACP 2022 and the SEMMLAD conference of young innovators were organized. Students were involved in the solution of the project (9 dissertations, 28 diploma and 11 bachelor's theses). International cooperation with universities in Europe and business entities was developed.

Fig. 1/ Multianalyte analysis of groundwater with the investigation of matrix effects.
Fig. 2/ Procedure for monitoring organotin compounds in sediments.
Fig. 3/ Industrial water treatment investigating the contaminant removal efficiency factors.
Fig. 4/ Procedure of the analytical method based on single-drop microextraction combined with gas chromatography and mass spectrometry.

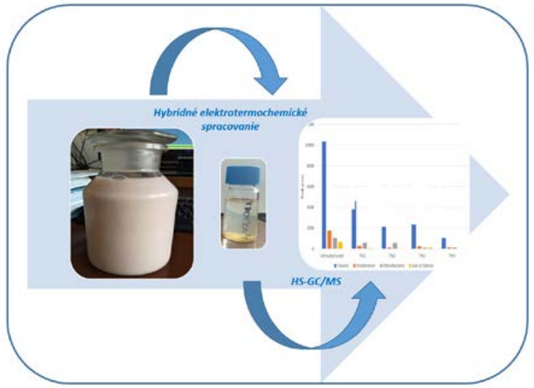

Fig. 3

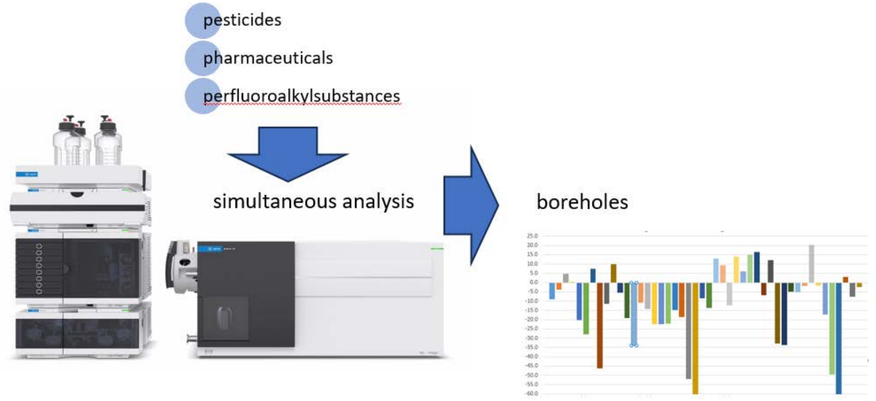

Fig. 1

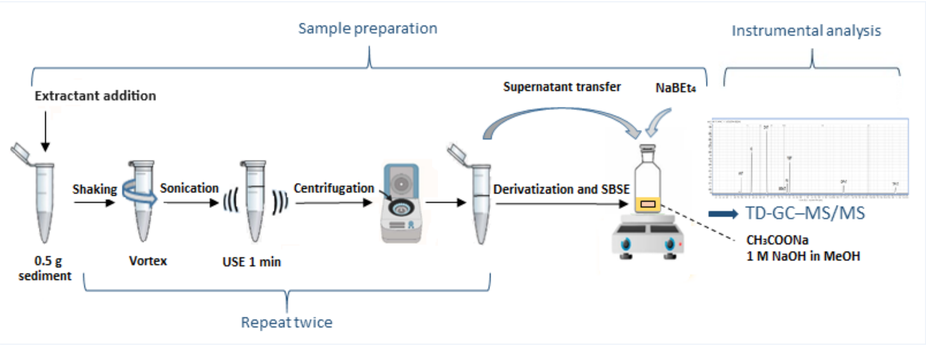

Fig. 2

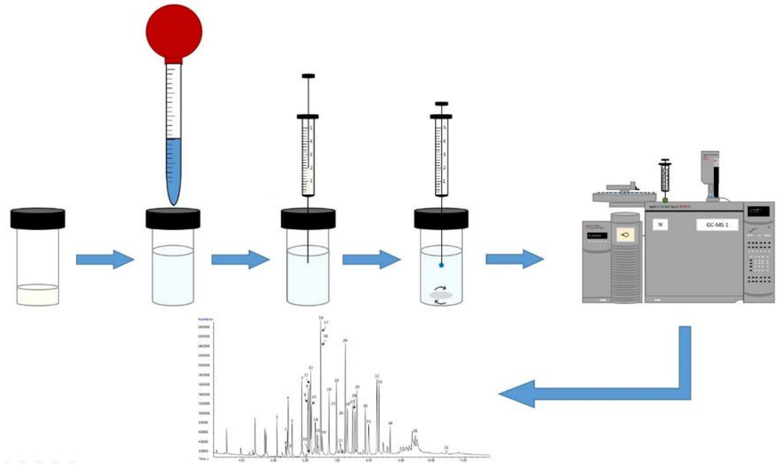

Fig. 4

HIL Emulator for Small Hydropower Plant Control

Principal investigator
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Applicant organisation
Technical University of Kosice - Faculty of Electrical Engineering and Informatics
Term of solution
07/2020 - 06/2023
Budget from agency
234 319 €
Project ID
APVV-19-0210

Research Subject

Small Hydroelectric Power Plants (SHPs) are relatively simple, technically undemanding energy structures whose importance in electricity generation has been continuously growing worldwide over the past decades.

Systematic and rational design of SHPs, as well as the investigation of their dynamic properties, requires the development of technical and software tools that enable the efficient creation of high-quality implementation projects—that is, within a short timeframe, with a high degree of reliability, and at minimal cost.

Among the key features of these tools must be sufficient computational performance, universality, and flexibility—meaning they should be applicable to a wide range of systems, from small hydroelectric plants to large power blocks with various parameters, and capable of connection to real-world technology using standardized electrical signals.

Aim of the Research

The main objective of the project was the design and implementation of a technical tool for the design and control of small hydroelectric power plants (SHPs), specifically a HIL (Hardware-in-the-Loop) emulator for SHP control along with the corresponding software, which was experimentally verified using real data obtained from measurements of an actual technology in practice.

This main objective was achieved through the following four specific goals:
1. Development of models for individual energy and control subsystems of SHPs and their appropriate control structures.
2. Design and implementation of the technical components of the SHP HIL emulator.
3. Software implementation and optimization of SHP control in a DCS (Distributed Control System), and its verification using experimentally measured data.
4. Collection of experimental data from a real SHP and its physical model.

Achieved Results

The main result of the project is a prototype of a universal SHP (Small Hydroelectric Power Plant) emulator with the capability to study its energy subsystem, specifically an asynchronous-type electric generator.

The emulator consists of two AC drives equipped with standard frequency converters and three-phase induction motors, which are connected by a solid shaft. The first drive simulates the hydromechanical part of the SHP along with its control, while the second drive physically emulates the electric generator and the turbine's electrical load.

The control system for the first drive is a PLC from the company B@R, equipped with software for modeling, visualization, and control of SHP modules. The control system for the second drive is a PLC unit from Schneider, intended for programming various types of electrical networks.

As part of the scientific research component of the project, the basic SHP modules were designed, programmed, and verified. These were used to assemble a complete model that includes a fuzzy model of turbine efficiency. For this model, the dynamic processes of the electromechanical subsystem were analyzed during the three main startup phases of the SHP: turbine acceleration to grid speed, generator connection to the electrical grid, and the transition to power regulation.

Additionally, control of the SHP's hydromechanical part was designed and its functionality was verified using real-world data from the Dobšiná III SHP.

The project results were continuously published at scientific conferences and in journals both domestically and internationally. Among the most significant outputs are 5 publications in peer-reviewed international journals and 4 publications in international journals indexed in the Web of Science (WOS). One patent application was also submitted as part of the project.

The emulator is currently located in the KEM FEI TUKE laboratory. Based on Framework Agreement No. 143/104001/20/D, the future user of the project results is company Energo Contro, s. r. o., Košice.

Benefits for Practise

The energy systems emulator is designed to significantly optimize design work during the planning of small hydroelectric power plants (SHPs) and to considerably shorten the implementation time of such projects directly in operation.

Specific benefits for practice:
- Significant reduction in the time required for SHP project design;
- Improved quality of the resulting implementation projects;
- Lower implementation costs;
- Verification of SHP designs through modeling;
- Additional economic benefits from using the emulator for training and education of operators;
- Environmental protection due to the energy optimization of the systems.

Fig. 1 / Struct_HIL_Emul
Fig. 2 / HIL_Emulator
Fig.3 / Connecting_AG_grid

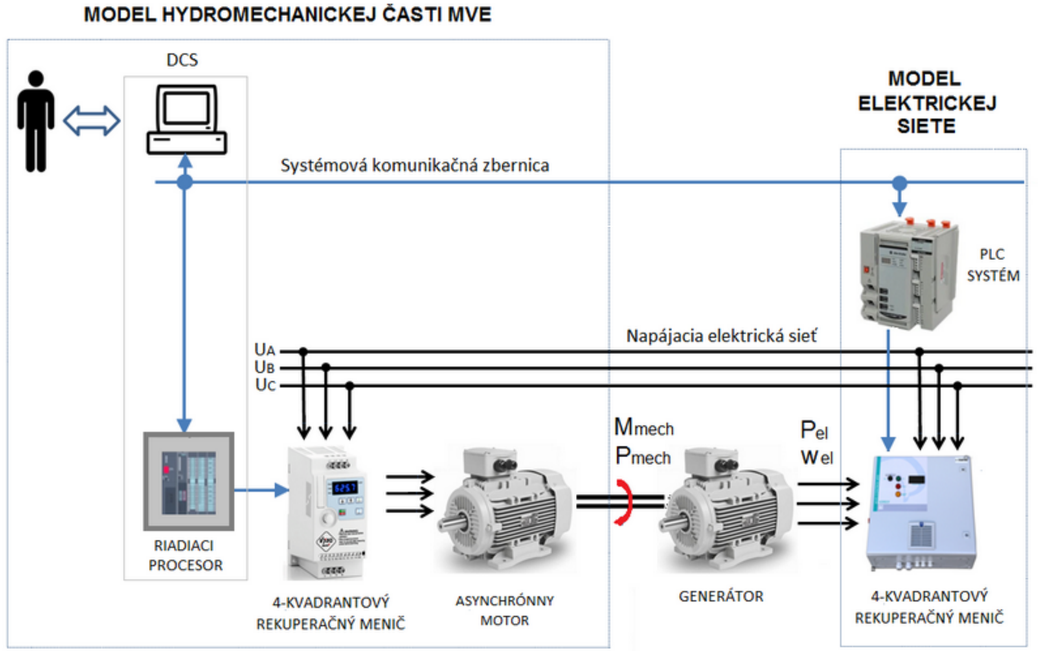

Fig. 1

Fig. 2

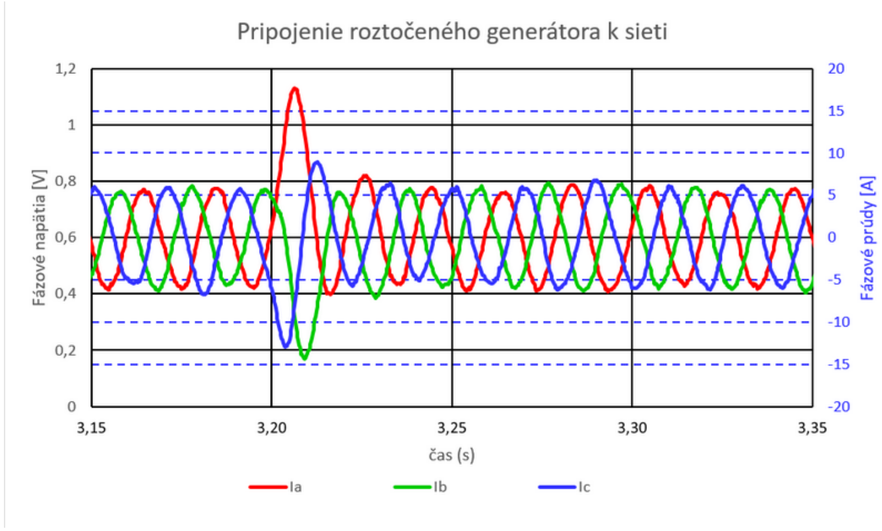

Fig. 3

The occurence of microplastics and selected micropollutants in surface and drinking waters of Slovakia and their effective removal by progressive processes

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Applicant organisation
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Participating organisations
Comenius University Bratislava - Faculty of Natural Sciences
Slovak Academy of Sciences, Polymer Institute
Term of solution
07/2020 - 06/2024
Budget from agency
250 000 €
Project ID
APVV-19-0250

Research Subject

The subject of the APVV-19-0250 project was the occurrence of microplastics and selected micropollutants (pharmaceuticals, drugs, pesticides, and their metabolites) in surface, drinking, and wastewater in Slovakia, including their distribution, sources, and possibilities for their effective removal using innovative technologies. The project responded to the growing problem of water pollution, which poses a risk to ecosystems and public health.

The research involved monitoring micropollutants and microplastics in various types of water, including the Váh River basin, high-mountain lakes, caves, and thermal waters. The behavior of contaminants in the environment and their interactions with microplastics were also studied.

The project also focused on the development and testing of advanced water treatment technologies, such as ozonation, ultrafiltration, the use of nanomaterials (biochar, g-C_3N_4), and ferrate oxidation. The developed technologies were verified under semi-operational conditions.

As a result, new analytical and technological approaches were established, enabling more effective monitoring and removal of contaminants. The project thus contributed to understanding and addressing environmental challenges related to micropollutants and microplastics.

Aim of the Research

The main objective of the APVV-19-0250 project was to investigate the occurrence and behavior of microplastics and micropollutants (pharmaceuticals, drugs, pesticides) in Slovak waters and to propose effective technologies for their removal. The project included monitoring various types of water, identifying pollution sources, developing advanced analytical methods, and testing treatment technologies such as AOPs, ozonation, ultrafiltration, biochar, g-C_3N_4, and ferrates. The developed solutions were verified under semi-operational conditions.

Achieved Results

The APVV-19-0250 project has delivered numerous significant results in both scientific and practical domains. More than 300 samples of various water types (surface, drinking, groundwater, wastewater, thermal, high-mountain, and cave waters) were analyzed. The most common micropollutants and types of microplastics were identified, and their movement and interactions with organic pollutants were studied.

A unique outcome was the introduction of a new analytical technique for microplastics using the LDIR 8700 instrument – the first use of this technology in Slovakia. It enabled automated, high-resolution identification of microplastics in environmental samples. Additionally, LC-MS/MS methods were optimized to quantify micropollutants at ng/l levels.

Based on the results, advanced water treatment technologies (ultrafiltration, biochar, g-C_3N_4, ferrates) were tested under semi-operational conditions and demonstrated high efficiency. The findings were published in dozens of scientific articles, including prestigious journals with impact factors above 6 and one article in a journal with an IF above 12. The project significantly expanded scientific knowledge and paved the way for the practical application of modern water treatment methods.

Benefits for Practise

The APVV-19-0250 project had a significant impact in environmental engineering, water management, and public health. The results are directly applicable to improving water monitoring and treatment, especially given growing pressure on drinking and surface water quality in Slovakia. The use of new analytical methods, including LDIR infrared spectroscopy for microplastics and LC-MS/MS for micropollutants, allows more efficient detection of contamination and its sources.

Advanced water treatment technologies were tested and can be applied as tertiary or supplementary purification steps. Techniques such as ultrafiltration, biochar and g-C_3N_4 sorbents, and eco-friendly oxidants (e.g., ferrates) offer effective alternatives to conventional methods that often fail to remove micropollutants and microplastics. These solutions support both the upgrade of existing plants and the design of new systems.

The project also introduced methods for assessing drug and pharmaceutical consumption through wastewater analysis, useful to health and security sectors. An interactive map of contaminant occurrence across water types was made available to both professionals and the public, raising environmental awareness.

The results support legislative planning, environmental strategies, and provide expert tools for authorities, utilities, and wastewater operators, delivering concrete solutions to improve water quality.

Fig. 1 / Comprehensive analysis of microplastics using LDIR analysis
Fig. 2 / A semi-operational model installed at a wastewater treatment plant, used to test innovative technologies capable of comprehensively removing pathogens, microplastics, and micropollutants
Fig. 3 / Biochar as an effective sorbent in granulated form
Fig. 4 / Sampling of surface waters for the occurrence of micropollutants and microplastics

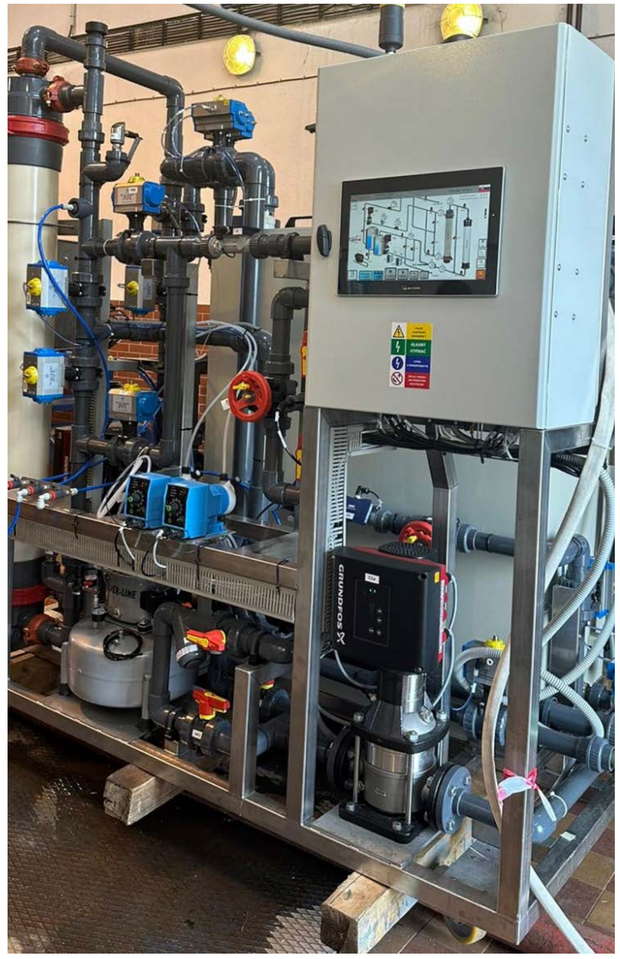

Fig. 2


Fig. 4

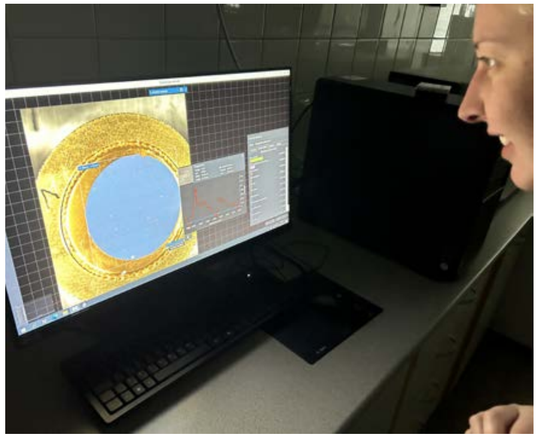
Fig. 1


Fig. 3

Research of the environmentally stable wood bio-composites preparation by the innovative methods of targeted modification of polycondensation adhesives with natural polymers and additives

Principal investigator
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Participating organisation
VIPO a.s.
Term of solution
07/2020 - 06/2024
Budget from agency
249 920€
Project ID
APVV-19-0269

Research Subject

The project was focused on the preparation of multiphase wood bio-composites with reduced emissions of hazardous substances. The bio-composites were developed and prepared by targeted modification of thermosetting polycondensation resins with natural and synthetic polymers using the technology of gluing wood particles. It was a combination of physico-chemical and mechanical attributes, especially wood components, plant and animal polymers, additives and adhesive mixtures. The project was oriented towards research in the field of using disintegrated bark of economically important trees as a substitute for previously used fillers in adhesive mixtures. The research was focused on the quantification of bark types, size of used fractions, proportions in fillers and proportions of fillers in adhesive mixtures.

Aim of the Research

The main objective of the project was the preparation of bio-composites with reduced emissions of hazardous substances into the indoor air of interiors and research into the composition of polycondensation adhesive mixtures by applying natural plant using bonding technology.

The partial objectives of the project solution were:
1. Identification and analysis of the possibilities of applying disintegrated wood bark as a substitute for fillers in adhesive mixtures for bonding wood bio-composites.
2. Research and analysis of the suitability of using individual types of bark, the size of the fractions used and their mass fractions.
3. Research of the modified adhesive mixtures used on the technological operation of pressing, especially on the rate of heat transfer and the distribution of heat and moisture.
4. Identification of the impact of the application of selected types of fillers on selected mechanical, physical and chemical properties of bio-composites.

Achieved Results

The selection of suitable wood species, optimization of methodological and technological procedures, analysis of experimental data was carried out. Preparation of fillers consisted of drying and conditioning of selected types of bark of wood species, their grinding to a fine fraction, hydrolysis and modification of biopolymers and polyphenolic compounds extracted from tree bark.

The results of the achieved densities of experimental plywoods showed that both in laboratory conditions and in industrial practice it was possible to produce relatively homogeneous flat and molded plywoods while achieving consistent densities that are comparable to each other and did not affect the results of subsequent tests of physical, mechanical and other properties.

The achieved bending strengths, shear strengths and other properties of plywoods were better than the values of bending strengths for standard plywoods available on the market. The values achieved prove that the tested adhesive mixtures are correctly developed and suitable for the production of flat and molded plywood.

The developed and tested plywood samples reliably met the requirements for formaldehyde emissions E1 and E0.5 according to measurements carried out at the Technical University of Zvolen. The official authorized test of formaldehyde emissions from molded plywood with beech bark as a filler in the adhesive mixture produced under industrial conditions was carried out in an accredited foreign independent laboratory in Poland. The fulfillment of the requirements according to both methods is satisfactory with a large and clear margin of the limit value.

Benefits for Practise

The results are applicable in practice; the proposed new modified adhesive mixtures using disintegrated bark of forest trees are suitable for direct production of plywood. Technological operations of pressing, heat transfer rate and distribution of heat and moisture in the pressing process of bio-composites have been verified and are problem-free. Selected mechanical and physical properties of bio-composites are stable and suitable. The originality and innovation of the project proposal results from the application of the latest knowledge in the development of new types of environmental adhesive mixtures, consisting of commonly used polycondensation adhesives and new components (bark and other natural polymers) which in the prepared composition, depending on the bonding factors, determined new parameters of adhesive mixtures. The conclusions and recommendations of the project, which results from the research carried out, also have an economic impact and can be reflected in the development of regions and an increase in employment.

Fig. 1 / Disintegrated beech bark as a filler for the adhesive mixture (fraction up to 0.125 mm)
Fig. 2 / Plywood with beech bark as a filler in the adhesive mixture pressed in the factory

Fig. 1

Fig. 2

Hybrid Composites for Complex Treatment of Industrial Waters

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Institute of Geotechnics
Term of solution
07/2020 - 06/2024
Budget from agency
250 000 €
Project ID
APVV-19-0302

Research Subject

Water is essential for life on Earth and is also a finite renewable resource whose quality and availability affect ecosystems and people. Due to intensive industrial, agricultural, and commercial activities, ever-growing amounts of contaminants -heavy metals (Cu, Ni, Cd, Pb, Hg, As, Mn) and other highly toxic substances - enter water bodies.

One of the most problematic groups of contaminants is persistent organic pollutants. These are compounds resistant to photolysis as well as chemical and biological degradation, which accumulate in the environment over the long term, enter the food chain, and thereby adversely affect human health and biodiversity. Traditional remediation methods, such as physico-chemical precipitation or biodegradation, are of low effectiveness for these substances because high-molecular-weight and refractory compounds remain practically unchanged in the geologic environment. Residues of pharmaceutical products and antibiotics represent another group of contaminants that lead to the development of pathogen resistance and threaten public health.

Water protection and treatment are among the priorities of research and innovation in the 21st century. Both the National Smart Specialisation Strategies of SR and the European “Europe 2020” strategy emphasize the need to develop progressive technologies - from advanced sorption materials through photocatalytic processes to biological and hybrid systems. The goal is not only to increase the efficiency of contaminant removal but also to ensure the energy and economic sustainability of treatment methods.

Aim of the Research

The project aimed to develop advanced micro- and nanosorbents prepared by the sol-gel method, capable of selectively capturing organic pollutants and heavy metals from contaminated waters. Testing focused on evaluating their sorption capacity, selectivity, and practical applicability in treating various types of industrial and wastewater.

Achieved Results

During the project, new hybrid sorbents bearing various functional groups were developed, designed to efficiently capture harmful substances from water. Spherical silica-based particles were prepared with their composition and properties modified as needed, for example, by changing the addition method of components or the type of chemical bridges between silicon atoms. Materials carrying different amino groups (e.g., 3-aminopropyl, ethylenediamine) were thus produced; their structure and surface allowed them to capture metal ions such as copper, nickel, neodymium, and dysprosium, as well as dyes like methylene blue and fluorescein. Some particles were coated with polymers containing acidic functional groups, enabling selective iron removal or dye extraction from water.

Of particular interest were Janus particles with specialized surface functionalities: amino groups successfully removed europium and certain dyes, while thiol groups targeted silver and gold. Such materials can also be employed in sensor fabrication.

Another key class of materials comprises magnetic sorbents, particles with a magnetite core that can be manipulated with a magnetic field. Their surfaces were functionalized to target Au, Hg, As, or even antibiotics like doxycycline. Some of these magnetically responsive particles were further modified with zinc oxide, imparting photocatalytic properties: upon activation with hydrogen peroxide, they degraded up to 96 % of the azo dye methyl orange.

The project demonstrated that by tailoring surface chemistry, one can produce sorbents custom-designed for efficient, economical, and eco-friendly treatment of industrial wastewaters. The findings were disseminated through 26 scientific publications and at international conferences via 80 oral and poster presentations.

Benefits for Practise

This project has opened up new possibilities in water treatment. The developed materials, special micro- and nanosorbents, can effectively capture various harmful substances such as heavy metals and organic pollutants commonly found in contaminated waters. Their advantage is that they can be tailored to the specific type of contamination, making purification more efficient and generating less waste.

These new materials can be integrated into existing water-treatment systems or used in portable solutions, for example, in agriculture or industry, where reclaimed water can help reduce costs while preserving natural resources. The project also advances the SDGs by addressing one of today’s greatest challenges: ensuring clean and accessible water for everyone.

Fig. 1 / Application of spherical organosilica particles bearing ethylenediaminetriacetic acid groups for the selective removal of Cu(II) ions and their separation from Ni(II) ions in contaminated water from the Ruzhín dam
Fig. 2 / Utilization of magnetic composites functionalized with thiourea groups, prepared by the developed synthetic method, for the concentration of gold ions (Au(III)) from water of the gold-rich Ida River without sorbent regeneration
Fig. 3 / Silica microparticles functionalized with secondary amino groups were synthesized by hydrolyzing silanes in ammonia and exhibited high affinity for the extraction of the anionic dye RB19

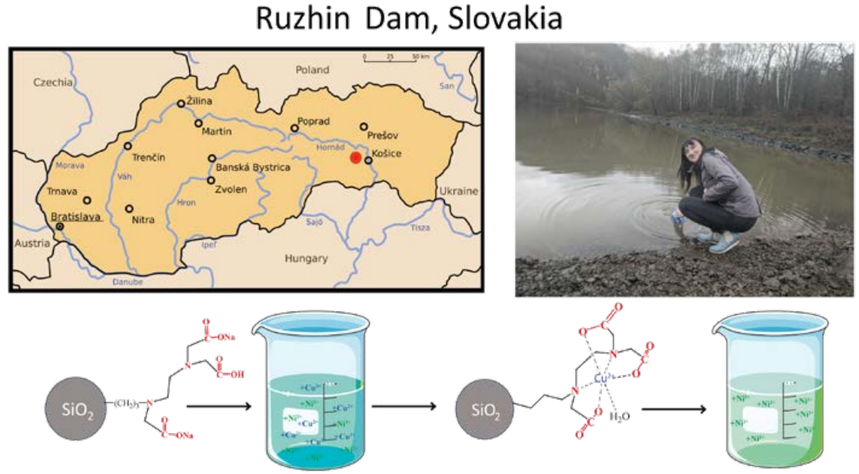

Fig. 1

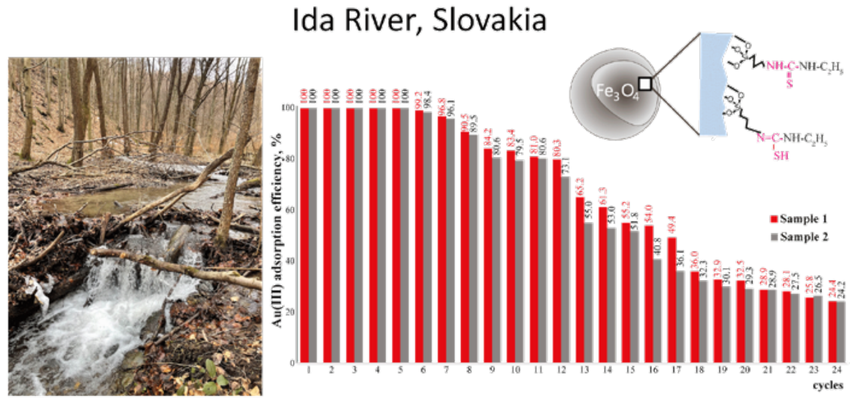

Fig. 2

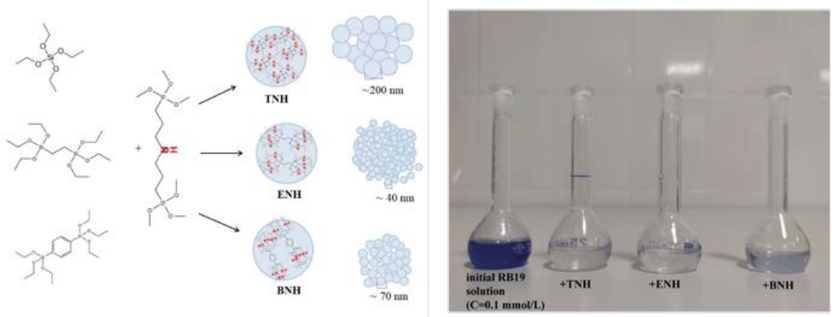

Fig. 3

Integrated Modular System of a Factory Twin

Principal investigator
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Applicant organisation
University of Zilina - Faculty of Mechanical Engineering
Participating organisation
Asseco CEIT, a.s.
Term of solution
07/2020 - 06/2024
Budget from agency
247 880 €
Project ID
APVV-19-0305

Research Subject

The project focused on the design and development of an integrated modular system to support the concept of a digital twin plant, using digital design, simulation and emulation, virtual and augmented reality, and sensor-based data capture, collection, processing, and utilisation technologies. Close cooperation of the research organizations of the Department of Industrial Engineering and Asseco CEIT, a.s. provides the prerequisites for effective transfer of knowledge gained during the project and application of the proposed modular system in industrial practice.

Aim of the Research

The project's main objective was to design an integrated modular system to support the digital twin plant concept. The sub-objectives of the project were as follows:
• Research on new technologies and approaches to design, control and optimisation of smart factories.
• Development of a methodology for designing, controlling and optimising adaptive manufacturing and logistics systems in the digital twin plant concept.
• Design of a module for the creation of a digital parametric model of a manufacturing and logistics system.
• Design of a module for the collection, storage and processing of data from production and logistics processes.
• Design of a data link between real and virtual systems for the purpose of planning, control and optimisation of production and logistics processes.
• Design of a module for planning, control and optimisation of production and logistics processes.
• Hardware and software platform design of an integrated modular system.
• Establishment of a pilot plant digital twin site.
• Verification of the proposed integrated modular system in laboratory and industrial practice conditions.

Achieved Results

The main outputs of the project are:
• Analysis of the state of the art carried out in the areas of design of production and logistics systems, the concept of digital twin and the supporting technologies for the creation of digital twin
• Design of a methodology for the design, management and optimisation of adaptive manufacturing and logistics systems in the digital twin factory concept, which includes: digital intelligent system design, building the physical system, and linking the physical and digital systems into a common data platform
• The design of the individual modules of the integrated modular system of the digital twin of the manufacturing factory, which includes a module for data collection, storage and processing, a module for the creation of a digital parametric model, a module for the planning, control and optimization of production and logistics processes, and a data link between the real and virtual systems.
• Integration of the individual modules via standardised communication protocols. The concept is based on the ELLA platform, which was developed for the design and testing of an integrated modular system.
• Verification of the proposed integrated modular system in laboratory conditions (pilot site set up within AT Park) and industrial practice conditions (Velux Commercial, Ostbirk, Denmark)

Benefits for Practise

The main benefits of the project are:
• Creation of a new product: the proposed integrated modular system of the digital twin of the production plant, consisting of the corresponding software and hardware platform, represents a unique solution for comprehensive monitoring, control and optimisation of production and logistics processes in smart manufacturing.
• development of new technologies: the project solution included the development of custom software and hardware solutions for digital design, monitoring, data display and analysis, simulation, emulation and optimisation of production and logistics processes and presentation of outputs using virtual reality tools.

The proposed modular digital twin system has undergone a two-stage verification (pilot verification in laboratory conditions, verification in industrial practice). The system is prepared as a final product for the purpose of deployment in industrial practice and guarantees an increase in the quality of the design of its own production and logistics system, an increase in efficiency and a reduction in operating costs and, above all, an increase in the transparency of business processes and an increase in the adaptability of the entire system, which is a key component of the competitiveness of the enterprise in the conditions of kustomized and personalized production.

Fig. 1 / Monitoring outputs in the Digital manager module
Fig. 2 / Experiments carried out to improve processes
Fig. 3 / Digital twin pilot workplace
Fig. 4 / Design of the network infrastructure for monitoring the physical logistics system and its interconnection with the data system

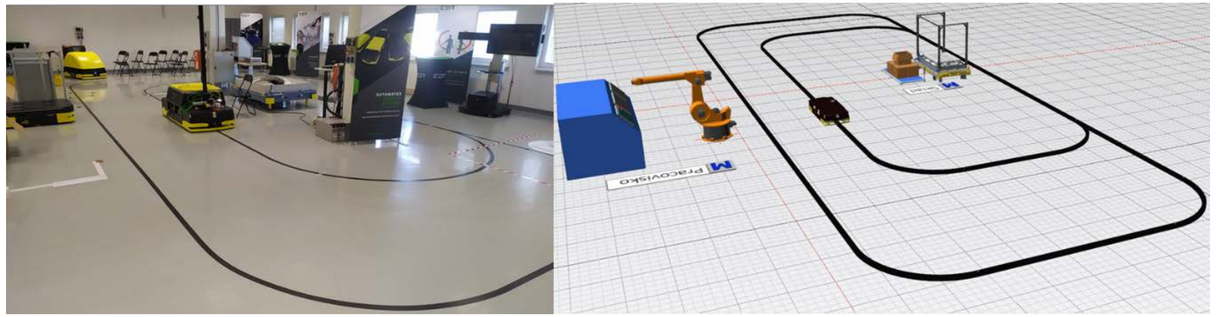

Fig. 3

Fig. 2

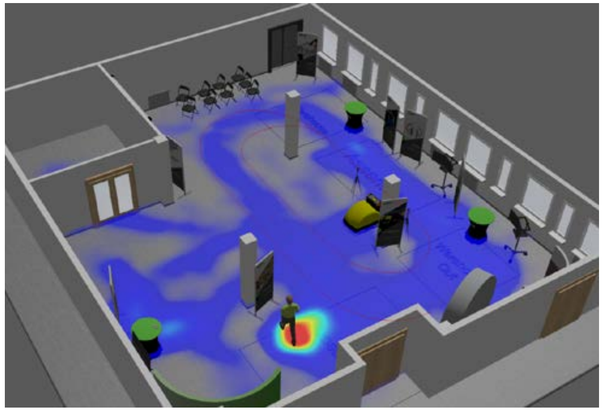

Fig. 1

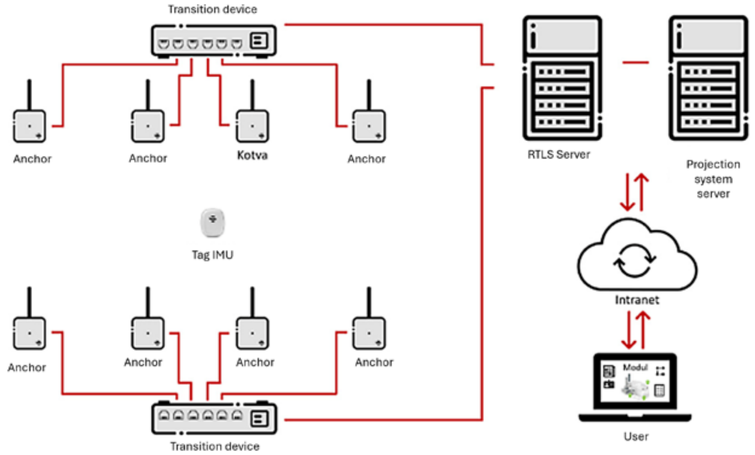

Fig. 4

CONnecTivity and flood RunOff dynamics in headwater catchments of SLovakia

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Participating organisations
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Technical University in Zvolen - Faculty of Forestry
Slovak Academy of Sciences, Institute of Hydrology
Term of solution
07/2020 - 06/2024
Budget from agency
249 808 €
Project ID
APVV-19-0340

Research Subject

The effectiveness of so-called non-systemic flood control measures is a constant subject of debate within the hydrological, ecological and water management communities. The reliability of these measures is determined by a variety of physical and geographic conditions, and thus assessment requires localized research. In this context, very few experimental and quantitative results are available. Process-oriented modelling of hydrological processes and their parameterisation in models has therefore been a major research priority within the APVV project.

Aim of the Research

The first objective of the project was to evaluate the way in which precipitation, snowmelt and land use affect the generation and storage of water in the landscape, the formation of preferential runoff pathways and its dynamics. Answers to questions such as which parts of the watershed contribute to runoff during flood events, what are the runoff pathways, how much precipitation is needed to trigger a significant watershed response, or what is the role of topography, land use, soil and bedrock characteristics, or other watershed characteristics are key to better understanding runoff shaping processes. The information obtained in these areas is valuable not only at the national but also at the international level.

The second objective of the project was to identify individual hydrological linkages, understanding and seeking relationships and dependencies between accumulation, snowpack water content and soil moisture and runoff dynamics in different parts of the catchment. Understanding how elements of hydrological connectivity function under different physiographic environmental conditions is important for improving the structural and non-structural capacity of the area to cope with floods, as well as for sustainable watershed management, including habitat protection.

The third objective was the development of innovative hybrid models representing the governing processes of runoff generation. These types of models are important for predicting changes in runoff processes under land use change and for assessing the effectiveness of nature-based flood mitigation measures.

Achieved Results

Experimental watersheds in the Western Tatras and Poľana were expanded and instrumented, and the measurement results were used to evaluate how precipitation, snowpack height and snowmelt, and land use affect the amount of water storage in the landscape, the formation of preferential runoff pathways, and the dynamics of runoff within temporary and low-order flows. Models have been developed to simulate the drivers of deforestation following windstorms. Analysis of flow variability in the headwater catchments of the Western Tatras provided a better understanding of runoff dynamics, their evolution over the past three decades, and the definition of parts of the catchment that contribute to runoff during flood events. The information obtained in these areas is valuable not only at the national but also at the international level. Individual hydrological linkages and dependencies between accumulation, snowpack water content and runoff and soil moisture dynamics in parts of the experimental catchments have also been identified. Understanding the functioning of hydrological connectivity elements under different environmental physiographic conditions is important for effective resilience enhancement (improving the structural and non-structural capacity of the area to cope with floods), sustainable watershed management, and including habitat and species conservation. Finally, distributed conceptual models representing the governing processes of runoff generation have been refined and can be used in watershed management to estimate potential changes in runoff dynamics and for flood mitigation.

Benefits for Practise

The project has provided knowledge in process-oriented hydrological modelling that better enables the assessment of extreme runoff and erosion conditions and consequently the effectiveness of flood and erosion control measures related to land use, agricultural and forest landscape management taking into account runoff generation parameters

The developed methodology contains a set of procedures that can be creatively adapted to any local application in risk management practice. This allows a more professional assessment of the effectiveness of nature-based methods and the combination of newer modelling tools to quantitatively assess land use and land management for the reduction of flood runoff and erosion-transport processes.

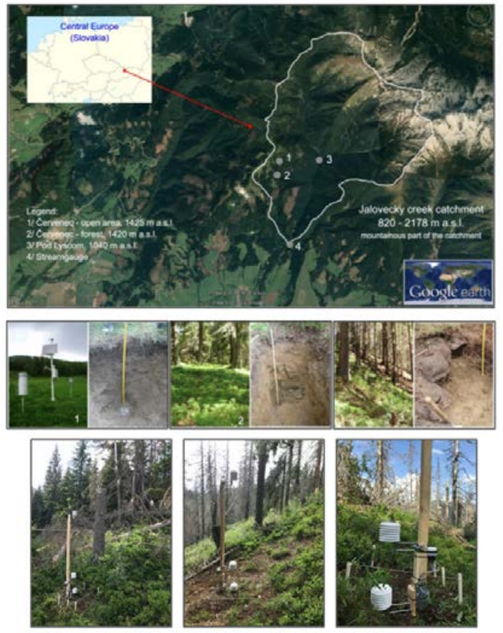

Fig. 1 / Jalovecký Creek basin, location of the sites for which soil runoff was simulated (1, 2 and 3), vegetation and soil profiles; the outlet of the basin where the runoff from the basin was measured - 4.
Microclimatic stations in the experimental basin - Červenec (Western Tatras Mountains)

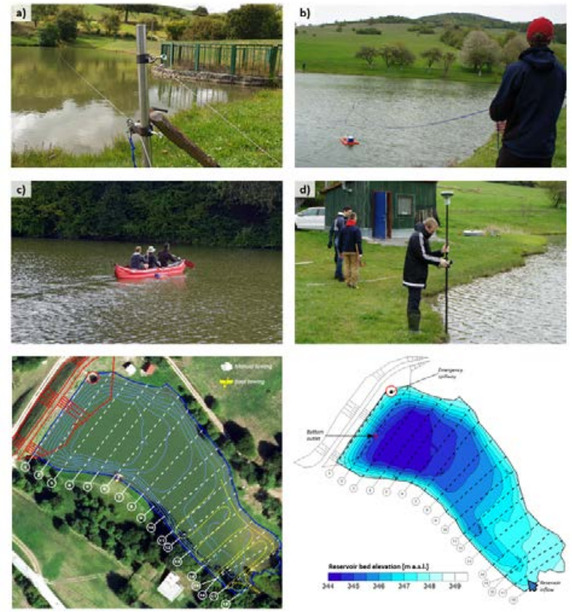

Fig. 2 / The bathymetric survey of a small reservoir at different times: a) profiles with wire rope guidance; b) hand towing of the ADCP; c) towing of the ADCP behind the inflatable boat; d) geodetic measurement.

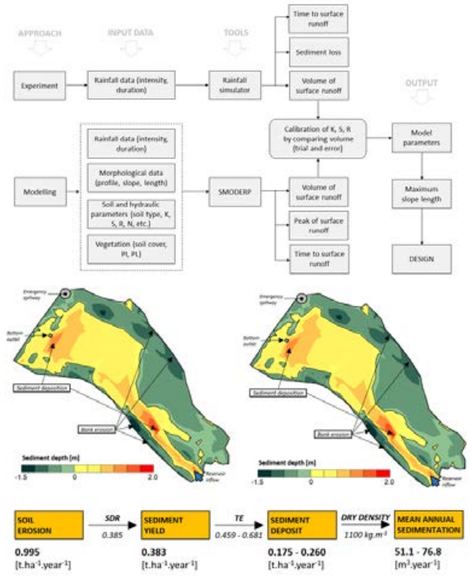

Fig. 3 / Estimated sediment thickness based on comparison from individual bathymetric measurements from 2008-2017 and 2017-2020 and results for estimating the average annual sedimentation rate in the reservoir.

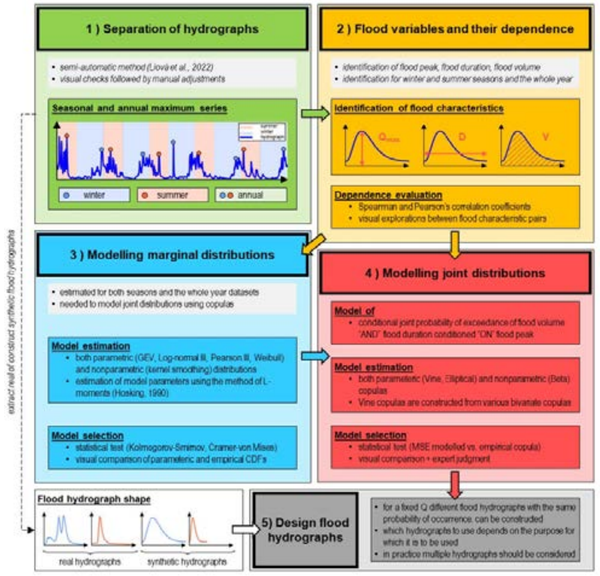

Fig. 4 / Flow chart describing the developed methodological procedure for the estimation of design flood hydrographs

Integrated Process Safety Management Approach Framework for the Smart Enterprise

Principal investigator
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Term of solution
07/2020 - 06/2024
Budget from agency
246 900 €
Project ID
APVV-19-0367

Research Subject

Management of production processes within the framework of the smart industry strategy requires the application of safety principles as one of the pillars for ensuring its competitiveness. The effectiveness of these processes is conditioned by integrating risk analyses into management systems so that they are part of all processes within the enterprise. The goal must be to minimize human, technical and cyber risks. Its implementation can be ensured by applying process safety within the individual stages of production technologies. Safe production technologies create conditions for effective working conditions for employees as well as the production of a safe final product and thus for the overall economic balance of the enterprise. Within the structure of an intelligent enterprise, process safety must become part of an integrated approach to their management.
Within the project, the subject of research was focused on the theoretical and practical framework for the application of process safety in a complex model of intelligent enterprise management so that it includes the areas of safety and health protection, safety of machines and machine systems, property protection and cyber security. The modular structure of the model is based on the principle of digitalization, as a basic condition for the possibility of effective management of an intelligent enterprise in the spirit of Industry 4.0 as well as Industry 5.0.

Aim of the Research

The aim of the project (named PATH4ME) was to create a theoretical and practical framework for safety management in a comprehensive sense, i.e. occupational health and safety (OHS), safety of machines and machine systems, protection of property and cybersecurity in enterprises.

Achieved Results

The results of the project entitled "Framework for an Integrated Process Safety Management Approach for the Intelligent Enterprise (PATH4ME), despite certain restrictions during the COVID19 pandemic (e.g. travel), were continuously fulfilled and achieved at a high level, as evidenced by a total of 16 scientific articles in foreign peer-reviewed journals throughout the entire period of the project. Since the beginning of the project, activities have been focused on examining the solution of machinery and its safety strategy, especially in organizations with a tendency to implement Industry 4.0 principles. The GAP analysis was based on basic assumptions and assessments of machine safety requirements (Directive 2006/42/EC and the requirements of harmonized standards). Approximately 160 pieces of machinery were assessed at 5 production facilities. From the perspective of the complexity of OSH management, the level of maintenance management in the automotive industry was also analyzed, as the development of process integration is particularly important in this industrial area. A methodology for examining the SMART Maintenance application in industrial sectors was created based on the new version of the EFQM 2019 model. Empirical research on a randomly selected sample of top managers of various Slovak organizations showed that they perceive the readiness of their organizations in the field of integrated safety at a better level than the readiness of maintenance management to transform in accordance with the requirements of I4.0. Another significant research activity of the project was the study of humans and their activities in an intelligent enterprise. The CAPTIV system was purchased as part of the project, allowing for the quantitative assessment of human workload (assembly activities, quality control, etc.). The entire structure of the PATH4ME model, in the form of a software application, is built on holistic management with regard to human safety and health protection, but also with regard to management requirements based on a comprehensive assessment of business risks.

Benefits for Practise

The contribution of the work to practice is a new holistic approach to risk management. By using digitalization and modern technologies, it improves the identification and analysis of risks, thereby reducing the likelihood of their occurrence and minimizing the impacts. The practical application of the model has shown an improvement in the efficiency of resource management and support for strategic planning. The results enable organizations to respond to dynamic changes and increase their competitiveness in a global environment. The work offers practical recommendations for improving organizational culture, safety and long-term sustainability.

Fig. 1 / Structure of the PATH4ME software application framework
Fig. 2 / Holistic structure of the PATH4ME

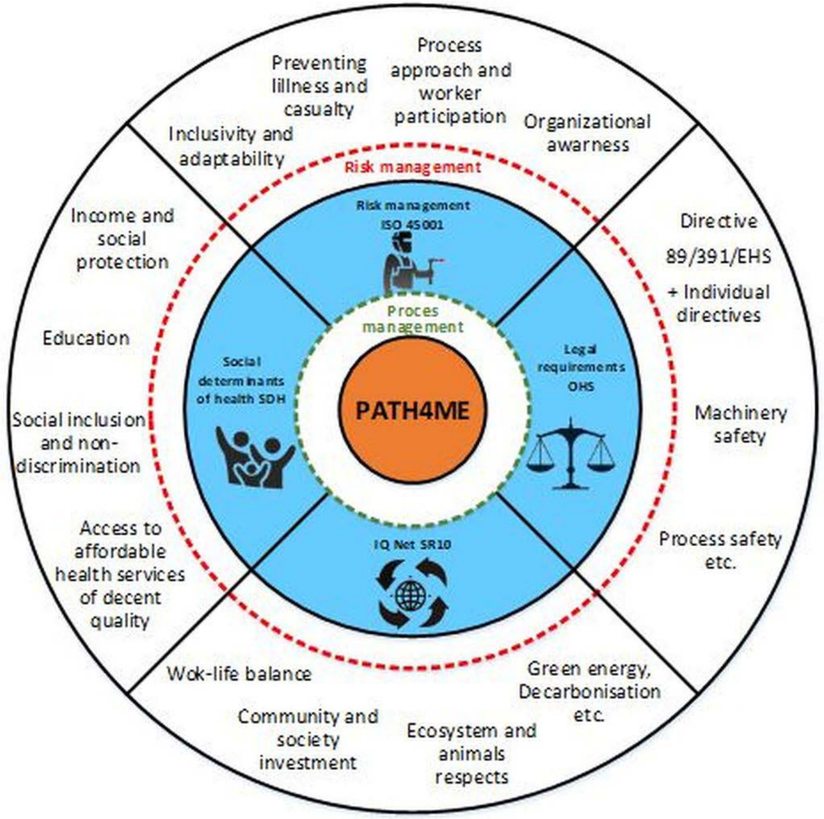

Fig. 1

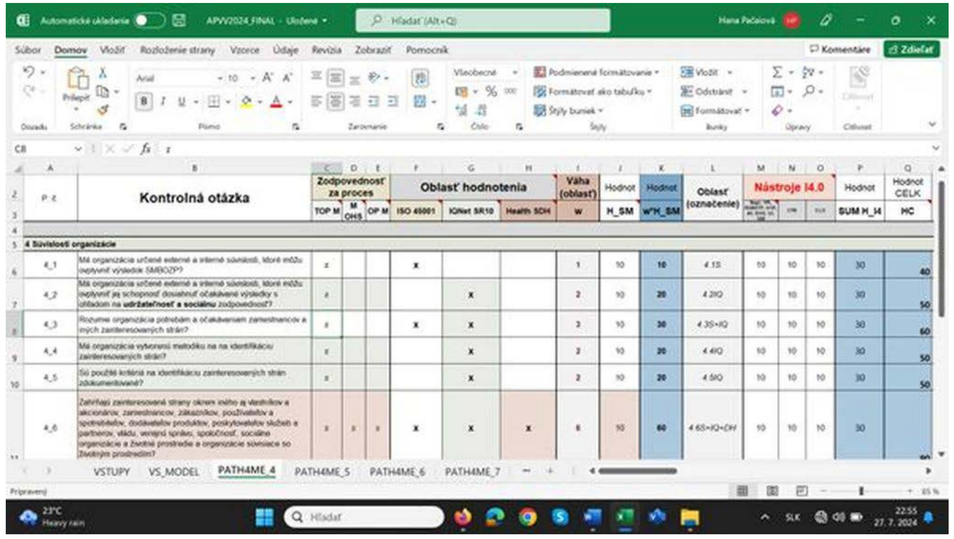

Fig. 2

Novel nano / micro-structured metallic materials prepared by unconventional processing routes

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Participating organisation
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Term of solution
07/2020 - 06/2024
Budget from agency
249 895 €
Project ID
APVV-19-0369

Research Subject

Verification of possibilities of controlling structure and properties of selected systems by means of unconventional processing techniques for improvement of physical and technical properties

Aim of the Research

The basic objective was to verify the possibility of controlling structure and properties of selected systems by means of unconventional processing techniques for improvement of physical (and technical) properties, focusing especially on nanocrystalline magnetic systems prepared by rapid quenching, on structures with potentially suitable catalytic activity (prepared as calculated systems and partly as real samples), on CCA/HEA-like multi-component systems and on additional selected emerging systems that came to the attention of world research during the project duration. We tried to identify processes controlling the change of structure and properties in the investigated materials, especially during the application of unconventional processing techniques after preparation. Primary objective of the project, in addition to partial objectives, was synthesis of acquired knowledge and its generalization.

Achieved Results

Methods and techniques of fast and ultra-fast annealing developed in the project were successfully applied to diverse systems of own rapidly quenched amorphous alloys, achieving efficient and economical preparation of high-quality magnetically soft materials.

Unconventional technique of ultra-fast heat treatment using preheated massive copper blocks enables creation of a sufficiently fine nanocrystalline structure even without critical elements to prevent grain growth (Nb, Hf, Zr, ...). This leads to an increase in saturation magnetisation for this type of material and to a potential reduction in production costs and to a fundamental reduction in energy requirements for heat treatment. Methods are also applicable to a wider spectrum of materials where the development of the structure by heat treatment leads to a targeted improvement of physical (and technical) properties.

In a similar and targeted manner we purposefully optimized materials suitable for sensors based on the principle of giant magnetoimpedance (GMI), where optimization of the shape of the hysteresis loop was achieved by tailoring the annealing technique in suitably oriented medium and strong magnetic fields (applied in the project to several classes of materials – rapidly quenched metallic glasses, glass-covered amorphous wires, systems of magnetic nanoparticles, etc.).

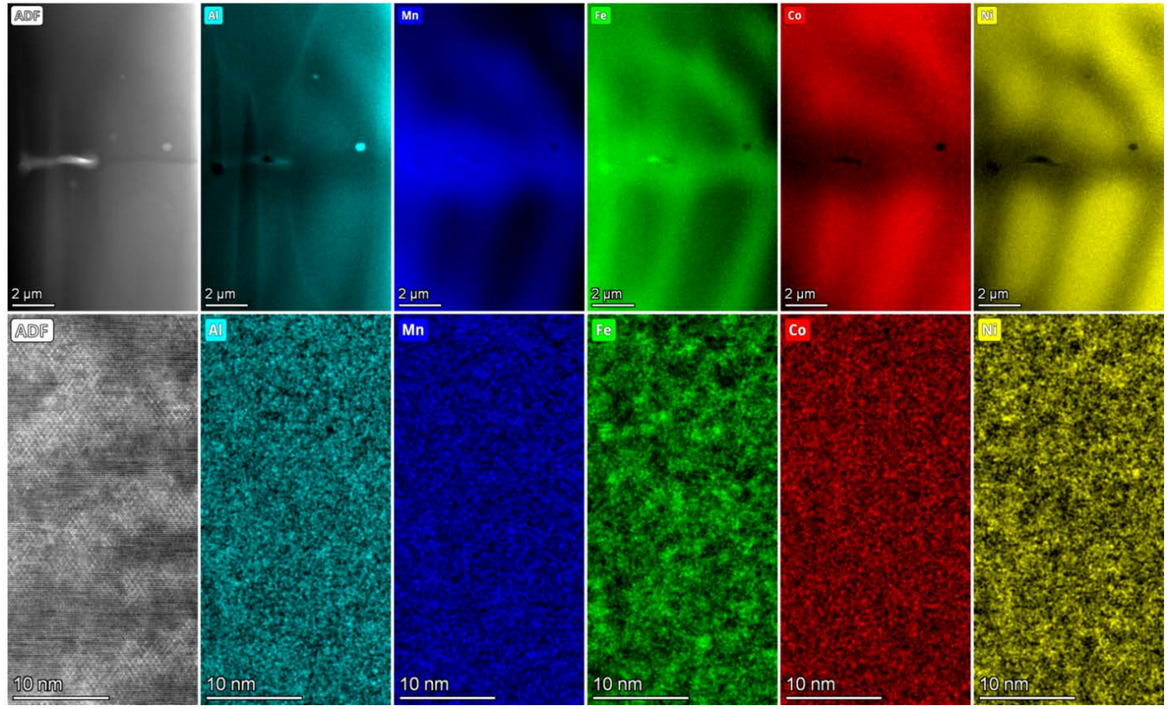
The key techniques of advanced thermodynamic, structural, phase and local (atomically resolved) chemical analysis together with the methods of first-principle calculations and atomic modeling, which were simultaneously developed and implemented in the project on the investigated systems, were applied a.o. in the identification of phenomena controlling the processes of oxidation, hydrogenation and other processes controlling technically interesting catalytic reactions. During these studies, we discovered and explained several hitherto unknown phenomena potentially leading to more efficient chemical technologies. The use of developed theoretical, experimental and technological methodologies also led to initial studies forming the basis of future research of new materials created on the basis of systems of alloys, ceramics and dielectrics with high entropy of mixing and hitherto still not sufficiently well understood structure and properties.

Benefits for Practise

We have used rapid and ultra-rapid annealing in nanocrystallization of soft magnetic amorphous alloys in order to achieve efficient and economical preparation of high-quality soft magnetic materials. Our results showed that rapidly annealed Fe-Co-B-(Cu)-based alloys with high saturation induction exhibit very good long-term thermal stability of soft magnetic characteristics in the range of their expected operating temperatures of 30–250 °C, making them promising candidates for technical applications in which soft magnetic materials are exposed to prolonged elevated operating temperatures.

We have demonstrated the effects of annealing in external magnetic field on the magnetic properties, domain structure and magnetoimpedance parameters of amorphous and nanocrystalline thin ribbons based on Fe-Ni-Nb-B. The results of our experiments showed that samples in the nanocrystalline state exhibit significantly higher values of the GMI effect compared to the starting amorphous material and enable the creation of sensitive magnetic field sensors with significant added value.

Fig. 1 / ADF STEM–EDS elemental mapping in suction cast (3mm wide rod, medium quenching rate, cca 104 K/sec) FeCoNiMnAl alloy at different magnifications. Evident elemental separation of Fe and Ni is present on both length scales (μm vs. nm).
Fig. 2 / Prototype of rapid annealing device for ultra-rapid annealing of thin ribbons.



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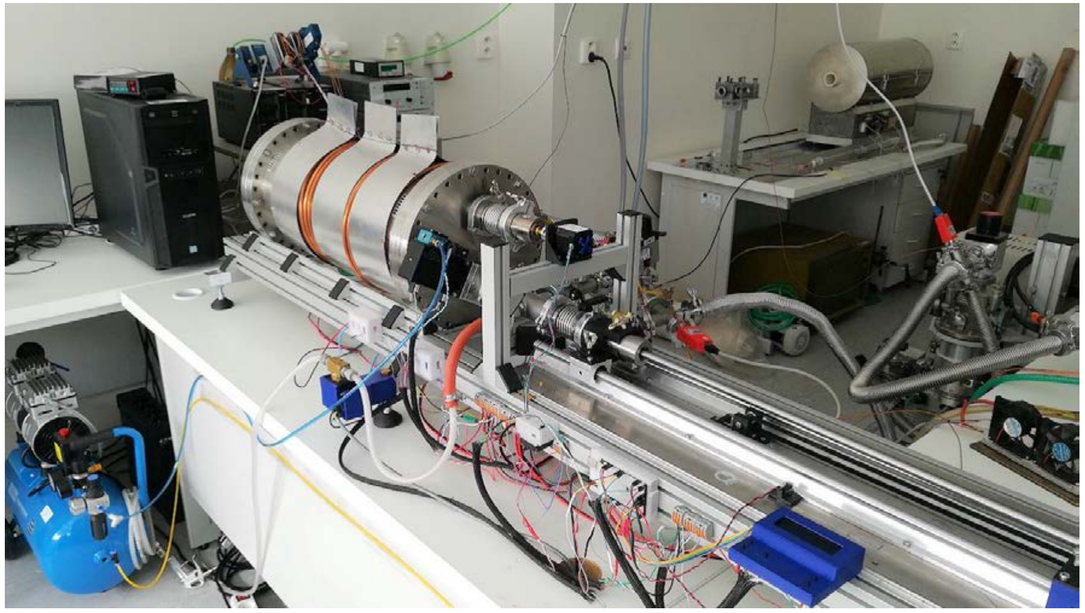

Fig. 2

Research and development of multi-component cementitious blends for special construction materials

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Institute of Construction and Architecture
Term of solution
07/2020 - 06/2024
Budget from agency
232 645 €
Project ID
APVV-19-0490

Research Subject

The project focused on the development and optimization of multicomponent cementitious composites intended for specialized structures in the field of nuclear energy and radiation shielding. The primary objective was the design of heavy-weight self-compacting concretes with high density, excellent workability, and long-term durability. The research involved a detailed analysis of the hydration processes of multicomponent binders, as well as the development of the microstructure and pore structure of the resulting cement-based composites. Ordinary Portland cement was partially replaced with supplementary cementitious materials, and heavy-weight aggregates based on baryte and magnetite were used to achieve the required engineering and functional properties of the developed concretes.

Aim of the Research

The objective of the project was the optimization and development of new types of cementitious binders with a focus on hydration heat evolution. A comprehensive optimization of concrete mixtures was also conducted, taking into account chemical composition (including radionuclide content), rheological properties, and technological requirements specific to self-compacting concrete. At the same time, requirements for density were met in the context of heavyweight concrete development. The physical and mechanical characteristics of the developed materials were subjected to long-term experimental validation.

Achieved Results

As part of the project, two series of fiber-reinforced heavy-weight self-compacting concretes were developed and optimized using supplementary cementitious materials (finely ground limestone, ground granulated blast-furnace slag, and metakaolin) in proportions of up to 35 wt.% of the total binder content. A detailed study of the hydration processes was conducted using isothermal calorimetry, thermal analysis, and X-ray fluorescence spectroscopy, enabling quantification of reaction kinetics, identification of hydration products, and determination of their thermodynamic stability. The concrete mixtures were also subjected to neutron activation analysis and prompt-gamma activation analysis in order to assess their applicability in environments exposed to ionizing radiation. The ongoing and final results obtained throughout the course of this research were published in 24 ADCA-category articles, supplemented by an additional 28 outputs. Two granted patents further complement these outputs. The first patent, registration number SK 289147 B6, was awarded for the design, development, and experimentally optimized method for preparing a pure cubic form of analcime from alkali-activated aluminosilicates of suitable composition. The second patent, registration number SK 289208 B6, was granted for an optimized composition of a cement mixture suitable for use under hydrothermal conditions in the temperature range of 200 to 300 °C. The publications have collectively received over 170 scientific citations, excluding self-citations.

Benefits for Practise

The practical impact of the project lies in the potential application of the developed cementitious composites in construction structures exposed to ionizing radiation (e.g., nuclear power plants, cyclotrons, medical facilities), as well as in geothermal wells, where materials are required to withstand high pressure, temperature, and chemically aggressive environments. The project outcomes significantly contribute to advancing radiation-resistant and thermochemically stable concrete technologies.

Fig. 1 / Compressive strength of cement composites without supplementary cementitious materials.
Fig. 2 / Compressive strength of cement composites including supplementary cementitious materials.
Fig. 3 / Thermal analysis of referential binder.
Fig. 4 / Thermal analysis of blended binder.
Fig. 5 / SEM analysis of steel fiber-reinforced sample.

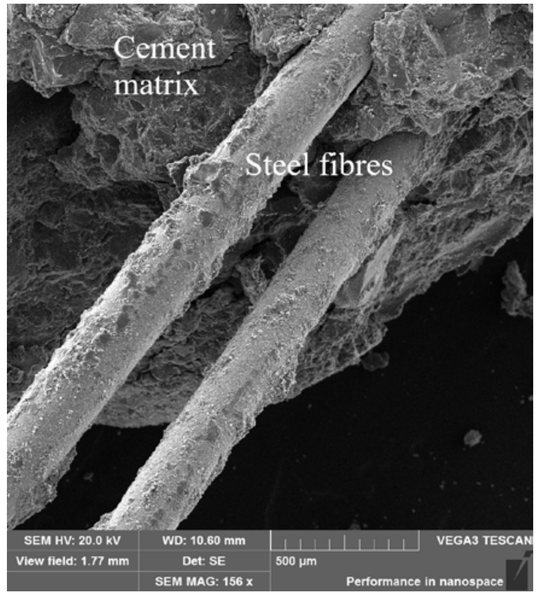

Fig. 5

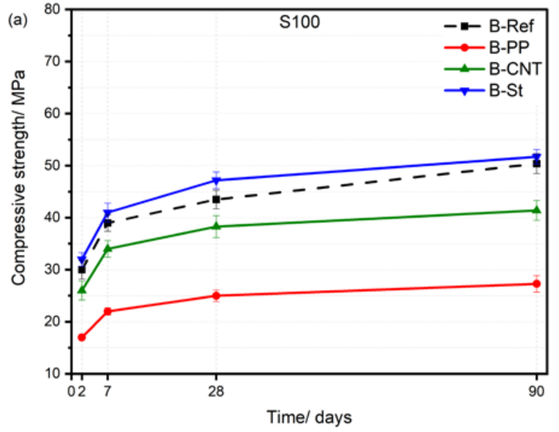

Fig. 1

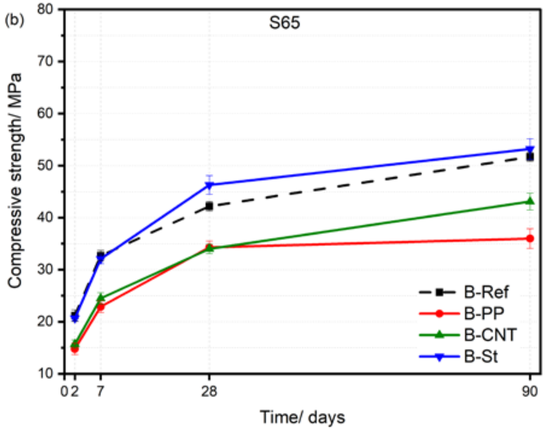

Fig. 2

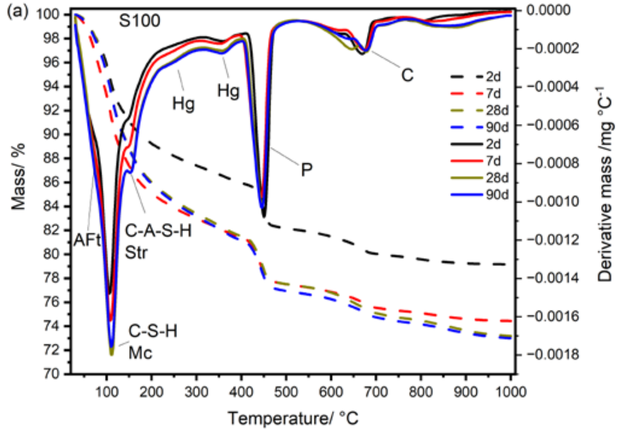

Fig. 3

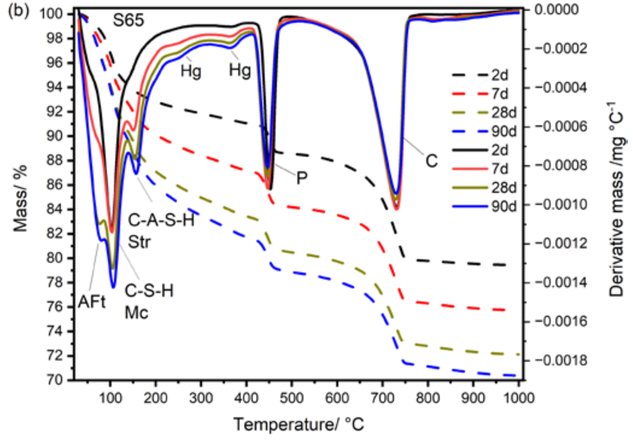

Fig. 4

New High - Entropy Ceramics for Advanced Applications

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Institute of Materials Research
Participating organisation
Slovak Academy of Sciences, Institute of Inorganic Chemistry
Term of solution
07/2020 - 06/2024
Budget from agency
249 800 €
Project ID
APVV-19-0497

Research Subject

In recent years, there has been a growing interest in the development of new types of ceramic materials capable of withstanding extreme mechanical and thermal conditions. One of the most progressive research areas involves high-entropy ceramic materials based on carbides and borides of transition metals. These materials exhibit an exceptional combination of high hardness, thermal stability, and wear resistance. The project focused on the design, synthesis, and characterization of multicomponent carbide systems of the type (Hf-Ta-Zr-Nb-Ti) C and (Mo-Nb-Ta-V-W)C, as well as carbide-boride systems (Ti-Zr-Nb-Hf-Ta)C + (Ti-Zr-Nb-Hf-Ta)B_2, with the aim of optimizing their mechanical and tribological properties. Sintering parameters, microstructural characteristics, hardness, wear resistance, and fracture toughness were studied, along with the effect of SiC whisker additions on strengthening and toughening of materials. The results confirm the potential of these materials for high-temperature (>1800 °C) and high-load applications, such as in aerospace, energy, and fusion reactor research.

Aim of the Research

Development and research of new high-entropy ceramic materials (HECs) focused on enhanced mechanical and tribological properties at both room and ultra-high temperatures. Optimization of properties for extreme conditions as materials suitable for applications such as thermal protection systems for supersonic and re-entry space vehicles, heat-resistant components, propulsion elements, and high-temperature technologies. Focus on systems based on transition metal carbides and borides produced using advanced technologies such as high-energy milling, plasma-assisted sintering etc.
Application of advanced characterization techniques including micro/nanomechanical testing and high-resolution transmission electron microscopy for the investigation of micro/nanostructures. Study of densification mechanisms and structural properties aimed at clarifying the relationships between preparation methods, microstructure, and resulting material properties. Expansion of knowledge in the field of HEC systems where currently only limited data exist, particularly regarding structure and sintering mechanisms at the atomic level.

Achieved Results

As part of the submitted project, a new group of HEC based on transition metal carbides and borides was successfully developed and comprehensively characterized. These materials, defined by high mixing entropy and multicomponent composition, demonstrated exceptional combinations of mechanical, tribological, and thermodynamic properties, making them suitable for use in extreme service conditions.

The research focused on the development and comparison of multicomponent systems such as (Hf-Ta-Zr-Nb-Ti)C and (Mo-Nb-Ta-V-W)C, as well as their boride analogues. In parallel, composites reinforced with SiCw were also prepared. The materials were sintered using Spark Plasma Sintering under optimized conditions, ensuring high densification and fine-grained microstructure. Microstructural analysis revealed a homogeneous distribution of elements and a dominant single-phase structure with a NaCl-type lattice (HECs) and an AlB_2-type lattice (HEBs). The carbide systems exhibited high hardness, while the boride materials confirmed their thermal stability and potential for use at ultra-high temperatures. The addition of SiCw did not negatively affect the hardness but significantly improved the fracture toughness. Tribological tests showed a reduced coefficient of friction and enhanced wear resistance compared to monolithic systems. The obtained results confirm that high-entropy transition metal carbides and borides, especially when reinforced with SiCw, represent promising materials for applications where high hardness, fracture toughness, wear resistance, and high-temperature stability are simultaneously required.

Benefits for Practise

The developed HEC exhibit a combination of extreme hardness, high thermal stability, and excellent wear resistance, which makes them highly suitable for the most demanding applications. In practice, they can be employed in high-temperature protective coatings, cutting tools, load-bearing structures under thermomechanical stress, components for the aerospace and space industries, as well as linings for plasma reactors and devices for nuclear fusion. Their potential lies in replacing existing UHTC materials in order to increase the lifespan, reliability, and performance of technologies where conventional materials tend to fail.

Fig. 1 Schematic of the preparation of the reference sample (Hf-Ta-Zr-Nb-Ti)C and the composite (Hf-Ta-Zr-Nb-Ti)C–SiCw.
Fig. 2 Microstructure of reaction-sintered ceramics – biphasic high-temperature high-entropy HEC/HEB observed at the micro/nano/atomic scale.
Fig.3 Investigation the strength of HEC and HEB grains (~ 8 GPa) and grain boundaries (~ 4.5 GPa) in reactive sintered equimolar dual-phase high-entropy ultra-high temperature ceramics using a microcantilever bending experiment and detailed fractography-based analysis.

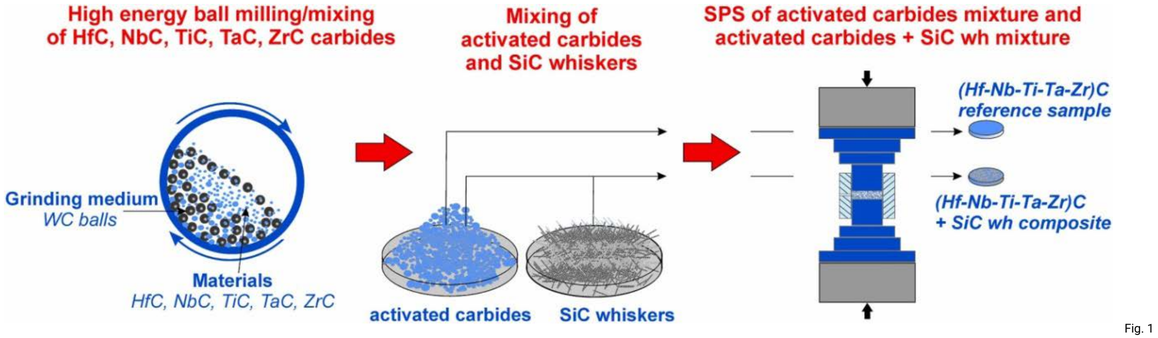

Fig. 1

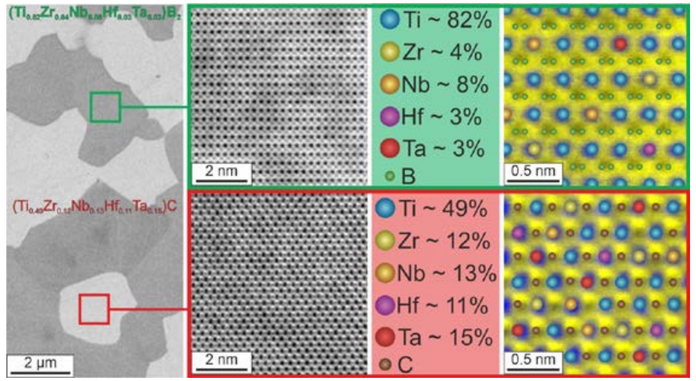

Fig. 2

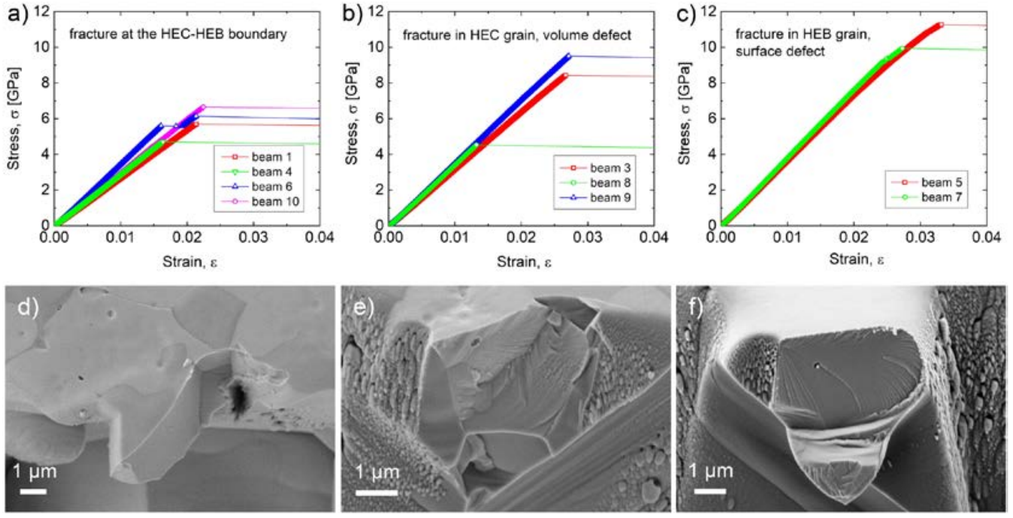

Fig. 3

Modification of asphalt mixtures by waste polyolefins as a method of environmental burden reduction

Principal investigator
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Applicant organisation
VUIS-CESTY Ltd. - VUIS-CESTY Ltd.
Participating organisation
VÚRUP, a.s.
Term of solution
07/2020 - 12/2023
Budget from agency
249 995€
Project ID
APVV-19-0520

Research Subject

The project design responded to the issue of the increasing amount of plastic waste, which results in the creation of serious environmental problems. In accordance with the current five-stage waste management hierarchy, the research team engaged in research into the reuse of plastic waste, which has reached end-of-waste status by being added into the asphalt mixtures in structural layers of the roadway/pavement.

Aim of the Research

The main objective of the project was to contribute scientifically and technologically to the solution of the basic physicochemical and technological processes involved in the effective incorporation of recycled plastics into asphalt mixtures. The recycled low-density polyethylene (LDPE) from the company RE-PLAST, s.r.o., Zvončín, which was produced by mechanical recycling of worn-out films and bags, such as covering and protective film, waste bags for construction, kitchen and garden waste, was used in the work. The massive production and consequently generated waste of such films is enormous in Slovakia; therefore the main objective of our research was to offer a suitable technical solution for the recovery of this type of plastic waste. The prepared and tested types of asphalt mixtures with recycled plastic under laboratory conditions were subsequently prepared in the asphalt mixtures production plant of VIAKORP, s. r. o., Zvolen and laid on the verification section by the village Dolná Strehová.

Achieved Results

Three types of asphalt mixtures, namely conventional asphalt mixture, asphalt mixture with added commercially available polymer and suitable recycled plastic, were designed, laboratory prepared and characterized by a systematic study. Since not every type of plastic forms a homogeneous material with the asphalt mixture, it was necessary to find a suitable type of plastic. This suitable candidate was recycled low density polyethylene. In the case of using recycled polymer, we have to take into account many factors that can affect the outcome, and these can be due to the fact that we need to know exactly the source of the waste plastic, the separation of the different components and, of course, the resulting properties of the recyclate.

Although the basic rheological and thermal properties of the sample do not show large variations, even a small change in the physicochemical properties can cause variations in the resulting mixture. Commercially available LDPE from Slovnaft, a. s., Bratislava was used as a comparison polymer. The optimum amount of plastic added to the asphalt mixture was 6 wt. % of plastic while maintaining all prescribed properties. After successful preparation and characterization of the asphalt mixtures in laboratory conditions, the asphalt mixtures were prepared directly in the asphalt mixing plant. Based on the results of the scientific analysis and verification directly on the validation road section, it was proven that this type of recycled plastic under the tested reaction conditions can be used for the production of standard asphalt mixtures.

Benefits for Practise

Although the project was classified as applied research, the main contribution was on the one hand the scientific research itself, based on the understanding of the fundamental physicochemical processes between the asphalt mixture and the recycled plastic, and secondly the technological, namely the implementation of the results from the scientific part into a practical application. The results of our scientific research and their subsequent implementation into practical application show that polyethylene-based plastic recyclate under suitably selected reaction conditions can be effectively incorporated into asphalt mixture without negatively changing its final properties. Moreover, if such waste were unusable it would end up in landfills. With the current set-up of the principles of the circular economy, this is the worst option for waste management. The big positive for practice is that this technology is suitable for the current asphalt mix plants in Slovakia without having to invest additional money in current equipment. Such a unique combination of a scientific research team, an innovative construction company and a suitable producer of recycled plastic has resulted in an extremely wide-ranging and successful scientific and technological project, which was implemented in Slovakia for the first time in this area.

Fig. 1 / Granules ready for mixing with asphalt and aggregate (white granulate is PE-LD, black is PE-LDre).
Fig. 2 / The asphalt mixture plant
Fig. 3 / Asphalt mix preparation process in the asphalt mixture plant
Fig. 4 / The asphalt mix laying process on the verification section.

Fig. 1A

Fig. 1B

Fig. 4

Fig. 2

Fig. 3

Relationships between structure and unusual physical properties in highly nonequilibrium oxides prepared by unconventional mechanochemical synthesis

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Institute of Geotechnics
Participating organisation
Slovak University of Agriculture in Nitra – Faculty of Engineering
Term of solution
07/2020 - 06/2024
Budget from agency
249 990 €
Project ID
APVV-19-0526

Research Subject

The subject of the research was the application of unconventional mechanochemical methods in the synthesis of new types of highly non-equilibrium nanooxides. The study of the early stages of the processes of mechanically induced nucleation and growth of non-equilibrium phases provided an approach to elucidating the microscopic mechanism of the unconventional mechanochemical preparation method. This represents one of the fundamental and scientific problems of contemporary mechanochemistry/solid state chemistry. The research was also oriented towards a detailed study of quantitative information on the atomic and electronic structure, on local structural disorder, as well as on dynamic and kinetic processes in mechanochemically prepared nanomaterials. The mechanical, magnetic and electrical response of highly non-equilibrium nanophases was experimentally studied with the aim of determining the correlations between their local structure and functional behavior.

Aim of the Research

The main goal of the project was focused to understand the relationships between the structure and functional physical properties of unconventionally synthesized high-nonequilibrium nanooxides. The partial objectives of the project consisted of:

- Unconventional mechanochemical preparation of new types of nanomaterials
- Microscopic study of early stages of nucleation and growth processes of non-equilibrium phases
- Morphological study of synthesized oxides prepared by mechanochemical methods
- Structural refinement of highly metastable nanooxides
- Study of cation population, short-range structural disorder and dynamics of ions in nanomaterials
- Study of local coordination, oxidation and magnetic state of ions in highly metastable nanostructured oxides
- Study of mechanical and transport properties of “interface/surface dominating” nanomaterials; study of magnetic, mechanical and electrical response of mechanochemically prepared oxides

Achieved Results

In accordance with the set scientific objectives of the project, the following results were achieved:
i) Several nanocrystalline complex oxides were prepared by unconventional single-step mechanochemical methods (mechanical activation and mechanosynthesis) and multi-step (combined) preparation procedures involving a mechanochemical process.
ii) The morphology of nanooxides prepared by mechanochemical methods was revealed. Spherical nanoparticles of complex oxides showed a non-uniform core-shell structure consisting of crystallographically ordered regions surrounded by structurally disordered surface layers or interfaces.
iii) It was proven that mechanochemical activation leads to a change in the morphology, chemical composition and structure of TiO^2 nanoparticles, which has a significant impact on the photocatalytic activity of the given substance in the purification of waters containing azo dyes.
iv) Quantitative information was provided on the structural disorder of the prepared nanooxides with rhombohedral structure (Gd_6UO_{12-d}), mullite structure ($Bi^2(M_{0.5}Al_{0.5})_4O_9$, M=$Fe^{3+}$, Ga^{3+}), perovskite (Sr_2FeMoO_6) and spinel (MFe_2O_4, M = Zn^{2+}, Mg^{2+}, Cu^{2+} , Co^{2+}).
v) The macroscopic magnetic behavior of mechanosynthetic BiFeO3 was explained by the superposition of ferromagnetic and antiferromagnetic contributions with a large coercive field and remanent magnetization.
vi) The value of the activation energy of K+ ion transport in mechanosynthetic K2Ti6O13 was determined, correlations between the size of the mobile cation and specific conductivities and activation energies were derived.
vii) Several new types of complex oxides with a spinel structure were prepared by mechanochemical synthesis. Their lithium-containing oxyfluoro and oxychloro derivatives were also prepared for the first time.
viii) It was found that the high-entropic oxides prepared in this way exhibit high capacitance values.
ix) The mechanism of bulk conductivity in mechanosynthetically prepared Gd1-xCaxAlO^3-d perovskites was derived.
x) The study of the thermal stability of the prepared nanocrystalline substances pointed to a relaxation mechanism, thermal treatment caused a transition from a nanocrystalline to a low-energy crystalline state.

Benefits for Practise

The developed procedures enable the simple preparation of a wide range of complex nanooxides with modified physical properties for industrial and technological practice.

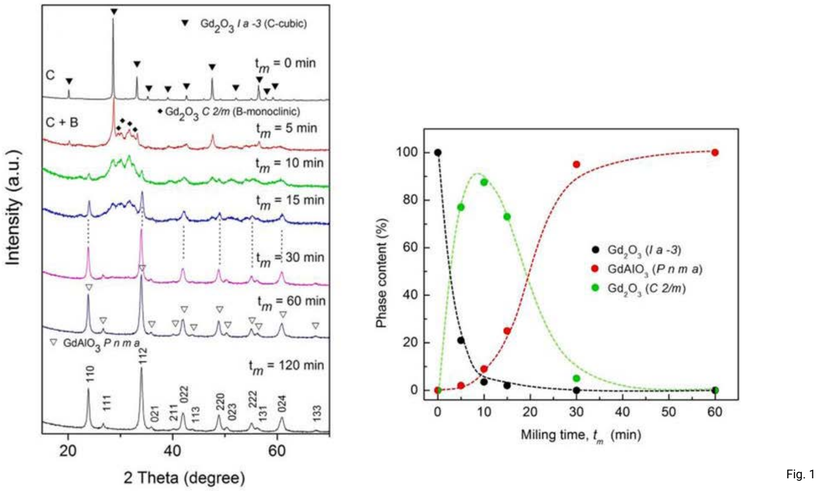

Fig. 1

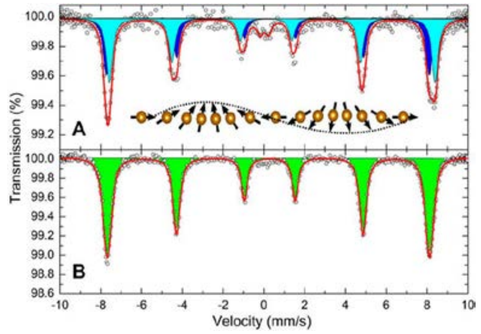

Fig. 2

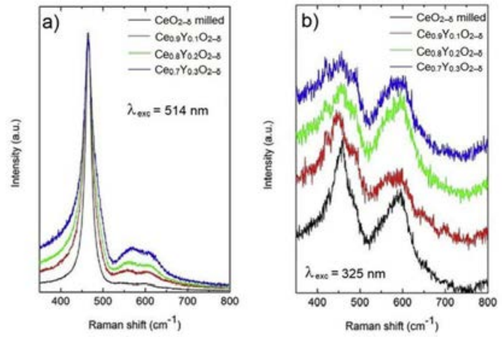

Fig. 3

Fig. 1 / (left) XRPD patterns of the mixture of precursors (Gd_2O_3 + γ-Al_2O_3) milled for various times (up to 120 min) - the milling times, tm, are shown in the figure. Vertical lines represent a guide to the eye to the formation of the perovskite structure, (right) Content of particular phases during high-energy ball milling of Gd2O3 and γ-Al2O3 precursors.
Fig. 2 / Room-temperature 57Fe Mössbauer spectra of (A) $BiFeO_3$ synthesized by the ceramic method and (B) BiFeO3 prepared by the combined mechanochemical–thermal route. The inset schematically shows the cycloidal arrangement of spins in the reference $BiFeO_3$ synthesized by the ceramic method.
Fig. 3 /Evidence of formation of defects on the suface of nanoparticles. Raman spectra of the ball milled CeO2-δ and mechanosynthesized Ce1-xYxO2-δ samples recorded with (left) 514 and (right) 325 nm excitation laser lines.

Personalized Optimisation of Cardiac Resynchronization Therapy in Heart Failure Based on Multiple Lead ECG Measurement

Principal investigator
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Applicant organisation
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Term of solution
07/2020 - 12/2023
Budget from agency
249 994 €
Project ID
APVV-19-0531

Research Subject

The project was focused on exploring ways to improve the success rate of Cardiac Resynchronization Therapy (CRT), which is currently the most advanced therapeutic method used to treat patients with heart failure. Despite the significant benefits of CRT, 20–40% of patients do not experience the desired effect, and there is a considerable number of responders among patients who do not meet the criteria for CRT. Therefore, there is substantial effort directed toward finding better criteria for therapy indication and for optimizing its parameters. In this project, we investigated whether recording surface ECG potentials using a large number of electrodes and computational modeling of the heart's electrical activity—utilizing computed tomography and solving the inverse problem of electrocardiography—has the potential to more reliably detect electrical dyssynchrony and assist in designing the optimal placement and timing of pacing electrodes.

Aim of the Research

The main goal of the project was to identify methods based on multilead ECG measurements that would enable personalized optimization of CRT and to validate these methods using both simulated and real patient data. The project objectives included:
- Identifying parameters from surface potential maps that could serve as suitable indicators of ventricular electrical dyssynchrony or its changes due to CRT,
- Designing an inverse method for non-invasive localization of the region of late ventricular activation and using it to propose optimal left ventricular electrode placement,
- Simulating the activation of a failing heart to better understand the underlying processes and how they manifest in surface ECG signals,
- Developing a specialized ECG measurement system necessary for acquiring real multilead ECG data from patients indicated for CRT.

Achieved Results

Autocorrelation (AC) maps derived from the QRS complex interval of the ECG were proposed as a suitable indicator for evaluating the dynamics of ventricular depolarization. In the AC maps of healthy subjects, larger regions with negative correlation are typically present. These regions are usually absent in patients with heart failure but appear after successful CRT. Parameters derived from AC maps were proposed as potential indicators for identifying likely responders and for optimizing the settings of cardiac resynchronization therapy (Fig. 1).
To noninvasively localize the region of latest ventricular activation and use it for placing the stimulation electrode in the left ventricle, a method was proposed that utilizes the patient's surface potential maps and a CT scan of the chest. The region is localized using an equivalent dipole source model (Fig. 2). Compared to an epicardial-potential-based method from a collaborating institute (Tubitak, Turkey), our method proved to be more accurate and was less affected by neglecting chest inhomogeneities.

To understand the heart activation processes during spontaneous action and under CRT therapy, heart activations and the corresponding surface potentials on the chest were simulated. Using realistic geometries of the heart and thorax from patient data, and an activation model based on cellular automaton or reaction-diffusion equations, simulations were performed for activations originating near the His bundle and at CRT pacing sites. A satisfactory match was achieved between simulated activation patterns and surface potentials compared to real measurements (Fig. 3).
To obtain real multilead ECG data from patients indicated for CRT, the ProCardio 9 measurement system was developed. It allows for recording of up to 132 ECG leads and wireless data transmission to a host computer via Wi-Fi. The proposed system uses a Raspberry Pi Compute Module 4 as the control unit and 8-channel ADS1298R ECG modules. A functional prototype of the device was built, including both electromechanical design and software (Fig. 4).

Benefits for Practise

Praktickým prínosom projectu je možnosť použitia autokorelačných máp ako nového ukazovateľa vhodnosti nastavenia časovania stimulačných elektród pri CRT a použitia meracieho systému ProCardio 9 na klinické mnohozvodové merania EKG. Ďalšími prínosmi sú možnosti využitia navrhnutých metód realistického modelovania aktivácie srdca a generovaného elektrického poľa srdca na neinvazívnu lokalizáciu neskoro aktivovaných oblastí komôr na simuláciu dôsledkov CRT na zmeny v priebehu aktivácie srdca a výsledné povrchové EKG potenciály merateľné na povrchu hrudníka.

Fig. 1 / Autocorrelation maps of a healthy subject with typical (blue) regions of negative correlation (a), maps of a patient during spontaneous activation (b), and under CRT stimulation. In mode (c), the CRT setting was suboptimal, while the map in (d) most closely resembles map of a healthy subject
Fig. 2 / Noninvasive localization of the activation site in a patient with confirmed activation in the right ventricular septal region. Using measured ECG maps (a), a torso model (b) and a heart model (c) obtained from CT, and applying a dipole source model, the activation region was identified at the location marked by a blue marker in (c)
Fig. 3 / Patient-specific heart model (a) and simulated transmembrane potentials at 30 ms (b) and 100 ms (c) after stimulation. In panel (d), measured ECG potentials [mV] are compared to potentials simulated by stimulation at the site marked with a green marker in (a)
Fig. 4 / The ProCardio 9 device for measurement and wireless Wi-Fi transfer of 132 ECG leads

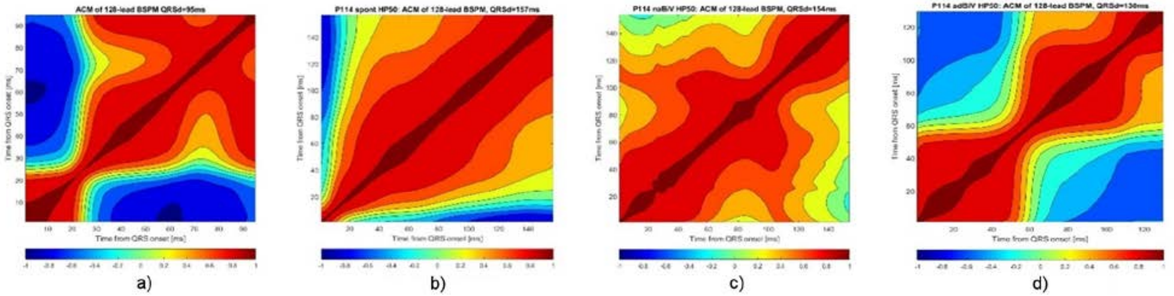

Fig. 1

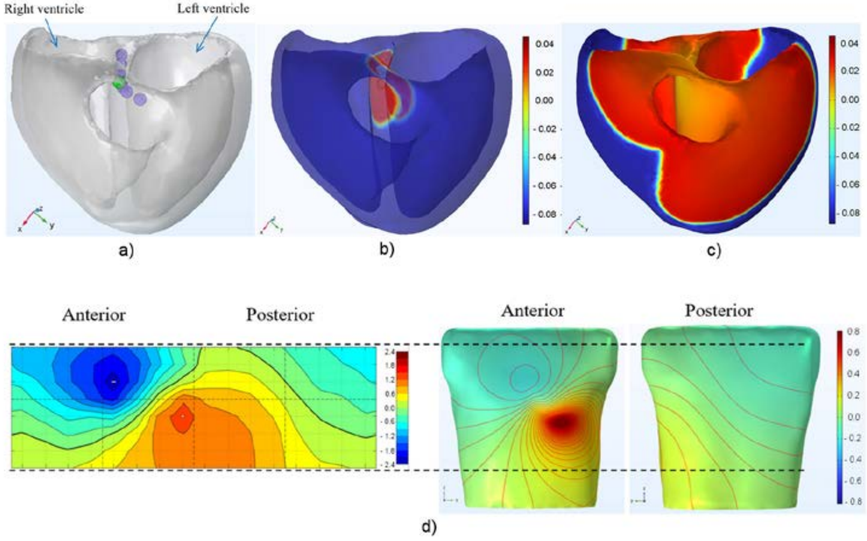

Fig. 3

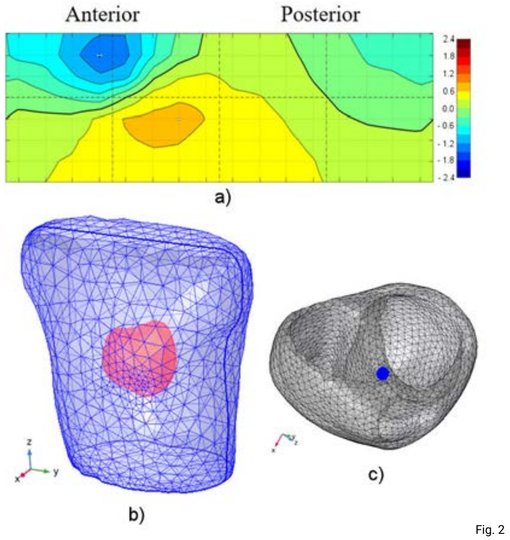

Fig. 2

Fig. 4

Progressive hybrid high-speed spinning actuator

Principal investigator
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Applicant organisation
Slovak University of Technology in Bratislava - Faculty of mechanical Engineering
Participating organisation
KINEX BEARINGS, a.s.
Term of solution
07/2020 - 11/2023
Budget from agency
250 000 €
Project ID
APVV-19-0538

Research Subject

The subject of research was to develop an optimized bearing with high rotational frequency of spinning headstock with permanent filling of grease lubricant without the necessity of re-lubrication and its protection from dynamic loading by ambient vibration at rotational frequency of 130 000 r/min and more with the exclusion of resonance frequencies, which significantly reduce bearing lifetime. The body of the spinning unit itself, the elastic bearing, the headstock bearing shaft drive, as well as the dynamic loading of the bearing from external vibration sources and the influence of the Eigen frequencies of the test equipment were also the subject of research.

Aim of the Research

The aims of the project focused on the area of reducing energy and economic costs in the production of textile fibres by improving the operating condition of high-speed bearings. These are an essential part of spinning technology, and the project aimed to reduce the rolling resistance factor by selecting and testing the most suitable lubricants. The project also involved verifying new components of spinning headstocks using frequency analysis, developing objective criteria for evaluating bearing quality, and processing a methodology for monitoring operational condition with a proposal for using vibration signal sensing in direct contact with the bearing. The research focused on primarily reducing dynamic loading and identifying the causes of increased dynamic loading in spinning headstocks to increase their lifetime and reliability without the need for maintenance during operation.

Achieved Results

Experimental tests were used to determine the amplitude of vibration generated by the spinning headstocks, as well as the transmission of dynamic load energy from the excitation sources to the spinning unit construction, by measuring the time history acceleration and its application. The quality and lifetime of spinning units increased with the reduction in dynamic loading. Reducing the dynamic load on spinning units resulted in reduced emissions noise and vibration, thus improving the working environment, which is also the aim of EU directives. Diagnostics on the outer ring of the bearing were used to assess the acceleration of vibration, on the basis of which a value exceeding the limits of the overload range of the spinning unit was determined. It was found that the temperature-based threshold values were unreliable, as was the vibration measurement outside the spinning unit bearing (Fig. 1). Figure 2 shows the frequency spectrum of a satisfactory (7) and an unsatisfactory (15) spinning unit. In the frequency range evaluated from 10 Hz to 1 000 Hz, the amplitude of vibration of the unsatisfactory headstock was up to 10 times higher than that of the satisfactory headstock. These effective values of vibration amplitude clearly confirm the different operational quality of the tested spinning units. Acceleration measurement is an objective parameter for assessing the operating condition of the spinning bearing.

Benefits for Practise

High-speed spinning headstocks are used in textile spinning machines of the OPEN-END system. The spinning machines are used worldwide, namely China (20 %), India (14 %), Turkey (18 %), other Asian countries (19 %), North and South America (14 %), Europe (6 %) and Africa (8 %).

The project designed, manufactured and tested a test facility (Fig. 3) for lifetime testing of a representative statistical sample of spinning headstocks using different lubricants and different modifications of bearing and spinning unit components, which is also used in the teaching process.

A diagnostic model for measuring the self-acceleration sources of vibration directly at the bearing of a spinning headstock was proposed in parallel with the measurement of the bearing temperature. The headstock diagnostic sensor was confirmed by the Industrial Property Office of the Slovak Republic as utility model No. 9571 (Fig. 3 and Fig. 4). This diagnostic measurement model has a wide application in practice, both in the diagnosis of bearings of stationary and non-stationary machinery.

The estimated annual cost savings associated with rotor bearing downtime (€3 750), oil purchase (€2 900), production interruptions due to re-lubrication (€3 000), energy efficiency (€3 600) and personnel costs (€2 500) are not insignificant.

Fig. 1/ Frequency spectrum of the bearing taken directly on the bearing (see Figs. 3 and 4), on the supporting frame (top right) and on the frame (bottom right).
Fig. 2/ Frequency spectrum of the bearings of the satisfactory (7) and unsatisfactory (15) spinning unit.
Fig. 3/ Laboratory test equipment and diagnostic sensor measuring point.
Fig. 4/ Rotor bearing system with high speed spinning unit disc.

Fig. 3

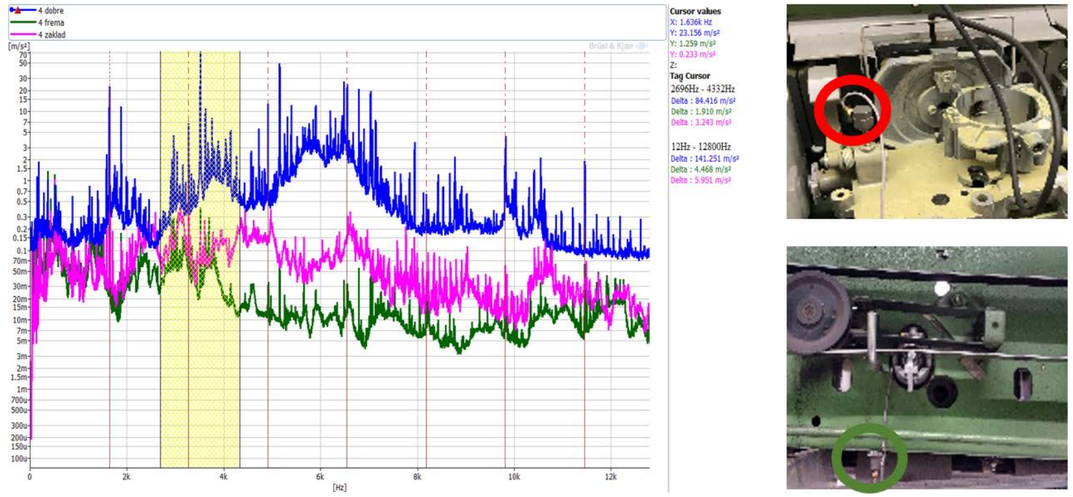

Fig. 1

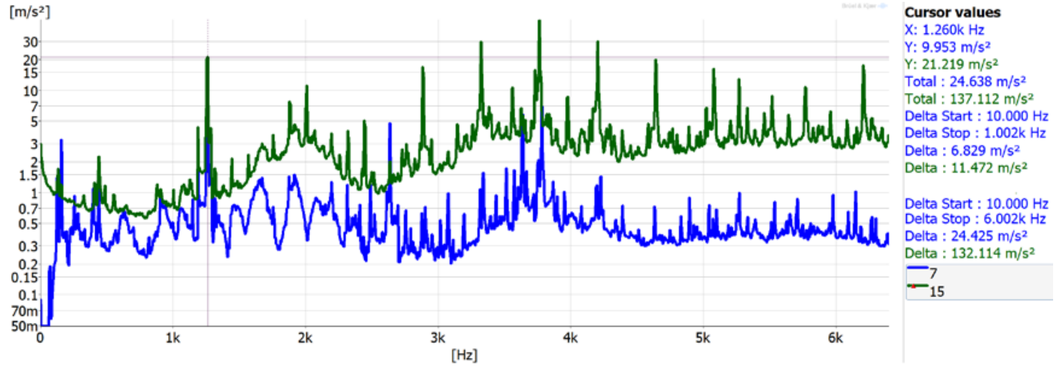

Fig. 2

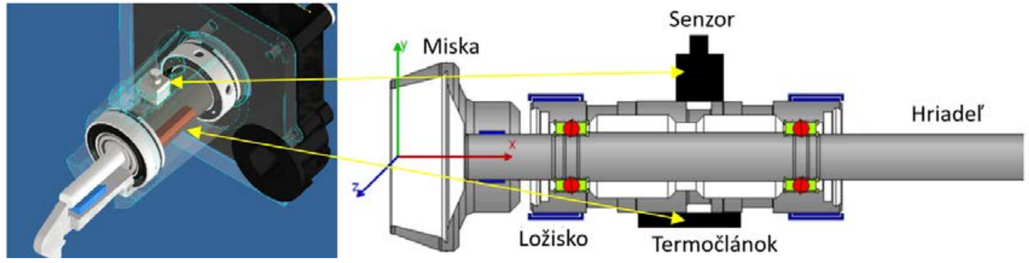

Fig. 4

Investigation of cellular material properties

Principal investigator
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Applicant organisation
Technical University of Kosice - Faculty of Manufacturing Technologies
Term of solution
07/2020 - 06/2024
Budget from agency
249 537 €
Project ID
APVV-19-0550

Research Subject

Cellular materials are commonly found in nature and are extremely efficient – they can perform demanding functions with minimal material consumption. They often have to withstand mechanical stress, store energy or prevent damage. This efficiency has inspired humans to develop artificial lightweight materials with specific properties. By choosing the right geometry, volume fraction and controlled distribution of cells (pores) of a sophisticated structure, it is possible to influence the functional properties of components and save material while maintaining the requirements for safety, reliability, operability and a sufficiently long service life of the manufactured component.

Given the complexity of the geometry of cellular materials, additive technology appears to be the most suitable choice for the production of lightweight bodies, which, despite its rapid development, still faces major challenges. However, the resulting properties of 3D-printed bodies are influenced not only by the material itself, but also by a number of different factors that enter into their production. Before implementing cellular structures into the cores of real components, it is therefore necessary to know their properties and behavior, especially in the connection between the topology of the structure and its manufacturing technology.

Aim of the Research

The fundamental goal of the project was to uncover new scientific outputs in the field of cohesive physical principles usable in the field of additive manufacturing and research into the qualitative, utility and mechanical properties of various types of so-called "geometrically defined porous structures" produced by additive technologies. This involves research and development of sophisticated samples with a lightweight porous structure, the weight of which is significantly lower than a solid body due to the presence of cavities in the structure of the material. These functional cellular bodies can give products an unusual combination of utility properties, such as their high strength accompanied by relatively low weight and good energy absorption.

Achieved Results

The team members worked with several metallic and non-metallic materials, and with various types of additive manufacturing During the solution, the properties of not only lattice structures, but also complex structures based on so called Triply Periodic Minimal Surfaces (TPMS) were investigated, while the effects of various topological and technological parameters on the quality of the manufactured samples and their physical properties were evaluated.

Fulfilling the tasks and goals of the project brought many interesting and internationally recognized results, which were presented by the members of the research team at international scientific conferences. The quality of the research is also evidenced by manuscripts published in many scientific journals registered in the CC WoS databases (Q1 and Q2) and a total of 12 filed applications for domestic and international patents or utility models.

Benefits for Practise

Reducing material consumption and its effective use for the needs of a given application can bring several benefits from an economic and energy perspective. For example, it is estimated that every 10% reduction in vehicle weight results in a 5-7% reduction in fuel consumption (similarly with aircraft). As a result, the use of lightweight materials results in a reduction in emissions, which also greatly helps protect the environment.

Unlike randomly distributed pores, which can be found, for example, in foam materials, bodies with a controlled distribution of cells allow for better prediction of their behavior, mathematical formulation of properties depending on input variables, and thus more reliable use of simulation software in the search for optimal solutions based on set criteria. Considering the properties of cellular materials designed in this way, their use therefore appears to be very promising not only from the perspective of various sectors of industry and economy, but also from the perspective of healthcare, health care, or biomedicine.

By using the results of the basic research carried out, it will therefore be possible to significantly increase the efficiency of production and thus contribute to savings in the application area.

A significant benefit is also the increase in the professional and technical level of the members of the research team, which will be reflected in the implementation of the acquired knowledge in the educational process.

Fig. 1 / Measurement of the sound absorption coefficient of 3D printed lattice cellular structures (from left ST - Starlit, RH - Rhomboid, CA - Cartesian, OC - Octagonal) made of ABS material
Fig. 2 / Measurement of bending mechanical properties of complex cellular Neovius structures made of AlSi10Mg aluminum alloy with different volume fractions
Fig. 3 / Experimental (left) and numerical (right) analysis of the modal properties of a cellular Gyroid structure made of Inconel 718

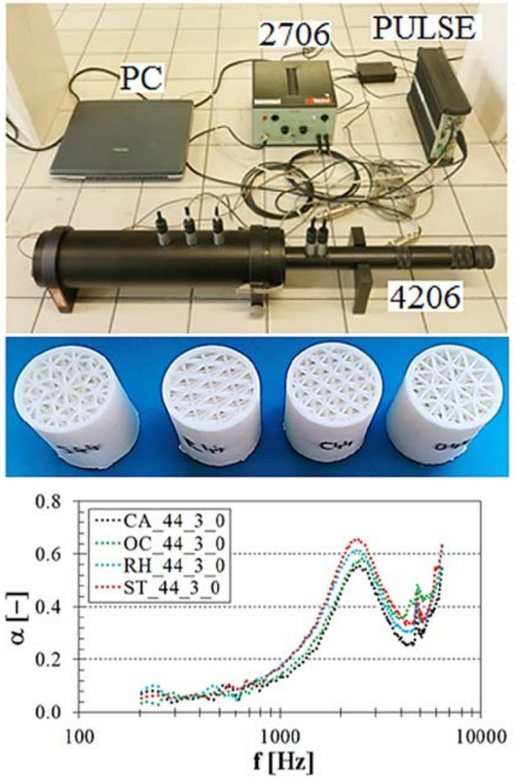
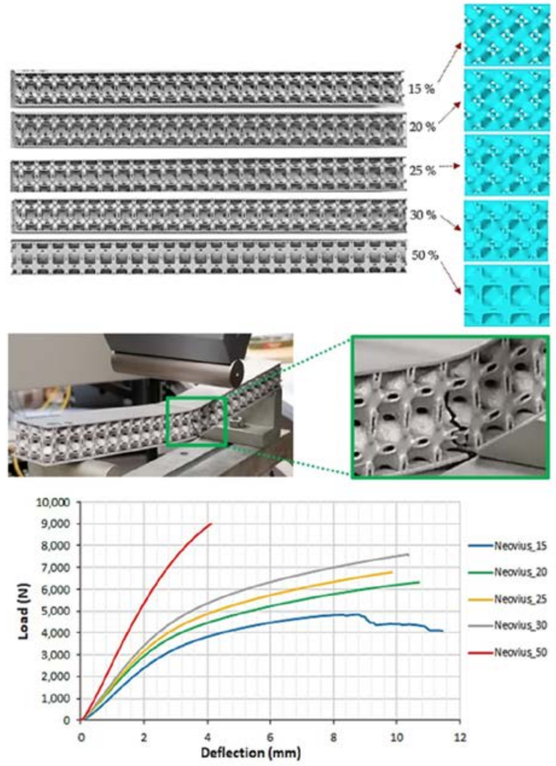


Fig. 1



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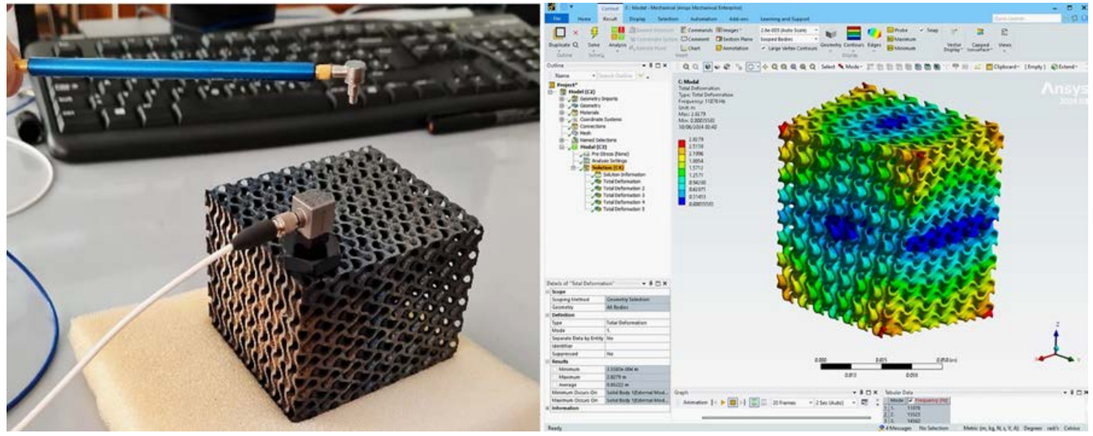

Fig. 3

Electricity self-sufficiency in conditions of liberalized electricity market

Fig. 1 / Modified design of the protection system circuit with radial topology for an industrial facility, including protection settings
Fig. 2 / Connection diagram of the circuit illustrating the impact of renewable energy sources on the power system using a battery storage system
Fig. 3 / Active power curve for a case simulation utilizing renewable energy sources and a battery storage system

Principal investigator
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Applicant organisation
Technical University of Kosice - Faculty of Electrical Engineering and Informatics
Term of solution
07/2020 - 06/2024
Budget from agency
243 922 €
Project ID
APVV-19-0576

Research Subject

The project focused on analyzing the possibilities of ensuring the self-sufficiency of the Slovak Republic's electricity sector under the conditions of a liberalized electricity market. The solution concentrated on new approaches to the efficient use of domestic renewable energy sources, options for optimizing the operation of distribution networks, and the analysis of the impact of electricity price fluctuations on the decision-making of electricity consumers and producers.

Aim of the Research

The main objective of the project was to identify and propose measures that could enhance Slovakia's energy self-sufficiency without disrupting the functioning of the liberalized electricity market. The partial goals included:

- analyzing the possibilities for integrating renewable energy sources and their impact on grid stability,
- examining the influence of fluctuating electricity prices on the use of renewable energy sources,
- proposing effective strategies for the management of electric vehicle charging and their use in Vehicle-to-Grid (V2G) systems,
- creating recommendations for the operation and modernization of distribution networks.

Achieved Results

Within the project, numerous significant results were published in indexed and other significant peer-reviewed scientific journals. Analyses were developed on the impact of price changes on the operational strategies of photovoltaic systems, studies on possibilities for increasing the ampacity of overhead lines using HTLS conductors, as well as strategies for managing electric vehicle charging within smart grid systems. The project made a substantial contribution to the popularization of results among students and the professional community through lectures, expert seminars, and the supervision of diploma and doctoral theses on related topics. The research outcomes were also presented at significant international conferences.

Benefits for Practise

The project provided recommendations for optimizing the use of renewable energy sources, proposals for flexible demand management through electromobility, and suggestions for increasing the transmission capacity of existing power lines without requiring large investments. The results have significant potential for implementation in the practice of the electricity sector, particularly in the modernization of distribution systems, increasing the share of renewable energy sources, and applying new technologies within the concept of smart grids. The project also contributed to the development of educational activities and laid the foundation for further specialized studies in the fields of electricity and electromobility.

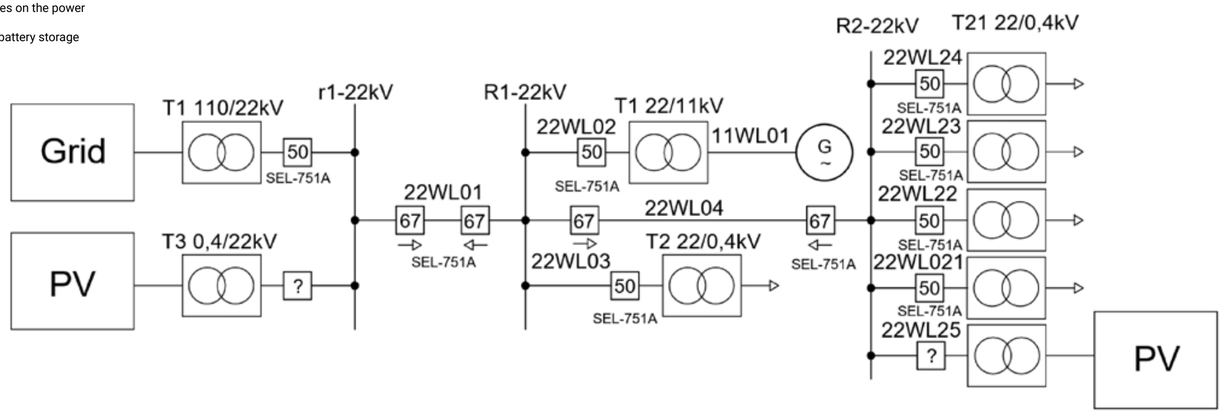

Fig. 1

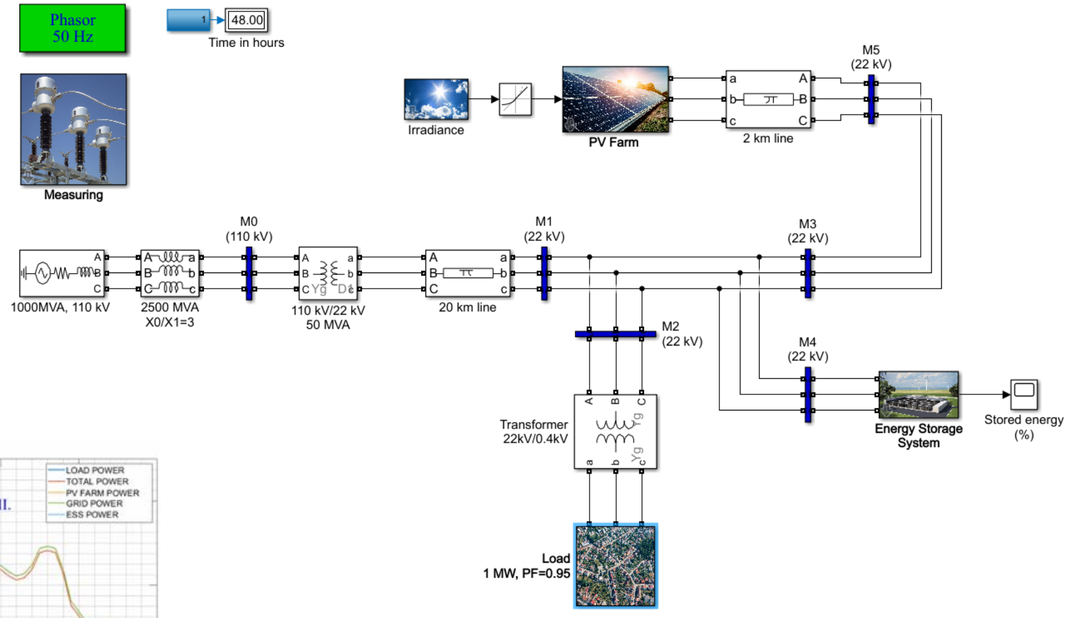

Fig. 2

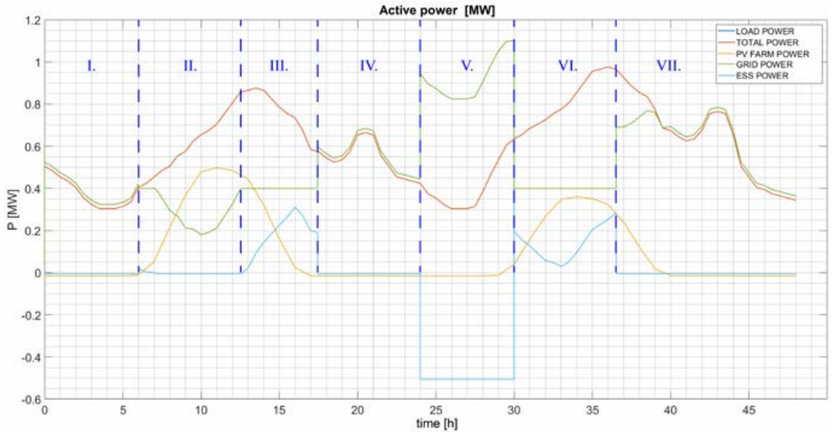

Fig. 3

Modular Multifunctional Inspection Workplace using Computational Intelligence Techniques

Principal investigator
prof. Ing. Piteľ Ján, PhD.
Applicant organisation
Technical University of Kosice - Faculty of Manufacturing Technologies
Term of solution
07/2020 - 06/2024
Budget from agency
249 977 €
Project ID
APVV-19-0590

Research Subject

Applied research in the field of product error identification by digitalization and processing them with computational intelligence algorithms. The multifunctionality of the solution enables the evaluation of shape and dimensional errors of inspected parts and products, including surface damage, using a multi-plane camera imaging system in combination with 3D profilometers.

Aim of the Research

The project aimed to design and implement multifunctional equipment for recognizing product discrepancies (shape and dimension) without interrupting the material flow on the conveyor, simultaneously inspecting products from multiple sides, while in addition to the recognition algorithms used so far (clustering, classification, deep learning), alternative approaches from the latest advances in computational intelligence in image recognition have been also tested.

Achieved Results

The results of analyzing newly acquired and previously published knowledge in the field of product error recognition showed that convolutional neural networks (CNNs) are particularly suitable tools for solving the project's problems. The following technologies were selected for advanced surface scanning: an industrial camera module for creating a 3D image using structured light (Fig. 1 left), an industrial camera module with variable illumination and setting of different wavelengths when illuminating the surface, the so-called "multispectrum" (Fig. 1 middle), an industrial scanning module based on linear laser triangulation with high accuracy and the possibility of integration into a conveyor system (Fig. 1 bottom right) and a computing unit for integrating CNN networks (Fig. 1 top right). The Tecnomatix software was selected for creating the simulation model, which has support for time validations and connection to the real system via OPC communication. Unreal Engine was chosen to create the digital twin, while the import of 3D models was carried out via the Datasmith plugin for direct integration of models created in the 3D design software Autodesk Inventor (Fig. 2).

Benefits for Practise

The proposed principle of a modular solution with the possibility of adding and removing individual devices (hardware and software modules) can significantly shorten the often-lengthy process of designing a measuring and inspection workplace for a specific production process in business entities. The implemented and tested universal modular inspection workplace with multiple sensing systems, including an integrated conveyor, its control, and a product identification system, as well as support for collaborative assembly, will be a model example and inspiration for specialists to implement inspection workplaces within automated production lines. By using automated data processing from the digitization of the recognition process using computational intelligence algorithms and storing the extracted results in cloud storage accessible for further processing by tools for assessing production quality, it is possible to subsequently optimize production processes with a positive impact on the production economy.

Fig. 1 / Industrial camera modules
Fig. 2 / Software platform for creating simulation models and digital twin
Fig. 3 / Methodology for continuous training of CNN networks
Fig. 4/ Synthesized product discrepancies: scratches (top), cracks (middle), dirt (bottom)

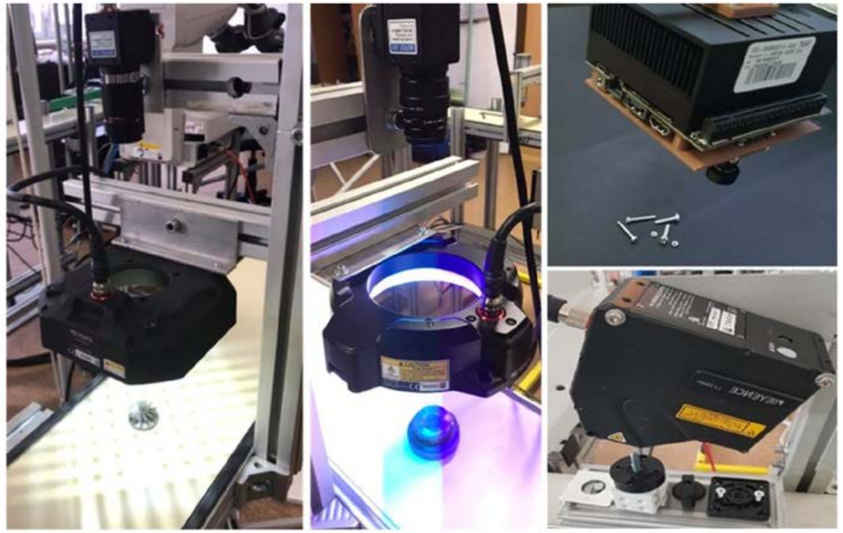

Fig. 1

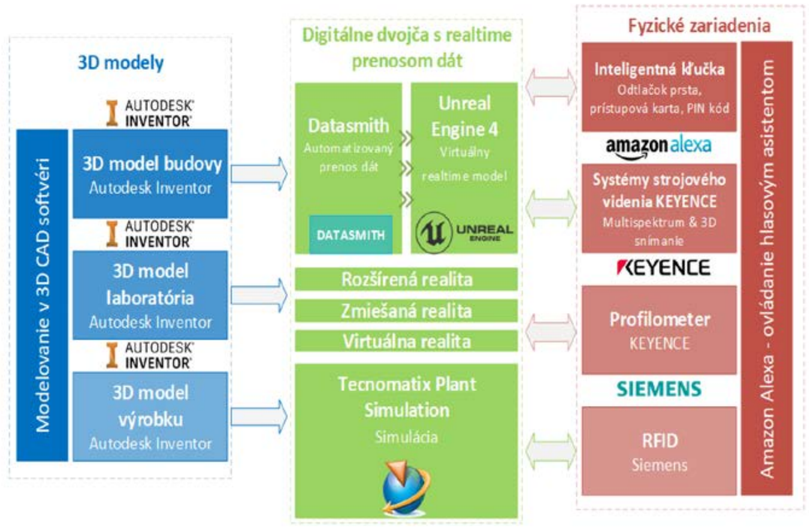

Fig. 2

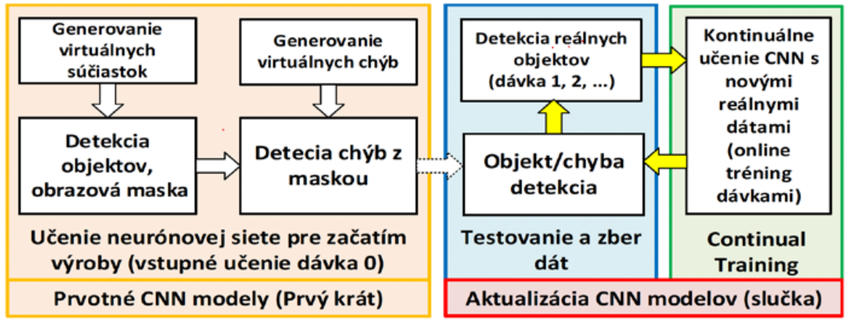

Fig. 3

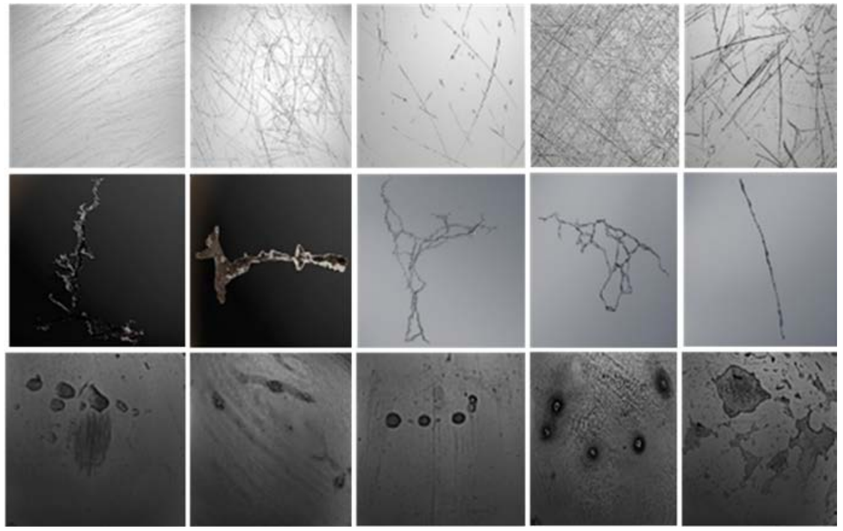

Fig. 4

3D photonic polymeric microsensors integrated with optical fibers

Principal investigator
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Participating organisation
NanoDesign ltd.
Term of solution
07/2020 - 06/2023
Budget from agency
249 897 €
Project ID
APVV-19-0602

Research Subject

The research for this project aimed to acquire new knowledge in the design, preparation, and characterization of photonic polymer microsensors that are integrated with optical fibers. The ultimate goal was to develop optical fiber sensors capable of measuring various physical parameters.

Through innovative approaches, we designed 3D photonic structures. This involved simulating their optical transmission properties and observing how these properties changed based on alterations in the structure's parameters and the surrounding environment. Consequently, we successfully designed photonic polymer structures for both measuring the vertical component of magnetic fields in magnetic materials and detecting organic solvent vapors.

We also investigated methods for producing these structures, specifically laser 3D printing and the microdeposition of uncured polymer resins. Concurrently, we studied ways to integrate these prepared structures with fiber end faces, leading to the development of prototypes for optical fiber sensors.

Aim of the Research

The primary objectives of this project were to design and fabricate specific photonic polymer structures and elements at the micrometer scale, ensuring their seamless integration with optical fibers for diverse physical sensing applications. The research significantly benefited from the principal investigator's established expertise in high-precision laser 3D printing.

Achieved Results

From an application perspective, the project successfully implemented the following:

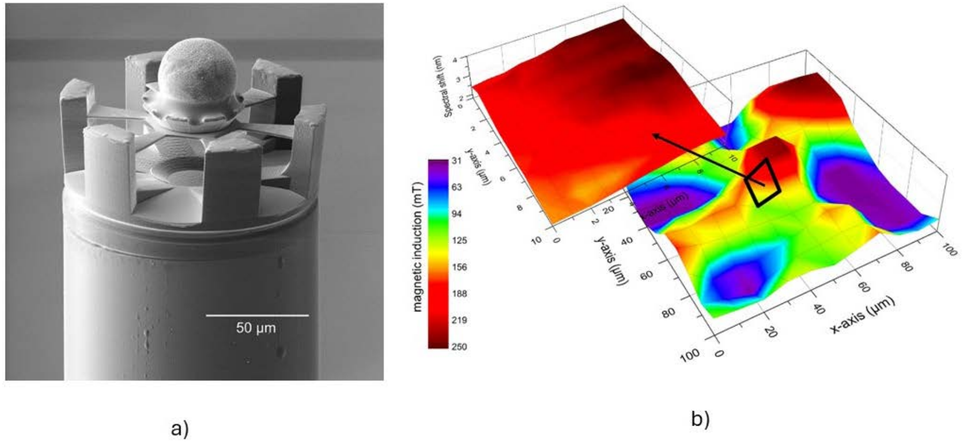
1. Optical Fiber Sensor for Measuring the Vertical Component of the Magnetic Field
We fabricated a sensing photonic structure using high-precision laser 3D printing in IP-Dip polymer and successfully integrated it with the end face of an optical fiber. This structure, modified with a 30 µm steel ball, demonstrated its ability to measure magnetic fields up to 450 mT with a sensitivity of 78.15 mT/nm. This was achieved by detecting light interference in the spectral range of 1480 nm to 1640 nm. The sensor's properties were verified by scanning a permanent magnet's magnetic field over a 300x300 µm² area with a 30 µm step.

2. Optical Fiber Sensor for Measuring Polymer Swelling Kinetics
The research team developed an optical probe to study the linear swelling of polymers. This probe consists of a conventional optical fiber with its output end positioned a few tens of micrometers from a polymer layer deposited on a fused silica substrate. PDMS was selected as the polymer for testing swelling properties. We investigated the swelling of PDMS in organic solvent vapors (isopropanol, acetone, and toluene) and examined the dependence of PDMS swelling on vapor concentration by measuring light interference in both the time and spectral domains.

3. Optical Fiber Sensor for Measuring the Dynamic Operation of Rolling Stock
As an unplanned but significant outcome, an optical fiber sensor for monitoring the dynamic operation of rolling stock was developed. This was a direct response to practical requirements, in collaboration with our partner company, Betamont s.r.o. Leveraging all the experience gained during the project, the research team designed a prototype optical fiber sensor based on measuring light interference in the time domain. This sensor was installed on a railway line and successfully monitored the passage of trains in real-world conditions, demonstrating its functionality by identifying various faults on rolling stock. Further research is needed to pinpoint the exact nature of these faults.

Benefits for Practise

From a practical perspective, this research provides new insights into the development of optical fiber sensors for measuring various physical, chemical, and technical parameters.
The polymer swelling kinetics sensor could be used to study the swelling of polymeric materials in different environments. This could offer valuable information to companies manufacturing polymeric materials about their suitability for various applications.
Similarly, the sensor for measuring the dynamic operation of rolling stock has potential applications for companies involved in the operation and maintenance of railway lines, as well as the operation and maintenance of rolling stock itself.



a) b)

Fig. 1

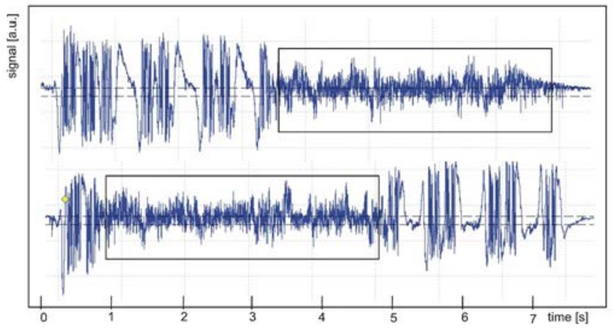


Fig. 2

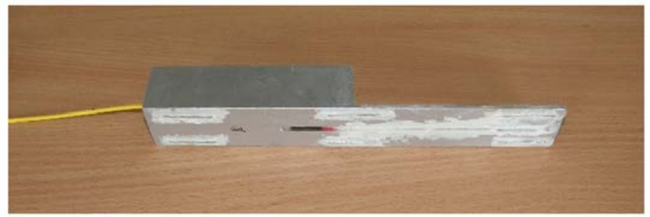


Fig. 3

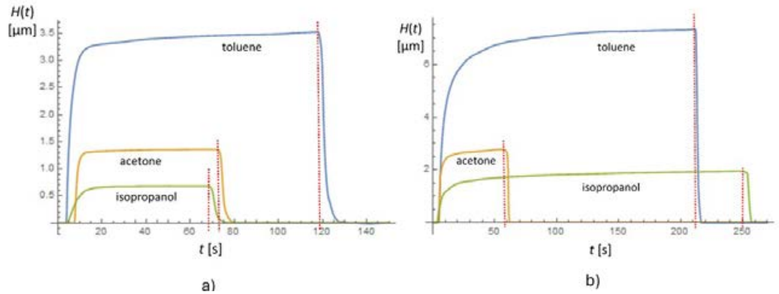


Fig. 4

Optimized progressive shapes and unconventional composite raw materials of high-grade biofuels

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Participating organisation
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Term of solution
07/2020 - 12/2023
Budget from agency
250 000 €
Project ID
APVV-19-0607

Research Subject

The project reflects on the deepening energy crisis and the related necessity of searching for and mass use of renewable energy sources. The global trend and the current necessity of replacing fossil fuels with renewable sources also affect the direction of research and development of efficient technologies for processing biomass and organic waste. Biomass represents a highly promising RES with the highest potential for use in Slovakia and the EU. Processed biomass provides effective options for storing, transporting and using this energy. However, limited sources of wood raw materials hinder the development of solid biofuel production. The project solution procedure was based on searching for and effectively processing new, previously unused sources of raw materials from various types of biomass into the form of a new composite biofuel. The subject of development was also the design of a compaction machine based on optimized biomass compaction technology.

Aim of the Research

The main objective of the project was to develop an original machine design for the progressive technology of biomass compaction into a new optimized shape of solid biofuels. The task of the researchers was to develop and manufacture a prototype of their own patented solution of the original design and its verification in the technological line. Achieving the main objective was conditional on the fulfillment of partial objectives. Research and optimization of the material composition of composite fuels based on biomass and organic waste from an environmental, economic and energy perspective brought new possibilities for the application of previously unused waste in the form of high-quality composite biofuels. Development and optimization of the technology and parameters of compaction of these raw materials ensured an increase in the energy efficiency of the process and a reduction in wear of functional parts of the machine, which results in an increase in machine productivity. Based on the research outputs, a new design principle of the machine was developed. This was followed by optimization of the developed design, the actual production and testing of the prototype in production practice conditions. The output of the project is a comprehensive technical documentation of the original design of the modular construction of the compaction machine, ready for practical use for its production. One of the goals was also the development of technology for environmental and energy upgrading of biofuels by increasing their energy density.

Achieved Results

As part of the project, new composite biofuels were developed based on biomass and organic waste that had not been used for energy purposes. As part of the comprehensive research, their material composition was optimized so that they met all the limits defined by the standard and their production was more economically advantageous than pure wood biofuels, which made them highly competitive on the biofuel market. This research goal was achieved and several types of composite biofuels were successfully developed.

At the same time, based on the shape and dimensional optimization of the solid biofuel compact, an original compaction machine design with rotary kinematics was developed, enabling the production of solid biofuels of a new optimized shape. The new design principle achieves higher energy efficiency of the compaction process and increased machine productivity. Technical and production documentation for this original compaction machine design has been prepared for practice. A type-dimension series of the design of this machine has also been developed.

As a result of the successful completion of the project, three patents and one utility model were registered. The researchers created two scientific monographs, one abroad and one in Slovakia. The results of the scientific work were published in a foreign CC journal, as well as in foreign scientific peer-reviewed periodicals.

Benefits for Practise

The project result directly applicable in practice is the development of new composite solid biofuels. The results of research into the material optimization of these biofuels provide a basis for their economic production and direct application on the solid biofuels market. Another applicable result of the project is the development of an original compaction machine design. The manufactured prototype was tested in production practice conditions. The outputs are prepared for practice in the form of technical and production documentation of this original machine design.

Fig. 1 / Material optimization of a new composite fuel based on digestate from biogas plants
Fig. 2 / Experimental research on ash melting of composite fuel
Fig. 3 / Optimization of technology and compaction parameters – dependence of radial pressure in the pressing chamber on the change in the apex angle
Fig. 4 / Prototype of the developed original design of a compaction machine for the production of optimized shapes of pressings

Fig. 1

Fig. 4

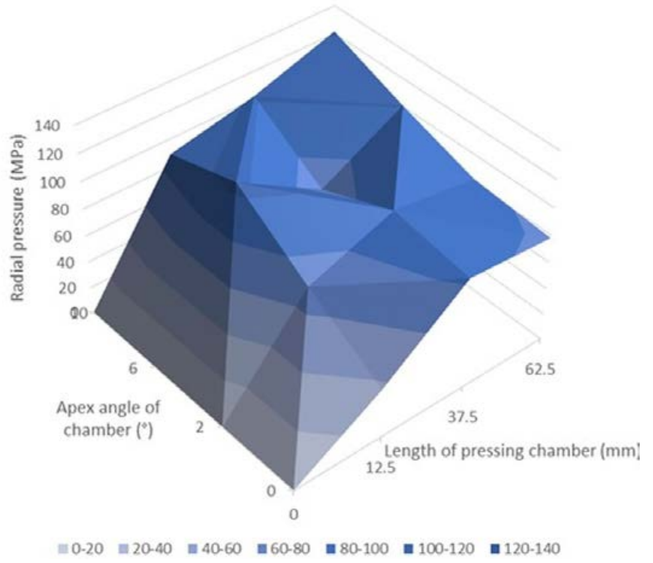

Fig. 3

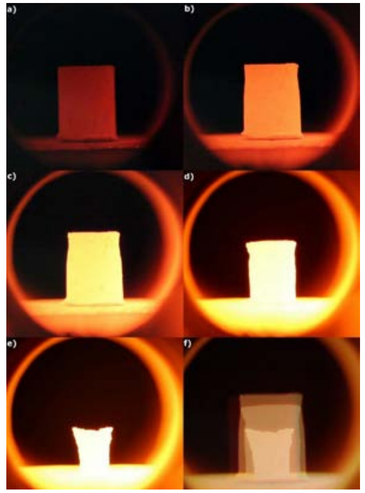

Fig. 2

MEDICAL SCIENCES

The role of Rho-kinase pathway in pathomechanism of allergic airway inflammation and the possibilities of its pharmacological modulation

Principal investigator
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Term of solution
07/2020 - 06/2024
Budget from agency
222 365 €
Project ID
APVV-19-0033

Research Subject

Allergic bronchial asthma is a chronic inflammatory disease of the airways, in which current therapeutic options are limited, and there remains a need to identify new drugs with complex anti-inflammatory and anti-remodelling effects. The experimental studies in the scientific literature have increasingly highlighted the critical role of the Rho-kinase signalling pathway in the pathophysiology of asthma, particularly in regulating smooth muscle contractility, inflammation, remodelling, and immune cell function. Two isoforms of Rho-kinase—ROCK1 and ROCK2—exist in the body, which likely differ in how they regulate inflammatory processes. Several membrane ion channels also function as active components of the Rho-kinase pathway.

Aim of the Research

The project aimed to investigate the role of the Rho-kinase signalling pathway and its isoforms (ROCK1 and ROCK2) in the pathogenesis of allergic asthma, particularly in inflammation, remodelling, and airway defence mechanisms. The study examined the effects of selective and non-selective Rho-kinase inhibitors, as well as substances that influenced this pathway indirectly, especially CRAC channel blockers, TRPV4 and TRPA1 receptor antagonists, and other modulators of ion channels that regulate or mediate Rho-kinase activity. The effects of the tested compounds were evaluated based on changes in the concentrations of inflammatory cytokines and the degree of cellular infiltration in the airways, changes in remodelling markers including growth factors, collagen, and mucin, as well as the expression of transcription factors STAT6, NF-κB, and the regulatory protein RhoA. At the same time, changes in airway defence mechanisms—cough, bronchoconstriction, and ciliary beat frequency—were monitored. Oral and inhalation administration schemes were compared, and the efficacy of the tested substances was compared against reference anti-asthmatic drugs used in clinical practice.

Achieved Results

The project led to several original findings. The most significant results concern the anti-asthmatic potential of hydroxyfasudil, a non-selective inhibitor of both Rho-kinase isoforms—ROCK1 and ROCK2. Both systemic (1 and 10 mg/kg i.p.) and inhalation administration of hydroxyfasudil for 14 days demonstrated strong anti-inflammatory and anti-remodelling effects in an experimental asthma model. In the context of allergic airway inflammation, hydroxyfasudil showed high anti-inflammatory activity, evidenced by decreased concentrations of cytokines produced by Th2 cells (especially IL-13) and GM-CSF in lung tissue. In addition to suppressing Th2-driven inflammation, hydroxyfasudil inhibited the release of cytokines typical for Th1 cells, such as TNF-α and IFN-γ. Following systemic and inhalation treatment, the reduction in leucocyte count in bronchoalveolar lavage fluid further confirmed its anti-inflammatory effect.

Regarding airway remodelling, hydroxyfasudil significantly reduced levels of the growth factor TGF-β1, the EGF receptor, and type III and V collagens in all dosing regimens (Fig. 1-2). Systemic administration led to normalising EGF levels to those comparable with healthy controls. Hydroxyfasudil exhibited a significant bronchodilatory effect after systemic and inhalation administration. However, it did not influence ciliary motility in allergen-sensitised respiratory epithelium. Analysis of transcription factors showed that hydroxyfasudil did not affect concentrations of STAT6 or NF-κB, suggesting that its effects may be mediated via alternative molecular pathways.

The combined inhalation treatment with hydroxyfasudil and the glucocorticoid budesonide at half doses yielded promising results. After one week, airway reactivity to histamine was suppressed, and after two weeks, inflammation and remodelling parameters were significantly reduced, indicating a potential synergistic interaction between the two agents.

Benefits for Practise

The project provided new insights into the molecular mechanisms underlying the pathogenesis of asthma and identified potential targets applicable to other chronic inflammatory airway diseases associated with remodelling. The results confirmed Rho-kinases' importance as promising therapeutic targets in asthma treatment. Compounds that indirectly modulate this pathway, particularly CRAC and TRPV4 ion channel blockers, also represent potential candidates for developing new drugs with simultaneous anti-inflammatory, bronchodilatory, and anti-remodelling effects.

Fig. 1–2. Concentrations of TGF-β1, EGF, EGF receptors (Fig. 1) and collagen type III (COL3) and V (COL5) (Fig. 2) in lung tissue homogenates after systemic administration of hydroxyfasudil. The healthy control group (OVA−) received saline for 28 days; the negative control group (OVA+) was sensitised with ovalbumin for 28 days. Experimental groups were also sensitised and treated with hydroxyfasudil (1 or 10 mg/kg i.p.) during the last 14 days. Effects were compared with reference anti-asthmatic drugs salmeterol (SALM) and budesonide (BUD). Data are expressed as mean ± SEM; n = 8; ###p < 0.001, ##p < 0.01 OVA+ vs. OVA−; ***p < 0.001, **p < 0.01, *p < 0.05 OVA+ vs. tested substance.

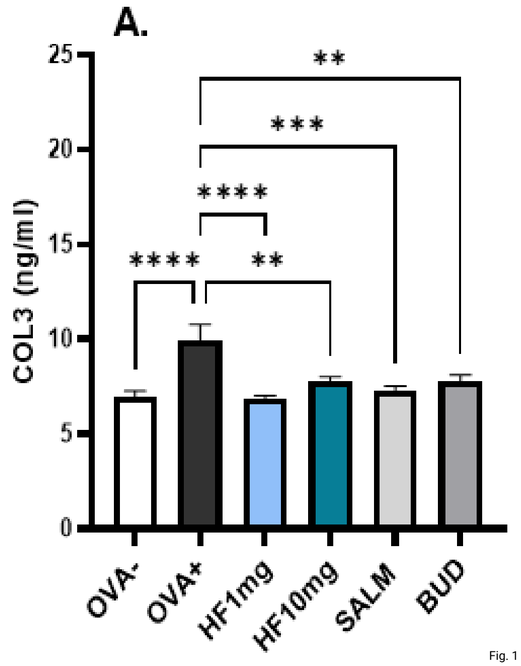

Fig. 1

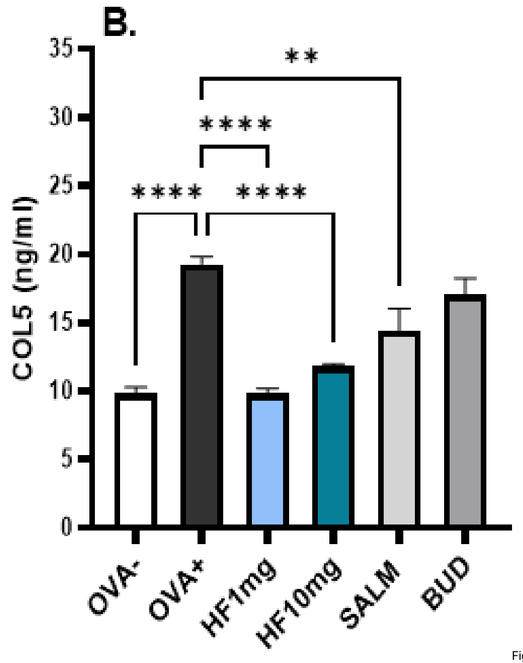

Fig. 2

Activation of drugs against tuberculosis

Principal investigator
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Applicant organisation
Comenius University Bratislava - Faculty of Natural Sciences
Term of solution
07/2020 - 06/2024
Budget from agency
241 600 €
Project ID
APVV-19-0189

Research Subject

Tuberculosis maintains its status as one of the most serious infectious diseases even in the 21st century. Despite the availability of several types of antibiotics for its treatment, the effectiveness of therapy is hindered by the emergence of multidrug-resistant and extensively drug-resistant strains of its causative agent, Mycobacterium tuberculosis. Several antitubercular drugs require activation inside the mycobacterial cell to exert their inhibitory effects, while resistance to these drugs often arises from mutations in the activation systems. Such resistance usually appears just a few years after a new drug is introduced into clinical practice. Therefore, in addition to developing new antibiotics, it is essential to pursue strategies aimed at enhancing or at least maintaining the effectiveness of treatment regimens. However, success in this approach depends on a thorough understanding of the mechanisms of action and activation of individual drugs.

Aim of the Research

The project focused on the characterization and subsequent exploration of the mechanisms of action and activation of new as well as clinically used antimycobacterial inhibitors to enhance the effectiveness of therapy. The aim of the project was to characterize the proteins that modify the antituberculosis drugs ethionamide and rifampicin in mycobacterial cells, and to elucidate the mechanism of action of the latest antituberculosis drugs - pretomanid and delamanid, their derivatives, as well as compounds that stimulate their effect.

Achieved Results

The most significant outcomes of the project include:
(i) Biochemical characterization of the proteins EthA and Rv0565c, which activate the antituberculosis drug ethionamide in mycobacterial cells. This drug inhibits the synthesis of mycolic acids, which are essential components of the mycobacterial cell wall. We optimized the protocol for the production and isolation of these proteins and contributed to the development of a method to monitor their activity. We discovered that Rv0565c also activates another antituberculosis drug - thiacetazone.
(ii) Identification of novel compounds that inhibit mycolic acid synthesis. We characterized the mode of action of a range of compounds that interfere with the production or modification of mycolic acids by inhibiting components of the fatty acid synthase complex or through inhibition of the folate pathway.
(iii) Characterization of the mechanism of action of pretomanid and its derivatives. We demonstrated that pretomanid in M. tuberculosis affects multiple NADH/NADPH-dependent processes, such as the production of keto-mycolic acids, the synthesis of the arabinosyl donor required for building arabinogalactan in the cell wall, and the elongation of mycolic acids. We also contributed to elucidating the mechanism of action of compounds that enhance the effect of pretomanid in a mouse model and have the potential to reverse resistance to this drug. We showed that these stimulators amplify pretomanid's inhibitory effect on arabinogalactan biosynthesis.
(iv) Characterization of the enzyme EphD, which catalyzes the formation of keto-mycolic acids. We showed that this protein is inhibited by the antituberculosis drugs thiacetazone, isoxyl, and the urea derivative AU1235.
(v) Discovery of the inhibitory effect of compound M06 on the production of keto-mycolic acids. We participated in clarifying the mechanism of action of this compound, which reduces the variability of M. tuberculosis cells, thereby increasing their susceptibility to selected antituberculosis drugs.

Benefits for Practise

As part of the project, the mechanism of action of the newest antituberculosis drug - pretomanid, which has been used since 2019 to treat resistant forms of tuberculosis -was characterized, along with its more potent derivatives and compounds that enhance its activity in a mouse model. The knowledge gained has high potential for clinical application.

At the same time, the mechanisms of action of compounds affecting the synthesis of mycolic acids, arabinogalactan, or folate metabolism were identified, as well as those acting through previously uncommon mechanisms, such as reducing cell population variability. These findings provide an important foundation for the development of these compounds as new antituberculosis agents.

Fig. 1 / The effect of the studied compound M06 (A.) and para-aminosalicylic acid derivatives (B.) on mycolic acid synthesis in M. tuberculosis. Analysis of fatty acid derivatives using thin-layer chromatography (published in (A.) Mistretta et al. (2024) Nature Communications 15: 4175 and (B.) Nawrot et al. (2023) Eur J Med Chem258: 115617).
Fig. 2 / Study of the inhibitory effect of pretomanid and "20" on the growth of various M. tuberculosis strains. (A.) Growth of macrocolonies on solid medium. (B.) Growth analysis in liquid medium using resazurin. Pink color indicates growth, blue indicates growth inhibition.
Fig. 3 / A view into the laboratory designated for work with the pathogenic M. tuberculosis strain (biosafety level 3).

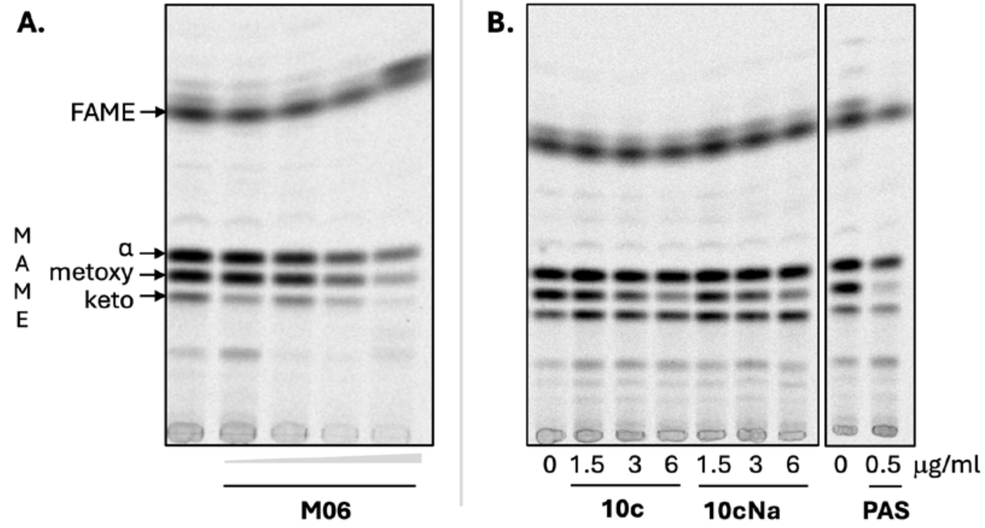

Fig. 1

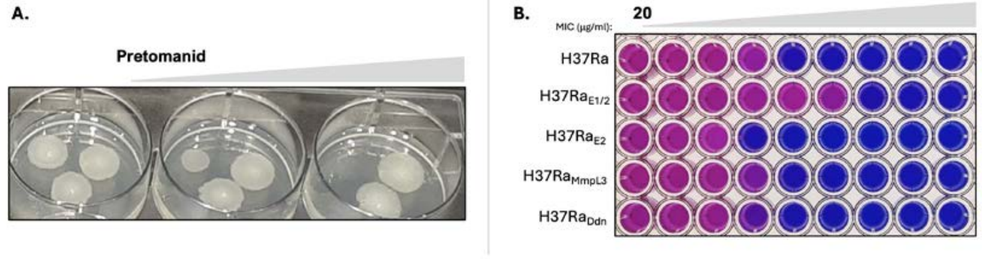

Fig. 2

Fig. 3

Harnessing the immunological mechanisms in various subtypes of B cell lymphoma

Principal investigator
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Biomedical Research Center - Cancer Research Institute
Participating organisations
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Slovak Academy of Sciences, Institute of Molecular Biology
Term of solution
07/2020 - 06/2024
Budget from agency
249 424 €
Project ID
APVV-19-0212

Research Subject

B-cell non-Hodgkin lymphoma (B-NHL) comprises a highly heterogeneous group of tumors, ranging from the most indolent to the most aggressive, and is characterized by malignant mature B cells that typically infiltrate lymphoid structures. Each B-NHL subtype can be assigned to a unique stage of B-cell differentiation, and is characterized by a set of genetic alterations that drive specific transformation pathways and disease progression. The B-cell tumor microenvironment (TME) contributes significantly to lymphoma development and progression by fostering key hallmarks of malignancy: sustained proliferation, stemness, resistance to cell death, enhanced cell homing and invasion, angiogenesis, and immunosuppression. In particular, the bidirectional relationship between malignant B cell and surrounding immune cells are integral to tumor initiation, progression, and response to anticancer therapies.

Aim of the Research

The overall objective of this study was to map the immune TME of different subtypes of B-cell non-Hodgkin lymphomas by advanced single-cell technologies like flow cytometry (FC) and cytometry by time-of-flight (CyTOF). We developed a multiscale immune profiling strategy for phenotypic dissection of tumor and surrounding immune cells as well as to capture the differences in functional potential to provide valuable knowledge of the pathogenesis of B cell malignancies. Moreover, we aimed to uncover key immune mechanisms involving activating or inhibitory immune checkpoint pathways, in tumor cells as well as in adaptive and innate immune cells exhibiting tumor-promoting or tumor-suppressing properties within TME of B-cell malignancies.

Achieved Results

Phenotypic profiling of the immune compartments within TME across B-cell malignancy subtypes revealed pronounced immunological heterogeneity (Fig. 1). We observed extensive immune remodeling, characterized predominantly by suppression of adaptive immunity alongside marked infiltration of innate immune populations. Specifically, in Waldenström macroglobulinemia (WM), we observed a striking expansion of mature effector helper CD4⁺ and cytotoxic CD8⁺ T cells, including effector CD4⁺ (CD4Te), effector memory CD8⁺ (CD8Tem) and γδ T (γδT2) cells, and an enrichment of monocytes and neutrophils, coupled with a substantial depletion of their precursor populations, including naïve and immature CD8⁺ T cells (Ti and CD8lowT) and myeloid progenitors (Fig. 2 and 3).

Expression profiling of a broad panel of immune checkpoints, inhibitory (PD-1, TIGIT, LAG-3, 2B4, TIM-3, CTLA-4, BTLA) and costimulatory (CD27, OX40, ICOS, 4-1BB, DNAM-1), across immune populations in B-cell malignancies was performed by FC and CyTOF technology (Fig. 4). Profiling the adaptive immune tumor microenvironment revealed a marked upregulation of the costimulatory receptor CD27 on CD4⁺, CD8⁺, and γ/δ T cells in all lymphoma subtypes, suggesting that the CD27–CD70 axis may be involved in lymphoma immunopathogenesis. In contrast, OX40 expression was significantly reduced on CD4⁺ and CD8⁺ T lymphocytes as well as on NK cells in most subtypes, and 4-1BB was similarly downregulated on γ/δ T cells in B-CLL, MCL, MZL, FL, and DLBCL, indicating attenuated effector T-cell costimulation. Among inhibitory checkpoints, PD-1 and TIM-3 were significantly decreased on CD4⁺ T cells in all subtypes and on CD8⁺ T cells in HCL and MZL, likely reducing peripheral tolerance. CTLA-4 was downregulated on γ/δ T cells in B-CLL, HCL, MCL, and MZL, whereas BTLA was specifically upregulated in B-CLL. Analysis of NK cells revealed significant downregulation of TIM-3 in most subtypes alongside paradoxical upregulation of 2B4 in nearly all subtypes, suggesting a shift toward inhibitory signaling and diminished cytotoxic function.

Benefits for Practise

By characterizing distinct immune cell phenotypes, patients can be stratified and prognosticated more precisely than with histopathology alone. Concurrent analysis of adaptive and innate alterations identifies biomarkers for early tumor-induced immunosuppression and escape, with direct relevance for diagnosis and disease monitoring. Comprehensive mapping of checkpoint dysregulation across B-cell malignancies has uncovered novel therapeutic targets and informs subtype-specific strategies to restore effector function or bypass alternative inhibitory pathways. Reconstructing a patient's immune TME will allow tailoring immunotherapeutic approaches to improve long-term outcomes.

Fig. 1 /Patient samples were analyzed by flow and mass cytometry using fluorescent and metal-conjugated antibodies, followed by bioinformatic and statistical analyses.
Fig. 2 /viSNE of a newly diagnosed WM (NDWM) patient shows single-cell resolution, with each point representing a cell colored by marker expression. Volcano plot showing significantly altered immune clusters in NDWM versus healthy donors.
Fig. 3 /Boxplots illustrate significant differences in immune cluster distributions between NDWM or relapsed/refractory WM (RRWM) and healthy donors. Kaplan-Meier analysis of overall and progression-free survival links aberrant T cell subtypes and NK cell levels to survival outcomes.
Fig. 4 /SPADE analysis of a NDWM patient showing immune checkpoint expression across TME, with node color indicating median marker expression. The heatmap depicts median expression of immune checkpoints on T helper, cytotoxic T, and NK cells across B cell malignancies.

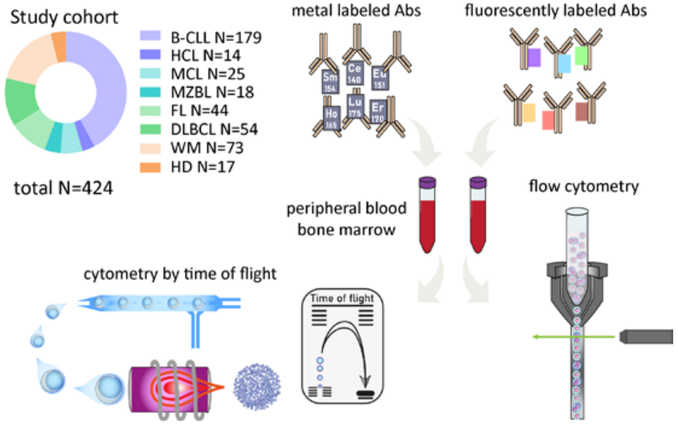
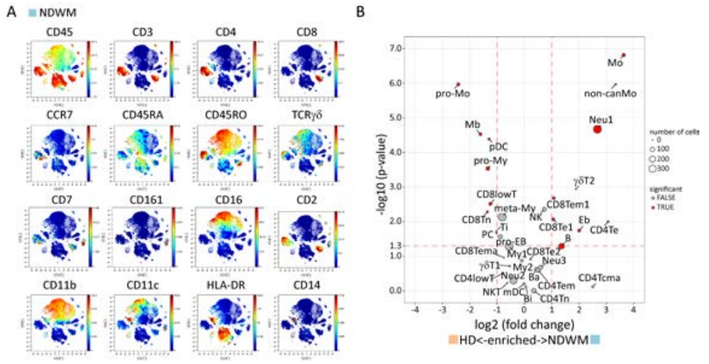


Fig. 1



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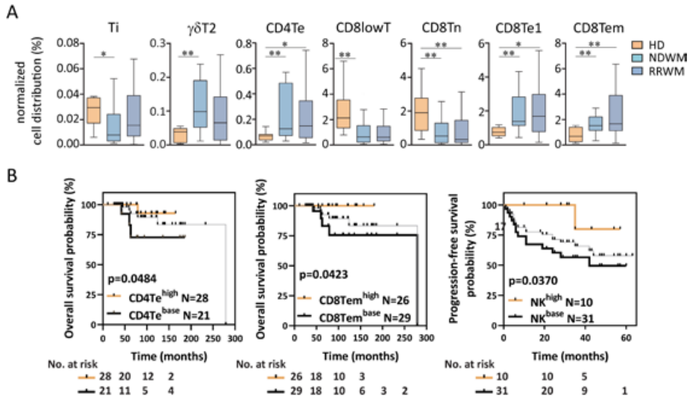

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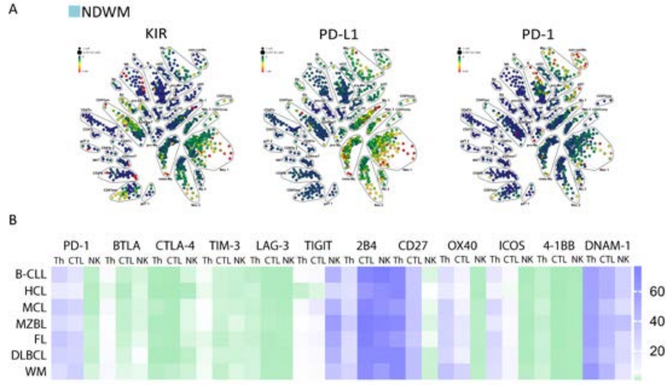

Fig. 4

The role of non-ischemic adaptive stimuli in protection of ischemic myocardium: study of triggering mechanisms and cardioprotective cell signaling

Principal investigator
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Applicant organisation
Slovak Academy of Sciences, Center of Experimental Medicine – Institute for Heart Research
Participating organisations
Comenius University Bratislava - Faculty of Pharmacy
Comenius University Bratislava - Faculty of Medicine in Bratislava
Term of solution
07/2020 - 06/2024
Budget from agency
223 880 €
Project ID
APVV-19-0540

Research Subject

Over the next decades, the incidence of HF is supposed to rise, in particular, due to the aging of the population and improved survival after AMI. Despite certain progress in the treatment of AMI, long-term prognosis is still not encouraging. Thus, the aims of the project were detailed elucidation of molecular mechanisms regulating the function of healthy and diseased myocardium and adaptive processes in cardiac cells that are crucial in the battle against pathological processes including myocardial ischemia.

Aim of the Research

SHR rats and in vivo experimental models and physiological, biochemical, and immunochemical methods were used to solve the project objectives, which allowed the analysis of processes in normal and ischemic myocardium and investigation of cellular signaling mechanisms involved in pathological as well as protective mechanisms in the myocardium. We investigated non-invasive adaptation mechanisms such as remote ischemic preconditioning (RIPC), intermittent hypoxic preconditioning (IHPC), preconditioning induced by physical activity (running), and various forms of pharmacological preconditioning.

Achieved Results

Among the most significant results is the finding that, contrary to expectation, aging did not significantly affect the basic functional parameters of the heart. Also, no decrease in the effectiveness of RIPC was observed in terms of protection against lethal damage (myocardial infarction) or in terms of protection against mechanical dysfunction. On the other hand, the occurrence of malignant tachyarrhythmias was not suppressed in hearts exposed to the RIPC protocol, as generally expected. 2. In our experiments, by administering the PPARβ/δ agonist GW0742 to adult rats in vivo, we induced a cardioprotective effect in their hearts exposed to global ischemia and ex vivo reperfusion. . Activation of PPARβ/δ not only reduced infarct size, contractile dysfunction, and incidence of ventricular arrhythmias, but also upregulated superoxide dismutase-2, catalase, and uncoupling protein 3, which alleviated oxidative stress. PPARβ/δ activation also increased the mRNA expression and enzymatic activity of aldehyde dehydrogenase 2 (ALDH2), inhibition of which abolished the anti-infarct effect of PPARβ/δ activation. 3. In isolated perfused rat hearts exposed to 30 min of ischemia and 10 min of reperfusion, impaired cardiac function was not alleviated by inhibition of receptor-interacting protein kinase 3 (RIP3), which is known to be involved in multiple signaling cascades including necroptosis, inflammation, and oxidative stress. Inhibition of RIP3 prevented plasma membrane rupture and delayed MPTP opening, a cardioprotective effect that was associated with the modulation of XO and MnSOD. The work shows that RIP3 regulates reperfusion injury through effects on oxidative stress and mitochondrial activity, but not through necroptosis. 4. An interesting result was also the finding that physical activity (free running) also increases the antioxidant capacity in the myocardium (increase in the expression of MnSOD) and the expression of beta3-adrenergic receptors in the heart, which can lead to activation of the Akt kinase, suppression of proapoptotic mechanisms and is related to protection myocardium against ischemia. 5. Other results include the finding that adaptation to chronic hypoxia protected the heart from post-ischemic contractile dysfunction, reduced the extent of myocardial infarction, creatine kinase release, and decreased mitochondrial respiration. We found that the activation of the RISK pathway is responsible for the protective effects of hypoxic preconditioning to a greater extent than the activation of the SAFE pathway.

Benefits for Practise

The project brings novel original results associated with the non-invasive application of the adaptive interventions that may be in future used in better treatment of the pacients with cardiovacsular diseases.

Fig. 1 / Simplified scheme of triggering of cardioprotection and transmission of signal to the distant organ and target end-effectors in the heart cells.
Fig. 2 / Potential non-invasive interventions triggering adaptive mechanisms of cardioprotection.

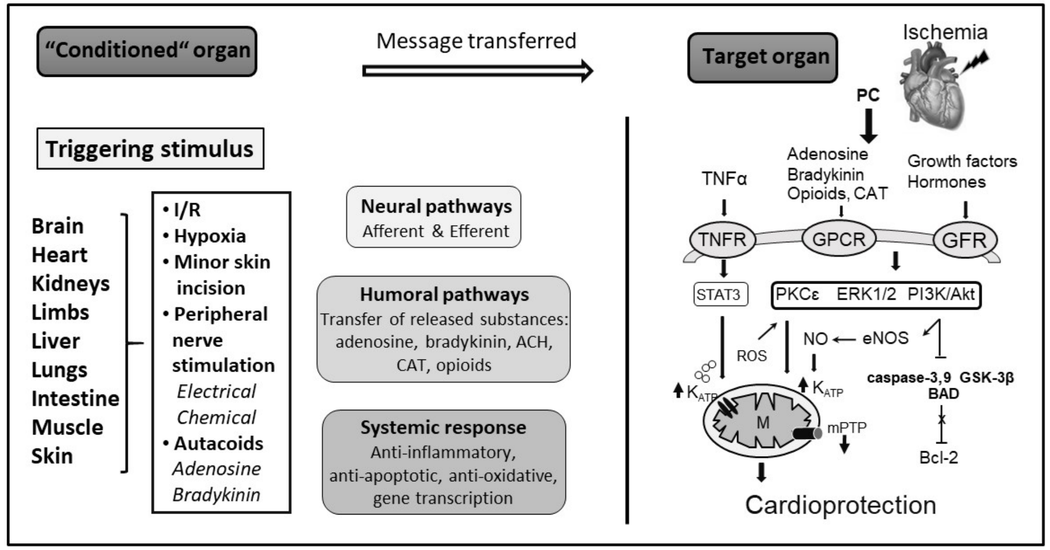

Fig. 1

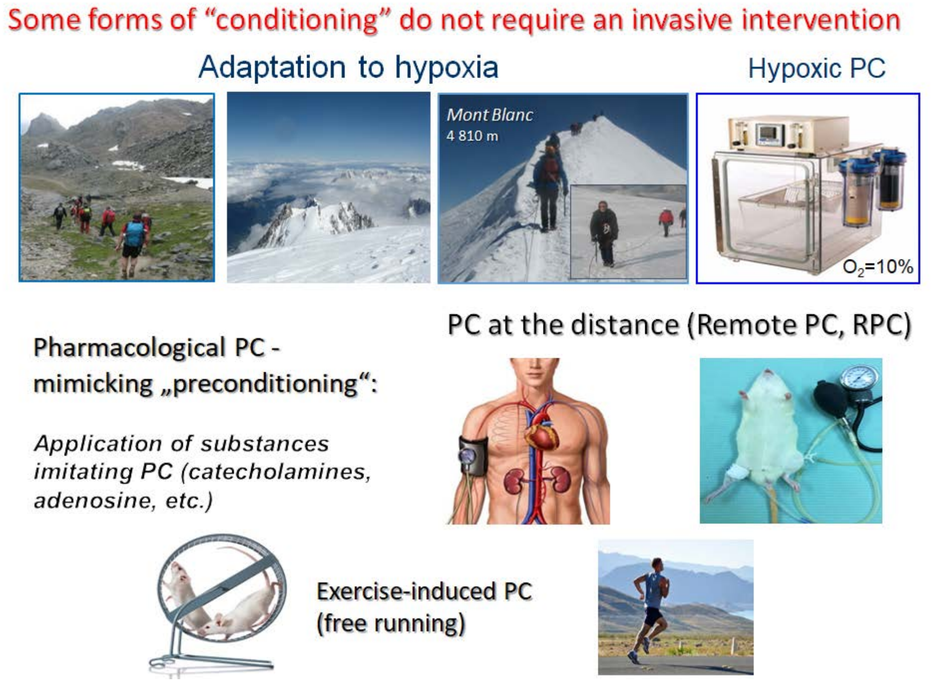

Fig. 2

In vitro bio-compatibility testing of medical devices (MDs) and new generation bio-materials for MDs

Principal investigator
Ing. Kanďárová Helena, PhD.
Applicant organisation
Slovak Academy of Sciences, Center of Experimental Medicine
Term of solution
07/2020 - 06/2024
Budget from agency
244 832 €
Project ID
APVV-19-0591

Research Subject

The project focused on the development, optimization, and validation of novel in vitro methods for assessing the biocompatibility of medical devices (MDs) and biomaterials intended for contact with the human body. Emphasis was placed on using 3D reconstructed human tissue models, specifically corneal and oral epithelia, which enable ethical, reliable, and clinically relevant testing without animal experimentation. The project also explored ways to enhance the predictive value of in vitro assays, including measurements of barrier properties, cytokine profiles, and the use of microfluidic systems to simulate physiological conditions. The research combined cell culture techniques with 3D tissue model testing to ensure the applicability of results in preclinical evaluation of medical devices and pharmaceuticals.

Aim of the Research

The primary objectives of the project included the development of standardised in vitro testing protocols for assessing eye irritation and phototoxicity, as well as the biocompatibility of products intended for contact with the oral epithelium. Another key aim was to explore the application of dynamic culture conditions using microfluidic systems that mimic fluid flow in the human body, thereby reflecting realistic interactions between materials and cells. The resulting protocols were designed in accordance with the requirements of ISO 10993 and OECD Good Laboratory Practice. The final goal of the project was to submit the research outputs to the ISO organization and to initiate processes that could support the implementation of new tests into ISO 10993.

Achieved Results

The project yielded significant results in the development and application of alternative methods for assessing the biocompatibility of medical devices. Key outputs are as follows:

- The research team developed two in vitro protocols for assessing eye irritation and phototoxicity using the reconstructed human corneal model EpiOcular.
- In the second phase, a protocol was developed for evaluating the biocompatibility of products intended for contact with the oral mucosa. The protocol can be applied using either the oral epithelial model (EpiOral) or the gingival epithelial model (EpiGingival).
- All testing procedures were developed in compliance with GLP documentation requirements, enabling their use in a regulatory-acceptable environment.
- The project also explored the potential of incorporating microfluidics into test systems. Using 3D models of the cornea and small intestinal epithelium, the applicability of dynamic culture conditions was evaluated to expand testing capabilities and enhance biological relevance.

The project included organization of trainings and lectures focused on Good Laboratory Practice, alternative methods, and interpretation of biocompatibility testing results. The findings were presented at various national and international conferences (e.g., EUROTOX, ESTIV, MPS World Summit) and published in peer-reviewed scientific journals with impact factor (ATLA, Toxicology in Vitro, Frontiers in Toxicology).

The project made a substantial contribution to advancing scientific knowledge, strengthening the regulatory framework for non-animal testing of medical devices, and promoting ethical safety assessment without the use of laboratory animals. The project outcomes were also recognized with several international awards.

Benefits for Practise

The developed protocols are applicable in preclinical biocompatibility testing of medical devices. Their publication and free availability as standardized operating procedures on the portal www.medicaldevicessafety.com will support broader implementation in laboratories and development centres engaged in biocompatibility evaluation of MDs. These protocols can also be used in the preclinical safety assessment of cosmetics and pharmaceuticals.

The results presented to the ISO TC194 working group supported the initiative to expand ISO 10993-23 by including additional in vitro models. The project made a significant contribution to reducing the need for animal testing, in line with the 3R principles (replacement, reduction, refinement) and European legislation.

The newly developed tests were applied in 2023 and 2024 during re-classification processes of selected medical devices under the Medical Device Regulation (MDR).

The project also significantly contributed to the professional development of PhD candidates and early-stage researchers, supporting long-term growth of scientific capacity in the field of in vitro toxicology in Slovakia.

Fig. 1 / Award from the American Medical Device and Combination Product Specialty Section at the US SOT 2025 Congress, Orlando, Florida. From left to right (Dr.Helena Kanďárova, ERT, Ing. Peter Pôbiš, Dr. Kelly Coleman, DABT, RAC, ATS, ERT

Fig. 1

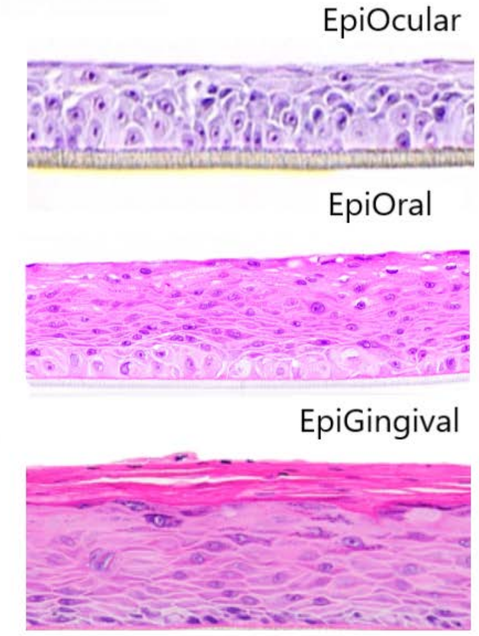

Fig. 2 / Reconstructed tissue model EpiOcular, cross-section, hematoxylin-eosin staining. Right – detail of the culture plate with cell culture insert of EpiOcular and chambers of the microfluidic device

Fig. 2

AGRICULTURAL SCIENCES

Cryopreservation of cattle gametes and embryos for gene banking

Principal investigator
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Applicant organisation
National Agricultural and Food Centre – Research Institute for Animal Production Nitra
Participating organisation
Centre of Biosciences SAS – Institute of Animal Biochemistry and Genetics
Term of solution
07/2020 - 06/2024
Budget from agency
248 810 €
Project ID
APVV-19-0111

Research Subject

A significant role in preserving animal gene resources belongs to cryopreservation and subsequent storage of gametes of genetically valuable individuals of various farm animals breeds. For the long-term preservation of the gene pool of rare and endangered animals, it is necessary to establish gene banks containing stocks of gametes and embryos of these animals. Methods of freezing gametes (oocytes, sperm) must ensure their good quality and viability after thawing. The project aimed to increase the viability of oocytes and minimize their damage due to cryopreservation by the vitrification method and to promote cell division and development of preimplantation cattle embryos produced in vitro from frozen oocytes. These embryos, when subsequently frozen, must be tolerant to the cryopreservation procedure to be suitable for long-term storage in a gene bank and able to survive and develop after repeated thawing. The subject of detailed analysis was the distribution of some tetraspanins - molecules that ensure protein-protein interactions in the cell membrane and mediate intercellular communication, including through extracellular vesicles. These processes are essential for proper embryonic development.

Aim of the Research

The research was aimed at improving the quality of embryos produced in vitro (IVP) from vitrified oocytes. The main objective was to optimize methods of oocyte cryopreservation and in vitro production of bovine embryos with increased cryo-resistance for their storage in a gene bank.

Achieved Results

The project resulted in an optimized methodology for cryopreservation of bovine oocytes, ensuring their stable quality after thawing. The used vitrification technique involves direct immersion of oocytes, placed on a vitrification carrier consisting of an electron microscopic mesh mounted on a holder, into liquid nitrogen. We managed to neutralize the negative impact of vitrification and improve viability to the level of fresh oocytes by adding antioxidants - glutathione and astaxanthin to the culture medium during oocyte regeneration after thawing. By applying astaxanthin after vitrification and warming of blastocysts obtained from vitrified oocytes, we obtained cryo-resistant embryos, which are comparable in quality to blastocysts derived from fresh oocytes.

By analysing the distribution of tetraspanins CD9, CD81, CD151, CD82 and CD63 on ovarian tissues and in vitro matured bovine oocytes after vitrification, as well as on fresh oocytes, we created a basis for comparative analysis of cryopreserved oocytes and embryos produced from them in vitro. The reaction pattern recorded in 4- to 8-cell embryos suggests that tetraspanins may be part of extracellular vesicles (EVs) produced by the embryo - important mediators of communication between the embryo and the mother during preimplantation development.

The results were published in 15 scientific papers, 23 contributions at scientific symposia and were part of 1 diploma and 1 doctoral thesis. 91 citations were registered for the published scientific articles already during the project running. The project outputs were popularized at events intended for the laic public: "Week of Science and Technology", "Weekend of the Slovak Academy of Sciences" and "European Night of Researchers".

Benefits for Practise

The presented project comprehensively addresses the issue of increasing the cryoresistance of matured oocytes and subsequently in vitro produced embryos for the needs of the national gene bank of animal genetic resources. Up to 90 % of the obtained cattle embryos are immediately transferred to the recipients, despite the disadvantages and high demands on the organization and synchronization of the animals. The possibility of long-term embryo cryostorage for later use brings undeniable advantages, yet it is used only in approximately 10 %, which is also related to the low resistance of IVP embryos to freezing.

A significant contribution of the project is the optimized technique of ultra-rapid vitrification of oocytes by direct immersion into liquid nitrogen, capable of ensuring good survival and quality of oocytes after warming, with the possibility of use in in vitro embryo production and embryo transfer. These procedures can subsequently be used in the protection of endangered breeds and the preservation of biodiversity.

The results of the analysis of tetraspanins open the possibility of characterizing extracellular vesicles for potential application in assisted reproduction technologies routinely used in livestock.

Fig. 1 / Immunofluorescent staining of tetraspanin CD9 (green) and integrin alphaV (red) in bovine ovarian tissue.
Fig. 2 / Immunofluorescent staining of tetraspanin CD63 (green) in bovine vitrified oocyte.
Fig. 3 / Fluorescent staining of actin (red) and chromatin (blue) in bovine vitrified oocytes.
Fig. 4 / Fluorescent staining of mitochondria (green), lysosome (red) and chromatin (blue) in bovine vitrified oocyte.
Fig. 5 / Fluorescent staining of actin cytoskeleton (red) and cell nuclei (blue) in bovine blastocyst after astaxanthin supplementation.

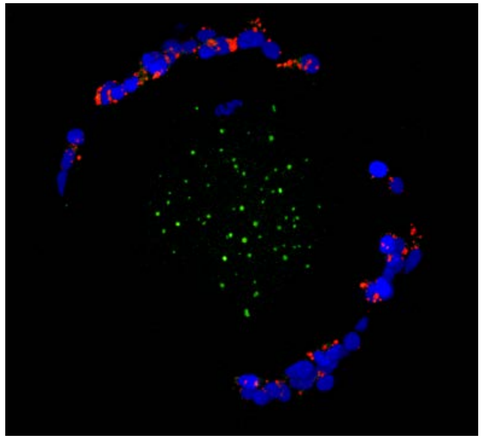
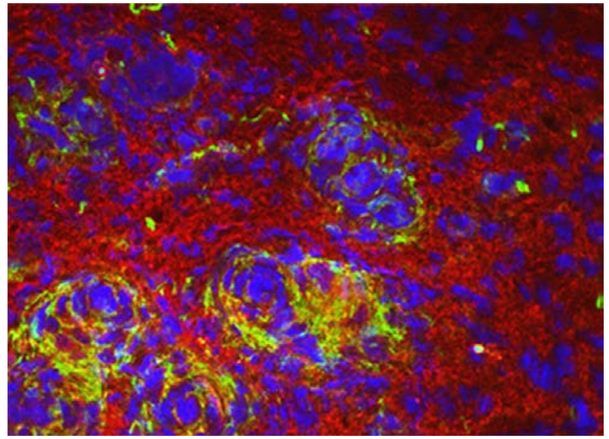


Fig. 4



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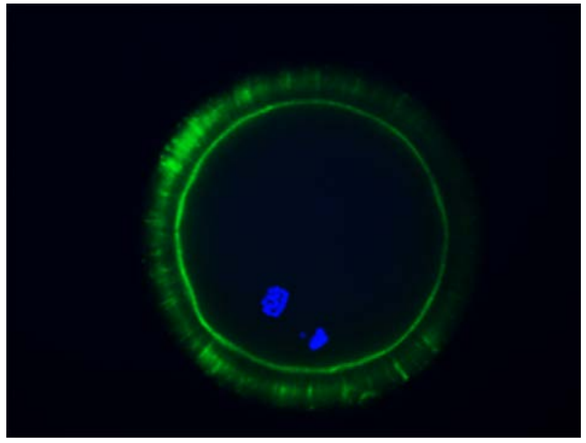

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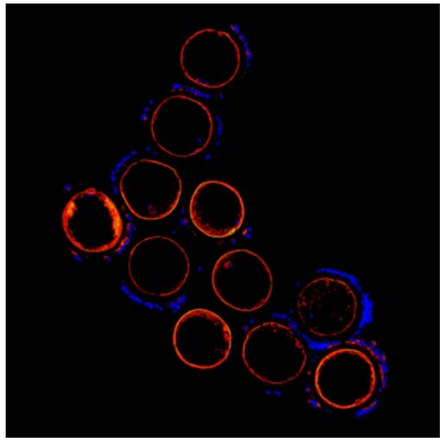

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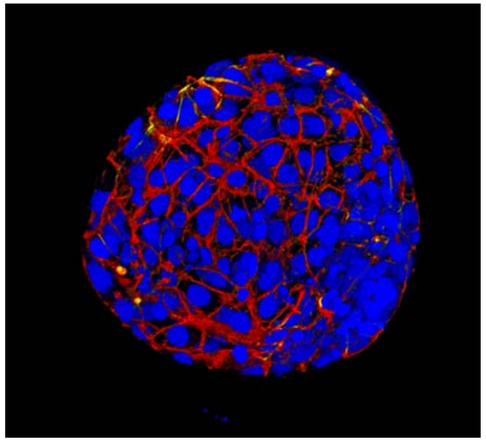


Fig. 5

Application of entomopathogenic fungi from the genus Beauveria against invasive insect species

Principal investigator
Ing. Vakula Jozef, PhD.
Applicant organisation
National Forest Centre
Participating organisation
Slovak Academy of Sciences, Institute of Forest Ecology
Term of solution
07/2020 - 12/2022
Budget from agency
249 834 €
Project ID
APVV-19-0116

Research Subject

The project focused on the research of biological methods for forest protection against invasive species of harmful insects, based on the use of entomopathogenic fungi of the genus Beauveria. The project addressed three model species: the northern bark beetle (Ips duplicatus), the black timber bark beetle (Xylosandrus germanus), and the oak lace bug (Corythucha arcuata).

Aim of the Research

- Testing of isolates of entomopathogenic fungi of the genus Beauveria against model species
- Development of carriers, application methods, and procedures
- Dissemination of new knowledge into forestry practice

Achieved Results

A part of the project focused on the biological protection of forests against the double-spined bark beetle (Ips duplicatus) using the entomopathogenic fungus Beauveria bassiana. Fungal spores were artificially applied to adult beetles using spherical carriers placed inside an applicator integrated into a pheromone trap. This method combines a biological agent (B. bassiana) with a biotechnical forest protection device – the pheromone trap. This alternative offers a highly selective method utilizing a bioinsecticide for plant protection, also known as the autoinoculation method. The principle of this method lies in attracting adult I. duplicatus individuals to the trap using a pheromone lure. Inside the trap, the beetles come into contact with the fungus-containing spherical carrier, become infected, and then leave the trap and return to the environment. The infected individuals subsequently spread the fungal infection within their galleries during mating, affecting both the parental F_0 generation and the offspring F_1 generation.

A registered Community design (No. 015023460-0001) was submitted for the trap applicator in 2023, and the carrier of the biologically active organism is protected under European Patent No. EP 3836789 from 2024.

The results were summarized in the article:

Vakula, J., Nikolov, C., Lalík, M., Horáková, M., K., Rell, S., Galko, J., Gubka, A., Zúbrik, M., Kunca, A., Barta, M., 2025: Selection, application, and pathogenicity of naturally occurring Beauveria bassiana strains against Ips duplicatus (Coleoptera: Curculionidae, Scolytinae), Biological Control 204, May 2025, 105740, https://doi.org/10.1016/j.biocontrol.2025.105740

Benefits for Practise

The results demonstrated the possibility of infecting bark beetles using pheromone traps under field conditions, with fungal spores in the carrier remaining sufficiently active for 21 days even under extreme environmental conditions. This enables the practical application of this highly selective method. The method can also be applied to other species of bark- and wood-boring insects for which a synthetically produced pheromone is available. This method is environmentally friendly and highly selective.

Fig. 1 / Screening, selection, infecting carriers and applying carriers in the trap applicator.
Fig. 2 / Daily mortality rate of I. duplicatus infected by B. bassiana spores through carriers in pheromone traps. This figure displays the cumulative mortality rates (%) of I. duplicatus subjected to B. bassiana pathogenic strains NRID11 and NRID43 in pheromone traps using a carrier as an applicator. The subfigures (A, B, C, and D) represent duration of the carriers in the traps (3, 21, 30 and 60 days), with D reflecting the longest deployment. The trend observed from A to D indicates that their prolonged exposure in pheromone traps leads to a decrease in the impact of the pathogen, emphasizing the importance to optimize the length of time they are exposed to maintain the effectiveness of biocontrol agents.

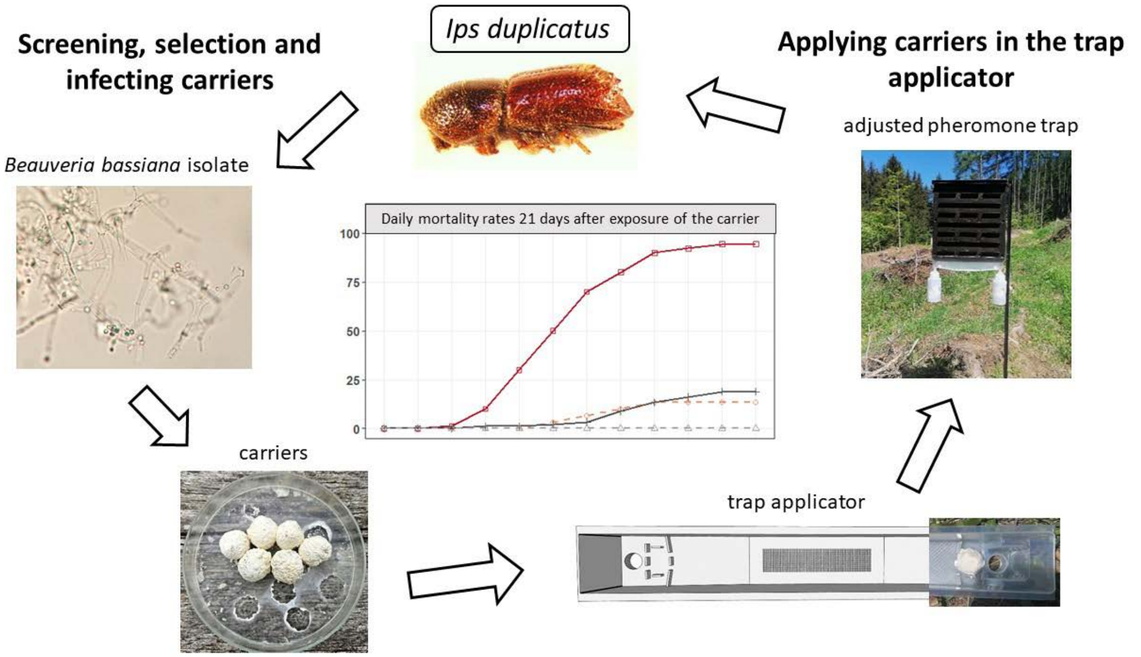


Fig. 1

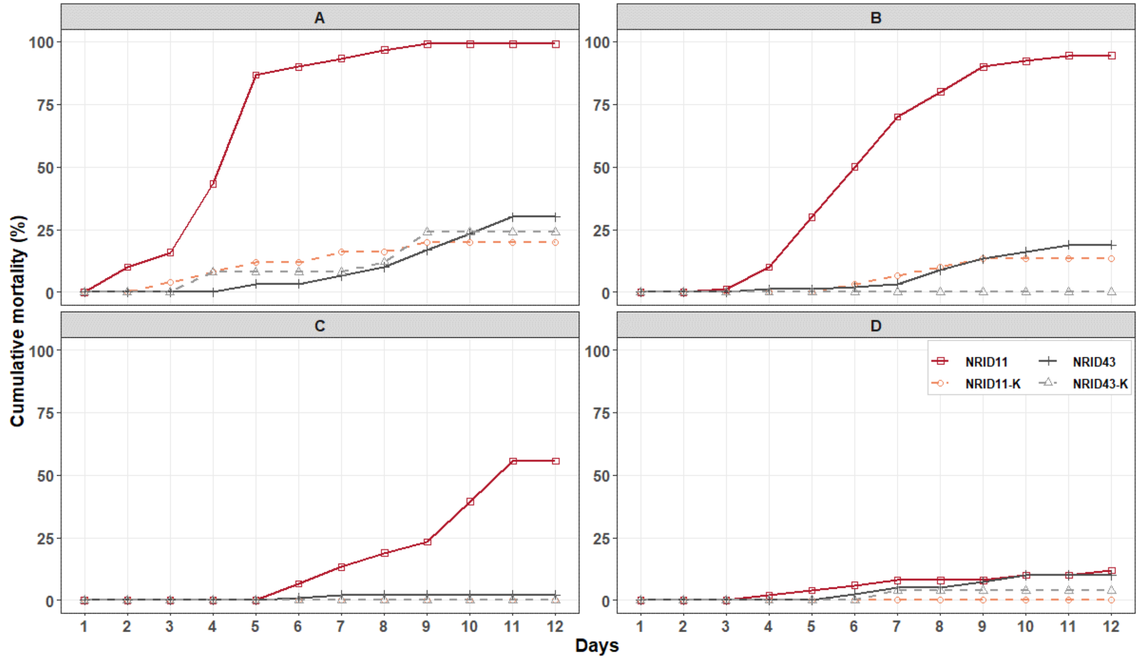


Fig. 2

Trade-offs between biomass production and biodiversity in beech-fir forests under changing environmental conditions

Principal investigator
Ing. Bošeľa Michal, PhD.
Applicant organisation
Technical University in Zvolen
Term of solution
07/2020 - 06/2024
Budget from agency
249 867 €
Project ID
APVV-19-0183

Research Subject

The project APVV-19-0183 “Trade-offs between biomass production and biodiversity in beech-fir forests under changing environmental conditions” investigated how microclimate, soil properties, disturbance history, and forest management affect biomass production, carbon fluxes, and multi-taxon biodiversity in fir–beech ecosystems. Extensive monitoring was conducted in three Carpathian old-growth forests (Dobroč, Badín, Hrončecký grúň) and their managed counterparts, including a spruce monoculture, enabling direct comparisons between unmanaged and managed systems. We integrated dendrochronology, continuous measurements of soil CO_2/CH_4 respiration, microclimate monitoring, and inventories of vascular plants, bryophytes, and fungi.

Aim of the Research

(1) Quantify the carbon balance of mixed fir–beech forests and compare it with that of a spruce monoculture; (2)Identify trade-offs and win–win relationships among timber production, soil respiration, and biodiversity; (3) Assess the impact of historical disturbances and current management on multi-taxon biodiversity; (4) Determine the drought resistance and resilience of beech, fir, and spruce, and model their growth until mid-century; (5) Establish long-term monitoring plots in fir–beech old-growth forests to track tree adaptation to climate change.

Achieved Results

- Biomass increment in mixed forests remained stable (5–8 t ha^{-1} yr^{-1}), whereas in the spruce monoculture it dropped from ≈11 to <3 t ha^{-1} yr^{-1} since 2000, with carbon sequestration nearly ceasing after the 2023 bark beetle outbreak.
- The 2022 drought reduced soil CO_2 fluxes in spruce monocultures to 25–50% of the mixed forest levels; post-clear-cutting, CO_2 emissions from soil rose sharply.
- Soil temperature emerged as the main regulator of CO_2 and CH_4 fluxes; microbial communities, particularly in monocultures and clearings, proved highly vulnerable.
- A conceptual model of developmental phases in fir–beech forests grouped herbs into decay, regeneration, and optimum-phase species, highlighting the cyclic dynamics of herb layer diversity (Fig. 3).
- Fungal and vascular plant diversity responded oppositely to structural changes: fungi benefited from increased competition variability, while herbs thrived under long-term structural stability.
- Bird species richness was significantly higher in old-growth forests compared to managed ones. Strict protection supported the conservation of threatened and EU-priority bird species. Forest fragmentation negatively affected Natura 2000 species.
- On 77 historical plots, herb cover decreased from 58% to 35% over 55 years, although alpha-diversity remained stable—indicating a shift of montane beech forests towards warmer submontane types.
- Models predict improved beech growth above 700 m a.s.l. by 2050, but reduced performance in lower elevations (Fig. 4); spruce was the least adaptable species.
- Drought resilience was similar in both old-growth and managed forests; beech was the most resistant, spruce the least.
- Combined drought and heatwave events significantly reduced fir growth in the Western Carpathians (Fig. 5).

Benefits for Practise

- Mixed fir–beech forests are more stable carbon sinks and maintain timber production more reliably during droughts. We recommend gradually replacing vulnerable spruce monocultures with species-diverse stands.
- Maintaining a fine-scale mosaic structure increases herb, moss, and fungal diversity and strengthens ecosystem services.
- Management that includes monitoring of soil temperature, moisture, and emissions can reduce post-harvest carbon losses; soil respiration should be integrated into enterprise-level LULUCF accounting.
- Game population control is vital to ensure natural regeneration of fir and valuable broadleaved species, contributing to long-term forest resilience.
- Quantifying species sensitivity and modelling fir–beech forest development stages provides a practical framework for applying selection or group harvesting methods, combining biodiversity protection with economic viability.
- The project delivers a comprehensive scientific foundation for “climate-smart” forestry in the Carpathians—enhancing forest resilience, safeguarding biodiversity, and supporting Slovakia’s climate commitments.
- Project outcomes are regularly published on the project website: https://probiofor.webnode.sk/

Fig. 1 / The project enabled the establishment of long-term monitoring using non-destructive, continuous sensors for trees, soil, and the atmosphere in three fir–beech old-growth forests in Slovakia.
Fig. 2 / Annual and seasonal soil carbon emissions following a bark beetle outbreak in a spruce monoculture (yellow) and a mixed forest (blue) (https://doi.org/10.1016/j.foreco.2025.122829).
Fig. 3 / Conceptual model of changes in the developmental stages of fir–beech old-growth forest over time (https://doi.org/10.1016/j.foreco.2023.121353).
Fig. 4 / Frequency distribution of regionally projected changes in the relative growth of European beech for the period 2021–2050 compared with average growth from 1952–2011 under the SSP2-4.5 emission scenario (https://doi.org/10.1111/gcb.17546).
Fig. 5 / A) Proportion of heatwave and drought events from 1950 to 2020; B) Growth response of silver fir to the occurrence of heatwaves and droughts (https://doi.org/10.1016/j.agrformet.2025.110610).

Fig. 1

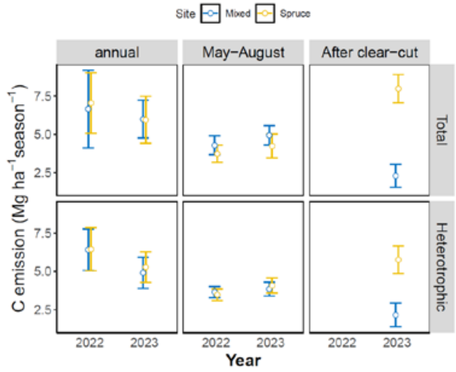
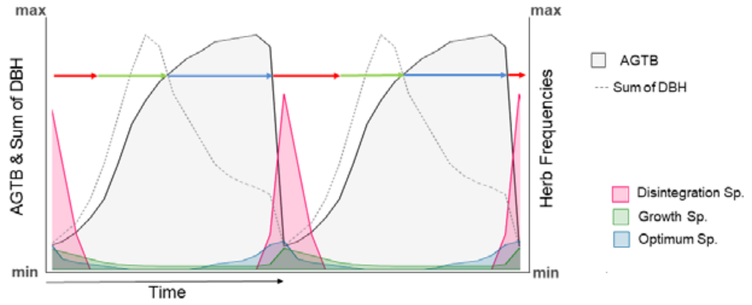


Fig. 2



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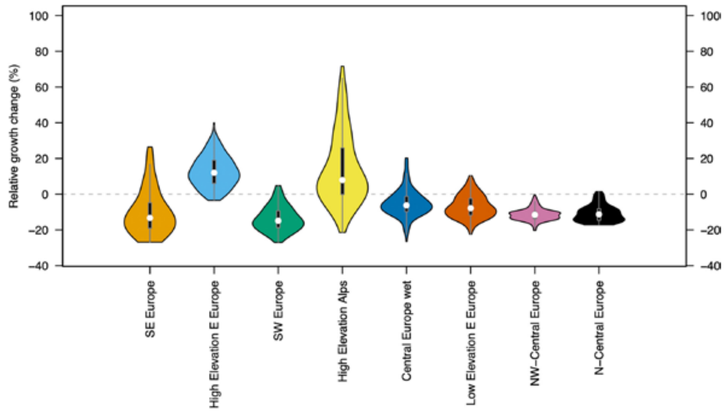


Fig. 4

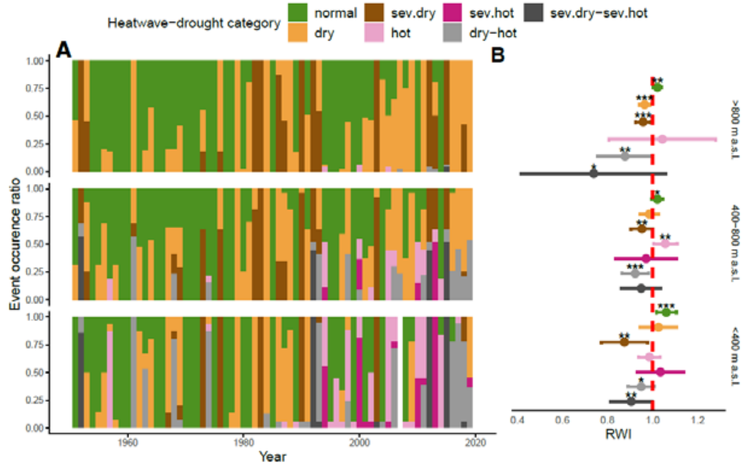


Fig. 5

New players in nanotherapy of neurodegenerative diseases: conditioned media (KM) and extracellular vesicles (EV) of somatic stem cells

Principal investigator
prof. MVDr. Čížková Daša, DrSc.
Applicant organisation
University of veterinary medicine and Pharmacy in Kosice
Term of solution
07/2020 - 05/2024
Budget from agency
248 008 €
Project ID
APVV-19-0193

Research Subject

The therapeutic potential of mesenchymal stem cells (MSCs) is most often mediated by their paracrine action, primarily through secretory products – conditioned medium (CM) and extracellular vesicles (EVs), including exosomes. These contain bioactive molecules (proteins, lipids, miRNA, mRNA, ncRNA, DNA) that influence the behavior of target cells. These acellular products are safe, storable and can be applied allogeneically, making them an affordable therapy, especially in neurodegenerative diseases, where effective treatments are still lacking. Currently, more and more attention is paid to dogs with spontaneous neurodegenerative disorders, which better reflect the course of diseases in humans and serve as a suitable model system.

Aim of the Research

The aim of the project is to elucidate the neuroprotective and neuroregenerative mechanisms of nanotherapy mediated by CM and EV isolated from canine MSCs from different sources (neonatal vs. adult tissues).
- The project follows the standardization of MSC isolation, expansion and characterization, as well as the preparation and analysis of bioactive fractions of CM and EVs.
- In the first phase, we will compare the immunomodulatory, neurotrophic and proteomic profile of MSCs from different sources and identify populations with the highest regenerative potential. CM and EVs will be analyzed in terms of cytokines, growth factors, proteins and miRNA content.
- Their biological efficacy will be tested in vitro on neural cultures and a glial scar model.
- In the final phase, the nanotherapy will be tested in vivo in dogs with spinal cord injury and other degenerative diseases by local or systemic application.

Achieved Results

Within the project, we obtained original results that showed differences in the yield and expansion potential of MSCs from neonatal and adult tissues, as well as in the content of bioactive substances in their CM.
- We standardized protocols for the isolation and cultivation of MSCs from amniotic membranes and adipose tissue.
- Amniotic membranes were the richest source of MSCs, while MSCs from adipose tissue showed the highest proliferative activity.
- Our results were among the first to demonstrate the antimicrobial potential of CMs from canine BM-MSCs, including inhibition of bacterial growth, biofilm, and virulence.
- Proteomic analysis of CMs from AM-MSCs and AT-MSCs confirmed the presence of regenerative trophic factors, the concentration of which was significantly increased after MSC stimulation with INF-gamma (priming).
- The biological efficacy of the CM thus obtained was confirmed in vitro, where strong anti-inflammatory effects were documented in the SH-SY5Y line exposed to an inflammatory environment.
- In dogs with chronic spinal cord injury, repeated administration of CM (BM-MSC/AT-MSC) was safe and, in combination with physiotherapy, promoted motor recovery.
- At the same time, the potential of neurofilament light chain (NFL) as a biomarker of neurodegeneration was confirmed, similarly to its use in multiple sclerosis.

Benefits for Practise

These results expand the knowledge on the mechanisms of neuroprotection and regeneration by acellular therapy, which is a promising alternative to cell therapy in veterinary medicine. Given the beneficial effects of CM observed in dogs after spinal cord and soft tissue injury, larger studies are needed to better understand the mechanisms of action, immune response and microenvironment. Our results confirm that carefully selected CM – according to MSC origin and proteome composition – can target key pathological processes, contributing to the success of the treatment. Acellular therapy has significant potential, especially in the treatment of small animals in cases of failure of conventional methods. Its wider clinical application could lead to standardization and introduction into routine practice.

Fig. 1 / Canine AM-MSCs presented a fibroblast-like morphology, AT-MSCs had a spindle-shape, typical of MSCs.
Fig. 2 / FACS analysis of surface marker expression of AT-MSCs and AM-MSCs, positive for CD29, CD44 and CD90 for mesenchymal markers, not for CD34 and CD45.
Fig. 3 / LC/MS-MS analysis of MSCCM and pMSCCM. (A, D) Venn diagrams of total amount of identified proteins in MSCCM and pMSCCM. (B, E) Principal component analysis score plot showing clustering of MSCCM and pMSCCM. (C, F) Heat maps of differentially expressed proteins in red and blue represent up-regulated and down-regulated proteins.
Fig. 4 / (A) Anti-inflammatory effect of MSC-derived CM on SH-SY5Y cell line. (B) Graphs showing changes in the amounts of anti-inflammatory cytokines IL-10 (IL6-dual), (C) pro-inflammatory cytokines IL-2, IL-8, IL-12 and MCP-1 (Luminex). Measured analytes released by SH-SY5Y cells after 24-hour induction with IFN-γ and SH-SY5Y cultured in IFN-γ followed by treatment with MSCCM for 24 hours.

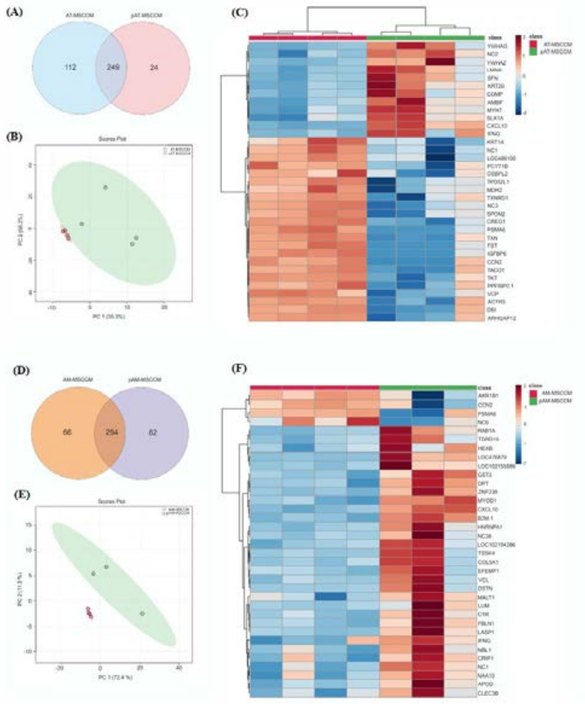


Fig. 3

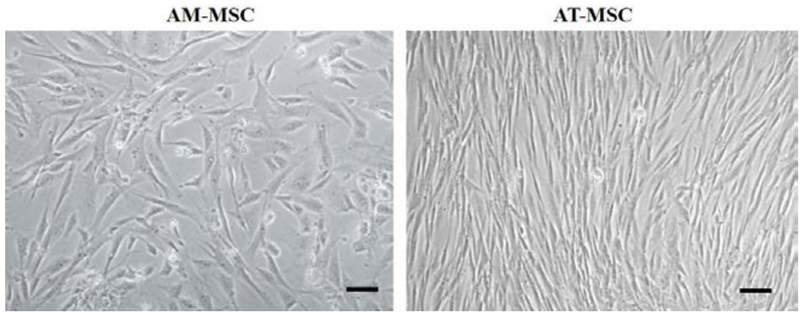


Fig. 1

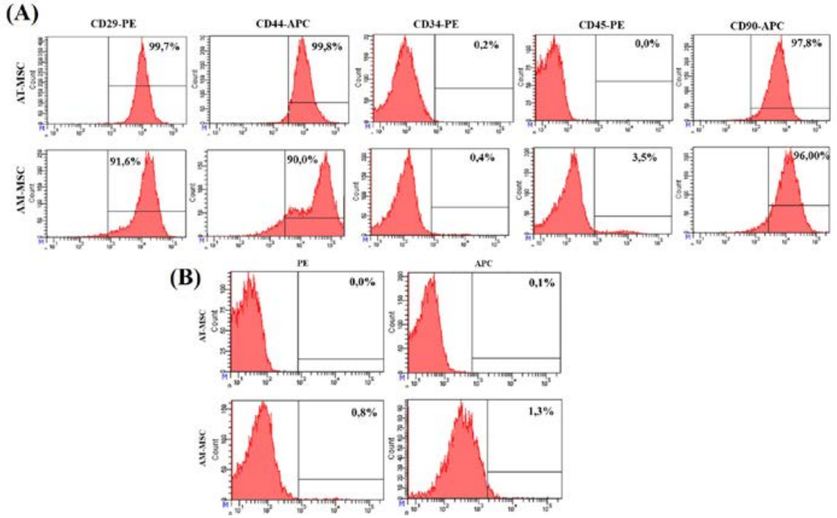


Fig. 2

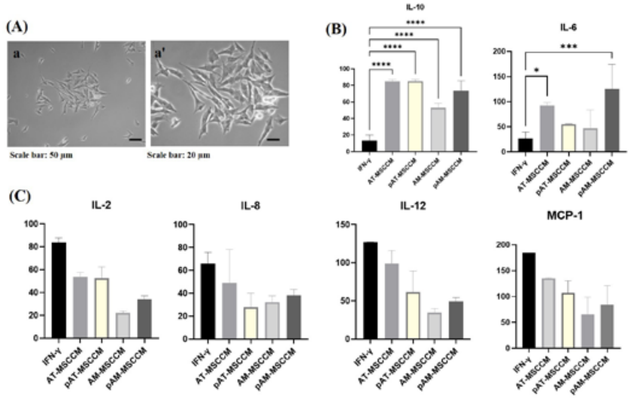


Fig. 4

Human land use legacies in decline of temperate forest vegetation diversity during global environmental changes

Principal investigator
Ing. Máliš František, PhD.
Applicant organisation
Technical University in Zvolen
Term of solution
07/2020 - 06/2024
Budget from agency
249 759 €
Project ID
APVV-19-0319

Research Subject

The project focused on the biodiversity decline of temperate oak forest vegetation due to global environmental changes, primarily forest and land-use change, nitrogen deposition and climate change. Three different approaches covering different time scales were used. Palynological and anthracological methods were applied to investigate the millennia-long human impact on distribution of oak forests. Changes over the past decades were investigated using re-surveys of permanent plots. The last approach was a field experiment that tested the impact of historical forest management and high nitrogen deposition on vegetation.

Aim of the Research

In the past, forests were intensively utilized by humans, including grazing or collecting of litter. Current research indicates that this supported oak in lower and middle elevations. The aim of palynological and anthracological research was to verify whether this intensive human impact led to the expansion of oak forests to higher elevations. Since the 1950s, oak forest management has changed significantly, historical forms have been excluded. The aim of the project was to identify changes in species composition during the last decades and reveal their potential link to management changes, nitrogen deposition or climate change. A field experiment was used to verify the potential of management interventions imitating historical forest use for the restoration of oak forest biodiversity.

Achieved Results

Analysis of fossil soil charcoal remains (anthracology) and peat profiles (palynology) showed that in the area of the Middle and Lower Považie, around 2 000 years before present, oak expanded above 600 m a.s.l. while beech retreated from positions below 300 m a.s.l. This shift in the oak-beech ecotone was very likely driven by human activities. After the abandonment of the historical management of oak forests after the World War II, shade-casting trees such as hornbeam and beech expanded back to lower positions. Together with other environmental changes (nitrogen deposition, climate change) caused a diversity decline and changes in the species composition, mainly in favor of species with higher demands for nutrients (nitrogen) and temperature (Fig. 1). Using the data from multiple resurveys, it was also possible to evaluate the acceleration of vegetation changes. Species composition changed twice as fast during the period 2006-2022 as during the period 1967-2006. The findings confirmed the assumption that forest vegetation has a certain resilience to environmental changes, but increasing and combined impact of various environmental changes accelerates the forest vegetation response. The vegetation dynamics at the field experiment demonstrated that interventions inspired by history can very quickly restore vegetation of oak forests, even under high nitrogen inputs. In plots where the canopy was reduced and litter was annually raked (regardless on fertilization), the number of species increased threefold within the first few years. Moreover, invasive or early-succession species typical for forest disturbances did not colonized the sites and the vegetation became prevailed by graminoids, what is a typical feature for oak forests (Fig. 2). More information about the experiment is available at eutrofyt.tuzvo.sk.

Altogether, 21 scientific articles were published within the project. The data gathered during the project were shared with the international community (initiatives forestREplot, SoilTemp, Cost Action CA18207, etc.) and the results became more international and published in the highest-raked journals. For example, a study using data from permanent plot re-surveys across temperate Europe was published in the Science. Study reveals that forest plant species migrated west rather than north despite climate change. The main cause was nitrogen deposition (Fig. 3).

Benefits for Practise

The project results are of great importance for forestry and conservation practice. The understanding that the character and distribution of oak forests are largely related to humans and historical forms of forest use is essential. Successful restoration of oak forest biodiversity can be achieved by management interventions inspired by the historical forest-use. The practical importance of results was also confirmed by the funding of a new international project from Interreg scheme HUSK/2302/1.2/168 #oakadapt, which is focused on restoration of oak forest diversity and increasing of forest resilience to climate change using the science-based applications.

Fig. 1 / The most significant changes of oak forest vegetation over last decades (Y axis) were associated with an increase of thermophilous (X axis) and nutrient-demanding species (color scale and line type). Image from Kotrík et al. 2023 (DOI: 10.1016/j.foreco.2023.121151)..
Fig. 2 /Experimental canopy reduction and litter raking rapidly restored diversity and species composition of oak forests. Upper part shows changes in species richness (black) and cover of herb layer (red) during application of 3 treatment combinations (canopy reduction, litter raking, fertilization). In the lower part, pictures demonstrate the development of vegetation over 7 years (from top left to bottom right) on the same plot.
Fig. 3 / Forest plant species have migrated more westward than northward over the past decades. This direction of distributional shift was unexpected with respect to climate change and driven by nitrogen deposition. Taken from Sanczuk et al. 2024 (DOI: 10.1126/science.ado0878).

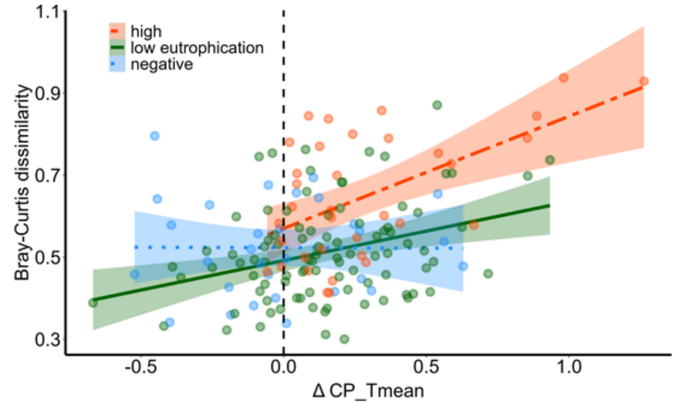


Fig. 1

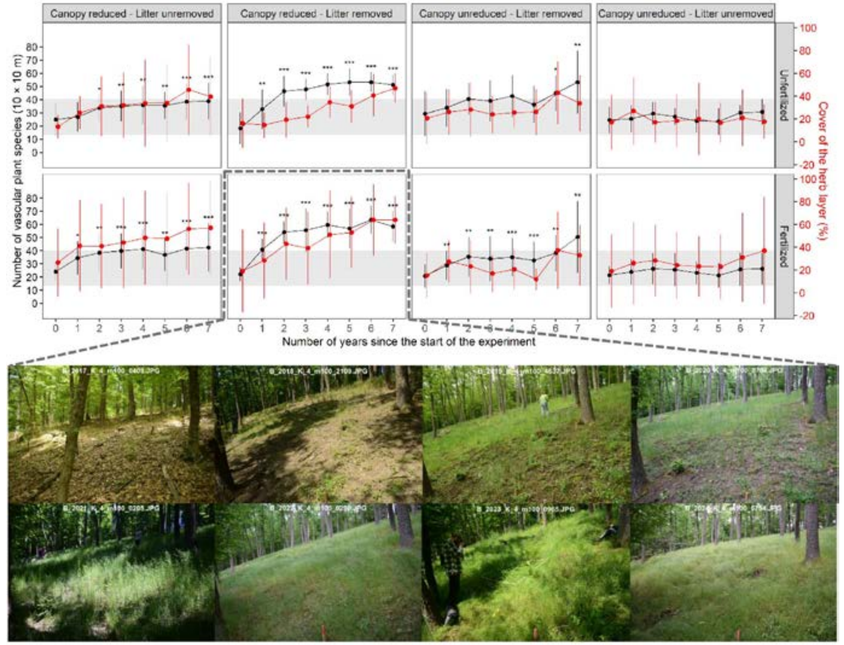


Fig. 2

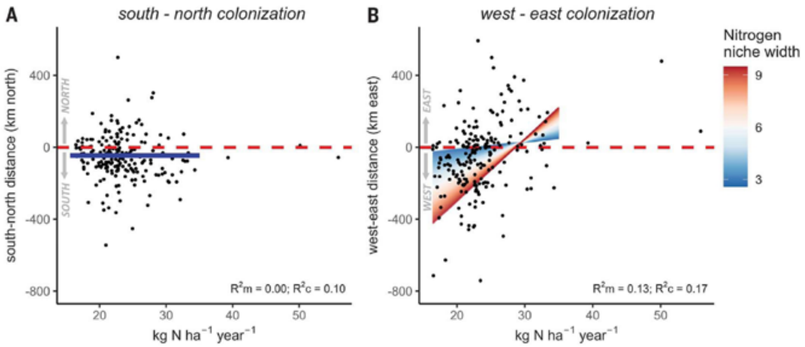


Fig. 3

Tree and stand level biomass (carbon) models for young man-made forest of European beech and Norway spruce

Principal investigator
Ing. Pajtík Jozef, PhD.
Applicant organisation
National Forest Centre
Term of solution
07/2020 - 06/2024
Budget from agency
249 986 €
Project ID
APVV-19-0387

Research Subject

The subject of observation in this project were forest stands of European beech and Norway spruce originating from artificial regeneration, defined by a maximum tree diameter at base d_0=10 cm (or $d_{1.3}$ ≈8 cm; where d_0 is measured at the stem base and $d_{1.3}$ at a height of 130 cm above the ground), or by an average stand diameter d_0=7 cm ($d_{1.3}$≈5 cm). The stands were approximately up to 15 years old. The research focused mainly on quantifying the biomass of individual tree components and on the amount of carbon sequestered in the biomass.

Aim of the Research

The main objectives of the project were to:
- Create regression models to calculate tree biomass (entire tree as well as individual components) at the tree level in relation to its size (stem diameter, tree height, or their combination) and age.
Construct regression models to calculate tree biomass stock at the stand level based on average diameter, average height, and stand density.
- Develop a model to calculate annual production at the stand level based on average diameter, height, age, and stand density.
- Assess interspecies differences in the observed production-ecological and physiological indicators between beech and spruce from artificial and natural regeneration.
- Construct regression models to estimate specific leaf area and total leaf area at the individual tree level in relation to size (stem diameter, tree height, or their combination), and potentially other tree and stand characteristics.
- Create a model to estimate the average leaf area index at the stand level.

Achieved Results

During the course of the project, new regression models were created for calculating the biomass of individual tree components from artificial regeneration at the stand level, depending on average stand diameter, height, and age. The main findings from interspecies comparisons of these models include:

- At the same average stand diameter, beech has a larger stock of stem with bark, branches, and roots, but a smaller stock of foliage. Branches constitute the largest fraction of biomass in beech, while needles dominate in spruce.
- When comparing biomass component stocks by age, spruce has a larger stock of all evaluated tree components than beech. This is due to the faster growth of spruce compared to beech in the juvenile stage.

Models were also developed to calculate the annual aboveground biomass production of spruce and beech, along with their mutual comparison. The comparison showed that the annual aboveground biomass production of spruce is 2.5–3 times higher than that of beech, which is due to spruce's greater annual growth in both diameter and height.

The newly created regression models for calculating biomass of individual tree components from artificial regeneration were compared with models for biomass calculation in young spruce and beech individuals from natural regeneration. The most important findings from these comparisons are:
- Young spruce and beech stands from artificial regeneration differ from those from natural regeneration mainly in the number of individuals per unit area.
- Spruce from artificial regeneration has a higher proportion of needles and branches compared to natural regeneration, which is related to competition from surrounding individuals.
- In young beech stands, the difference in the biomass of branches and leaves between artificial and natural regeneration was negligible.
- In both tree species, a greater proportion of roots in total tree biomass was observed in stands from artificial regeneration.

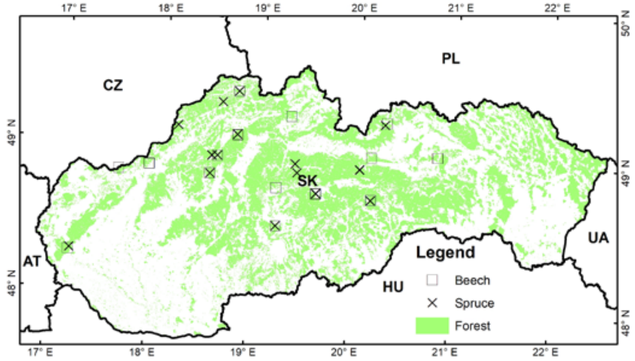
Benefits for Practise

We constructed user-friendly yet sufficiently accurate mathematical models for beech and spruce at both the individual tree and stand levels. These models address both biomass stock and production. They are based on easily obtainable or quickly measurable characteristics. One of the predictors is also the age of the forest stand, which is particularly important for the potential use of these models as tools for estimating the amount of carbon sequestered over a certain period.

Our stand-level models enable calculations of stock or production based on a basic measurement unit (per hectare) or stand unit (e.g., forest compartment). These models can be used for carbon balance assessments in beech and spruce forests, or their mixtures.

Solving the project tasks brought scientific knowledge in the field of forest production and production ecology. It also provided tools that landowners can use when claiming carbon credits.

Fig. 1 / Location of research plots of beech and spruce originating from artificial regeneration.
Fig. 2 / Excavating spruce trees in the field.
Fig. 3 / Separation of spruce tree components in the field.
Fig. 4 / Samples of belowground biomass in the laboratory before drying.
Fig. 5 / Beech and spruce biomass stocks (artificial regeneration with tree spacing of 2.0 x 2.0 m) based on stand age.



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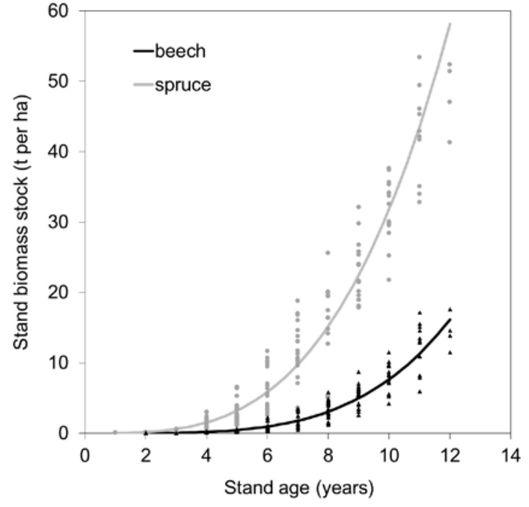


Fig. 5

SOCIAL SCIENCES

Success, Failure, and Aspirations of Children Living in Poverty

Principal investigator
doc. Ing. Želinský Tomáš, PhD.
Applicant organisation
Technical University of Kosice - Faculty of Economics
Term of solution
07/2020 - 06/2024
Budget from agency
249 885 €
Project ID
APVV-19-0329

Research Subject

The aspirations of young people are considered a key determinant of their future economic status and quality of life in adulthood. Experiences of success or failure can influence the process of aspiration formation, either positively or negatively.

Aim of the Research

The primary goal of the project was to design an innovative approach to experimentally measure aspirations and to explore the mechanisms involved in aspiration formation. The project focused on several influencing factors: experiencing success or failure, the role of feedback, the presence of choice, and the impact of social norms.

Achieved Results

One of the tested hypotheses suggested that previous success or failure may affect both future aspirations and subsequent performance. Results from an online experiment conducted across three countries (Slovakia, the UK, and the US) indicate that informing participants about their prior task performance significantly influenced their aspirations for future tasks, though it did not affect their actual performance. Notably, the negative impact of failure on aspirations was stronger than the positive effect of success. Similar patterns were observed in a natural setting with university students during physical education classes.

Findings from research among primary school students suggest that generic positive feedback (praise) has no statistically significant effect on aspirations. However, in parts of the study where students were given the choice of test type, those with the option to choose reported higher aspirations and expectations and experienced lower levels of anxiety compared to students in the standard, non-choice condition.

Research into the normative aspects of aspirations indicates that social pressure plays a key role, with self-image emerging as a central mechanism. A major finding was that most participants justified presenting higher professional aspirations than they actually hold by noting that aiming for occupations perceived as requiring less education could evoke feelings of shame.

Another segment of the project investigated social norms surrounding academic degrees. Findings from Slovakia suggest that academic degrees are often viewed by respondents as the most important outcome of higher education - more so than practical experience. However, providing information about labour market needs for graduates with bachelor's or master's degrees had a statistically significant effect on shifting perceptions of social norms related to the necessity of completing a master's degree. This suggests that a strong "credential culture" persists in Slovakia, but that students remain flexible and responsive to new information.

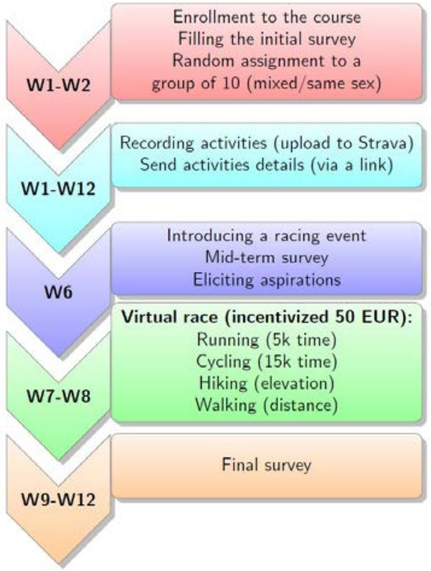
Benefits for Practise

The project's findings enhance understanding of how aspirations are shaped in different contexts and are particularly relevant for educational policy. The fact that previous failure can significantly dampen an individual's aspirations - and potentially their future performance - has strong implications for education. Students who repeatedly perform poorly may develop a persistent sense of failure, which could harm their labour market outcomes and future economic well-being.

Moreover, social pressure to favour certain types of careers contributes to norms that devalue specific occupations. This can reduce interest in educational tracks and professions that are essential to the labour market, leading to mismatches between individual aspirations and economic needs. People choosing so-called "less prestigious" jobs may experience stigma, while the labour market suffers from shortages in undervalued professions. It is therefore necessary to develop tools and interventions that increase the social recognition of all economically essential occupations, regardless of field or level of education.

Finally, the perception that academic titles are more important than the practical skills gained through higher education suggests a need for interventions aimed at reshaping societal attitudes. Specifically, efforts should focus on affirming the value of a completed bachelor's degree as a full and legitimate form of tertiary education.

Fig. 1 / Task example (online experiment)
Fig. 2 / Experimental conditions (online experiment)
Fig. 3 / Procedures (experiment with university students)
Fig. 4 / Test sheets (experiment with primary school students)



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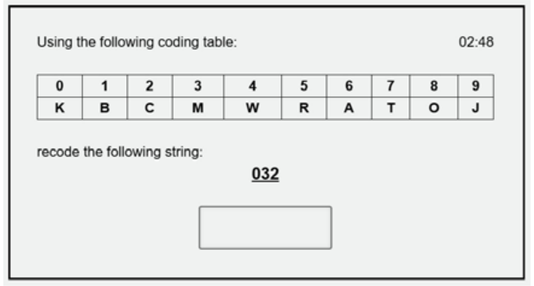

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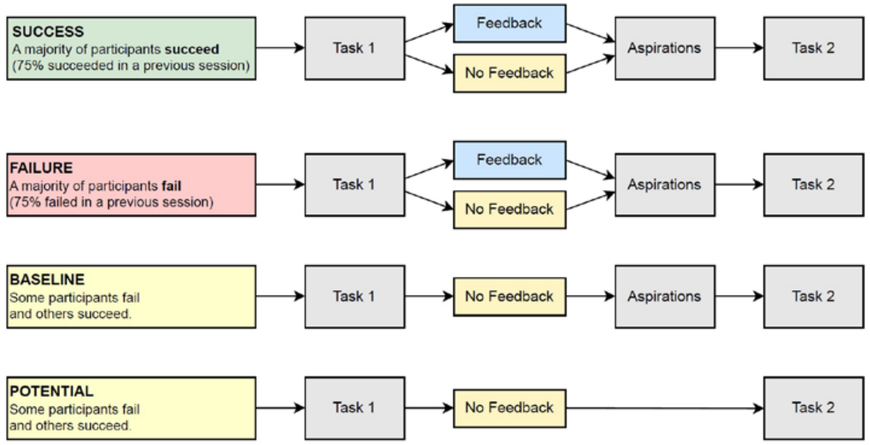

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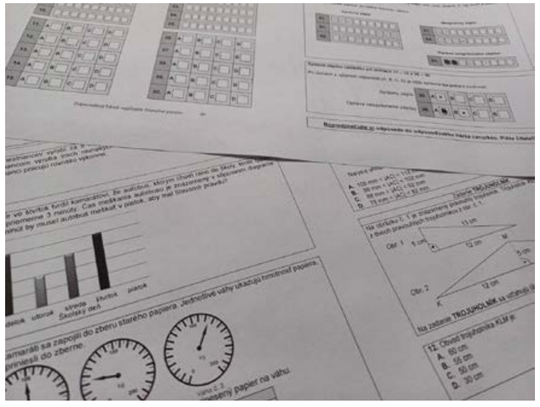


Fig. 4

100 years of Treaty of Trianon

Principal investigator
doc. JUDr. Štenpien Erik, PhD.
Applicant organisation
Pavol Jozef Safarik University in Kosice - Faculty of Law
Term of solution
07/2020 - 06/2024
Budget from agency
190 000 €
Project ID
APVV-19-0419

Research Subject

The project focused on researching the Treaty of Trianon in the context of the adoption of peace treaties of the Versailles Peace System in 1919. In this context, it was necessary to conduct research into the history of international legal processes leading to the conclusion of peace treaties, specifically those that regulate borders between states. The project involved researchers from three countries: Slovakia, Hungary, and Poland. It was an applied project, therefore the research results were intended to be transformed into activities by the partner organization, the Historical Society in Košice. Since the subject of the research also included the development (especially private) law in the three participating countries during the interwar period, another significant effort was to improve the future legislative activities in Slovakia, Hungary, and Poland.

Aim of the Research

The primary goal was to analyze the causes and consequences of the Treaty of Trianon using legal-historical and legal research methods. Since this approach was new, the project required conducting partial research tasks:

1. comprehensive research of all relevant features of international diplomatic and consular law from the times of ancient Rome to the second half of the 19th century
2. research on the creation and changes of the borders of Austria-Hungary, especially in the 19th century, but ending with the outbreak of World War I, especially at the level of county borders in the so-called buffer zone
3. research on the creation of state power of the successor states and their mutual relations after World War I
4. analysis of the Treaty of Trianon and its impact on the current existence of the successor states of the Austro-Hungarian monarchy. The aim was to try to reconcile the historical view of Slovakia with the views of mainly the Hungarian professional public.
5. the participation of Polish colleagues was to ensure a kind of independent view in the context of the influence of the Versailles treaties on the constitutional development of Poland in the examined period.
6. last but not least, the aim was to help the activities of the Historical Society by participating in lectures it organizes for the public, as well as to organize its own events and workshops where the research results would be presented.

Achieved Results

From the second year of research, application outputs were conducted - public lectures held in premises provided by the Historical Society, on topics that were key to its activities - total number: 6. The planned 3 international conferences took place (one of which was online due to protective measures related to the Covid-19 pandemic) and one international doctoral conference. In addition, the researchers organized 2 of their own workshops, one in Košice and the other in Budapest. They regularly participated in (not only their own) conferences and published in domestic and foreign periodicals (including indexed ones). At the end of the project, they published 7 monographs, which concluded the solutions to their partial tasks. In the monitored period of 3 years after the completion of the project, the publication of 1 more monograph is expected.

Benefits for Practise

Applied research assumes fundamental contributions to practice. These are the lectures delivered for the Historical Society in Košice - the very topics of the lectures were beneficial for the members of the Society, as the research on the formation of borders with Hungary constitutes a substantial area of the Society's activities.

The publication of 7 monographs itself is, of course, also a significant contribution to practice. Especially the works of colleagues from abroad (published in English, thus made accessible to our professional public) are a significant step towards mutual understanding of experts and possible future closer harmonization of the evaluation of the studied period (today often perceived contradictorily by both sides). While there are still some areas for improvement, the first step has been made. Both scientific camps (Hungarian and Slovak) were able to calmly exchange views and perhaps they will understand each other even better in the future. Since the project also examined the development of legal systems and the impact of these changes on current (especially private) law, the results obtained by the researchers who focused on positive law are a hope for the future for improving the adoption of laws in Slovakia, Hungary and Poland. Without knowledge of history, one cannot create the future.

Fig. 1 / Team of Researchers at the online Conference in 2021
Fig. 2 / Opening of The Conference in 2023
Fig. 3 / Workshop with Students in 2022
Fig. 4 / Lecture at the Historical Society in Košice - JUDr. Pištejová
Fig. 5 / Monograph - Štenpien

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Effective land consolidation

Principal investigator
prof. JUDr. Vrabko Marián, CSc.
Applicant organisation
Comenius University Bratislava - Faculty of Law
Term of solution
07/2020 - 06/2024
Budget from agency
180 000 €
Project ID
APVV-19-0494

Research Subject

The project "Efficient Land Adjustment" focused on a comprehensive analysis and optimization of the legal framework for the land adjustment process in Slovakia. The starting point was an examination of the issue from the perspective of law, economics, and ecology. The project entailed a detailed analysis of substantive and procedural law aspects, compared them with foreign regulations, and addressed specific challenges such as lands with unknown owners and public procurement. The project was distinguished by a high level of interdisciplinarity in the field of law, with contributions primarily from experts in administrative law, civil law, and legal history. The initiative became a significant element for creating a community of experts dedicated to land law issues. Essentially, the project focused on strong partnerships with the public sector, particularly emphasizing central government bodies - the Ministry of Agriculture and Rural Development of the Slovak Republic and the Public Procurement Office, as well as regional governments - the Association of Towns and Communities of Slovakia. The project became a fundamental building block for the development of land law at the Comenius University in Bratislava, Faculty of Law. The research tasks were overseen and led by Prof. JUDr. Marián Vrabko, CSc. The idea to apply for APVV support and develop the basic outline of the project was conceived by Mgr. Maroš Pavlovič, PhD., LL.M.

Aim of the Research

The aim of the project was to comprehensively optimize the legal framework for the land adjustment process. To achieve this objective, several sub-goals were pursued, such as defining legal instruments to streamline ownership, proposing solutions for adaptation measures in the landscape in the context of climate change, examining and optimizing public procurement, designing solutions for municipalities in land settlement, and supporting professional discussion, as well as building and connecting a community of stakeholders consisting of researchers and experts in fields such as law, geodesy, and public administration. A key focus was examining the current state of public administration in land management and subsequently proposing reforms for its modernization. The project team placed special emphasis on education and awareness-raising in the subject area.

Achieved Results

The research team primarily engaged in scientific, analytical, and publication activities. A significant portion of the findings emerged from the analysis of substantive and procedural legal aspects, which were compared with foreign legal frameworks. The team examined land consolidation and related legislation not only in Slovakia but also in the Czech Republic, Austria, Hungary, Ukraine, Poland, Germany, France, and Croatia. They successfully identified challenges in the process of land consolidations through consultations with representatives from state administration, planners, and mayors. These activities facilitated an understanding of the baseline situation and ensured a comprehensive perspective on the issue. The research team developed numerous legislative proposals and solutions, created a specialized educational module for municipalities as one of the stakeholders in land consolidations, and provided inspiration for new project initiatives focused on environmental protection and the development of agrarian law. The project significantly contributed to expanding publication resources at the level of monographs, scientific articles in the SCOPUS database, as well as professional publications, studies, and comparative analyses. To support educational development, a publicly accessible textbook focused on land law was published from the project, serving the pedagogical process at Comenius University in Bratislava, Faculty of Law.

Benefits for Practise

The project's practical benefits included supporting legislative changes and improving public administration. It proposed solutions for local governments, leading to an amendment of the Land Consolidation Act, which clarified state property ownership under buildings owned by municipalities and regions. The research team advised the Slovak Towns and Communities Association on this. The findings enhanced expertise and raised awareness of land law among professionals and the public. Overall, it significantly contributed to land law theory and practice in Slovakia and provided a foundation for education and future reforms.

Fig. 1 / View of Auditorium III during the conference on land law held on December 8, 2023.
Fig. 2 / Mgr. Maroš Pavlovič, PhD., LL.M. at a training session for mayors in the Orava region.
Fig. 3 / Cover of the monograph whose publication was supported by the project.
Fig. 4 / Photograph of speakers from the 4th annual conference on land law. From left: Prof. JUDr. Marián Vrabko, CSc., Mgr. Maroš Pavlovič, PhD., LL.M., JUDr. Lucia Filagová, JUDr. Ľudovít Máčaj, PhD., and Mgr. Anton Martvoň, PhD.
Fig. 5 / Photo from the signing of agreements on the transfer of research and development results from the project. From left: JUDr. Miroslav Hlivák, PhD., LL.M., Public Procurement Office; JUDr. Samuel Vlčan, Ministry of Agriculture and Rural Development; and Mgr. Branislav Tréger, PhD., Slovak Towns and Communities Association.

Fig. 1

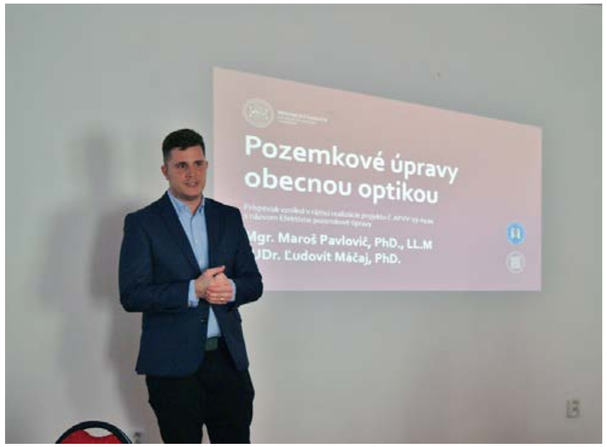


Fig. 2

Fig. 3

Fig. 4

Fig. 5

Modelling the detrimental natural hazards ocurrence risk impact on the economic complex forestry - wood processing under conditions of the ongoing climate change

Principal investigator
prof. Ing. Holécy Ján, PhD.
Applicant organisation
Technical University in Zvolen
Term of solution
07/2020 - 12/2023
Budget from agency
220 000 €
Project ID
APVV-19-0612

Research Subject

An ongoing climate change influences all economic processes in forestry and wood processing industry that is directly dependent on the forestry outputs, as well. A project was focused on the investigation of actual economic issues caused by the growing specific risk of detrimental natural hazards in both branches. The research was concentrated to the measurement of this risk levels and its impact on the GDP generation in both these branches under the conditions of ongoing climate change. The subject of research was also the impact of mentioned one-sided dependence of timber processing on the outputs of forestry.

Aim of the Research

The main objective of a project was to obtain information about dependencies between an ongoing change of climate and the growing specific risk of forestry and wood processing including its impact on the volume, structure and value of production in both branches. Auxiliary objectives included the statistical analysis of models concerning primary abiotic and secondary biotic natural hazards occurrence in these branches as inputs for the formulation and analysis of their econometric models. The forecast of selected kinds of risk and the formulation of adaptation measures focused on the elimination or mitigating this kind of risk impact.

Achieved Results

There were investigated issues connected with econometric modelling the activities of forestry and wood processing in the presence of selected kinds of risk concerning production activities in relation to the macroeconomic measures of physical and economic performances of this complex. A statistical analysis of linear correlation among the time-series of population proportions of danger days measured by the values of fire weather indices used as the measures of a climate change during years 1951-2019 and fire occurrence probabilities in spruce stands in the same period has brought a reliable forecast of this kind of risk development. Also new knowledge about the macroeconomic significance of Slovak forestry, especially the level of profitability concerning the annual capital investments to the planting new forest, as well as the economic value of forest land and forest stands has been acquired. As inputs for a formulation of the econometric model data about the generation of GDP and its structure in both branches were used. The analysis of economic efficiency concerning a whole complex assumes the presence of long-term comprehensive risk of forestry projects connected with the random occurrence of natural hazards and the long-term shortage of direct foreign capital investments to the wood-processing industry. Important is also information about the risk-adjusted and risk-free interest rates of investments to planting under given conditions. Interesting is also the formulation and analysis of a utility function of forestry in relation to the provision of external ecosystem services for a country population. Using both the Ohlin theorem and marginal rate of substitution of produced timber for positive externalities both the point and interval shadow price estimates of aggregated external benefits annually provided by forestry to a whole economy were calculated. Researchers elaborated 61 publications from which 9 of them have been in the CCC database registered and WoS and Scopus databases the number of 65 citation of these outputs have already recorded.

Benefits for Practise

Results of a forest fire occurrence probability development analysis pointed out a fact that a risk level prediction is significantly dependent on a changing climate. The levels of risk calculated under this assumed dependence are substantially higher than the levels of this kind of risk estimated without this assumption. It means that if somebody ignores an ongoing climate change and decides to include this risk in forest management projects only as a stationary input is making a gross error. Among outputs of the econometric model applicable directly in practice also belong point and interval estimate of annual volume of subsidies necessary for both the approaching sustainable forestry and the elimination of natural elements occurrence risk impact on forestry and processing of timber.

Fig. 1 / Representatives of the research team
Fig. 2 / The comparison of stationary and changing in time destruction probabilities in scenarios with and without the assumed impact of an change in climate
Fig. 3 / Effect of changes in species composition on the risk of stand damage or destruction by age class.

Fig. 1

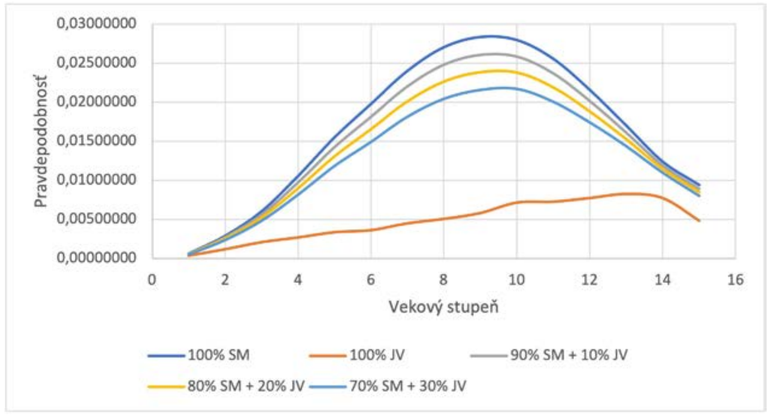


Fig. 3

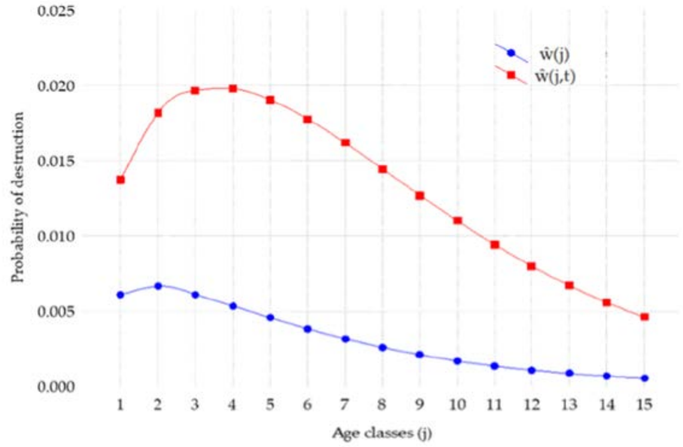


Fig. 2

HUMANITIES

Onomatopoeia - what's in a name?

Principal investigator
prof. PaedDr. Körtvélyessy Lívia, PhD.
Applicant organisation
Pavol Jozef Safarik University in Kosice - Faculty of Arts
Term of solution
07/2020 - 06/2024
Budget from agency
222 600 €
Project ID
APVV-19-0003

Research Subject

The research was aimed at the examination of onomatopoeia in over 100 languages. Although every language acknowledges its existence, its understanding is not universal. It turns out that this is somewhat of a terra incognita in linguistics. Everyone knows this territory exists, but what it is like has yet to be explored.

The relevance of a research area is determined by the lack of relevant examination. The larger the number of unexplored issues, the more attention the problem requires. The significance of studying onomatopoeia arose from our survey, which showed that onomatopoeic words:
- have not been studied comprehensively from the perspective of all linguistic levels, nor have been mapped from a cross-linguistic perspective;
- are often described as unique words in the language system without an in-depth analysis;
- are insufficiently distinguished from ideophones;
- are not subject to cross-linguistic or typological comparison;
- are usually only described from a phonological perspective.

Aim of the Research

The project had three main goals:
a) typological description of onomatopoeia
b) assessment of the prototypical features of onomatopoeia from the perspective of various linguistic levels
c) a monograph

The achievement of these main goals was guided by six research objectives:
i) creating a sample of languages
ii) characterizing the concept of onomatopoeia
iii) compiling descriptions of sound types for a potential sample of onomatopoeia
iv) collecting onomatopoeia from 100 languages
v) defining the final research sample of onomatopoeia
vi) analyzing the collected material
vii) providing a representative description of onomatopoeia in the world's languages

The goals and objectives aimed to confirm or refute three basic hypotheses:
Theoretical approaches to onomatopoeic words are not uniform. They depend on the linguistic tradition and theoretical framework of researchers.
Onomatopoeia differs from the dominant part of the vocabulary at all linguistic levels in the language system.
There are universal properties of onomatopoeia manifested to varying degrees in different languages.

Achieved Results

The most significant results of the project are reflected in two main publications. The first one was published by Mouton de Gruyter, Onomatopoeia in the world's languages (2024). Its editors are two members of the research team – principal investigator Lívia Körtvélyessy and co-investigator Pavel Štekauer. The publication has three main sections: the introductory chapter, in which the main editors describe the research methodology, sample selection, categorization of sound phenomena, etc.; it is followed by the descriptive part, in which over 100 experts from around the world describe onomatopoeia in 88 languages. All chapters have a uniform structure. The final chapter provides a typological comparison of onomatopoeia. The entire publication has 1132 pages. This publication represents a unique resource for further study of iconic vocabulary. It is the first publication of its kind.

The second publication is the monograph by principal investigator Lívia Körtvélyessy, Onomatopoeia: the colorful world of sounds (2025), published by Cambridge University Press. This monograph, based on data from 124 languages, offers a detailed analysis of onomatopoeia as iconic images of sound phenomena from both theoretical and empirical perspectives. It identifies prototypical semiotic, phonological, morphological, syntactic, word-formation, and socio-pragmatic features of onomatopoeia. Supported by numerous examples from the analyzed languages, the monograph highlights the unity of onomatopoeia while emphasizing their diversity across languages, their relationship to ideophones and interjections, and the role of sound symbolism, especially phonesthemes, in the creation of onomatopoeia. It presents an onomaziological model of onomatopoeia formation, identifies onomatopoeic patterns, and specifies the factors influencing similarities and differences between onomatopoeia representing the same sound phenomenon.

Benefits for Practise

Both publications fill a significant gap in linguistics and are essential reading for researchers and students of phonology, morphology, semiotics, stylistics, and linguistic typology. The research is unique in various ways: it has created a network of over 120 collaborating linguists, provides answers to previously unanswered questions, and creates an inspiring space for new research.

Fig. 1 / Front cover of the publication Onomatopoeia in the World's Languages
Fig. 2 / Back cover of the publication Onomatopoeia in the World's Languages

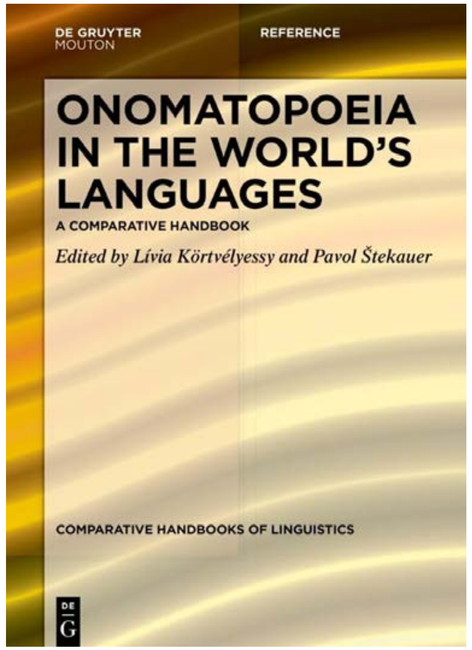


Fig. 1

Fig. 2

Ars moriendi. Phenomenon of Death in the Medieval Kingdom of Hungary

Principal investigator
PhDr. Mgr. Hlavačková Miriam, PhD.
Applicant organisation
Slovak Academy of Sciences, Institute of Historical Studies
Term of solution
07/2020 - 06/2024
Budget from agency
140 000 €
Project ID
APVV-19-0131

Research Subject

The subject of the research was a comprehensive interdisciplinary perspective on the perception of death during the Middle ages, with a focus on the Kingdom of Hungary in comparison to the medieval West, and with relevance to the present day. No other era was as permeated by thoughts of death as the Middle Ages. Death was omnipresent and a part of everyday life.

However, in modern societies, the topic of dying is being increasingly repressed. In Slovakia, not only is there a lack of public discourse on matters related to dying and death, but a scientific reflection on the issue has also been missing. As a result, Slovak historiography has significantly lagged behind European counterparts. Extensive academic and archival research on the territory of present-day Slovakia, within the context of the Kingdom of Hungary, aimed to answer the main research question: How did people in the Middle Ages come to terms with this existential question, and to what extent did their perception of death differ from that of contemporary society? The research team also addressed questions such as: What rituals and ceremonies were associated with dying and burial? How did people prepare for death? What were their beliefs about the afterlife? How was death reflected in narrative sources, law, or art?

Aim of the Research

The main goal of the project was the publication of a representative interdisciplinary work entitled Death in the Middle Ages, which offers the reader a comprehensive view of the phenomenon of dying and death in the medieval period.

In Slovak historiography, this is a unique achievement, as no scholarly work of this type and scope had existed until now. The publication of the monograph was preceded by an international conference attended by experts from various academic disciplines. With the aim of achieving international reach, the research team also undertook to publish the results of their study in a thematically focused issue of the electronic academic journal Forum Historiae, titled For the Salvation of the Soul (2023). The studies extended beyond the context of the Kingdom of Hungary and connected with European medieval research. The team's ambition was to present the knowledge gained during the project not only to the academic community but also to the general public (through articles and media appearances), with the intention of sparking a discussion about one of the most important themes in human culture.

Achieved Results

The most important outcome was the publication of the collective volume Death in the Middle Ages (2024, 619 pages), featuring contributions from all project members. Equally important was the thematic issue of the scholarly journal Forum Historiae, which featured studies by members of the research team. During the project period from 2020 to 2024, we published 9 studies in peer-reviewed and indexed journals in Slovakia and 1 in an international indexed journal, 21 studies in peer-reviewed domestic journals, 3 studies in international peer-reviewed journals, and several others in non-peer-reviewed journals. A significant achievement was the publication of 5 monographs, including 1 published abroad. International cooperation was ensured through active participation in foreign conferences and subsequent publication in international journals. The highlight of our international cooperation was the conference Ars Moriendi Then and Now (2023).

Benefits for Practise

In parallel with the development of medicine and healthcare, the taboo surrounding death has progressed disproportionately quickly over the last century – both on an individual and societal level. According to surveys, nearly 7 out of 10 people in Slovakia feel that death and dying are hardly discussed at all, while healthcare professionals perceive the situation even more acutely (as many as 8 out of 10). Therefore, we devoted considerable attention to the popularization of our research findings. Individual team members participated in discussions and lectures organized by libraries, educational institutions, and museums; published popular science articles; appeared on radio and podcasts; and collaborated on the production of documentary films for RTVS. In total, these activities amounted to 38 public outputs, all with the goal of sparking public discourse on this neglected topic. A roundtable discussion we held before both a scientific audience and the general public at the international conference in Levoča met with extraordinarily strong public response.

Fig. 1 - 2 - 3 Selected publications by the research team

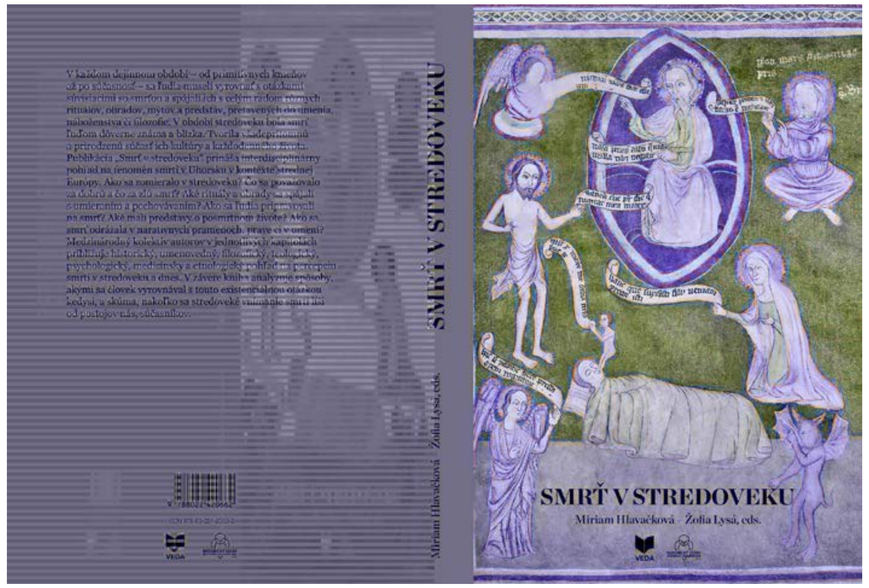
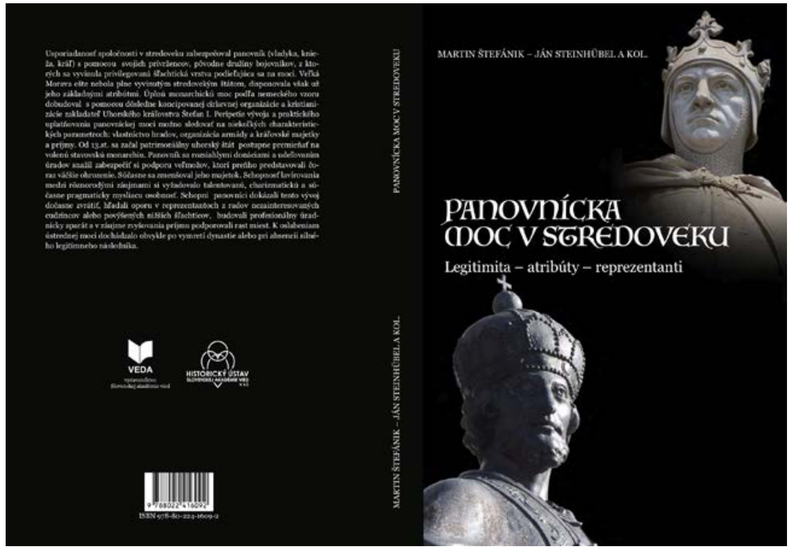


Fig. 1



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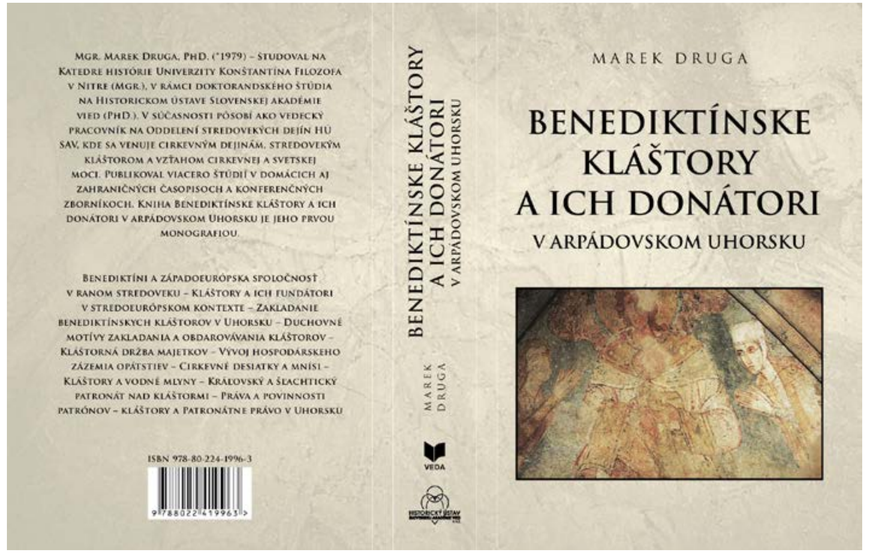

Fig. 2

Methodological Procedures in Literary-Scholarship Research with an Impact on the Media Environment

Principal investigator
prof. PhDr. Gbúr Ján, CSc.
Applicant organisation
Pavol Jozef Safarik University in Kosice - Faculty of Arts
Participating organisation
Slovak Academy of Sciences, Institute of Slovak Literature
Term of solution
07/2020 - 06/2024
Budget from agency
213 741 €
Project ID
APVV-19-0244

Research Subject

The central aim of the project was to strengthen the exactness in the research of Slovak literature by employing diverse methodological approaches and interdisciplinary connections into the media environment. The project focused on the study of source texts, the reassessment of interliterary relationships, and established theoretical frameworks. The primary interest was in specific authors from the late 19th and the first half of the 20th century, their current classification within literary history, and the evaluation of their poetics and creative contributions to the development of Slovak literature. In relation to the Central European context, the comparative research of interliterary connections concentrated on the genetic and poetological specifics of Slovak literature within broader cultural contexts.

Aim of the Research

The core goal of the project research was to publish, in monographic form, revised and original findings on Slovak literature from the late 19th and the first half of the 20th century. These are genetically, typologically, and systemically interconnected within the national and Central European context or situated in the media environment, with reach into world literature. A complementary goal was the production of a documentary film about a prominent figure in Slovak literary scholarship, meeting the criterion of sustainability by being made available in an electronically accessible format. A supporting objective was the engagement of early-career researchers under the age of 35, along with science communication efforts that ensured the presentation and dynamic dissemination of research outcomes within the academic community.

Achieved Results

The scientific research, progressing from fundamental material-based and archival studies to ongoing presentation in both Slovak and international journals and proceedings, resulted in 101 publication outputs, with an emphasis on various methodological approaches (heuristic, hermeneutic, formal-structuralist, constructivist, cognitive, adaptological). The summative outcome of this multi-year research effort is seven scholarly monographs published in the Slovak Republic, which engage with established theoretical frameworks on authorial production, poetics at the turn of the century (realism–modernism), and the understanding of Central European literatures. The key audiovisual output is a documentary portrait on the life and work of Prof. Ján Gbúr, capturing the personality of this literary historian and university professor. Additionally, in cooperation with Matica slovenská, the project supported the production of the film Tichý génius (Silent Genius, 2022), dedicated to Pavol Jozef Šafárik.

Benefits for Practise

The published monographs and documentary films, focused on key figures in Slovak and Central European literature at the turn of the 19th and 20th centuries and on the media environment with links to 21st-century world literature, represent a valuable contribution to current research in Slovak literary studies, as well as to educational practice and the broader cultural context.

Fig. 1 / Publications produced within the project
Fig. 2 / Participants of the international scientific conference Allusions 2024
Fig. 3 / Prof. PhDr. Ján Gbúr, CSc., in a scene from the documentary film

Fig. 1

Fig. 3

Fig. 2

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