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28HSKIKI

28th CROATIAN MEETING OF CHEMISTS & CHEMICAL ENGINEERS

6th SYMPOSIUM VLADIMIR PRELOG

MARCH 28–31, 2023
HOTEL LONE • ROVINJ
CROATIA

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6th Symposium Vladimir Prelog

Book of Abstracts

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Prof. Tatjana Gazivoda Kraljević
Chair of the Scientific and Organizing committee

Dear Colleagues, Partners and Friends,

On behalf of the Scientific and Organizing Committee of the 28th Croatian Conference of Chemists and Chemical Engineers, I am honoured and pleased to invite you to support the Conference which will be held from the 28th to 31st of March 2023 in Hotel Lone, Rovinj, Croatia.

Since its first edition in 1969, the meeting has been traditionally organized every two years by the Croatian Society of Chemical Engineers and the Croatian Chemical Society. It gathers around 400–500 chemists and chemical engineers from Croatia and neighbouring countries that, coming from academia, institutes and industry, actively participate and contribute to the success of the meeting with posters and oral presentations.

The Meeting will provide an interdisciplinary platform for leading academic scientists, researchers and research scholars to present and share both their experiences and research results on all aspects of chemistry and related fields in a friendly, interactive and collaborative atmosphere, while discussing the latest achievements and novel approaches, the most recent innovations, trends as well as challenges and adopted solutions.

An exhibition of chemical industrial and laboratory equipment and instrumentation, computer software and hardware, literature and other relevant material, will be organized as an accompanying manifestation.

We will be glad to host you at this Meeting as we believe, other participants and coming delegates would love to hear and learn from your experience.

We look forward to welcoming you at the 28HSKIKI in Rovinj!

Tatjana Gazivoda Kraljević

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EDUCATION

Towards useful composites of polymers and nanoparticles

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The development of functional and useful composites of polymers and 1D/2D materials requires: i) effective dispersion and distribution of the nanoparticles in the polymer matrix, ideally using cost-effective, sustainable and environmentally friendly processes without the use of organic solvents; ii) controlled and tailored interfacial interactions between nanoparticle and polymer chains and critically and, iii) an understanding of the structure, morphology and properties of the interphase region between the polymer and nanoparticle. [1-3] In this presentation, different approaches to both covalent and non-covalent functionalization, [4-6] to enhancing the interaction between 1D/2D materials and model polymer systems is described. We show the rigorous characterization of these materials [7-9] and demonstrate how the properties of the polymer matrix can be tailored given favorable interactions between components. [10] Moreover, we confirm that the methodology adopted for functionalization is compatible with the melt processing of the polymer of interest.

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Microbiome metabolites: Syntheses and surprises

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The microbiome is composed of different microorganisms such as bacteria or viruses that live on or in a complex host, such as *e.g.* humans or plants. Estimates suggest that bacterial cells outnumber their human host cells by as much as 10:1, leading directly to the question:

Who is in control?

Interactions, and ultimately control of the microbiome with their host might involve the trading and trafficking of chemicals. We will present recent studies from our group investigating small molecule chemicals that serve as signals for bacterial communication, [1] cyclitols for chemical offense, [2] and a recent total synthesis of peyssonnoside A [3] which might be produced by the microbiome of red algae, complemented with other terpene syntheses. [4]

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Bio-nano tools in medicine: From *in vivo* biosensors to drug delivery

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Modern molecular science is merging our knowledge of biochemistry, molecular biology, physics and even artificial intelligence to come up with materials that have a potential to take us into the era of precision medicine. Particular advances have been made in the design of bio-nano hybrids, which combine the biomolecules and man-made nanostructures and overcome intrinsic differences between individual elements. [1]
In this talk we will have a look at the design principles and biomedical applications of bio-nano hybrids, in particular in development of *in vivo* biosensors for ageing cells and early detection of cancer [2] and in tissue re-engineering [3] and drug delivery [2], as well as explore what the future holds for the field of biomedical nanomaterials.

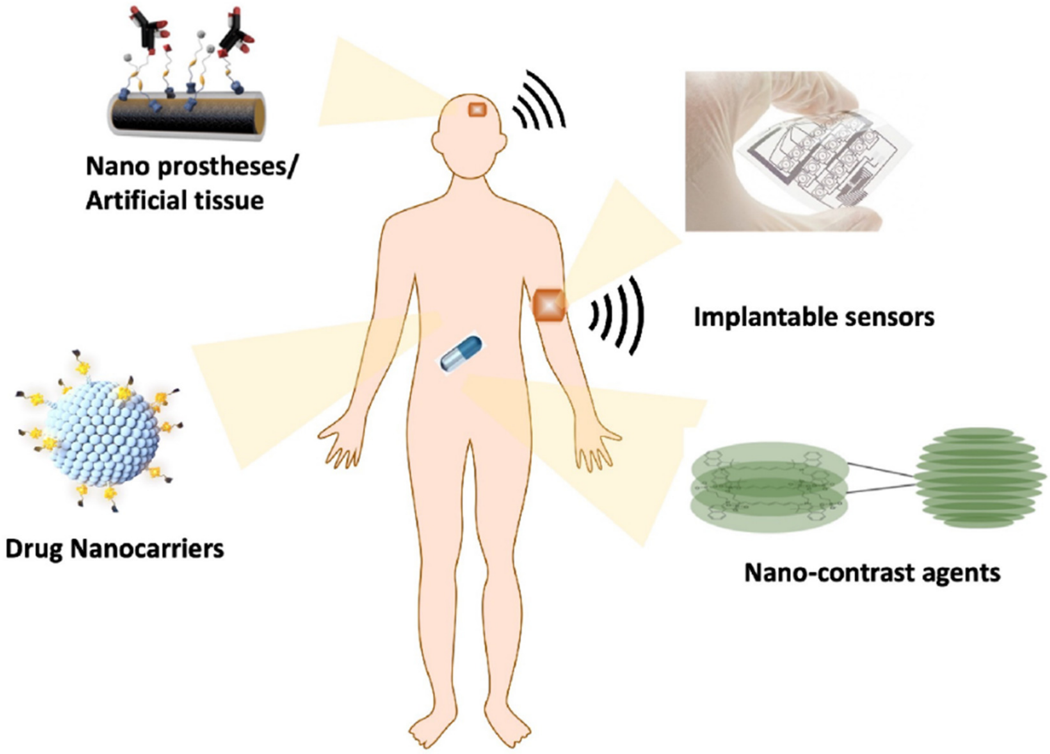

Fig. 1: Bio-nano tools in medicine: From in vivo biosensors to drug delivery.

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The beautiful simplicity of rearrangements: Towards ideal reactions?

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The turn of the century brought about a pressing need for new, efficient and clean strategies for the chemical synthesis of biorelevant compounds. Our group has studied the use of various molecular rearrangements and atom-economical transformations as particularly appealing means towards the streamlined synthesis of complex small molecule targets.

In this lecture, we will present an overview of our research in these areas focusing on the chemistries of sulfonium salts, keteniminium ions and small strained rings, and how they provide efficient solutions for the discovery of unusual reactivity or concise total synthesis. [1,2,3] Furthermore, we will discuss innovative approaches to reactions that might come a step closer towards “ideality”. [4]

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The best of both worlds: How to combine chemistry and biology to discover greener biocatalysts using artificial, cell-like compartments

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The application of enzymes in chemical industrial processes is increasingly important to achieve the EU's sustainability goals and strengthen the bioeconomy, representing a greener alternative to oil-based chemistry. Society demands more environment-friendly, healthier products and cleaner energy. While enzymes have the potential to meet these demands, they still find several hurdles for their industrial application: low success rates of discovery and engineering; tedious and expensive methods to explore diversity and limited activity/stability in the final application.

Microorganisms represent an unfathomable source of enzymes for the bioeconomy, but only a small fraction of them can be cultivated in the laboratory. For this reason, it remains an underexplored source of bioactive compounds, carbohydrate polymers and enzymes, among others. Sampling the natural microbial diversity, screening, identifying and isolating the relevant enzymes is cumbersome, expensive and results in a heavy environmental burden, low yields, high costs and long times to market. Throughout the course of EU-funded projects CarbaZymes, MetaFluidics, RadicalZ and BlueTools, we have been developing (and will develop) technology to overcome these limitations. Our methods for enzyme discovery and engineering make use of cells or artificial cell-like compartments that combine the best of chemistry and biology and have enabled us to access uncharted enzyme space and thus, true novelty.

The sustainable approach in battery research and development

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Electrification of different sectors requires large production scales of batteries and it is planned that by 2030, Europe will produce more than 100 GWh of battery cells per year. That will create huge demand for Li-ion cells and consequently many raw materials will become critical raw materials (CRM). Among cobalt and graphite, elements such as nickel, silicon, copper, and lithium will be highly strategic. Thus, there is an urgent need for the development of high-energy-density cells based on abundant, sustainable, and cost-effective materials. Suitable elements that can be considered should be highly available in the earth's crust.

Multivalent metal anode (Mg, Ca, Al) batteries are currently considered an attractive and realistic technology; however, they suffer from the lack of suitable cathode material. The most promising cathode material that offers reversible electrochemical activity with cations of different sizes and charges are redox active organic materials. Organic materials could be produced from biomass-derived feedstock and are typically synthesized at lower temperatures, importantly contributing to the reduced CO_2 footprint and sustainable battery production.

The alternative solution is sulfur, which can deliver high energy density during the reduction process from sulfur to sulfide. The major difficulty of using sulfur-based cathodes is related to the continuous dissolution of sulfur and polysulfides, which react with metallic anode and create polysulfide shuttle. This problem is even more pronounced when polysulfides are created in the electrolytes used in multivalent batteries.

Some recent achievements and potential future directions will be discussed along with the EU strategy for the electrification of different sectors.

Redox biochemistry for biopolymer degradation

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Lignocellulolytic oxidoreductases such as lytic polysaccharide monooxygenases (LPMO), laccases, peroxidases, *etc*. are industrially applied as biocatalysts for the deconstruction of plant biomass. To elucidate their biocatalytic and physiological function we study enzyme binding, their spatial distribution and their interaction with lignocellulosic material. In this study, selected fungal hydrolases and oxidoreductases were localized on poplar wood by confocal laser scanning microscopy. Together with scanning electrochemical microscopy (SECM) we were able to study LPMO activity in combination with the auxiliary enzymes cellobiose dehydrogenase and cellobiohydrolase II. The action of these enzymes supports biomass hydrolysis by increasing saccharification efficiency and rate. The localized and time-resolved determination of LPMO activity on poplar wood cell walls was achieved by measuring the H_2O_2 concentration with a piezo-controlled H_2O_2 microsensor. The investigated LPMO binds to the inner cell wall layer and consumes enzymatically generated H_2O_2. The results point towards a high catalytic efficiency of LPMO at a low H_2O_2 concentration that auxiliary oxidoreductases in fungal secretomes can easily generate. Measurements with a glucose microbiosensor additionally demonstrate that LPMO promotes cellobiohydrolase activity on wood cell walls and plays a synergistic role in the fungal extracellular catabolism and in industrial biomass degradation. The methods presented in this presentation are suitable for the visualization of enzymes during catalytic biomass degradation and can be further exploited for interaction studies of lignocellulolytic enzymes in biorefineries.

Metallosupramolecular architectures and inorganic-organic polyoxometalate-based hybrids

Višnja Vrdoljak, Mirna Mandarić, Jana Pisk, Edi Topić, Mirta Rubčić, Tomica Hrenar,
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Metallosupramolecular architectures and polyoxometalate POM-based hybrids have gained considerable interest in many fields of science due to their structural versatility, compositional adjustability, and chemical features. Our extensive work has involved the synthesis and characterization of such complex species expected to exhibit superior catalytic activity. In part, it refers to metallosupramolecular compounds $[MoO_2(L)]_x$ (x = 2, 4, and n) obtained utilizing coordination-driven self-assembly of $\{MoO_2\}^{2+}$ core with nicotinylhydrazoate or aminobenzoylhydrazonate ligands. [1,2] In $[MoO_2(L)]_x$, the ligand is coordinated to the $\{MoO_2\}^{2+}$ core *via* the *ONO* donor atoms. The remaining sixth coordination site is occupied by the nitrogen atom N′ of the aminobenzoyl or nicotinoyl moiety of the neighboring molecule. The potential of these assemblies depends on their geometrically constrained nature and Mo–N′ bond distances. The second part of our research relates to the self-assembly of POM-based hybrids from Mo^{VI} hydrazonato complex cations and POM anions. [3] Their formation relies almost entirely on the structure-directing effects of the metal-organic components and chosen solvents. These compounds can be divided into two types of hybrids. *Class I* includes the ionic materials $[MoO_2(HL)(D)]_2[Mo_6O_{19}]$ or $[MoO_2(HL)(D)]_4[Mo_8O_{26}]$ (D = CH_3COCH_3, H_2O, or CH_3CN) and *Class II* relates to covalently anchored hybrids $[\{MoO_2(HL)\}_2Mo_6O_{19}]$ and $[\{Mo_2O_4(HL)(H_2L)\}Mo_8O_{26}\{MoO_2(HL^2)\}]$. Almost all *Class I* assemblies additionally accommodate lattice solvent molecules, and their utilization is limited due to low stability. In the *Class II* hybrids, Lindqvist or the *β*-octamolybdate anion acts as an inorganic link between two peripheral Mo-complex units through the $Mo–O^t=Mo_{POM}$ linkages. Such compounds with long $Mo–O^t$ bond distances offer easy access to highly reactive pentacoordinated species and, therefore, exquisite catalytic activity.

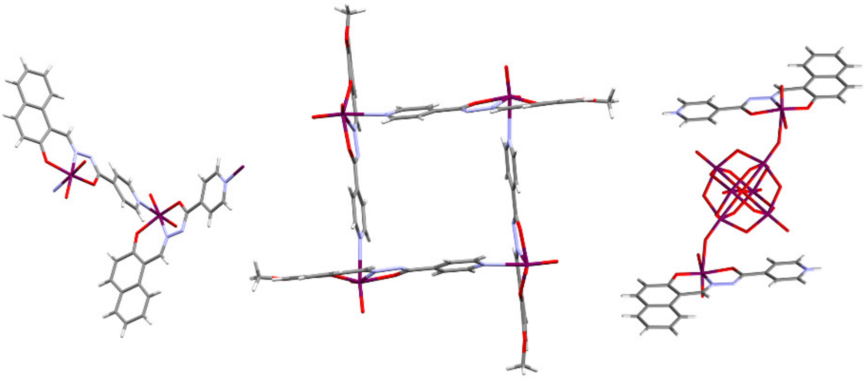

Fig. 1: Metallosupramolecular *zigzag* chain polymer, molecular square, and hybrid compound.

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Biodegradable composite materials as scaffolds and drug delivery systems for bone tissue engineering application

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The malignant diseases frequently affect the population of early and middle age and represent a high burden to healthcare system in the last few decades. [1] The development of less invasive smart materials as drug delivery systems has emerged from the need for advanced procedures of tumor treatment. The targeted drug delivery ensures localized treatment of tumor tissue minimizing the exposure of the whole body. [2] The innovative drug delivery approach lies in a less invasive treatment by the combination of biodegradable polymer, metal ions and antitumor drug in order to administrate lower drug dosage. The use of transition metal ions, such as copper, will inhibit the growth of tumor cells through their redox activity in living organisms. [3] The biocompatible and biodegradable materials such as pH-sensitive chitosan-based carriers are exceedingly promising systems for the encapsulation and simultaneous release of antitumor drug and therapeutic metal ions that will act synergistically to inhibit the growth and survival of tumor cells under lower concentration of the drug. Natural human bone is a metabolically active tissue that undergoes continuous process of formation, resorption and remodeling. When it comes to small defects of damage, bone possesses the self-healing ability. [4] However, larger defects originated from surgical resection of tumor require implants, i.e. scaffolds that serve as a support for tissue regeneration and tumor inhibition. Furthermore, highly porous chitosan-based scaffolds modified by bioactive agents can be developed as dual functional carriers that will provide simultaneous antitumor activity to inhibit bone tumor and to induce tissue regeneration at defect site.

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Silicon carbide for radiation detection

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Increasingly complex risks, like geopolitical instability or decentralized terrorism threats, have led to the urge for deploying nuclear screening systems for the detection of illicit trafficking of nuclear materials, and from that to a growing interest in the field of research and development of new radiation detection technologies suitable for homeland security applications. Recent progress in the manufacturing of high-quality epitaxial silicon carbide (SiC) enables unprecedented detection properties of future SiC-based detectors for neutron and alpha-particle emissions. Unlike existing and commonly used neutron gas-based detectors, SiC-based devices have the potential to be simultaneously portable, operable at room temperature, and radiation hard.

In this talk, we will present recent findings on the development and efficiency optimization of the thermal neutron converter films as an important part of the 4H-SiC-based neutron detector. This is achieved by optimizing the thermal neutron converter thicknesses. 6LiF and 10B4C have been used for the thermal neutron converter materials. We have reached the highest reported efficiency for the 4H-SiC-based neutron detector of almost 5% for the thermal neutrons. Moreover, we have successfully assembled a set of electronic components for the read-out system, 4H-SiC-based detector heads, and thermal neutron converters to develop a fully functional, portable, and battery-powered state-of-the-art thermal neutron detector.

Direct C−H arylation

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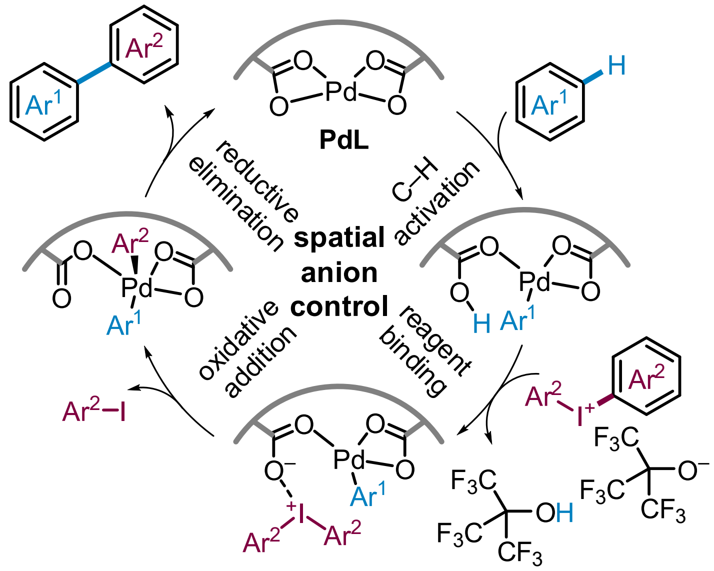
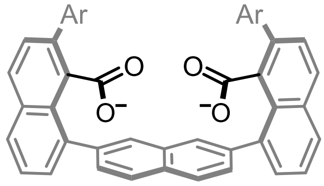
Direct transformation of C−H bonds to C−C bonds using transition metals such as palladium shows great promise for the synthesis of complex molecules and materials. However, the development of catalytic systems that offer high reactivity and control over site-selectivity is an outstanding challenge. [1,2] We have recently developed spatial anion control as a concept for the design of catalytic sites for C–H bond activation, thereby enabling nondirected C–H arylation [3] of arenes at ambient temperature. [4] The site-selectivity of the reaction was controlled mainly by the electronic and steric properties of the substrates, with electronically-rich and sterically-exposed C–H sites displaying higher reactivity. In this presentation, in addition, our recent progress on the development of site-selective C–H arylation reactions will be described. [5]





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Total synthesis of penicyclone A

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Penicylone A is a naturally occurring polyketide compound containing a spiro[5.5]lactone moiety which was recently isolated from *Penicillium* sp. F23-2. [1] Our motivation for the synthesis of penicyclone A, aside from its exotic structure, was its reported antibacterial activity (MIC = 0.3 µg/mL for *Staphylococcus aureus*). The variety of functional groups and chiral centers in a relatively small molecule presented a considerable synthetic challenge. We developed the first total synthesis of penicyclone A, which was accomplished in 10 steps starting from a known D-ribose derivative. [2] The key step was a double Grignard reaction enabling the diastereoselective construction of a crucial tertiary alcohol intermediate. This new methodology was also tested on several other model compounds to determine the scope of its applicability. The synthesis also featured a tandem oxidation/cyclization for the synthesis of the lactone moiety and a photooxygenation followed by an oxidative rearrangement to introduce the enone functionality. The synthetic penicyclone A was thoroughly characterized using NMR spectroscopy, mass spectrometry, circular dichroism and optical rotation measurements. Its absolute configuration was confirmed using single crystal X-ray diffraction. After reevaluation of the reported biological activity of penicyclone A, the synthetic sample showed no antimicrobial activity. Discrepancies in the values of optical rotation between the natural and synthetic sample point to the possibility that the natural compound was isolated as an enantiomeric mixture which directed the research towards the synthesis of the other enantiomer. [3]

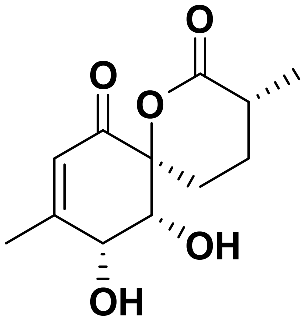

Fig. 1: Structure of penicyclone A.

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Probing leukemic vulnerabilities via small molecules inspired by natural products withanolides

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Throughout history, the field of drug discovery has been fascinated by the therapeutic potential of natural products (NPs) and the biological relevance encoded in their chemical scaffolds. Unsurprisingly, recent years have seen a rise in the design of approaches to generate NP-inspired small molecule compound libraries. [1] One strategy to expand the tangible molecular space is biology-oriented synthesis (BIOS). [2] Through chemoinformatic analysis, core scaffolds in NPs are identified which in turn serve as starting points for the synthesis and further diversification of a small molecule library. Such fine-tuning of chemical space can, above all, yield compounds that display improved or even unexpected biological activities.

In this work, we explored the antileukemic properties of small molecules inspired by withanolides. [3-4] Comprising of more than 900 NPs, this class of plant-derived steroidal lactones has been associated with exhibiting rather diverse pharmacologic properties. Profiling a focused compound library generated by BIOS in the context of leukemia has thus the potential to unveil novel small molecule modulators of bioactivity. Phenotypic screening in a panel consisting of main lineages of leukemia cell lines, revealed a cytotoxic analogue exhibiting sub-micromolar potency. To elucidate the mode-of-action, we used state-of-the-art multi-omics approaches (including expression proteomics and transcriptomics) as well as functional genomics screens. Taken together, we uncovered a novel class of sterol transport inhibitors at inter-organelle membrane contact sites.

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Governing principles behind interfacial processes in energy conversion and storage systems

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Electrochemical reactions take place at the electrochemical interface, the region in which the properties change from those in the bulk of the electronic conductor (electrode) to those in the bulk of the ionic conductor (electrolyte). Not surprisingly, then, efficiency of energy conversion and energy storage processes are almost entirely determined by the richness of interfacial processes that control the rate of electron transfer and various types of interactions between the substrate and reactants, intermediates, and products of the reaction.

The "interfacial bridge" between the bulk of the electrode and the electrolyte manifests itself as i) differences in atomic arrangements close to or at the electrode surface; ii) differences in electrode composition close to the surface; iii) adsorption of species from electrolyte onto the electrode; iv) ordering of solvent and/or electrolyte molecules observed in the proximity of the surface; v) changes in electrolyte composition in the proximity of the electrode; and vi) formation of solid film between the electrode and electrolyte. All of these processes are rather complex, requiring special arsenal of tools that are capable of resolving interfacial properties at atomic and molecular levels. Moreover, it makes the electrochemical interface extremely hard to control.

In this presentation, a general outline of our current understanding of aqueous and non-aqueous electrochemical interfaces in energy conversion and storage systems will be given. Our recent advances in understanding the interfaces in water electrolyzers, Li-ion and lead acid batteries will be shown as specific examples of how entirely different systems on the macroscale follow very similar fundamental principles on the atomic scale.

Hydrogen isotope exchange and the kinetic isotope effect in mechanochemical reactions of bulk solids

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Contrary to the notion of solids being rigid and limiting motion of atoms to vibrations, and thereby limiting reactivity in the solid state, mechanical agitation of solids, in addition to crystal comminution, readily facilitates large-scale atom and molecule migration, all types of chemical reactivity, and also crystal growth. [1,2] In addition to enabling fast, selective and sometimes unique reactivity, in this talk I will present experimental evidence of the dynamic nature of the mechanochemical reaction environment, with a particular emphasis on exchange of hydrogen atoms as deduced from the use of isotope-labelled solids and the kinetic isotope effect (KIE) in mechanochemical reactions resulting from the use of deuterated reactant solids. [3-7]

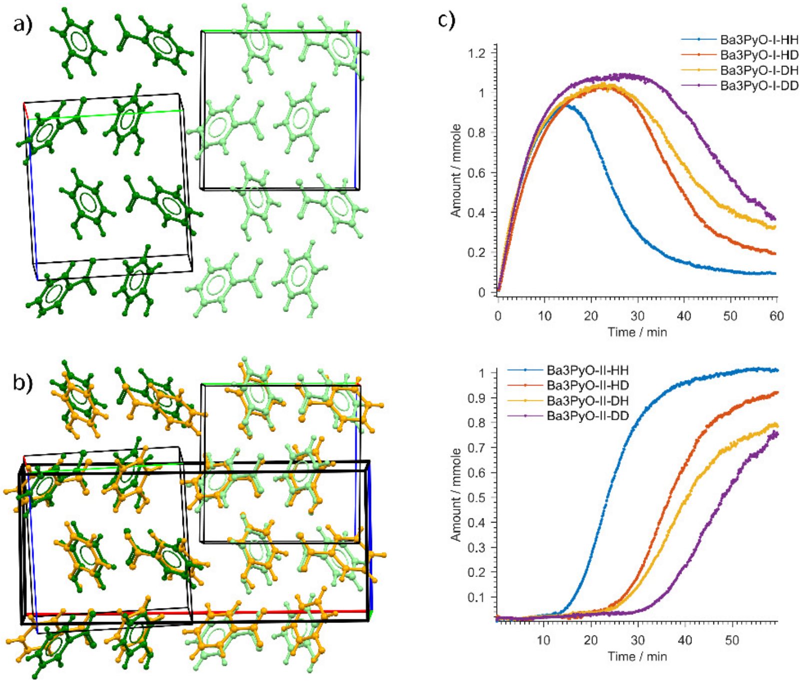

Fig. 1: (a,b) Comparison of crystal structures of the two polymorphs exhibiting the KIE upon deuterium substitution and (c) the kinetic curves for the non-deuterated, partially and fully deuterated reactants.

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Nonadiabatic processes in condensed phase systems with ΔSCF

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Nonadiabatic molecular dynamics (NA-MD) enables direct insight into processes taking place after photoexcitation by elucidating mechanistic details at the atomic scale, explaining photoproducts' branching ratios, and mapping all the relevant excited electronic states along the time-evolving NA-MD trajectories. Computing the appropriate observables for the latter, spectroscopic data can be directly obtained, for example, the time-resolved transient absorption spectra by determining the absorbance of all electronic states along the NA-MD trajectories. Accurate calculation of excited electronic state properties in the condensed phase systems represents the main bottleneck for efficient application of NA-MD methods for investigation of nonadiabatic processes in the condensed phase systems. A variational delta self-consistent field (ΔSCF) density functional theory (DFT) based method [1,2] represents a potential approach to address the aforementioned constraints in addition to perturbative time-dependent density functional theory (TD-DFT). We applied a restricted-open Kohn-Sham formulation of ΔSCF with constrained occupation numbers for the direct construction of singlet and triplet excited electronic states and their corresponding properties. [3] By utilizing the combined Gaussian and plane waves approach with periodic boundary conditions the method is easily applicable to full atomistic DFT simulations of condensed phase and it can be combined with subsystem density embedding to further expand its capabilities. [4] We applied our methodology for the investigation of nonradiative deactivation mechanisms in a number of solvated systems, emphasizing the details of chromophore-environment interactions and their influence on photochemical processes in condensed phase systems. [1,5]

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Process engineering strategies towards efficient biotransformations

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The application of nature's catalysts "enzymes" for the synthesis of chemicals is a key emerging field of industrial biotechnology to meet current and future needs of our society for sustainable manufacturing of chemicals. Nature uses an elegant and efficient synthetic strategy: Coupling enzymes in multi-step pathways without intermediate isolation and purification steps with a precise spatial control of catalysis. Inspired by nature, the design of multi-step biotransformations has been attracting great attention within the biocatalysis community. The talk covers enzymatic (cascade) reactions and demonstration of those at the industrially relevant conditions with the help of process engineering. In particular, two use cases will be introduced covering decarboxylases and peroxygenases in cascading systems exploring the use of non-conventional media and different operational mode for enhancing the efficiency of these enzymatic applications.

Insights into green techniques for the extraction of bioactive compounds: Current research and future challenges

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Recent trends in the extraction field are to use eco-friendly techniques to extract bioactive compounds. The focus is mostly on finding solutions that minimize the use of harmful solvents and allow the use of alternative, so-called "green" solvents, as well as to develop more "sustainable" processes that ensure safe and high-quality extracts/products. The mostly used organic solvents have major drawbacks such as the insufficient recovery of extracts, long extraction time, high amounts of by-products and waste, and high energy consumption. With the green and creative extraction techniques, the extract is produced in such a way so as to have as little negative impact on the environment as possible (reduced energy usage and solvent usage, *etc*.).

A brief overview of the up-to-date knowledge regarding selected green extraction techniques (such as supercritical/subcritical extraction, ultrasound-assisted extraction, *etc*.) will be presented, with special emphasis on the specific examples of the extraction of plant bioactive compounds provided at the Faculty of Food Technology Osijek.

In this presentation, special emphasis will be put on the possible commercial valorization of the research results and on the actual application of these results, with further insights into future trends.

Acknowledgement This work has been supported by the Croatian Science Foundation under the project *Application of innovative techniques of the extraction of bioactive components from by-products of plant origin* (UIP-2017-05-9909).

Effective approaches to limit the input of microplastics into the aquatic environment

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Plastic pollution of the environment has become one of the most important problems in recent decades, with small pieces of plastic, known as microplastics, gaining considerable scientific and public attention due to their widespread occurrence. Research efforts have focused primarily on monitoring microplastics, their interactions with other anthropogenic pollutants, and their effects on biota. Less effort has been devoted to identifying sources and finding ways to limit the input of microplastics into the environment. The aim of our work was to evaluate the efficiency of a conventional wastewater treatment plant with activated sludge, to investigate the retention of microplastics in a constructed wetland, and to present a novel strategy for *in situ* phytoremediation. The results showed that conventional wastewater treatment plants are not effective technologies for removing microplastics from wastewater, as many of the microplastics ends up in the effluent. On the other hand, constructed wetlands showed high efficiency and can be considered as effective barriers against microplastics entering the aquatic environment. They could be used as a tertiary treatment step in conventional wastewater treatment plants or separately for the treatment of domestic wastewater or stormwater. *In situ* phytoremediation is one strategy that could be used to remove microplastics if they are already in the aquatic environment or are the result of fragmentation of larger plastic pieces. However, further research is needed on large-scale phytoremediation and waste management strategies for contaminated biomass.

From nanoscale to bulk: Nonlinear optical properties of materials

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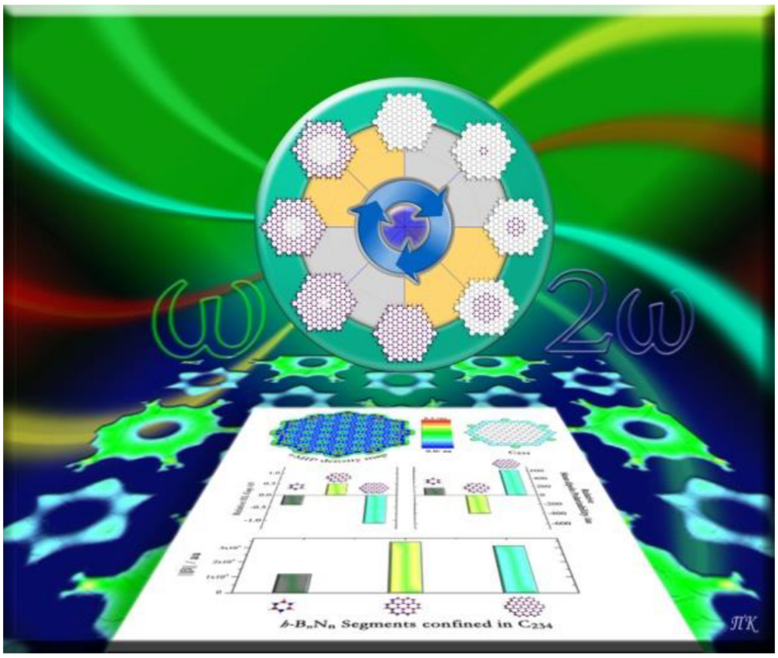
When light travels inside a nonlinear optical material, its intensity and frequency might be changed due to the, so called, material's nonlinear response. The field that deals with this unconventional interaction between light and matter is the field of nonlinear optics. A common example of a nonlinear optical phenomenon is second harmonic generation (SHG). In SHG, a high-intensity beam of light passes through a nonlinear optical material. The interaction of the photons of light inside the material generates a second beam of light with exactly twice the frequency of the original beam. SHG is used in a variety of applications, including in imaging techniques such as two-photon microscopy, in telecommunications for wavelength conversion, and in the development of lasers. The materials bearing this quality are called nonlinear optical materials. They can be inorganic (*e.g.* lithium niobate), organic (*e.g.* donor-π-acceptor chromophores), organometallic (*e.g* organic metal frameworks). The applications of such phenomena are substantially wide and range from the realm of telecommunications, sensing and optical computing to bio-photonics and quantum cryptography. This lecture aims to make an introduction to the exciting world of nonlinear optical materials, which can interact with light in unconventional ways. The basic principles of nonlinear optics will be provided together with an overview of the different types of nonlinear optical materials. The lecture will also explore the diverse range of applications of nonlinear optical materials. Finally, the future directions of research in the field of nonlinear optical materials, including the development of new materials with even higher non-linear susceptibilities, and the exploration of new innovative applications will be discussed.



Sustainable synthesis of biosurfactants from renewable resources

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SFAEs (Sugar-Fatty Acid Esters) are a class of non-ionic surfactants characterized by excellent surface and interfacial tension reduction capability, low toxicity and biodegradability. Depending on their carbon chain length and the nature of the sugar head group, SFAEs can cover a wide range of hydrophilic-lipophilic balance (HLB) values, which result in tunable surfactant properties. Moreover, SFAEs can be obtained from renewable resources (*i.e.* industrial waste and biomass) by enzymatic and/or chemoenzymatic approaches, thus answering the need for sustainable and circular chemistry. [1]
In this context, a small library of SFAEs were prepared by the lipase-catalyzed esterification of isomeric mixtures of alkyl glycosides (namely α-/β-D-glucosides and α-/β-D-galactosides) with molten fatty acids (lauric, palmitic and stearic acid), using CalB (Novozym® 435) as biocatalyst in an easily scalable solvent-free system. Conversion of glucose and galactose into alkyl glycosides before the esterification reaction played a key role in circumventing the striking different solubility of the two reagents. The physico-chemical properties of the synthesized tensides (interfacial tension features, W/O emulsification capability and W/O stability over time) were then finely investigated. [2]

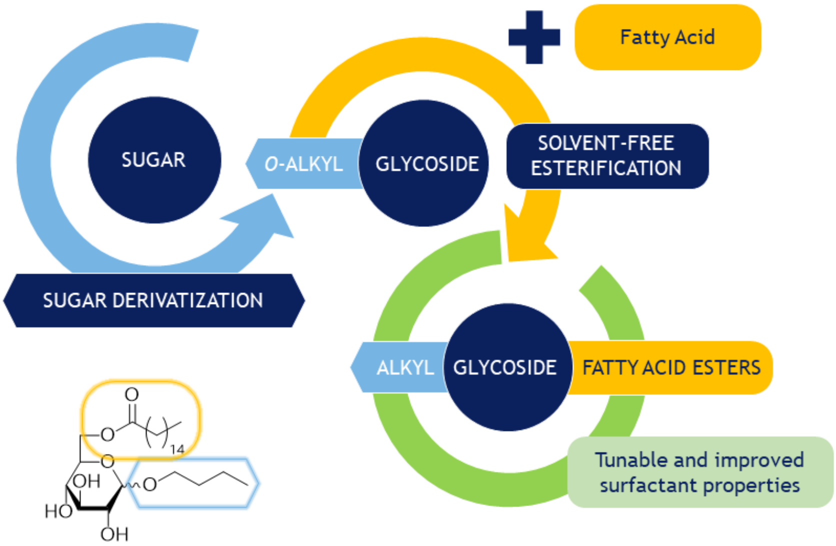

Fig. 1: Chemoenzymatic strategy for the synthesis of SFAEs.

Acknowledgement This work was financially supported by the Cariplo Foundation (Italy), call Circular Economy for a sustainable future 2020, project BioSurf, ID 2020-1094, https://www.biosurfproject.it/.

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Process intensification trough miniaturization

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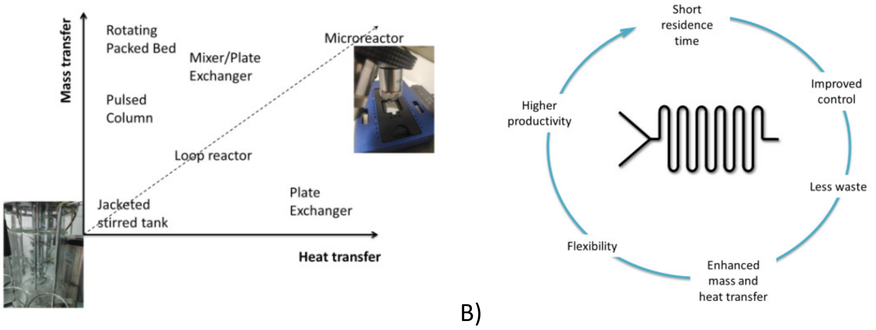
Redesigning equipment or combining multiple processes in a continuous production line can result in significant increases in process throughput. Scaling down of processes to increase mass and heat transfer (Fig. 1A), increase surface-to-volume ratios, and shortened diffusion paths can significantly affect the outcome of various chemical and biochemical processes. The introduction of microfluidics is one of the most promising redesigns of equipment in the field of chemical engineering. The shift to flow technology and micro-scale brought many additional positive benefits, such as better process control and higher productivities. Reactions are often accelerated and the processes that take hours or days in batch reactor can be carried out in microreactors in a few seconds/minutes. The reduction of reaction time also minimizes the formation of various by-products and increases the overall productivity of the process (Fig 1B). Modularity is one of the advantages of microfluidic systems, too, which allows for the integration of several different steps in a small space (even in one micro-system). With this approach, it is possible to combine several reaction steps with parallel purification in one continuous process stream. The use of microfluidics further simplifies the scale-up of the process, since the scale-up is based only on increasing the number of reactors (numbering-up) and not on increasing the scale itself. Microfluidics thus retain all their properties, and once the process has been optimized in a single unit, the optimal conditions are transferred to each additional unit, which can be connected either in parallel or in series.
In this presentation several case studies will be presented where microfluidics have been used to intensify various processes such as extraction (extraction of proteins and polyphenols [1]), biocatalysis (hexanal production and coenzyme regeneration, [2] biodiesel synthesis [3]), organic (photo)synthesis, [4] and click reactions. [5]



A) B)

Fig. 1: A) Mass *vs* heat transfer in different reactor types; B) Advantages of microfluidics.

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Organic synthetic photochemistry: Providing novel and green organic transformations

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Organic synthetic chemistry is in a continuous lookout for the introduction of novel reactivities and new platforms of activation. Photochemistry, the use of light to promote organic transformations, is a field of research that, although it is known for more than a century, nowadays is flourishing since it provides access to alternative activation modes, compared to polar chemistry. Photoorganocatalysis, the use of small organic molecules as photocatalysts, is a low-cost and environmentally friendly alternative, which further increases the sustainability options of photochemistry. Our group has introduced in literature a photochemical protocol that is easy to operate, employing cheap household lamps as the source of irradiation and phenylglyoxylic acid as the photoinitiator. The application of this photochemical protocol was found in the hydroacylation reaction of unactivated olefins, C-H functionalization of heterocycles and synthesis of disulfides from sulfides. Other types of organic photocatalysts will be also discussed. [1-5]

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Preparation of diamide derivatives of a disubstituted ferrocene with desmuramyl peptide and mannose subunit

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Muramyl dipeptide (*N*-acetylmuramyl-L-alanyl-D-isoglutamine, MDP) is the smallest structural unit of peptidoglycans showing immunostimulating activity. [1] MDP analogues without the hydrophilic *N*-acetylmuramyl moiety are called desmuramyl peptides (DMP) and are extensively studied by our group as potential new adjuvants. [1] This work is a continuation of our ongoing SAR study of amphiphilic mannosyl DMP analogues and their adjuvant activity in which lipophilic subunits used so far have been adamantyl, adamantyl triazolyl, dodecyl. [2] Herein, we are optimizing the synthesis of diamide derivatives of disubstituted ferrocenes with DMP and mannose subunit (Fig. 1a). The key structures in this syntheses will be disubstituted ferrocene ester amines with various alkyl chain lenghts (*n* = 0-4, Fig. 1b) which will be also prepared starting from ferrocenecarboxylic acid. Disubstituted precursors will be connected to *O*-benzyl protected mannose through glycol linker at the amine part and, after removal of methyl ester by saponification, to benzyl protected DMP. Commercially available Boc-L-Ala-D-isoGln-OBn will be used for this purpose and subsequently deprotected at the L-alanyl part in standard acidic conditions (TFA). The final step in the syntheses of these compounds will be the removal of all benzyl protecting groups by hydrogenolysis.

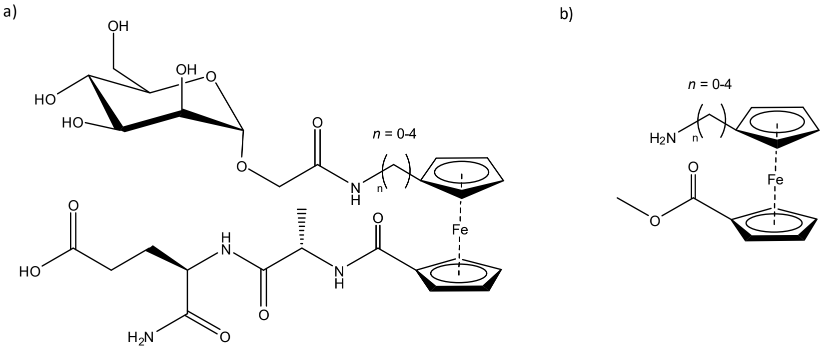

Fig. 1: a) Target mannosyl DMP analogues; b) key precursors in their synthesis.

Acknowledgement This work has been fully supported by the Croatian Science Foundation under the project IP-2020-02-9162.

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Synthesis and biological activity of novel benzazole acrylonitriles

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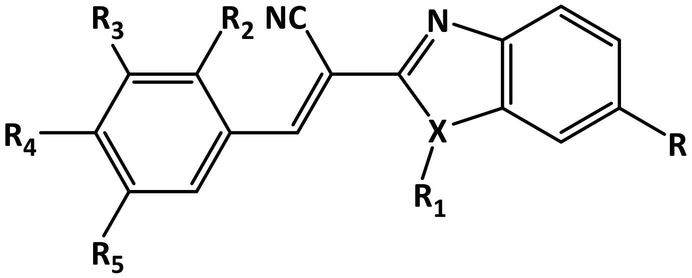
The most important benzazole representatives, benzimidazole and benzothiazole derivatives, have been well established as principal structural motifs in medicinal and pharmaceutical chemistry. Acrylonitriles bearing heteroaromatic or aromatic moieties have been recognized as promising biologically active compounds possessing a wide range of biological activities like anticancer, antituberculostatic, antibacterial or antioxidative effects. [1] In this paper, we report the synthesis of novel biologically active methoxy and hydroxy substituted benzimidazole and benzothiazole derivatives, related to 2,3-disubstituted acrylonitriles. Novel compounds were prepared by classical reactions of organic chemistry and by microwave assisted reactions. Acrylonitrile derivatives bearing benzimidazole nuclei were prepared by aldol condensation of *N*-substituted 2-cyanomethylbenzimidazoles with corresponding hydroxy substituted benzaldehydes in moderate to good yields. Acrylonitrile derivatives bearing benzothiazole nuclei were prepared by condensation of 2-benzothiazoleacetonitrile with corresponding methoxy and hydroxy substituted benzaldehydes. All newly prepared compounds will be screened for their antioxidant capacity using several spectroscopic methods as well as antiproliferative activity on several human cancer cells *in vitro*. [2-3]



X = N, S
R = H, CN
R_1 = H, CH_3, phenyl, isobutyl
R_2, R_3, R_4, R_5 = H, OCH_3, OH

Fig. 1: Structures of newly prepared acrylonitrile derivatives

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Synthesis of hydrazone derivatives of vitamin B6, pyridine-4-carbaldehyde and 2-quinolinecarbaldehyde

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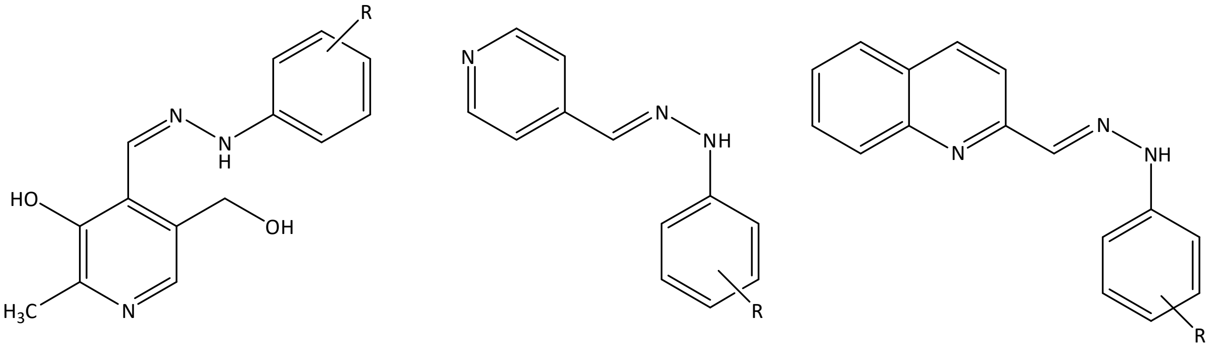
Hydrazone derivatives of vitamin B6, pyridine-4-carbaldehyde and 2-quinolinecarbaldehyde (**1**-**15**) were synthesized. Phenyl-hydrazine and substituted phenyl-hydrazines were used for the synthesis: 2,4-dinitrophenyl-hydrazine, 4-chlorophenyl-hydrazine, 4-fluorophenyl-hydrazine, 4-methylphenyl-hydrazine. The reactions were performed in two different solvents, acetone and ethanol, to examine the effect of solvent polarity and absorption power on the reaction yield. The structures of the synthesized compounds were confirmed by ^{1}H and ^{13}C NMR spectroscopy and mass spectrometry. The syntheses were carried out under the influence of microwave radiation, a more environmentally friendly method by which the desired product can be obtained in a much shorter time. The research investigates how microwave radiation, as one of the alternative synthesis methods, and the choice of solvent affect the chemical yields compared to conventional synthesis methods of hydrazone derivatives. The obtained results were compared with the research results of other authors who obtained similar or same hydrazones by classical organic synthesis. [1-3]



1-5 **6-10** **11-15**

R= -Ph, 2,4-diNO_2, -Cl, -F, -CH_3

Fig. 1: Structure of compounds (**1**-**15**).

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Chemical energy storage utilising catalysis: Hydrogen, ammonia, CCU and beyond

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The current climate, health and economic condition of our globe boundaries demands the use of renewable energy sources, harvesting, and the development of the abundant novel materials for an efficient generation, storage and transportation processes of this sustainable energy. Hydrogen has been recognised as one of the most prominent chemicals, carriers and a green energy source with a challenging pressurised storage, enabling de-carbonization. Electro- or photocatalytic H_2 (renewable green hydrogen) production processes are targeting the intensification of separated solar energy harvesting, storage and electrolysis stages, conventionally yielding O_2/H_2.

To address storage, the conventional large-scaled method for synthesizing ammonia is a power hungry process that requires a high operating temperature (400–500 °C) in addition to extremely elevated pressures (150–300 bar). Reaction is normally catalysed by magnetite-based material particles, is known for quite some time, and occurs between a single stoichiometric mole of nitrogen, three moles of hydrogen and energy to form two moles of ammonia. The original Haber–Bosch production process was discovered, developed and patented in 1916 by Fritz Haber and Carl Bosch, but is bound to be subjected to reengineering. The analogous apply with the power to gas or liquid, where high performance computing enables optimisation. There has been a growing persistent trend to couple the different temporal/spatial levels of modelling, such as going from the first principle calculations to meso- (*e.g.* kinetic Monte Carlo, KMC), and macro- (*e.g.* computational fluid dynamics, CFD) and planetary boundary scale. In current multi-scalar investigation, a CFD study of the CO_2 hydrogenation to methanol for the heterogeneous reacting flows in the reactors with complex shape geometries is put forward, coupled with first principle calculations (density functional theory, DFT).

Process intensification in the photocatalytic degradation of imidacloprid by permanent magnets

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The theoretical and experimental investigations carried out in this work relate to the application of chemical engineering and process intensification methodology in the development of advanced photocatalytic processes. The aim of this work is to investigate the possibility of intensification of photocatalytic processes by using a permanent magnet. Photocatalytic degradation of imidacloprid was carried out in a batch photoreactor with controlled and constant recirculation of the reaction mixture using a suspended photocatalyst. Imidacloprid was chosen as a model component because its intensive use poses a risk and hazard to the aquatic environment, including living organisms in contact with such contaminated water sources. Neodymium magnets (NdFeB) were used as the strongest permanent magnets to enable effective separation of charge carriers and improve the overall photodegradation efficiency. Magnets with different dimensions and magnetic flux densities on their surface were used (50×2.5 mm, 0.20 T; 50×10.0 mm, 0.34 T) (Fig. 1). The experimental design included three parameters: the presence of a permanent magnet (i.e. different values of magnetic flux on the surface of the magnet), the radiation intensity, and the mass of the photocatalyst. Commercially available powdered TiO_2 P25 (Degussa/Evonik) was used as the photocatalyst. Photoactivation was performed using the UVA part of the electromagnetic spectrum and UVA-LED lamps (30 W). The products were analysed by high performance liquid chromatography. The obtained results showed that the intensity of the radiation and the mass of the photocatalyst have the greatest influence on the efficiency of the photocatalytic degradation of imidacloprid. It was also found that imidacloprid conversion increased with increasing radiation intensity and photocatalyst mass.

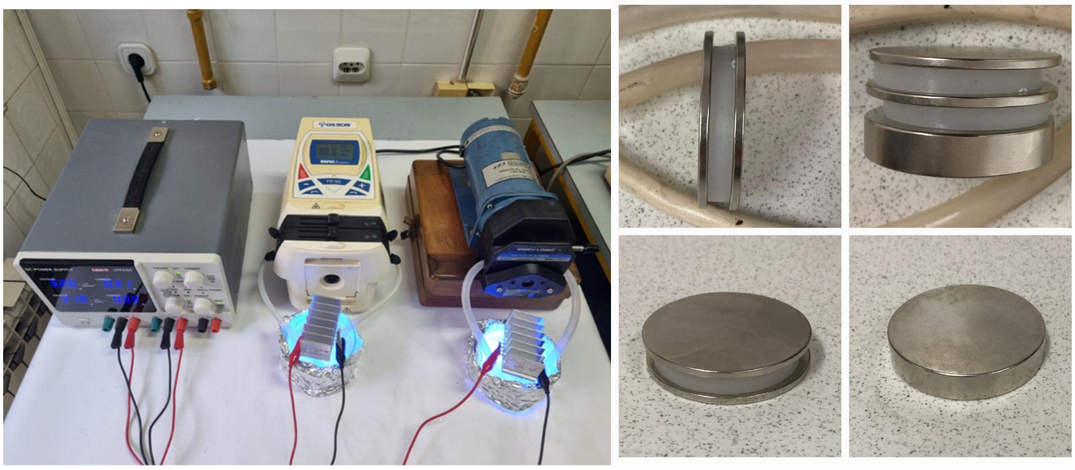

Fig. 1: Experimental setup and neodymium magnets used.

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Effect of static mixers on biodiesel synthesis in microreactors

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Biodiesel is used as an alternative to fossil diesel fuel. The latest EU regulations require diesel fuel to be sold at every service station as a blend with a larger proportion of fossil diesel and a smaller proportion of biodiesel (fatty acid methyl ester, FAME).

The objective of this research was to develop enhanced microreactor systems with static mixers for the synthesis of biodiesel. The production of microreactor systems with static mixers using stereolithography and the effects of different channel shapes and residence times on conversion were investigated.

Four microreactors were manufactured using 3D printing: a simple tubular reactor, a reactor with channels shaped like a basic Tesla structure, a reactor with channels shaped like a figure eight, and a reactor with channels shaped like a more intricate Tesla structure. Two piston pumps that ensured the flow of reactants were used to create biodiesel in microreactors. Using differential scanning calorimetry and Fourier transform infrared spectroscopy, the effectiveness of the reactions was determined.

The results show that the reactors are suitable for biodiesel synthesis. The reactor with channels in the shape of a figure eight and a reactor with channels in the shape of a simple Tesla structure both achieved the highest conversion, 52%, with a residence time of six minutes.

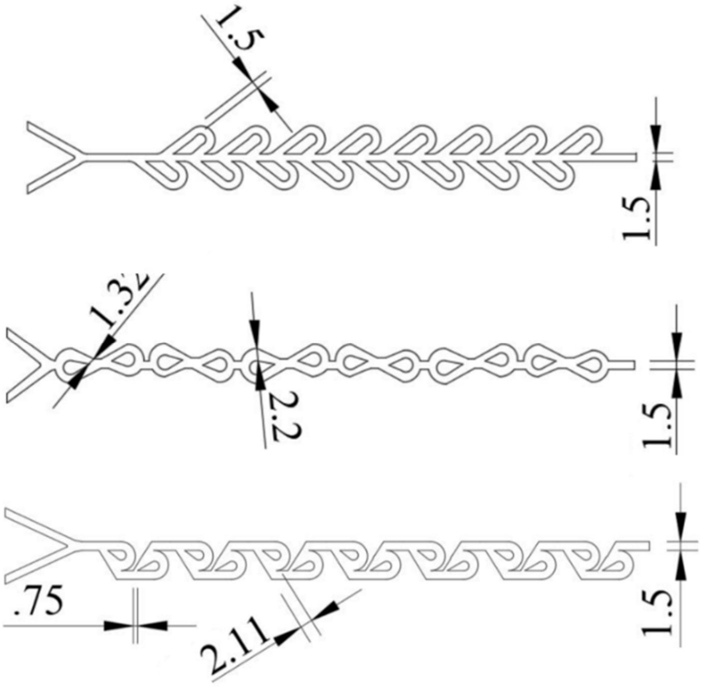

Fig. 1: Basic Tesla structure microreactor (top), figure eight structure microreactor (middle), intricate Tesla structure microreactor (bottom).

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Reducing energy demand and carbon footprint of distillation columns

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Global striving for energy saving as a direct means for necessary reduction of carbon dioxide emissions has led in chemicals processing industries worldwide to a strong push towards minimization of heat requirement of distillation operations, which are both of the immense industrial scale as well as importance for our present and future wellbeing. [1,2] Distillation is by far the most widely used and most energy and capital intensive among separation technologies. Indeed, distillation has many virtues, but only one decisive weakness, i.e. a low thermodynamic efficiency that becomes worse with decreasing relative volatility. It certainly cannot be replaced on industrial scale in the foreseeable future, and, therefore, it needs to be improved accordingly to allow process industries to achieve proclaimed energy saving and related carbon dioxide emissions reduction goals.

In present study we address an effective approach and related ways to maximize energy efficiency of multistage distillation columns which are by virtue of their nature often last columns in complex sequences that have demanding (close boiling mixtures) separation task to deliver polymer grade purity products. [3,4] Since high reflux ratios are involved and production scales are large, related energy demands are immense, *i.e.* usually, reboiler duties well above 10 MW are required.

Since long, a relief in this respect was expected from development and implementation of an internally heat integrated distillation column (HIDiC), which is essentially a heat pump assisted distillation combined with uniform distribution and transfer of heat (diabatic operation) along the integrated part of a hot rectification and a cold stripping section. [1,3,4] It is theoretically a proven, but regarding the hardware design and functioning, in many respects still an uncertain distillation energy conservation concept. This presentation addresses outcomes of large scale experimental efforts arranged in last decennia to deal adequately with related uncertainties, indicating techno-economic barriers that have discouraged practical implementation of concentric column approach for both packings and trays. Finally, it sheds light on prospects for a wide industrial acceptance of a scalable, industrially viable dual pressure single shell, discretely heat integrated column (an adiabatically operating HIDiC!), which has been recently commercialized in Japan. [5]

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Biocatalytic synthesis of enantiopure fluorinated building blocks: Discovering the bottlenecks by enzyme reaction engineering approach

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Optically pure fluorinated organic azides represent synthetically valuable building blocks in a range of industrial applications. Since the direct fluorination of molecules is challenging from both economic and environmental perspective, the development of novel methods for modifying existing fluorinated synthons is highly desirable. In this work, enantioselective azidolysis of fluorinated aromatic epoxides catalyzed by halohydrin dehalogenase (HHDH) was explored. A series of 11 fluorinated epoxides were evaluated as substrates from the viewpoint of hydrolytic stability and enzyme kinetics. Synthesis of enantiopure (*R*)-2-azido-1-[4-(trifluoromethyl)phenyl]ethanol with HheC-W249P variant was selected for detailed kinetic investigation. Reaction bottlenecks were identified. Epoxide hydrolysis, enzyme inhibitions and operational stability decay were found to undesirably affect the reaction outcome. Understanding the kinetic limitations and applying model-based process simulations enabled the selection of reactor type and initial conditions favoring biotransformation. By selecting a repetitive batch reactor setup, the reaction yield of 95% could be obtained, together with the increase in the reaction selectivity of 100% compared to the batch reactor.

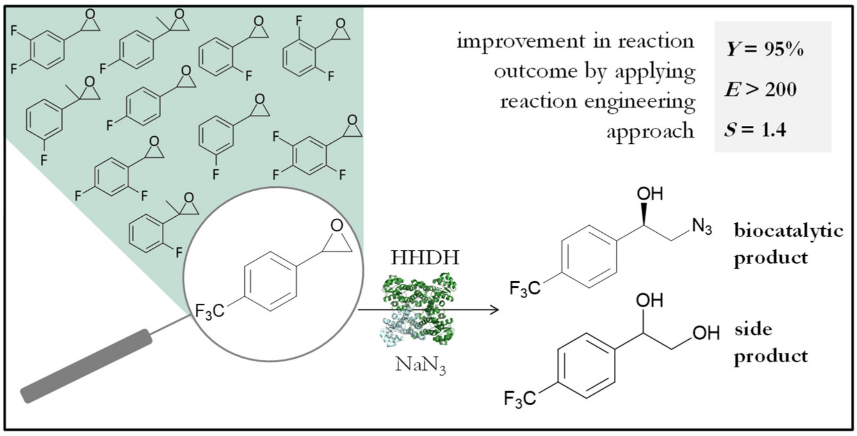

Fig. 1: Substrate screening and improvement in the HHDH-catalyzed biotransformation outcome by applying reaction engineering approach.

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Bioremediation modelling of highly polluted wastewater using microorganisms

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Environmentally friendly technologies based on the use of microorganisms have become an increasingly accepted method for the effective removal of pollutants from water systems. In recent years, there has been an increase in the number of research papers on the use of effective methods to clean and reduce pollution in water bodies. In this context, much attention has been paid to the use of bioremediation processes. [1] Bioremediation with microorganisms has a great potential for future development due to its ecological compatibility and possible cost-effectiveness. A variety of microorganisms plays a crucial role in the treatment and recovery of wastewater, making it less harmful to the environment. These microorganisms can be used as a promising green technology for wastewater treatment. [2] In return, the microorganisms receive the energy for their growth and reproduction. In this work, bioremediation of highly contaminated leachate from biowaste was carried out at ambient temperature under submerged conditions. By determining the substrate concentration, biomass and dissolved oxygen as well as pH in biowaste leachate, an insight into the process of biodegradation of the contaminants present is gained. A kinetic analysis was carried out and certain mathematical models were applied. During the experiment, a microbiological analysis of the indigenous cultures present, which are responsible for the biodegradation of the pollutants present, was carried out.

Fig. 1: Microbial mixed culture from biowaste leachate.

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Kinetic modelling of aldolase immobilized on magnetic nanoparticles

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Statins are a group of drugs used for lowering blood cholesterol levels. They all contain the same (3*R,* 5*R/S*)-dihydroxyhexanoate side-chain, which can be synthesized by both chemical and biocatalytic pathways. The biocatalytic route for synthesis of the statin side-chain precursor (Fig. 1), using 2-deoxyribose-5-phosphate aldolase (DERA, EC 4.1.2.4), offers many benefits over standard chemical synthesis, but its main problem is enzyme inactivation caused by the reaction substrates. [1]

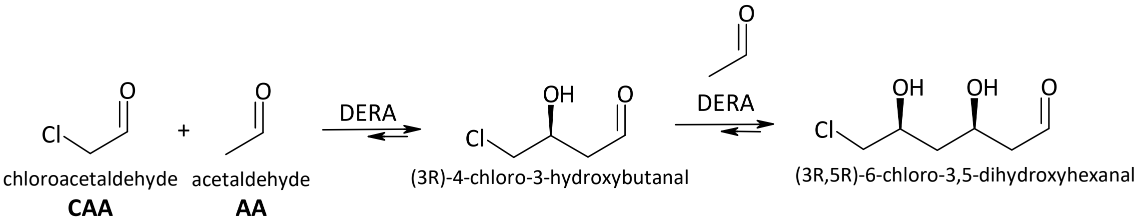

Fig. 1: Aldol addition reaction for synthesis of a statin side-chain precursor.

One way to address this problem is to immobilize enzymes on solid supports, which can lead to greater enzyme stability while retaining most of the enzyme activity. [2] To gain a detailed insight into the influence of each substrate on immobilized enzyme activity, kinetic measurements should be performed. The obtained kinetic model can be used together with the reactor model to develop mathematical models of the process. These models allow for significant cost and time savings in defining reactor setup, process design and scale-up. [3] The aim of this work was to perform kinetic measurements of covalently immobilized DERA enzyme in the aldol addition reaction. Magnetic nanoparticles (MNP) used as a carrier were synthesized by hydrothermal method and functionalized with 3-aminopropyltriethoxysilane (APTES). The MNPs were activated by 10% succinic anhydride. Kinetic measurements were performed for both the first and second steps of the reaction (Fig. 1). The kinetics was described using the Michaelis-Menten equation and the kinetic parameters were estimated using the nonlinear regression method of the MicroMath SCIENTIST software.

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Selection of the natural deep eutectic solvent for extraction of the *Aspergillus oryzae* lipase from liquid formulations

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The development of clean, sustainable, and effective extraction techniques has received much attention in recent years due to the growing interest in green extraction. For downstream processing (extraction) of biomolecules, natural deep eutectic solvents (NADES) are considered as efficient, adaptable, and significant new green solvents. Their advantages include low-cost constitutive elements such as choline chloride, which serves as a representative hydrogen bond acceptor (HBA), and naturally occurring hydrogen bond donors (HBDs), including different sugars, alcohols, and amides. Because of their stability, biodegradability, non-toxicity, and low volatility, NADES are of particular interest and are considered as "green solvents" within the context of green chemistry.

The aqueous two-phase system (ATPS) based on NADES was investigated as a possible extraction medium for the purification of *Aspergillus oryzae* lipase from raw liquid enzyme formulations. Choline-chloride was selected as the hydrogen bond acceptor while fructose, glucose, glycerol, malonic acid, urea, thiourea and ethylene glycole were considered as hydrogen bond donors. After the NADESs were prepared and characterized (pH, density, and viscosity) the σ-profile for each NADES was determined. The extraction process was carried out in a batch extractor and the extraction efficiency and enzyme activity in each NADES based aqueous two phase system (ATPS) were determined. Based on the experimental results and σ-profiles, a model for the prediction of enzyme activity and extraction efficiency in different ATPSs was developed using the COSMO-RS program. The obtained model was validated on a set of independent experiments performed with ATPS based on different NADES.

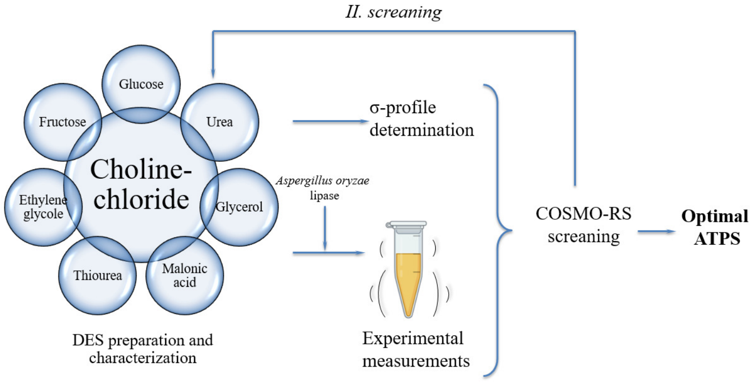

Fig. 1: Schematic diagram of selection of the natural deep eutectic solvent for extraction of the *Aspergillus oryzae* lipase.

Acknowledgement This work has been fully supported by PhosAgro/UNESCO/IUPAC Partnership in Green Chemistry for Life (Contract N° 4500461754).

Importance of the precursor layer for tuning the properties of chitosan/carboxymethyl cellulose polyelectrolyte multilayers

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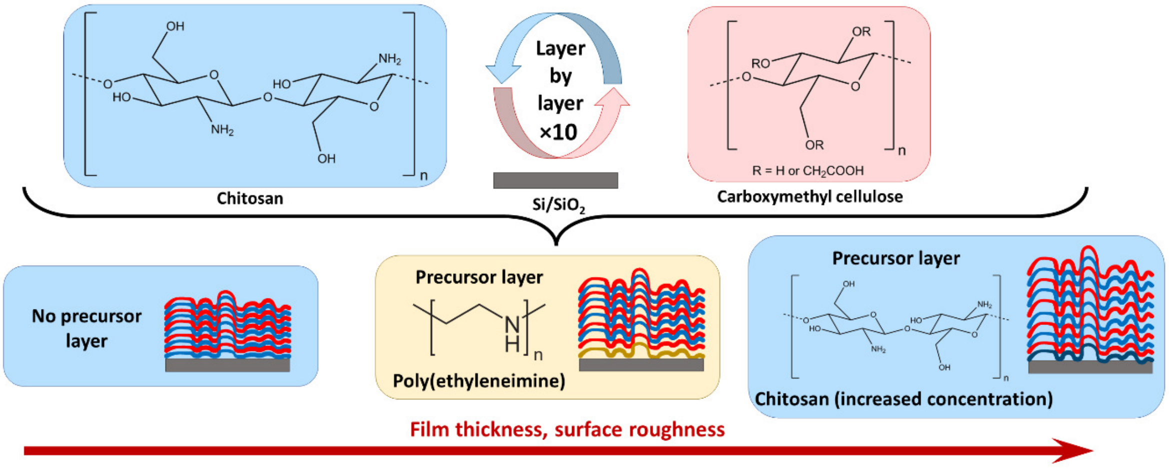
Polyelectrolyte multilayers (PEMs) composed of chitosan (CS) and carboxymethyl cellulose (CMC), two natural polyelectrolytes, have been recently getting attention as environmentally safe and non-toxic food coatings. [1,2] Traditionally, these materials are prepared using layer-by-layer (LbL) deposition method. As CS and CMC have low initial adsorption to a targeted surface during LbL build-up, the addition of another polyelectrolyte as the first layer, a precursor, plays an important role. Usually, poly(ethyleneimine) (PEI) is used as such layer but its toxicity to both bacterial and, especially, human cells is concerning for the application of these films. [3]

The aim of this study was to provide an alternative, biocompatible and environmentally safe precursor layer to replace PEI. Moreover, we studied the effect of addition of NaCl to the polyelectrolyte build-up solutions on the surface properties of all examined nanofilms. The main methods used in this study were ellipsometry, for monitoring the film thickness and growth during the build-up process, and atomic force microscopy (AFM), which was used to determine surface morphology, film thickness and roughness of the prepared nanofilm.

Our results confirmed that using concentrated solution of chitosan as a precursor layer is a viable alternative to PEI. This method produces nanofilms which have double the thickness of films prepared with PEI, but this is also followed by an increase in surface roughness. Finally, the addition of NaCl strongly influences the properties of the films depending on its concentration in polyelectrolyte solutions used during the build-up process.



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Influence of methacrylic polymer additives with different composition and molecular weight on the low-temperature behaviour of diesel fuel

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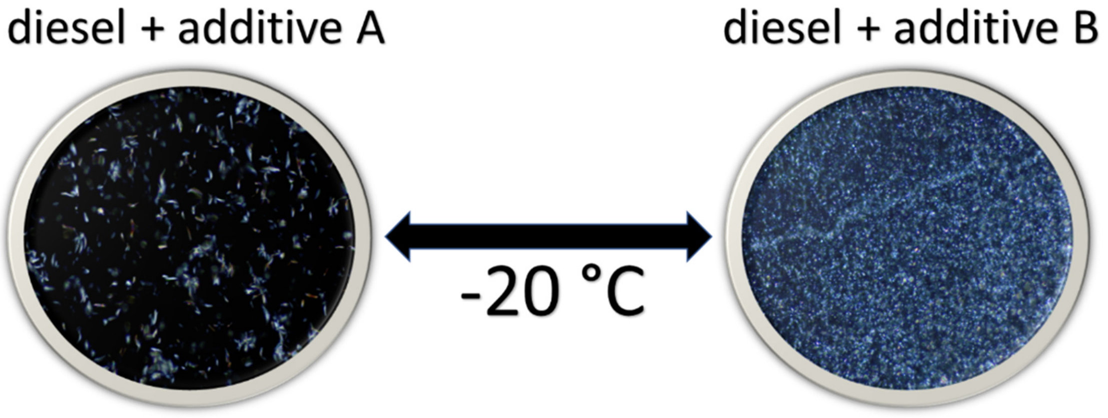
The challenge in improving the flow behavior of diesel fuel at low temperatures is mainly due to the crystallization of paraffins present in the diesel fuel. At lower temperatures, paraffins crystallize into needle-like crystals that separate from the diesel and combine to form a 3D network that clogs the pores of the fuel filter. This leads to a deterioration of the low-temperature properties and reduces the temperature range in which the fuel can be used. [1] This problem is currently being addressed in several ways. Blending distillates with a higher *n*-paraffin content with other components with a lower *n*-paraffin content can lower the concentration of *n*-paraffin in the fuel and improve low-temperature properties. However, the process is not economical because the proportion of the higher-quality lighter derivative increases compared to the lower-quality derivative with a higher *n*-paraffin content. The improvement can also be achieved by a catalytic dewaxing process or a crystallization dewaxing process [2,3] but from an economic point of view, the addition of additives is the most profitable method to improve the properties at low temperatures. In our research, we synthesized methacrylate additives with different compositions and varied the molecular weight of the additives with a chain transfer agent. The influence of these two parameters on the low-temperature properties and crystallization of diesel fuel was studied. Depending on the proportion of short-chain and long-chain comonomers in the polymer additive, a different influence on the low-temperature properties of the fuel was observed. The synthesized additives had a positive effect on the pour point (PP) of diesel fuel, by lowering it by more than 30 °C, and influenced the crystal morphology of diesel fuel observed by optical microscope with polarization by changing the size, number, and morphology of crystals in diesel fuel.



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Influence of Pt/SnO_2 synthesis procedures on the catalytic reduction of 4-nitrophenol to 4-aminophenol

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In this work, we performed a one-step microwave-assisted hydrothermal synthesis to disperse platinum (Pt) on a reducible SnO_2 support. Tin tetrachloride and hexachloroplatinic acid dissolved in water were used as starting chemicals. The syntheses were carried out with and without the addition of ammonia. The molar ratios of tin and platinum [$Pt^{IV}/(Sn^{IV} + Pt^{IV})$] were varied between 0 and 0.15. The XRD results of the Pt/SnO_2 sample synthesized in the presence of ammonia and 5 mol% Pt showed five crystalline phases: cassiterite (SnO_2), NH_4Cl, $(NH_4)_2PtCl_4$, $(NH_4)_2PtCl_6$ and $(NH_4)_2SnCl_6$. SEM images and EDS analyses showed the presence of different particles in terms of morphology and chemical composition. The STEM image (Fig. 1) shows that the small platinum nanoparticles are well dispersed on the SnO_2 support. The synthesized samples were used for the catalytic reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP) in the presence of excess $NaBH_4$. The catalytic activity of the Pt/SnO_2 samples for the reduction of 4-NP to 4-AP was optimized by varying the synthesis parameters and Pt loading. Fig. 2 shows the catalytic reduction of 4-NP to 4-AP in the presence of excess $NaBH_4$ as a function of time using Pt/SnO_2 samples containing 5 mol% Pt synthesized in the presence of ammonia.

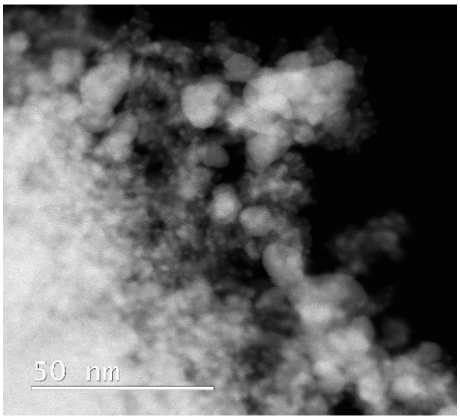

Fig. 1: STEM micrograph of Pt/SnO_2 samples with 15 mol% Pt.

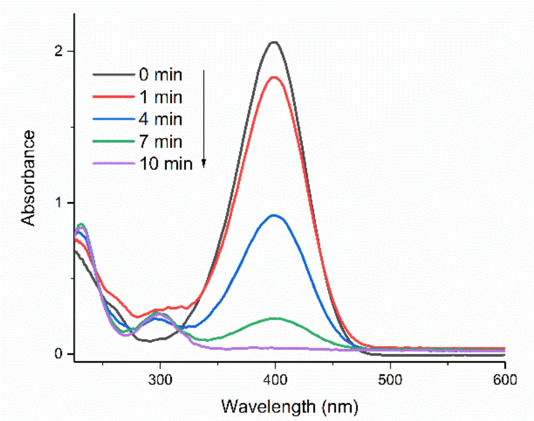

Fig. 2: The catalytic reduction of 4-NP to 4-AP as a function of time using Pt/SnO_2 sample with 5 mol% Pt and synthesized in the presence of ammonia.

Acknowledgement This work was financially supported by the Croatian Science Foundation under the project IP-2019-04-1195 *Platinum decorated iron tin oxide solid solutions for hydrogen gas sensing* (HydGasSens) and by the Croatian Government and the European Union through the European Regional Development Fund – the Competitiveness and Cohesion Operational Programme (KK.01.1.1.01.0001).

Radiation crosslinking of self-assembled monolayers for corrosion protection of metals

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Self-assembled monolayers (SAMs) are ordered molecular assemblies of organic molecules that form spontaneously on the substrate surface by exposing the substrate to a solution or gas containing molecules with self-assembling properties. Their application can change the surface properties of an object by forming a barrier between the substrate material and its environment. Therefore, their application has been extensively studied, including the protection of metals. Among their many advantages, studies have shown that while SAMs of many molecules exhibit good short-term protective properties, they are easily removed from the surface when exposed to corrosive media. Accordingly, many studies have focused on improving the long-term protective properties of SAMs. Crosslinking the already well-ordered molecular layer on the surface of a metal would make the film more resistant and significantly extend its lifetime by reducing the penetration of external molecules into the coatings. Radiation crosslinking is the process of using high-energy gamma rays or electron beams to initiate rapid chemical reactions between monomers and/or polymers that follow the free radical mechanism. The radiation-induced crosslinking is homogeneous, fast and can be carried out at room temperature without the use of solvents, initiators and/or catalysts.

In this work, SAMs of different fatty acids were crosslinked on copper using gamma radiation. The protective properties of the crosslinked coatings were investigated by electrochemical measurements under simulated atmospheric conditions, while the surface properties of the coated metals were studied by contact angle measurements, Fourier transform infrared spectroscopy, and atomic force microscopy. The results have shown that crosslinking of the coatings significantly improves the long-term properties.

Acknowledgement We thank the Croatian Science Foundation (HRZZ IP-2020-02-4344) for supporting this research.

Potentiometric determination of QAC based biocides and PHMB in multi-component mixtures using highly sensitive homemade ionic surfactant sensors

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It is well known that multicomponent mixtures of cationic surfactants used as biocides and/or disinfectants can act significantly more effectively against a broad spectrum of microbial organisms such as bacteria, fungi, viruses, and algae, than any of them individually. For example, Bardac™ 205M and Bardac™ 208M, both by Lonza, are made of four QAC in formulations optimized for effective action against a broad spectrum of microbial organisms in products such as hard surface disinfectants, sanitizers and/or certain types of water treatment formulations. [1] In the investigations presented here we analysed model multicomponent mixtures using highly sensitive home-made PVC based liquid membrane surfactant selective potentiometric sensors. [2,3] Model solutions (Fig. 1) were made of quaternary ammonium compounds (QACs) used as disinfectants with a wide spectrum of action: didecyldimethylammonium chloride, dioctyldimethylammonium chloride, and polycation polyhexamethylene biguanid. All of them have confirmed disinfection and biocidal activity against SARS-CoV-2. [4,5]

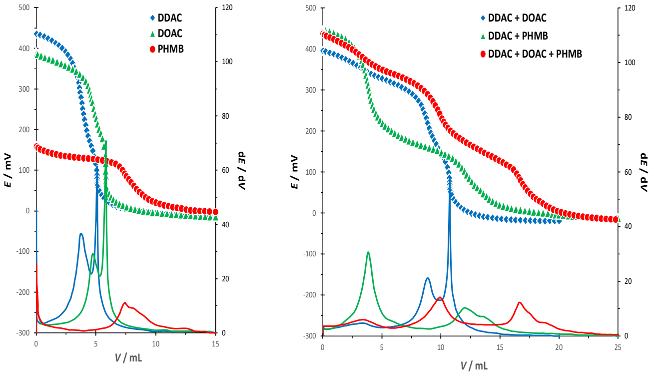

Fig. 1: Potentiometric titrations of didecyldimethylammonium chloride (DDAC; Bardac 22), dioctyldimethylammonium chloride (DOAC; Bardac LF) and polycation polyhexamethylene biguanid (PHMB; Lonzabac BG), all by Lonza, and their model solutions, with highly sensitive HTA-TPB sensors [1] for ionic surfactants as an indicator, and sodium tetraphenylborate as a titrant (c = 4 mmol/L).

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Synthesis and characterisation of polymer nanoparticles and their behaviour in aquatic environments

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Plastics in the environment has become a global problem, not only due to their presence as macro-scale marine litter, but also as small particles arising from the degradation of larger plastics under UV light and the mechanical action of waves. As the smallest fraction, nanoparticles of plastic, typically characterised by dimensions less than 100 nm, may be extremely widespread and available to biota, potentially leading to bioaccumulation and biomagnification within food chains that may ultimately impact upon human health. Moreover, as nanoplastics have significant ability to sorb secondary pollutants, understanding their behaviour and fate in marine waters is of great importance, particularly in terms of their toxicity potential towards biota.

In this direction, we report on the synthesis, characterisation and behaviour of polymer nanoparticles in aquatic matrices. Polystyrene (PS) and polymethyl methacrylate (PMMA) nanoparticles were synthesised by mini-emulsion polymerisation with sizes in range 25-430 nm. Narrow particle size distributions by volume were demonstrated by dynamic light scattering (DLS), and their morphology was confirmed by transmission electron microscopy (TEM) and atomic force microscopy (AFM).

The concurrent influence of abiotic parameters and natural organic matter (NOM) on nanoplastic stability was determined in aqueous matrices with varying electrolyte concentrations as proxies for freshwater, brackish water and seawater. Bovine serum albumin (BSA) was selected as a model for proteinaceous matter in wastewater, while humic acid (HA) and alginate (Alg) were selected as representatives of NOM in fresh and marine waters, respectively. The influence of salinity, ranging between S 0-38, pH values from 6.8 to 7.8 and NOM at concentrations in range 0-100 mg L^{-1} was determined. Additionally, the impact of oxygen saturation (50% and 90%) on nanoplastic behaviour was defined.

PMMA nanoparticles showed strong colloidal stability in all cases, in contrast to PS nanoparticles, and despite of the widely varying parameters did not show any indication of agglomeration/aggregation. This indicates that of the tested nanoplastics, PMMA may remain longer in the water column and be more available for sequestration by biota living in those environmental compartments. Ultimately, this work is a step in the direction of creating tailored polymer nanoparticles to enable greater understanding of their pathways through the environment and modes of toxicity in marine biota.

The preparation and optimization of poly(vinyl butyral) based membranes for *in-situ* formation of solid-state Ag/AgCl reference electrode

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Advanced insights into electroanalytical systems enabled developing sensors for health-care, environment and industrial processes monitoring. Manufacturing miniaturized devices has become a peculiar research topic aimed toward lower cost and easy-to-use analytical solutions. In scope of this, inkjet printing (IJP) has emerged as a powerful production technology; it is digitally controlled, mask-less and non-contact, fast, low-cost, environmentally viable, and suitable for upscaling. A previously published concept of a reference membrane based on the photoreduction of AgCl in a poly(vinyl butyral) (PVB) methanol solution [1] could be further developed towards manufacturing solid-state reference electrodes (SSRE) by means of IJP. [2] We have developed and optimized two PVB-based reference membrane solutions for *in situ* production of Ag/AgCl-based SSRE by means of IJP. The two membranes were prepared using tertiary solutions of $AgNO_3$ and $CaCl_2$ in methanol, ethylene glycol and butanol, with the aid of commercially available surfactant Triton X-100. The solutions were sequentially added on top of inkjet printed planar silver and carbon electrodes. Upon mixing the solutions AgCl is formed, which is then partially reduced by intense pulsed light (IPL). We have optimized the weight percentage of PVB, the degree of photoreduction and the conditioning procedure to obtain a stable reference electrode potential. The response to chloride and other ions was evaluated via potentiometry and electrochemical impedance spectroscopy, along with the influence of pH and light. Approaches like this could enable large scale manufacturing of low-cost miniaturized solid state reference electrodes to find use in emerging chemical sensing scenarios.

Acknowledgement This work was funded by the Croatian Science Foundation under grants UIP-2020-02-9139 and DOK-2021-02-2362.

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2-formylpyridine blue out of the blue

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For its continuous progress, science requires not only systematic work on the known systems or phenomena, but also a regular inflow of unexpected, *i.e*. serendipitous observations. Such discoveries cannot be anticipated and cannot even be planned; hence they are disruptive [1] by nature, both by their effect upon the current scientific knowledge and the industry, and upon their discoverers, who, having noticed something extraordinary, must either use their spare time for the exploration, or fall behind the schedule with their more ordinary work.

In this report an unexpected behaviour is described of what was originally supposed to be a stock solution for experiments in dynamic combinatorial chemistry [2] and the chemistry of photoswitches. Solutions of 2-formylpyridine in acidic ammonium acetate buffer turn blue over the period of several days and, after a few weeks, they start depositing fibrilar aggregates (Fig. 1). With multiple possible formation mechanisms, likely with at least two fundamental steps (addition and oxidation), as well as the high possibility of the reaction mixture being dynamic in nature, this system proves to be challenging to study. However, a possible new synthetic route towards polyconjugated polymers, as well as to new dynamers, [3] that this system offers, make it very attractive for further exploration.

Fig. 1: Fibrilar aggregates formed by condensation of 2-formylpyridine.

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Synthesis and characterization of porous organic polymers with different organic building units bridged by azo bonds

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Porous organic polymers (POPs) are a class of crystalline or amorphous porous solid materials that can be constructed by linking different organic molecular building units with strong covalent bonds. A variety of building units and synthetic routes can be used for the synthesis of POPs, enabling the design of materials with precisely defined properties. The characteristics of POPs, such as high thermal and chemical stability, low density, large surface area, adjustable pore size and structure, make them suitable for a range of applications. One of the most important potential application of POPs is gas storage and separation, especially the capture and separation of CO_2, the primary greenhouse gas. [1] Recent studies have revealed that various synthetic approaches and careful selection of building units for the synthesis of POPs can improve interactions between POPs and CO_2 molecules and increase the CO_2/N_2 selectivity. [2] Here, we synthesized a series of new azo-bridged polymers based on benzene, pyridine and triazine central units. Different synthetic methods were used for the preparation of azo-bridged polymers including reductive homocoupling of aromatic nitro monomers, oxidative homocoupling of aromatic amino monomers and heterocoupling of aromatic nitro monomers and various aromatic diamines differing in length and rigidity. The influence of different building units and synthetic approaches on the structural, thermal and porosity properties of resulting materials was investigated by IR spectroscopy, ^{13}C CP/MAS NMR spectroscopy, powder X-ray diffraction, elemental analysis, thermogravimetric analysis, N_2 adsorption–desorption experiments and computational methods. The prepared polymers were characterized as amorphous solids of good thermal stability, displaying various Brunauer–Emmett–Teller (BET) surface areas. The obtained results indicated that the building units and synthetic methods have a significant effect on the porosity of the final materials. [3] The highest BET surface areas of 606 and 351 $m^2\ g^{-1}$ were observed for the azo-bridged polymers with pyridine and triazine central units, prepared by copper(I)-catalyzed oxidative homocoupling of amino monomer and $NaBH_4$-mediated reductive homocoupling of nitro monomer, respectively. Introduction of linear linkers by using heterocoupling reactions of aromatic nitro monomers and aromatic diamines produced azo-bridged polymers exhibiting very low surface areas. Periodic DFT calculations and grand-canonical Monte Carlo (GCMC) simulations suggested that the introduction of linear linkers does not have a notable effect on CO_2 adsorption properties of model azo-bridged polymers.

Acknowledgement
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Variable-temperature crystallography and X-ray charge density study of π-stacking in single crystals of organic salts

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Crystals of planar organic radicals are a great playground for studying π-interactions and π-stacking. [1] Organic radicals usually form strong stacking interactions with energy as high as -20 kcal mol^{-1}. As such, these interactions can have non-negligible covalent character (two-electron multicentric bonding – *pancake bonding*). [2] Pronounced π-stacking motifs contribute to properties of the material, like electric conductivity and magnetism. [3] Today we use different X-ray crystallographic methods to study this phenomenon in detail.

Here we present a study on strong π-interaction, *pancake bonding*, in three different salts: 7,7,8,8-tetracyanoquinodimethane (TCNQ) salts with 1,4-dimethyl-DABCO (**1**) and *N,N*-dipyridylmethanium (**2**) and *N*,*N*,*N*′,*N*′-tetramethyl-*p*-phenylenediamine (TMPD) chloride salt cocrystal with 2,5-dichlorohydroquinone (**3**). In crystal structures of studied compounds, we observed two different types of stacks: dimers and trimers of TCNQ anions and dimers of TMPD cations.

Stacking interactions in crystals were studied by a combination of variable-temperature crystallography (80-400 K) and X-ray charge density. [4] These methods tested the stability of prepared compounds and revealed fine details of electron density between the stacked molecules. In all three structures the expected temperature dependent changes were noticed; distances between ring planes increased with increasing the temperature. Crystals **1** and **2** were stable from 80-400 K while crystal **3** was stable up to around 340 K. Within this work the *pancake-bonding* between radical cations was studied for the first time by X-ray charge density.

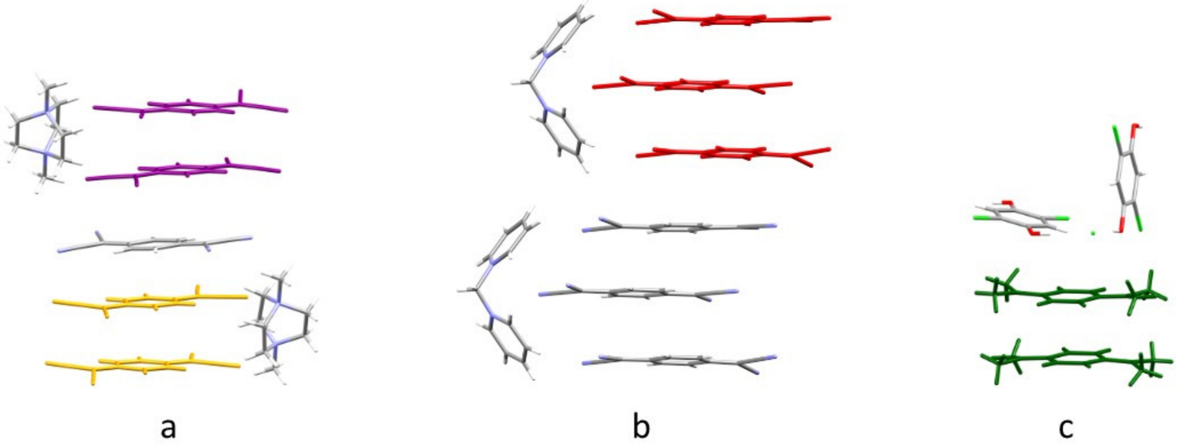

Fig. 1 : π-stacking motifs present in studied crystal structures : a) **1**, b) **2** and c) **3**.

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Impact of the histidine-triazole and tryptophan-pyrene exchange in the WHW peptide: Cu(II) binding, DNA/RNA interactions and bioactivity

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Small peptides like tryptophan–histidine–tryptophan (WHW) can form complexes with transition metals, for instance copper, and those complexes are related to many biological processes. Intriguingly, Cu^{2+} can cleave DNA or RNA backbone under certain conditions and some peptides with tryptophan bind non-covalently to ds-DNA/RNA. That inspired us to synthesize three new peptidoids, whereby central histidine in WHW was replaced by Ala-(triazole), and two derivatives also had one tryptophan replaced with pyrene-alkyls of different lengths and flexibility. Pyrene analogues show strong fluorescence at 480-500 nm, attributed to intramolecular exciplex formation between pyrene and tryptophan. All three peptidoids bind Cu^{2+} in water with strong affinity, with Trp-Ala-(triazole)-Trp binding affinity comparable to the parent WHW, and the pyrene analogues even stronger. The studied peptidoids strongly bind to ds-DNA and ds-RNA, whereby their complexes with Cu^{2+} exhibit distinctively different interactions in comparison to metal-free analogues, particularly in stabilization of ds-DNA against thermal denaturation. The pyrene peptidoids efficiently enter living cells with no apparent cytotoxic effect, whereby their red-shifted emission compared to the parent pyrene allows intracellular confocal microscopy imaging, showing accumulation in cytoplasmic organelles. Irradiation with 350 nm light resulted in antiproliferative effect on cells treated with micromolar concentrations of the pyrene analogues, attributed to the pyrene-induced production of singlet oxygen and consecutive cellular damage.

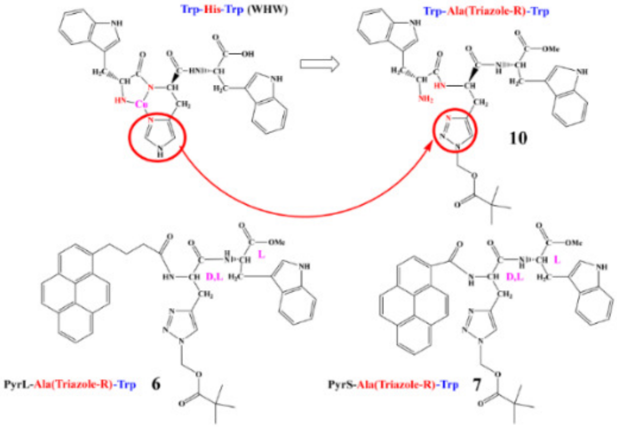

Fig. 1: Comparison of the WHW peptide with the here-designed and prepared W-A(triazole)-W analogue **10**, its close pyrene analogue **6** (pyrene linker length analogous to the linker in **10** for Trp) and the short and rigid pyrene analogue **7**.

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Synthesis and neutralization of sodalites with different anion content

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Red mud, a by-product of the alumina industry, is produced in large quantities (150 million tons annually) and causes a global problem due to its high alkalinity (pH = 10−13). [1] A solution to this major environmental issue could be the neutralization of red mud with mineral acid and the utilization of the thus formed product as secondary raw material. To understand the procedure of large-scale neutralization, the underlying reactions and governing mechanisms for red mud´s reactive components must be understood. To this end, we study sodalite, a type of aluminosilicate, which is one of the main components of red mud.

Sodalites ($Na_6[Al_6Si_6O_{24}]\times 2NaX$, where X can be OH^-, Cl^-, NO_3^-, $\frac{1}{2}CO_3^{2-}$, or $\frac{1}{2}SO_4^{2-}$) can contain many different anions (depending on the medium) [2] which can have a great effect on the neutralization behavior of the solids. In this work, sodalites with different anion content were synthesized from kaolinites mimicking industrial conditions. [3] The synthesized solids were characterized by X-ray diffractometry, infrared spectroscopy, thermogravimetry, total organic carbon (TOC) analysis, and scanning electron microscopy.

The dissolution and the neutralization of the sodalites was studied via titrating suspensions of SOD with hydrochloric acid. Then, the obtained products were also characterized by the above techniques.

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QSAR bioactivity prediction in clinical metabolomics

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Maternal pregnancy dietary intake, nutrition, and environmental exposure in the early postnatal period of a newborn child are of importance for its health. [1] To understand such relationships, we investigated the metabolomics in a mother-child cohort of n=602 mother child dyads. Amongst the metabolites, there were 79 quantified and annotated xenobiotics. Toxicological risk of the metabolites was evaluated by means of quantitative-structure activity relationships (QSARs). The QSARs were trained using Random forests tuned with Bayesian optimization on 203 molecular descriptors and 4096 Morgan fingerprints as features. [2] The underlying training data were the Tox21 [3] sets which consists of 12 bioactivity endpoints based on stress response and nuclear receptors from a total of n=8174 molecules. Metabolite structures were extracted using an automated pipeline for PubChem written in Python. The validated models were then applied to the metabolite data, which gave insight to which metabolites have a bioactive potential towards the selected endpoints. Results show an overlap in chemical spaces between the metabolites and the Tox21 data. Furthermore, there are many metabolites marked as bioactive, indicating their potential health risks if dysregulated in the body.

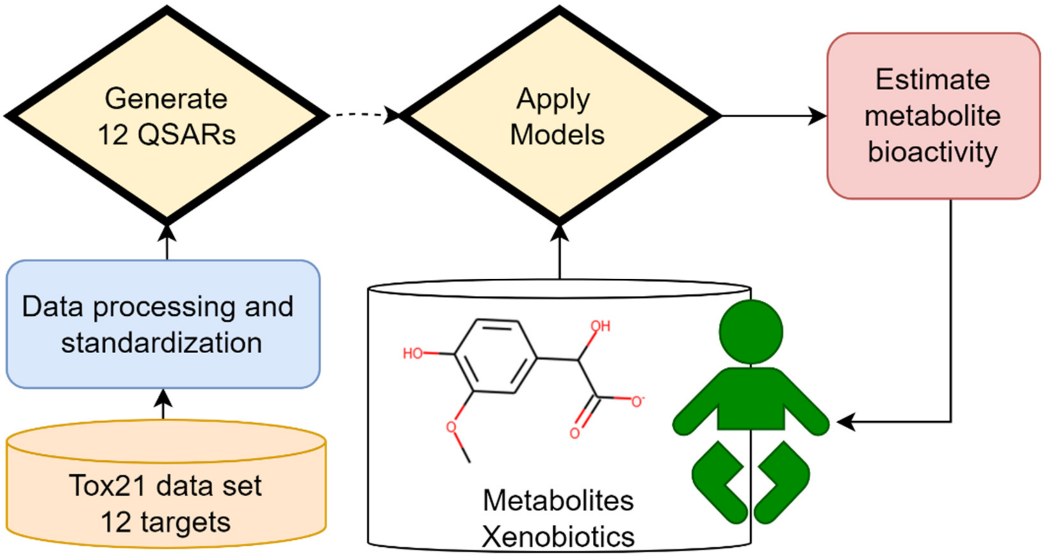

Fig. 1: A scheme of bioactivity model training and application on metabolites

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Synthesis and biological activity of novel 1,2,3-triazole derivatives of benzoxazole

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Cancer is a complex, prevalent and fatal disease that notably affects almost every tissue in the human body, and many anticancer drugs are currently being used clinically for the treatment of several malignancies. [1] However, solid tumors such as breast cancer, resist most of the clinically-available anticancer agents probably due to gene mutations or epigenetic modifications during the course of therapy that affect the uptake, metabolism of efflux of drugs from cancer cells. Benzoxazoles derivatives show significant pharmacophoric behavior with diverse range of biological activities including antitumor activity. [2,3] In this paper, we present the synthesis of novel 1,2,3-triazolyl benzoxazole derivatives by using click reaction in deep eutectic solvents (DES). The key precursors of Schiff bases were synthesized by ultrasound irradiation, and subsequent cyclization reaction with NaCN gave the corresponding 2-arlybenzoxazoles which are furthermore converted to *O*-propargylated benzoxazole derivatives by microwave assisted alkylation reactions. 1,2,3-triazolyl benzoxazole derivatives were prepared by click-reaction of *O*-propargylated benzoxazole derivatives with corresponding azides in DES (ChCl/glycerol). All synthesized compounds were evaluated against Gram-positive and Gram-negative bacterial strains as well as malignant tumor cell lines. 2-(4-(2-morpholinoethoxy)phenyl)benzoxazole showed the most pronounced activity against non-small-cell lung cancer cell lines (NCI-H460, IC_{50}=0.4 µM).

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Determination of significant parameters of the UV-C/$S_2O_8^{2-}$ process for the degradation of LDPE and PP microplastics

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Microplastics (MP) are plastic particles ranging in size from 1 µm to 5 mm. MPs can be found in all components of the environment. Low-density polyethylene (LDPE) and polypropylene (PP) are one of the most commonly found types of MP in the environment. [1] In order to find a suitable solution for the removal of MP from the environment, UV-C/$S_2O_8^{2-}$ process was examined for the degradation of LDPE and PP MPs. UV/$S_2O_8^{2-}$ process belongs to the advanced oxidation processes (AOPs) that are increasingly tested in the purification of various pollutants due to their ecological advantages compared to classical processes. [2] During processes, the influence of $Na_2S_2O_8$ oxidant concentration, mass of MP, pH value and length of exposure to UV-C light on the degradation of the mentioned plastic was examined. Degradation was monitored by FTIR spectroscopy before and after each process. After processing, the results showed that all tested parameters affect the process. Maximum degradation was achieved at the maximum time of exposure to radiation (90 min) with the minimum concentration of the oxidant (1 mM) and at the minimum exposure time (30 min) and the maximum concentration (20 mM). With higher concentrations of oxidants, their recombination occurs over time, so the degradation is most successful when the reaction is carried out for a shorter time. This phenomenon is known as the Scavenger effect. [3]

Acknowledgement The authors would like to acknowledge the financial support of the Croatian Science Foundation through project *Advanced water treatment technologies for microplastics removal* (AdWaTMiR, IP-2019-04-9661).

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Environmental risk assessment of volatile organic contaminants in the Sava river aquifer, Belgrade, Serbia

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The aim of this study was to investigate the environmental risk from the gasoline range volatile organic contaminants in the Sava river aquifer. The investigated area is located in New Belgrade, in the vicinity of the largest heating plant in Belgrade, the capital of Serbia. Our previous research on the oil pollutants in the groundwater at this locality was focused on the origin and spatial distribution of these contaminants, and estimation of potential human health risks from exposure to these compounds. [1] The purpose of our present study is a Tier I Environmental risk assessment in this part of the aquifer.

Groundwater samples were collected from 28 hydrogeological boreholes. Preliminary analyses of the organic compounds extracted from the groundwater samples were conducted by gas chromatography with flame ionization detection (GC-FID), and by gas chromatography – mass spectrometry (GC-MS). Volatile organic compounds (VOCs) were analyzed and identified by headspace gas chromatography – mass spectrometry. Chemicals of concern were quantified by headspace gas chromatography with flame ionization detection (HS-GC-FID).

In the groundwater samples analyzed, the most frequently detected VOCs were from the group of the gasoline range organics. Concentrations of the individual VOCs ranged from below detection limits to 5.2 mg/L. For each of the compounds quantified, the Risk Quotient (RQ) was calculated as the ratio of the measured concentration of that compound in the groundwater sample and the lowest Predicted Non-Effect Concentration for freshwater aquatic organisms (PNEC). The PNEC values were adopted from the European chemicals agency's (ECHA) Registration Dossier database. [2] At some of the sampling points, the detected concentrations of VOCs were higher than that of the PNEC values with resulting RQ > 1. Considering the fact that the VOC compounds analyzed were present as mixtures, the mixture RQ was calculated (as a sum of the individual RQs) for each sampling point. Out of 28 sampling points, at 7 of them the mixture RQs were higher than 1 which indicates a potentially medium to high ecological risk from these compounds in this part of the aquifer.

In addition to the conclusion from our previous study on the human risk assessment from exposure to the volatile organic compounds in the groundwater at this location, [1] this research emphasizes a necessity for a continuous monitoring of the water quality in the investigated area.

Acknowledgement
Project of the Serbian Ministry of Science and Technological Development, Grant no. 451-03-68/2022-14/200026 and 451-03-68/2022-14/200169.

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Organic compounds in particulate matter collected at Plitvice Lakes

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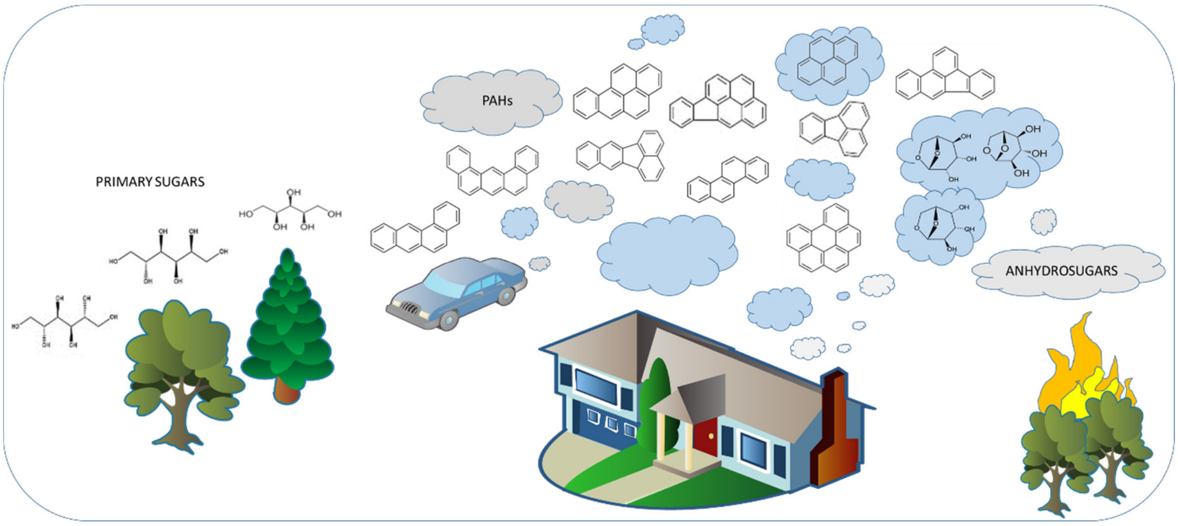
The origin of organic compounds in the air can be various and therefore an experimental and statistical analysis of particulate matter is crucial for their identification. This work focuses on organic compounds such as carbohydrates and polycyclic aromatic hydrocarbons (PAH). The sources of carbohydrates can be related to anthropogenic activities, essentially biomass burning, wood combustion, forest fires, and agricultural waste burning, but they are also released during primary biological activities of fungal spores, microorganisms, bacteria, and pollen. Along with pyrogenic sources, a large contributor to PAH emissions is the widespread petrogenic sources from households and traffic due to incomplete petroleum combustion. To distinguish between different sources of PAHs and carbohydrates in particulate matter, it is important to monitor their levels during a wider period when natural and anthropogenic activity trends are different. In this study, PM_{10} particulate matter samples (particulate matter with a diameter smaller than 10 µm) were collected seasonally at a background measuring station located at Plitvice Lakes. Samples were analyzed by two chromatographic techniques; high-performance anion-exchange chromatography with pulsed amperometric detection and high-performance liquid chromatography with a fluorescence detector. The results were statistically compared using Spearman correlation, factor analysis, and principal component analysis. Significant seasonal variations of organic compound levels and particulate matter levels were observed. Generally, the most pronounced carbohydrates in the particulate matter were levoglucosan, arabitol, mannitol, and glucose. The concentrations of PAHs were two orders of magnitude smaller compared to carbohydrates values but were present in all the samples. The maximum concentrations were detected in the winter season for levoglucosan and benzo(*b*)fluoranthene. The Spearman correlation revealed a strong correlation ($\rho > 0.6$) between PAHs and carbohydrates related to biomass burning in winter and autumn, while in the warmer seasons, their correlations differ. Factor analysis and principal component analysis suggested at least three different sources of PAHs and carbohydrates in particulate matter.



Computational study of microPET adsorption mechanism for benzene derivatives in water

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Microplastics (MPs) are now recognized as a new class of contaminants of emerging concern in waters. One of the concerning factors is their ability to adsorb and transport coexisting water pollutants. It has been reported so far that the adsorption of organic pollutants on MPs is governed by weak intermolecular forces, as hydrophobic interactions, van der Waals forces, electrostatic attractive and repulsive forces, π-π interactions, and hydrogen bonds. [1] However, the extent of each interaction remains unknown. Polyethylene terephthalate (PET) MPs (microPET) is one of the most frequently found types of MPs in the environment and a potential carrier of organic pollutants in water. Here we use the density functional theory (DFT) approach to identify interactions between microPET and benzene derivatives and calculate their interactions energies on different adsorption sites. Our results show that hydrogen bonds are the main mechanism controlling adsorption of small organic pollutants on microPET while π-π interactions do not play an important role. Water molecules do not act as competitive factors proving microPET can adsorb and transport organic pollutants in water. The number of adsorbed pollutants depends on the number of adsorption sites and the adsorption energy of a particular pollutant depends on the type of adsorption site. The strongest hydrogen bonds are formed with the carboxyl groups at the ends of PET chains. As ageing of microPET in the environment causes chain scissions and the formation of oxygen-containing groups, it increases the number of adsorption sites that can bind pollutants stronger. The quantitative and qualitative data presented in this work can contribute to a better understanding of the interactions between microPET and organic pollutants in the water environment.

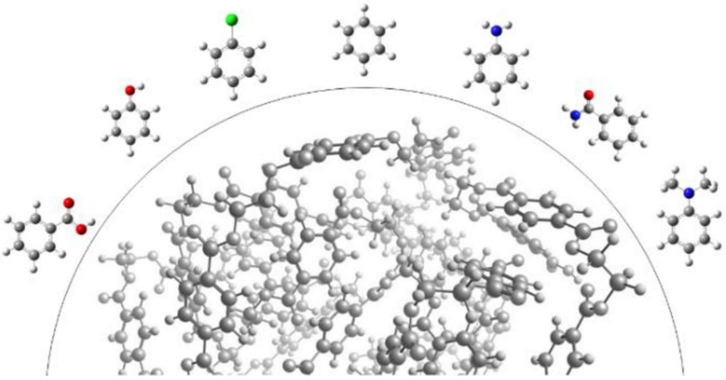

Fig. 1: PET microplastics as a potential carrier of organic pollutants in water.

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Cellulose aerogels and their acoustic properties

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The insulation of buildings and transportation systems has emphasized the necessity to develop advanced materials taking concern of the comfort of modern society with respect to noise reduction. A special class of advanced porous materials, *i.e.* aerogels, can be prepared from inorganic matter, polymers, as well as inorganic/organic composites. Among a variety of different porous materials, aerogels attract much attention due to their excellent properties such as high porosity, high specific surface area, a variety of macro- and mesopores, *etc*. The mechanisms of sound absorption are partly different from those of conventional porous absorbers with large macropores (different foams and fibrous materials). The understanding of the acoustic properties of aerogels is far from complete, and experimental results remain dispersed. The list of properties of aerogels could be extended to include non-toxic, biocompatible, renewable, and widely available materials. Most importantly, aerogels offer the possibility of functionalization of hydroxyl groups on the polymer backbone. [1-3] In this work, we prepared monolithic cellulose aerogels by the *sol-gel* procedure followed by their thorough characterization in terms of density, specific surface area and morphology. Samples are shaped to fit an impedance tube to be tested as sound absorbers. Frequency sweeps were performed, and data were recorded from 500 to 6000 Hz. Cellulose concentrations were varied from 4 to 7 wt% microcrystalline cellulose (MCC), and additionally, samples were mixed with sodium sulphate during the preparation procedure to impact pore size, which consequently affects the sound insulation properties, see Figure 1.

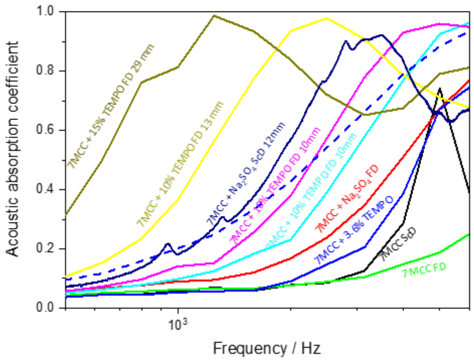

Fig. 1: Acoustic absorption coefficient of prepared aerogel samples.

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Dearomative two-component cascade for pyrrolo [3,4-*b*] indole preparation

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Polycyclic structure is convenient for developing multiple mechanism drugs as it can both serve as a moiety that may be added to improve the pharmacokinetic properties of drugs currently used in clinic trials, or drug candidates under development; or as a scaffold for the basis of the drug. [1] Our research aims to develop catalytic dearomatization reactions as the economical approach for the synthesis of a range of polycyclic molecules with structural novelty. [2] Development of novel dearomatization reactions of aromatic compounds with highly reactive nucleophiles/electrophiles and the ability to suppress possible rearomatization of the products by creating new quaternary carbon centers is the general strategy of the project. In consideration of the recent significant breakthrough achieved independently by the groups of You [3] and Zhao [4] who used catalytic systems consisting of a cinchona-derived amino-phosphine and silver salts we considered metal free reactions.

The aim of this work is the development of cascade dearomatization of indoles for the construction of pyrrolo [3,4-*b*] indoles with three consecutive stereogenic centers. Our strategy is based on the interrupted formal Barton-Zard reaction (Figure 1). In a base catalyzed reaction, isocyanide **2** is deprotonated, and the Michael-type addition occurs at the C2 position of the indole derivative **1**. The resultant indole anion intermediate **3** then undergoes diastereoselective 5-*endo-dig* cyclization onto the isocyanide. Optimal reaction conditions include indole derivative **1** (1.0 eq), isocyanide **2** (1.5 eq), Cs_2CO_3 (3 eq) as base, TBAB (10 mol%) as a phase-transfer catalyst in dicloroethane-water 1:1 at 60 °C. In general, the reaction is tolerant on a range of substituents on indoles and isocyanides, and products **4** are obtained in high yields. The asymmetric variant of this transformation is currently under way.

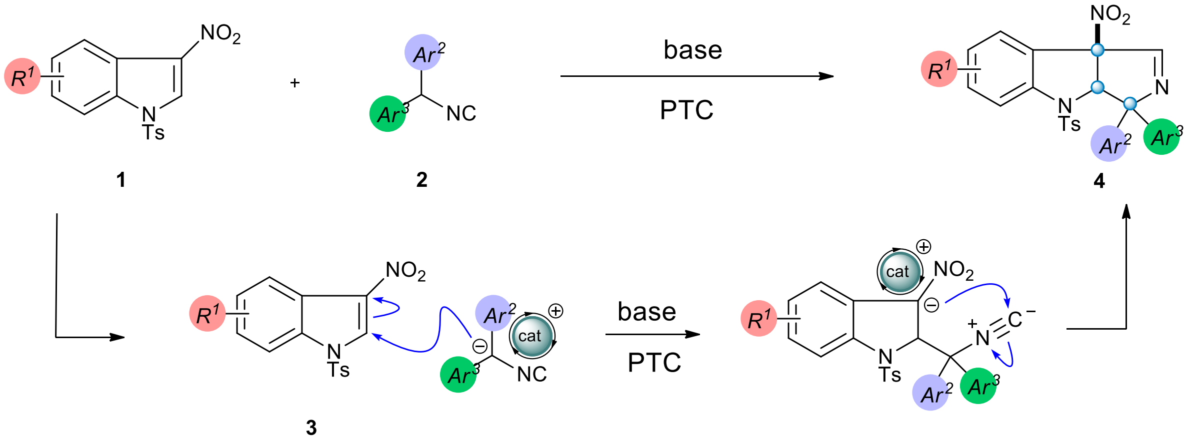

Fig. 1: The concept of the proposed dearomatization reaction.

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Sunlight or UVA-light-induced oxidation of aldehydes to carboxylic acids under aerobic conditions without the use of external photocatalyst

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Aerobic oxidations have recently attracted high academic and industrial interest, due to their low-cost and their “green” character as oxygen is a mild and environmentally friendly oxidant that is widely employed in oxidative transformations. [1] A fundamental and popular oxidative organic transformation which has attracted high academic and industrial interest is the oxidation of aldehydes to the corresponding carboxylic acids. Although it is known that aldehydes are prone to oxidation, synthetic methods for their oxidation to carboxylic acids under green and mild conditions are still scarce. According to the literature on aerobic oxidation of aldehydes, there is a number of stoichiometric approaches employing a variety of oxidants, as well as catalytic methods, organocatalytic or photocatalytic processes. [2,3] In our work, we report an efficient sunlight or UVA-light promoted oxidation protocol for the conversion of aldehydes to carboxylic acids under aerobic conditions. [4] The transformation is catalyst-free and is promoted by either sunlight or LED 370 nm irradiation using a mixture of acetone and water as the solvent. Various aliphatic and aromatic aldehydes were successfully employed, leading to the corresponding carboxylic acids in high to excellent yields. The mechanism of the oxidation was studied using direct infusion-high resolution mass spectrometry (DI-HRMS). A solvent-assisted oxidative transformation is proposed.

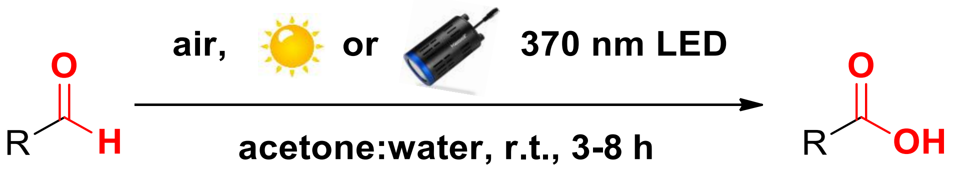

Fig. 1: Light-promoted aerobic oxidation of aldehydes to carboxylic acids.

H.F.R.I. Hellenic Foundation for Research & Innovation

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Perhalogenated aromatic amines as bifunctional donor molecules in cocrystals with ditopic nitrogen-containing acceptors

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Design of cocrystals relies on utilization of predictable and directional intermolecular interactions, predominantly hydrogen (HB) or halogen bonds (XB). [1] Most reports are focused on research of either hydrogen or halogen bonding. In contrast, the examination of competition or cooperation of the two interactions whenever they are present within the same crystal has been much less explored. [2]

To characterize the relationship between two interaction types, we have investigated supramolecular propensities of two perhalogenated aromatic amines, 4-bromo-2,3,5,6-tetrafluoroaniline (**btfa**) and 4-iodo-2,3,5,6-tetrafluoroaniline (**itfa**), as bifunctional donor molecules with one XB donor (iodine or bromine atom) and one HB donor (amino group) on the same perfluorinated aromatic backbone. These were utilized in preparation of cocrystals with three selected ditopic acceptors: 4,4'-bipyridine (**bpy**), 1,2-bis(4-pyridyl)ethane (**bpean**) and 1,4-diazabicyclo[2.2.2]octane (**dabco**). By crystallization from solution and liquid-assisted grinding, we have prepared nine cocrystals in 1:1 or 2:1 stoichiometric ratio for which crystal structure and thermal stability were determined. Structure analysis revealed that in four cocrystals both N···I or N···Br halogen and N–H···N hydrogen bonds were formed, in other four cocrystals with **btfa** dominant interaction was hydrogen bond, and in one cocrystal with **itfa** dominant interaction was halogen bond. These results suggest that HB propensity for **btfa** is, as expected, significantly higher than XB, with bromine atom (that is weaker halogen bond donor than iodine atom) involved only in Br··· type I interhalogen contacts. On the other hand, HB and XB propensities of **itfa** are similar, thus **itfa** has a great potential as a bifunctional donor. Utilizing **itfa** in crystal engineering of cocrystals could lead to the formation of supramolecular chains based on halogen and hydrogen bonds in a predictable and reliable matter.

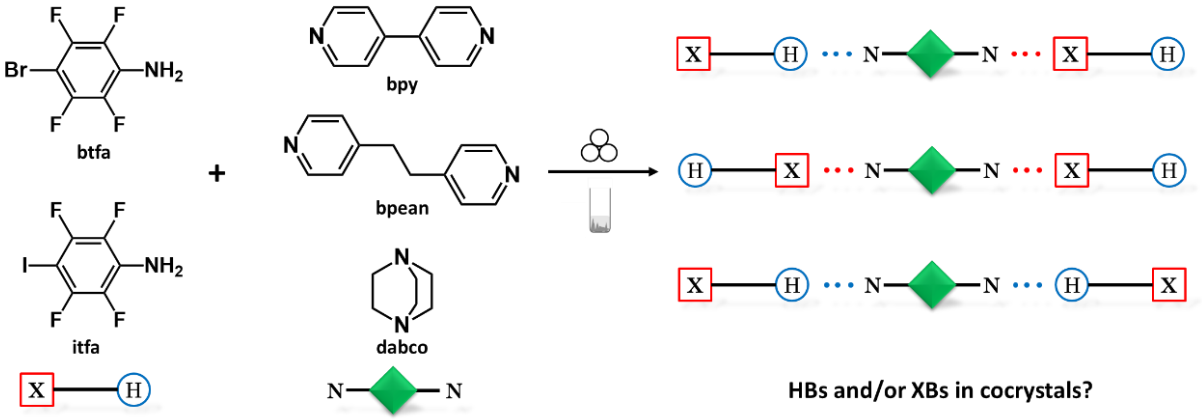

Fig. 1: Donors and acceptors used for preparation of cocrystals and possible outcomes of synthesis.

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Insights into the polymerization of aromatic dinitroso derivatives initiated by nitroso-terminated monolayer on Au(111) surface

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In solid state, aromatic C-nitroso compounds typically appear as *E*-azodioxides, while in solution the nitroso monomer-azodioxide equilibrium is established, with monomers being the preferred form under ambient conditions. An interesting class are compounds with multiple aromatic nitroso groups which can react intermolecularly to form oligomeric or polymeric azodioxides. The simplest such compound is 1,4-dinitrosobenzene, which polymerizes into very stable one-dimensional (1D) polymer, classified as a potential wide-bandgap organic semiconductor (OSC). [1] In addition to 1,4-dinitrosobenzene, a series of aromatic dinitroso derivatives were recently investigated as potential OSCs and several systems with interesting electronic properties were identified. [2] The ability of aromatic C-nitroso compounds to form azodioxides could be exploited for the systematic design of bilayer and multilayer films on metal surfaces. Due to the solid-state photochromic and thermochromic behavior of azodioxy/nitroso system, layers formed via azodioxy bonds could be disassembled and reassembled by UV radiation and heat, respectively.

Previously, we reported that the adsorption of aromatic C-nitroso derivatives through sulfur headgroups on Au(111) surface results in the formation of nitroso monolayers and azodioxy bilayers. [3-5] Herein, we explored the possibility of polymerization of various aromatic dinitroso compounds initiated by nitroso-terminated monolayer on Au(111) surface. Recently established experimental conditions [5] were used for targeted preparation of monolayers with exposed nitroso terminal groups which were subjected to interactions with the six structurally different aromatic dinitroso compounds. Ellipsometry was used to determine average film thicknesses at various adsorption times, while atomic force microscopy (AFM) was employed for studying their morphological and topographical characteristics. Valuable information about chemical composition of the films at the nanoscale was obtained from nano-FTIR spectra. The collected results indicated the formation of azodioxy oligomer films and a greater tendency towards on-surface oligomerization with a longer adsorption time. However, it seems that the films are composed of only a few monomeric subunits or that poorly organized surface structures are formed with tilted and intertwined chains.

Acknowledgement This work has been fully supported by Croatian Science Foundation under the project IP-2020-02-4467.

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Solid-state synthesis and structure of *o*- and *p*-substituted azobenzene amides

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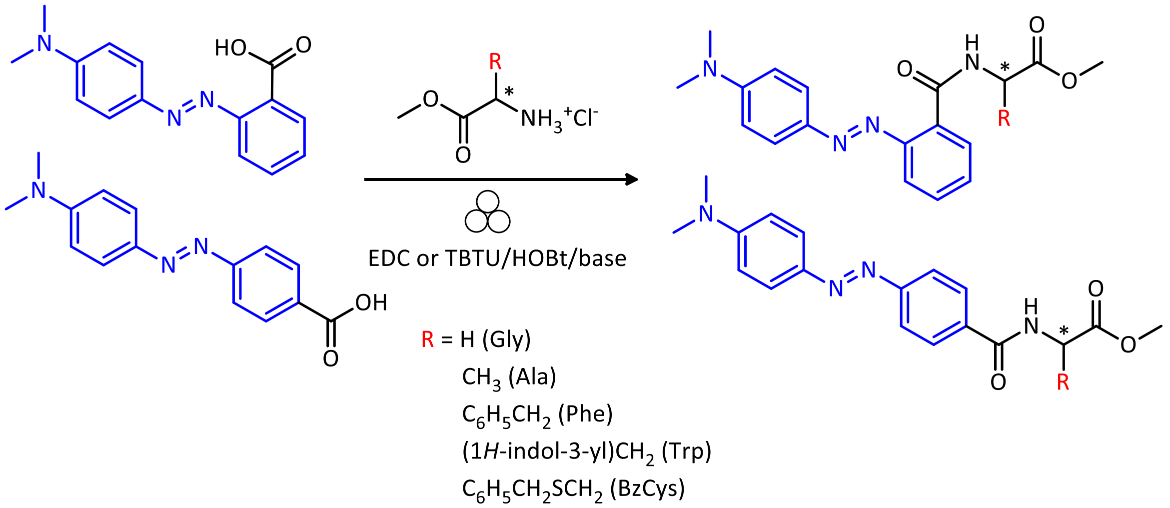
Azobenzene derivatives are extensively exploited as molecular switches for biological and material science applications [1] and functional light-responsive materials. [2] Introducing azobenzene amide scaffolds into biomacromolecules, *i.e.* proteins [3] and nucleosides, [4] have been utilized for controlling their structure, function, and interactions *in vitro*.

Within this work, a mechanochemical synthesis of *o*- and *p*-substituted azobenzene amides with selected amino acid functionalities (Scheme 1) was developed. Optimization of the reaction conditions included a variation of milling jar's and ball's materials, type and quantity of the added base as well as testing the effect of the liquid additive (DMF) and/or the solid auxiliary (SiO_2) on the reaction course. Mechanism of this reaction has been studied by *in situ* Raman spectroscopy and formation of the products was confirmed by NMR spectroscopy. The obtained amides were characterized by spectroscopic and crystallographic methods.



Scheme 1: Synthesis of *o*- and *p*-substituted azobenzene amides.

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New hydroxy substituted acrylonitrile imidazo[4,5-*b*]pyridines as potential antioxidants and pH sensors

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Many biological and geochemical processes occur in water and can cause changes in pH value. pH monitoring is especially important in acidic medium for exploring processes in lysosomes and endosomes in the living cells. For maintaining homeostasis, it is very important to obtain balance between reactive oxygen species and antioxidants. [1]

In this work we prepared imidazo[4,5-*b*]pyridine derived acrylonitriles in order to investigate their antioxidative and pH sensing properties. We investigated how different substituents placed at N3 position of imidazo[4,5-*b*]pyridine core as well as bromo-substituent at position 6, influence antioxidative activity in the presence of various number of hydroxy groups placed at phenyl core. The synthesis started with the amination of the pyridine core followed by the reduction of nitro group to amino. Obtained 2,3-diaminopyridine compounds reacted with ethyl-cyanoacetate. [2] In the final step of the synthesis 2-cyanomethylimidazo[4,5-*b*]pyridine derivatives reacted with hydroxy substituted benzaldehydes. The structures of newly prepared compounds were confirmed by means of ^{1}H and ^{13}C NMR spectroscopy as well as MS spectrometry. pH spectroscopic titrations were performed in order to determine possible application as pH sensors in solutions followed by determination of pK_a values experimentally. Compounds were tested for their antioxidative activity *in vitro* by using spectroscopic methods such as ABTS, DPPH and FRAP. [3]

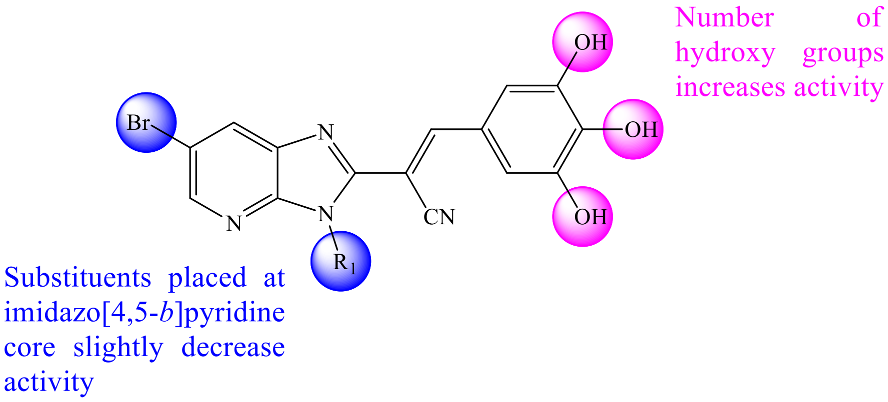

Fig. 1: SAR analysis of the targeted compounds.

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Method development for the determination of water-soluble vitamins in enteral food with LC-MS

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Vitamins are essential nutrients that must be regularly supplied to the body in small amounts to perform various chemical and physiological functions in the human body. [1] The role of enteral nutrition is to ensure the optimal concentration of vitamins and prevent the risk of malnutrition. [2] The development of a single method for the simultaneous determination of water-soluble vitamins in fortified enteral nutrition is difficult due to the different structures and chemical properties of the vitamin compounds, the trace amounts of vitamins present, the complexity of the matrix, instability to light and heat and solubility problems. [3]

The aim of this project is to develop a sensitive LC-MS method for the simultaneous determination of nine water-soluble vitamins, namely, ascorbic acid (C), thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine hydrochloride (B6), biotin (B7), folic acid (B9) and cyanocobalamin (B12), respectively. Various solvents and their mixtures have been tested for the extraction of vitamins from enteral food. The best results were obtained with a mixture of acetonitrile and ethanol, followed by protein precipitation. After precipitation, the supernatant was evaporated and reconstituted in 0.1 M TFA. After testing a range of chromatographic columns and gradients, the vitamins were well separated on Waters Atlantis™ column dC18, 4.6 x 250 mm, 5 µm. The solvents used for the analysis were 0.1% TFA in water (solvent A) and acetonitrile (solvent B). The gradient was applied as follows: 0 min 100% A, 0-13.5 min 100% A-97% A, 13.5-15 min 97% A -85% A, 15-22 min 85% A-80% A, 22-25 min 80% A-0% A, 25-40 min 0% A, 40.1-45 min 100% A. The flow rate was 1.4 mL/min. Samples were analyzed on the Shimadzu LC-MS in single ion monitoring (SIM) mode.

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The influence of drying process on the phenolic, flavonoids and anthocyanins content of chokeberry extract obtained by microwave-assisted extraction

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Chokeberry, also known as black chokeberry (*Aronia melanocarpa* (Michx.) Elliot, aronia) is a plant belonging to *Aronia* genus of *Rosaceae* family (subfamily *Maloideae*) [1,2] and its berries are known for their high content of secondary metabolites – namely bioactive phenolic compounds, such as phenolic acids and flavonoids: flavonols, anthocyanins and proanthocyanidins. Aronia berries have a relatively high antioxidant capacity and numerous health benefits. *In vitro* studies have shown that these berries exhibit anti-cancer effects, while *in vivo* they show anti-inflammatory, anti-diabetic and neuroprotective effects. All these effects are due to their high polyphenol content, which exceeds that of most other fruits and vegetables. [2]

The aim of this study is to determine the influence of four different drying methods (freeze drying, vacuum drying, dehydration, and convection drying) and extraction solvent on the yield of phenolic compounds of chokeberry obtained by microwave-assisted extraction (MAE). Microwave-assisted extraction is a modern, efficient, and environmentally friendly method that requires shorter extraction time, less energy, and little to no organic solvent consumption to achieve higher yield than conventional methods. [3] Quantitative analyses of total phenolics, flavonoids, and anthocyanins were done by spectrophotometric (colorimetric) methods. Identification of individual compounds was performed by high-performance liquid chromatography with mass spectrometry.

Obtained spectrophotometric results showed that drying methods and solvent choice, affect the content of phenolic compounds of black chokeberry MAE extract. The highest yield of total phenolic compounds, flavonoids and anthocyanins could be found in extracts from freeze-dried and vacuum dried chokeberries, with ethanol extracts generally producing higher yield than the water ones. The highest concentration of total phenolic compounds was found in ethanol extract obtained from freeze dried chokeberry (107.07 µg GAE/mg dry extract), as well as highest concentration of anthocyanins (23.20 µg C3GE/mg dry extract). The highest yield of total flavonoids was obtained from ethanol extract obtained from vacuum dried chokeberries (49.65 µg QE/mg dry extract).

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Very weak base pK_a determination

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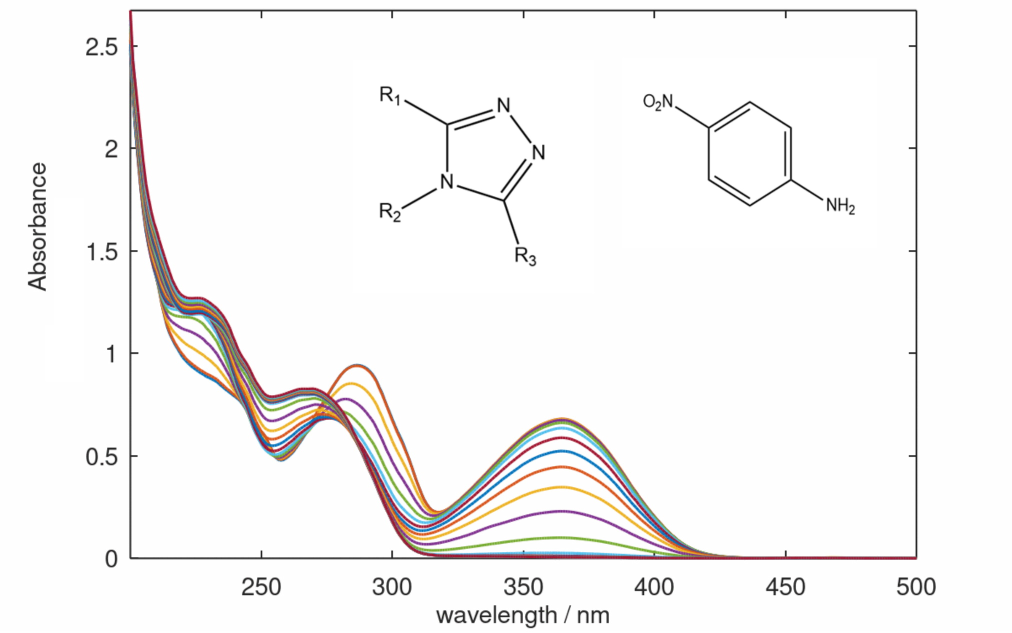
Due to the leveling effect of water, ionization constant(s) of very strong or very weak acids and bases, pK_a, cannot be determined by aqueous titration. One practical way to overcome this difficulty is pK_a determination by titration in non-aqueous solvent.
As direct measurement of medium acidity $a(H^+)$ in non-aqueous solvents is problematic and acid-base equilibria in these solvents is complicated due to ion pairing, homo- and heteroconjugation, pK_a in non-aqueous solvents is usually not determined directly, but relative (as ΔpK_a) to the referent acid or base, whose accurate pK_a value is known:

$$\Delta \mathrm{p}K_\mathrm{a} = \mathrm{p}K_\mathrm{a}(HB^+_\mathrm{ref}) - \mathrm{p}K_\mathrm{a}(HB^+) = \log\frac{[B]\cdot[HB^+_\mathrm{ref}]}{[B_\mathrm{ref}]\cdot[HB^+]}.$$

In this work, ionization constant of very weakly basic substituted triazole molecule was determined by (UV) spectropotentiometric titration with trifluoromethanesulfonic acid in dry acetonitrile, relative to the pK_a values of two referent molecules: 4-nitroaniline and 4-(trifluoromethyl)aniline. Experimental procedure was in accordance to the method by Leito et al. [1] with the enhanced data treatment, avoiding the need for accurate knowledge of analytical concentrations of substances used in the experiment. Also, to validate the procedure, (known) difference ΔpK_a between referent molecules was determined and compared to literature values.



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Influence of biphenyl-bis-urea receptor terminal substituents on anion binding properties

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In the field of supramolecular chemistry, anion recognition was explored at a later stage. However, nowadays, it has become a mature research area. [1] The formation of the host-guest receptor-anion complex is very often controlled by subtle interplay of several factors, including the structural and electronic complementarity between the two interacting partners. Receptor can form with guest hydrogen-bonding interaction, especially if it possesses strong hydrogen-bonded donor, such as N–H group present in urea derivatives. Receptor-binding affinity could be additionally increased if more than one urea group is combined with several anions.

We reported previously [2] anion binding properties of bis-urea derivative featuring a biphenyl spacer, 1,1'-(4,4'-biphenylene)bis(3-phenylurea) (**1**) (Fig. 1), through five receptor-anion complexes obtained using tetrabutylammonium salts, TBAX (X = AcO^-, $H_2PO_4^-$, Br^-, I^- and NO_3^-). Herein we present influence of terminal substituents of **1** on binding properties of TBA anions, electron-deficient one due to the electron withdrawing effect of $-NO_2$ group (**2**), and electron-rich in which phenyl rings are replaced with naphthyl groups (**3**) (Fig. 1). X-ray structures of five receptor–anion complexes of **2** and **3** showed different solid-state architectures compared to that of **1**. Solution studies and DFT calculations of anion-binding abilities of **2** and **3** will be also presented.

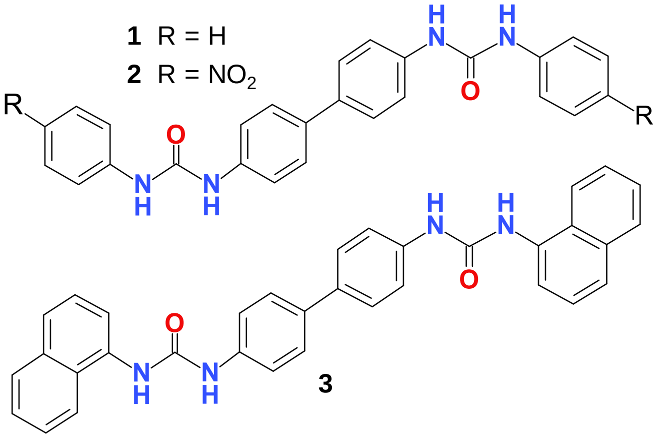

Fig. 1: Molecular structures of biphenyl-bis-urea receptors **1**-**3**

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N,*N*-di(2-picolyl)amine functionalized amino acid based supramolecular hydrogels: Synthesis, characterisation and potential biomedical application

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Supramolecular hydrogels are soft materials owing their properties to the non-covalent bonding that occurs in self-assembly. These self-assembled materials are often stimuli responsive, reversible, and biocompatible so they are applicable in various fields including biomaterials, tissue engineering, and sensors. [1,2] Due to these properties, supramolecular hydrogels have also been studied as vaccine delivery systems. [3] In this work, two new supramolecular hydrogels based on amino acids and containing *N,N*-di(2-picolyl)amine as a pH-sensitive moiety have been synthesized by conventional peptide synthesis methods in solution. The hydrogelation properties of the compounds were determined in water and aqueous buffer solutions. Compound **1** has a minimal gelation concentration (MGC) of 1.5% w/V, while compound **2** shows an MGC of 0.8% w/V. The molecular self-assembly of gels was studied by spectroscopic and microscopic methods such as variable temperature ^{1}H NMR spectroscopy, IR spectroscopy, and transmission electron microscopy to determine the driving force of self-assembly and morphology of these materials. The driving force of self-assembly was determined to be hydrogen bonding and π-π stacking. The hydrogels were further analysed for their ability to act as vaccine delivery system. Results show that immunization with the hydrogel-formulated OVA produces higher amounts of OVA-specific antibodies IgG in mice compared to OVA alone, suggesting the immunostimulatory activity of examined hydrogels and their potential in vaccine delivery.

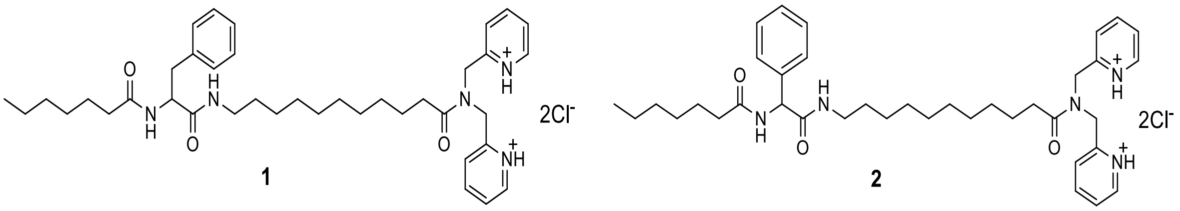

Fig. 1: Chemical structures of hydrogelators **1** and **2**.

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Synthesis of oligomers with embedded C-glycosyl α-amino acids

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C-glycosides are a unique class of naturally occurring compounds with a diverse array of biological properties. Because C-glycosides are metabolically more stable compared to their O- or N-counterparts, they are widely utilized in biomedical and drug discovery studies of glycopeptides and proteins. C-glycosyl amino acids represent a special group of C-glycosides. The interest in the synthesis of these compounds originates from their subsequent incorporation into peptides. [1] Oligomers composed of such non-natural amino acids represent highly valuable tools not just in medicinal chemistry but also in material science (self-assembly, formation of different types of nanostructures, *etc*.). Routes developed for the synthesis of C-glycosyl amino acids, and installation of an amino acid moiety onto a glycosyl framework relies on the use of well-established α-amino acid synthesis strategies, such as robust, stereoselective, multicomponent approach with sugar derivatives. [2,3]
We utilized a three-component Passerini reaction to convert carbonyl compounds to α-acyloxyamides. Passerini products were synthesized using two different isopropylidene-protected aldehydes (sorbose and galactose derivative) as carbonyl components, amino acid-derived isocyanides (with L and D configuration), and acetic acid, in high yields and diastereoselectivities. [4] Hydrolysis of Passerini products under basic conditions afforded α-hydroxy C-glycosyl derivatives. Further transformations aimed to transform OH to NH_2 group afforded dipeptides comprising C-glycosyl α-amino acid (Fig. 1). Such monomers will be used in the synthesis of homo- and heterochiral oligomers.

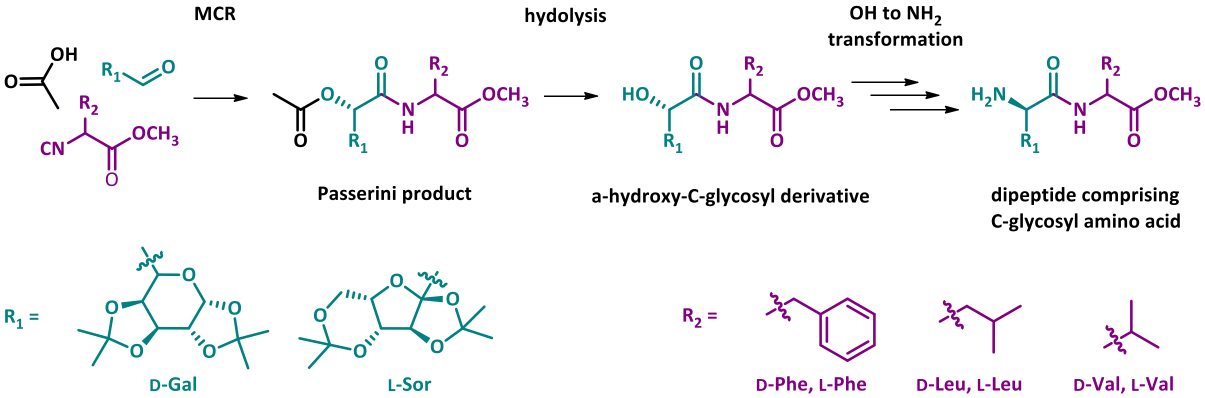

Fig. 1: Synthesis of C-glycosyl amino acid derivatives by post-condensation modification of Passerini products.

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Sonochemical synthesis and characterization of ZrO_2 nanoparticles

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Dimensions and properties of ZrO_2 nanoparticles enable their wide application. For the application of nanoparticles, energy-efficient preparation of small and pure particles without impurities is necessary; therefore, sonochemical synthesis is increasingly the chosen method. [1, 2] Here we report the sonochemical synthesis of ZrO_2 nanoparticles and the influence of the synthesis duration, the amplitude and the duration of the ultrasound-assisted synthesis pulse on the final phase ratio and crystallite size of ZrO_2 nanoparticles. For this simple and most of all cost-effective synthesis of ZrO_2, a nanoparticles stabilizer is necessary, to prevent their growth. Ethylenediamine was used for this purpose. The qualitative composition of precursors and calcined samples was determined by Fourier transform infrared spectroscopy (FTIR). Synthesized compound was further structurally characterized by powder X-ray diffraction (PXRD), while the nanoparticle size, grain size, size distribution, and morphology were investigated by transmission electron microscopy (TEM).

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Equilibrium and kinetic studies on the reactions of aquapentacyanoferrate(II) with 4-imidazoline-2-thiones

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Heterocyclic compounds based on 4-imidazoline-2-thione are especially important in medicine. They are used as inhibitors of dopamine β-hydroxylase, diuretics, anti-inflammatory and antithyroid drugs. The most commonly used drugs in the treatment of hyperthyroidism are propylthiouracil and two substituted 4-imidazoline-2-thiones, namely, methimazole and carbimazole. In addition, imidazoline-2-thiones serve as precursors in the synthesis of imidazole derivatives and various condensed heterocycles. In the coordination chemistry, imidazoline-2-thiones are important and versatile *N*,*S*-donor ligands. In the investigations of reactivity and coordination ability of ambidentate ligands, aquapentacyanoferrate(II) has proven useful. The $[Fe(CN)_5(OH_2)]^{3-}$, a structural model of biologically important octahedral iron(II) complexes, undergoes the water–ligand exchange reaction producing corresponding pentacyano(ligand)ferrates(II). The ligand substitution reactions of aquapentacyanoferrate(II) ion with 4-imidazoline-2-thione ($imtH_2$), 1-methyl-4-imidazoline-2-thione (meimtH, methimazole) or ethyl 3-methyl-2-sulfanylidene-imidazole-1-carboxylate (meimtR, carbimazole) were studied in aqueous solutions. The produced pentacyano(imidazoline-2-thione)ferrates(II) were characterized by UV/Vis and ^{13}C-NMR spectroscopy. The equilibrium constant for the formation of pentacyano(imidazoline-2-thione)ferrate(II) was determined spectrophotometrically. The rate constants and activation parameters for the formation as well as for the dissociation of pentacyano(imidazoline-2-thione)ferrate(II) complexes were determined by UV/Vis spectroscopy. The hydrolysis of free meimtR and meimtR coordinated on $[Fe(CN)_5]^{3-}$ moiety was investigated. On the basis of spectroscopic data and kinetic parameters it has been established that 4-imidazoline-2-thiones coordinate to iron(II) through the sulfur atom.

Data independent acquisition *de novo* sequencing technique

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Peptide or protein *de novo* sequencing, method that can acquire peptide and protein sequence without the assistance of a protein database, represents one of the most challenging tasks in proteomics. Peptide or protein mass spectra can be produced using either data dependent or data independent acquisition (DDA or DIA). DDA is selective, more informative and sensitive in terms of a single ion, and thus represents a method of choice for *de novo* sequencing. Compared to DDA, DIA is faster, easier to use and optimize, and it dissociates and analyzes all present ions. However, it presents a couple of drawbacks. Firstly, the *de novo* sequencing algorithm is not always able to deliver a complete sequence or it has uncertainty in a portion of the derived sequence. Moreover, peptide or protein identification score results are significantly lower compared to DDA. To overcome named disadvantages, development of different approaches in *de novo* sequencing techniques is required. In this research, chemically activated fragmentation (CAF) coupled with charge reduction conditions was applied to enable directed peptide fragmentation of bovine serum albumin (BSA) tryptic peptides for the production of y- and b-ions in positive and negative mass spectrometer ion mode, respectively. Peptide ion spectra obtained by DIA analysis showed that 96.2% of the BSA protein sequence was acquired in comparison to 41.0% sequence coverage provided by the conventional DDA analysis. Implementation of this methodology could improve the quality of *de novo* sequencing dataset and provide unambiguous identification results.

Carbazole derivatives as precursors of aza-*o*-quinone methides

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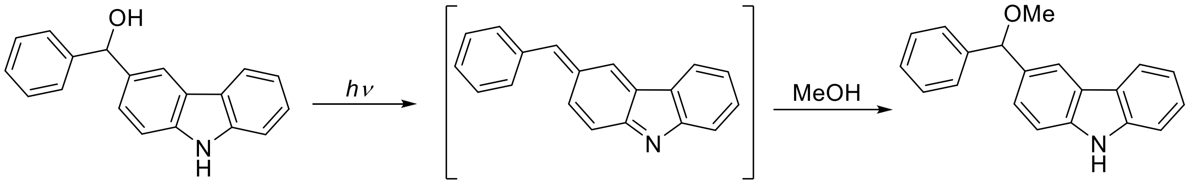
Aza-quinone methides derivatives (**a-QM**) are well-known reactive intermediates, albeit less represented in the literature compared to oxygen analogs. [1] The use of **a-QM** has been demonstrated in the synthesis of biologically important molecules such as hydroquinolines, indoles and benzotriazepines. Although **a-QM** are most often prepared by the ground state reactions, there are a few examples where **a-QM** were generated photochemically. [2,3] For example, **a-QM** was prepared in a dehydration reaction of *o*-aminobenzyl alcohol. However, its trapping in [4+2] cycloaddition reactions was not successful due to its intermolecular reactions. [3]

With the aim to develop novel classes of photoactivable anticancer drugs, we incorporated **a-QM** precursors in the carbazole derivatives. Carbazoles can be excited with near-visible light (>350 nm), and some of them have shown the capability to non-covalently bind to polynucleotides. Herein we report the synthesis of several carbazole **a-QM** precursors and investigation of their photochemical reactivity. The irradiation experiments in methanol and isolation of methyl ether photoproducts (Scheme 1) is an indication of the photochemical generation of *para*-**a-QM**, which to date has been reported only once. [4]



Scheme 1: Photochemical reaction of carbazole derivative of methanol.

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Dinuclear copper(II) complexes derived from benzopyrone ligand: Synthesis, structural characterization and antiproliferative activity

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Benzopyrones belong to a group of six-membered *O*-heterocyclic compounds that have been intensively studied by scientists in various fields during the last decades. Some of the reasons are easy availability, low toxicity profile and at the same time high functionality. [1]
Two new complexes were prepared using copper(II) salts (nitrate and acetate) and chromone-2-carboxylic acid (Fig. 1). They were synthesized by the method of classical solution chemistry in a stoichiometric ratio of 1:1 (metal:ligand). The complexes were characterized by FT-IR and NMR spectroscopy, thermal and electrochemical analyses, and their structures are proposed. The results indicate the formation of binuclear Cu(II) complex (**1**) and hydroxy-bridged binuclear copper(II) complex (**2**). The cyclic voltammetry showed that copper in both complexes was in the +2 oxidation state. Antiproliferative activity was determined by the MTT test on 2D cell models *in vitro* on seven human cell lines, one of which was a normal cell line, and the others were tumor cell lines. The test showed that complex (**1**) has an inhibitory effect on Hep-G2 cells at the highest concentration (10^{-5} mol dm^{-3}) by 35.2% followed by NCI-H358, MRC-5, HT-29 (54.4%; 54.7%; 56.6%) and the complex (**2**) showed an inhibitory effect on Hep-G2 cells at the highest concentration (10^{-5}mol dm^{-3}) by 36% followed by NCI-H358, KATO III, HT-29, MRC-5 (59.7%; 58.3%;53.2%; 51.3%). According to the obtained results of chemical and biological testing, it can be concluded that the chemical route of synthesis was successful. Gained copper(II) complexes are biologically active.

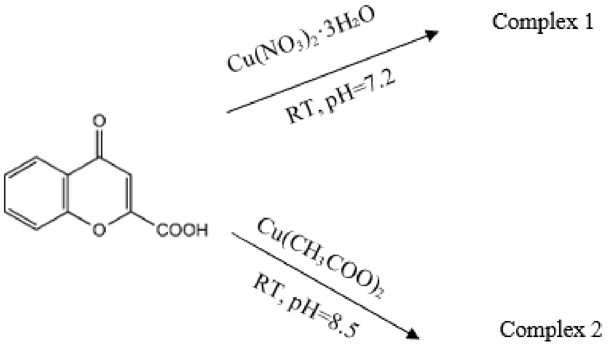

Fig. 1: Scheme of synthetic strategy of Cu(II) complexes

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Friedel-Crafts type arylation of aldehydes with indoles utilizing a photoacid generator and blue LED irradiation

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Friedel-Crafts arylation of aldehydes is one of the most common organic reactions and is an area of great importance in organic chemistry. Since 2014, the Kokotos' group is actively involved in the design of innovative organic photocatalysts and photoinitiators and their use in sustainable photocatalyzed processes. Among the several targets that can be achieved via Friedel-Crafts alkylation, the synthesis of bis-indolyl methanes (BIMs) and their analogues is considered a significant goal, for the biological and pharmacological properties of these compounds. Furthermore, in the last decade the research group of Fagnoni and Protti has investigated in detail the photoreactivity of arylazo sulfones. Among the different applications of arylazo sulfones in synthesis and in chemistry of materials, their use as non-ionic photoacid generators (PAGs) able to generate methanesulfonic acid in oxygen-saturated or air equilibrated solution has been recently investigated. [1] In this report, we demonstrate a mild, inexpensive and sustainable protocol for the preparation of valuable bis-indolyl methanes via visible light-mediated, utilizing arylazo sulfones as non-ionic Photoacid Generators (PAGs). A variety of aliphatic and aromatic aldehydes were converted into diarylmethanes in good to highly satisfactory yields, employing a low-catalyst loading (0.5 mol%) and irradiation at 456 nm. [2]

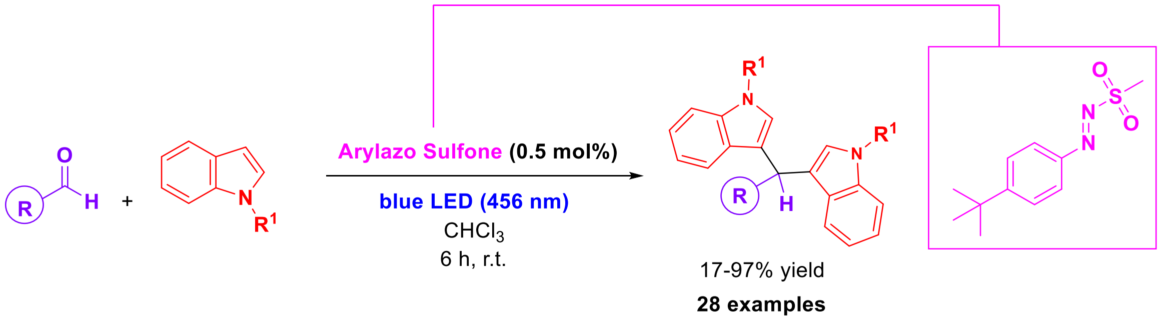

Fig. 1: Photochemical Friedel-Crafts arylation of aldehydes with indoles.

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Extraction of vitamin E from hens feed mixture

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Herbert Evans and Katherine Bishop discovered vitamin E in 1922. [1] Vitamin E is one of the main antioxidants, slows down the development of Alzheimer's disease, and protects the skin from unfavorable UV rays. [2] Its positive effect on the human body ensured its significant place in nutrition. Humans cannot synthesize vitamin E, therefore it must be ingested through food. Foods rich in vegetable oils and green vegetables are considered a good source of vitamin E, while food of animal origin contains less vitamin E. Determination of vitamin E concentration in feed for laying hens is important because eggs are one of the sources of vitamin E in the human diet, and the concentration of vitamin E in egg yolk depends on the composition of the feed consumed by laying hens. A method developed by Pinheiro-Sant *et al.* was used for extraction of vitamin E from feed for laying hens. [3] The influence of sample particle size, sample : extraction mixture ratio and optimizing the composition of the extraction mixture was investigated. All measurements were performed on a sample of laying hens feed available on the market, and the concentration of vitamin E was determined using HPLC. The determined concentration of vitamin E in the grinded and sieved samples was 266,613 mg/kg, while in the non-grinded samples it was 199,293 mg/kg, which is a difference of 33.78%. Sample : extraction mixture ratios (1:5, 1:10, 1:25 and 1:50) were investigated. The best determined ratio is 1:25 where the measured concentration of vitamin E was 329,319 mg/kg. By replacing hexane : ethyl acetate (85:15, v/v) with hexane : ethyl acetate (65:35, v/v) better results were obtained. The measured concentration of vitamin E was 11.17% higher.

Acknowledgement This study is supported by the European Structural and Investment Funds grant for the Croatian National Scientific Center of Excellence for Personalized Health Care (grant #KK.01.1.1.01.0010) and by the Ministry of Science and Education of the Republic of Croatia.

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A model for acute poisoning detoxification – binding of aristolochic acid with various cyclodextrins

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Aristolochic acid **I** (ARI) is a planar extended aromatic molecule, well-known for its carcinogenic, mutagenic and nephrotoxic activity and most commonly linked to the Europe Balkan region (particularly the Danube – Black Sea basin), causing severe endemic nephropathy. [1] Low aqueous solubility of ARI leads commonly to consequent hydrophobic-driven binding to serum albumin in the blood, [2] thus being distributed over the organism, strongly supported by ARI hydrophobicity and consequent slow clearance kinetics. The application of macrocyclic compounds as host molecules in biomedicine is generally well-known and intensively studied. [3] We showed that aristolochic acid toxin (ARI) and its fluorescent analogue form inclusion complexes with various cyclodextrins (CDs), including the clinically used γ-CD: Sugammadex. The binding affinity of ARI towards CDs was determined with UV-Vis and fluorescence spectroscopy in a phosphate buffer solution. Affinity varied on CD size and rim modifications, whereby the stability of the ARI/Sugammadex complex was 2-fold greater than ARI binding to serum albumin (BSA). These results [4] are a proof-of-concept that CDs could be used as a first aid upon acute intoxication with ARI by binding at least part of the toxin in competition with serum albumin and significantly reducing ARI absorption in the organism.

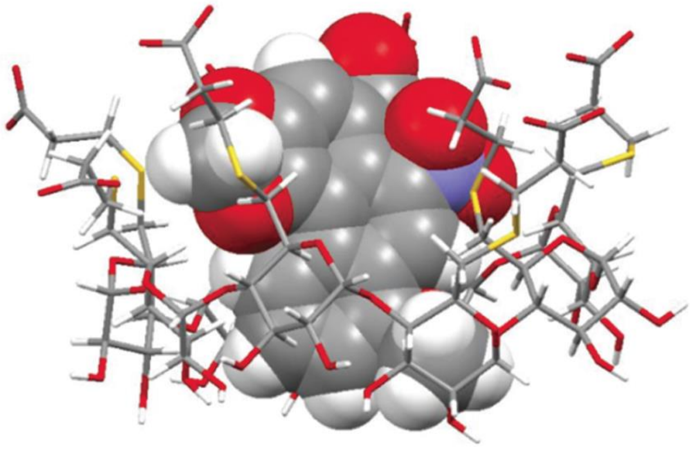

Fig. 1: Structure of the **ARI** (vdW balls) / **SMX** (sticks) complex.

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Novel, sustainable and green photooxidation protocols: Easy access to sulfoxides and phenols

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Historically, sulfoxides and phenols comprise important classes of molecules in pharmaceutical industry, beginning with the rise of antibacterial ingredients in the beginning of the 20th century. Several sulfoxide- and phenol-containing molecules are known to display a salient pharmacological profile and are marketed drugs. Photochemical aerobic oxidations merge two interesting fields, photochemistry and air-mediated oxidation processes. [1] Although for many years both areas received limited attention, with the upraise of modern synthetic photochemistry and increasing number of literature reports on oxygen-mediated oxidations, in the last five years the photochemical aerobic oxidation of sulfides to sulfoxides and boronic acids to phenols have attracted exponential attention. In our group, we have developed a general, fast, mild, green and industrial-friendly procedure to perform these reactions. [2] Initially, we explored the role of wavelength irradiation towards sulfides and boronic acids aerobic photooxygenation to the corresponding sulfoxides and phenols, respectively. Low-catalyst loading (up to 1.0 mol%) anthraquinone-mediated protocols (CFL or LED lamps) and photocatalyst-free aerobic protocols (LED lamps) are reported, combining short reaction time and overcoming the unwanted overoxidation reaction. [2] We also applied our photooxidation protocols towards the synthesis of sulforaphane, a promising anti-cancer agent and a potential SARS-CoV-2 inhibitor, and modafinil, a drug used to treat narcolepsy symptoms. [3]

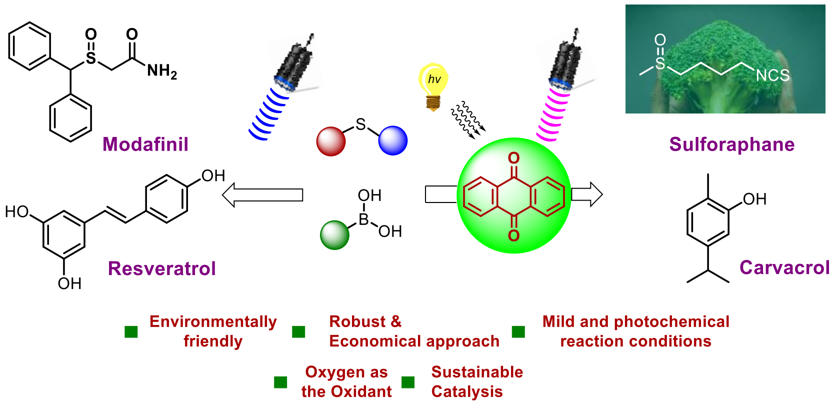

Fig. 1: Photochemical aerobic oxidations

Acknowledgement The authors gratefully acknowledge the Hellenic Foundation for Research and Innovation (HFRI) for financial support through a grant, which is financed by the 1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and the procurement of high-cost research equipment grant (grant number 655).

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Surfactant free microemulsion composed of heptanol, ethanol and water

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Microemulsions are defined as thermodynamically stable and optically transparent dispersions of at least two immiscible liquids (usually one polar and one nonpolar component) and an amphiphilic compound (or surfactant). [1] Surfactants play a critical role in the formation of such microemulsions, which are referred to as surfactant-based microemulsions (SBMEs). However, researchers have found that it is possible to prepare surfactant-free microemulsions in ternary systems consisting of two immiscible liquids and an amphi-solvent, hence the name surfactant-free microemulsions (SFMEs). [2] SFMEs have several advantages over SBMEs, such as lower exotoxicity and lower production costs because no surfactants are used. In addition, the separation and purification of nanoparticles synthesized in SFME systems is easier. The disadvantage compared to conventional microemulsions is that although SFMEs are thermodynamically stable for months, they eventually break down. The ternary system studied consists of heptanol, water, and ethanol. The phase behavior of the ternary system was studied and it was found that there was a single-phase microemulsion region and a multiphase region in the ternary phase diagram. Conductometric measurements were performed to determine microregions in the single-phase region of the ternary system. Structures with different hydrodynamic radius were determined in the vicinity of the binodal curve by dynamic light scattering (DLS).

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Selective deuteration improves the affinity of adenosine A_{2A} receptor ligands: A computational case study with istradefylline and caffeine

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The past few years have witnessed an emerging trend in the use of deuteration in the medicinal chemistry, particularly fueled by the FDA approvals of labelled drugs, Austedo in 2017 and Sotyktu in 2022. Precision deuteration goes beyond the simple amelioration of pharmacokinetic parameters of non-deuterated derivatives and might provide an opportunity when facing problems of metabolism-mediated toxicity, drug interactions, low bioactivation, and even broader, can be an efficient tool for improving ligand affinity without significant structural changes. [1] We employed a range of computational techniques to assess the effect of the selective C–H deuteration on the antagonist istradefylline affinity for the adenosine A_{2A} receptor relative to caffeine, a well-known and likely the most widely used stimulant. Our results revealed a large flexibility of smaller caffeine that exchanges between two distinct binding poses, while the additional C8-*trans*-styryl fragment in istradefylline locks the ligand within a uniform pose, which enhances its affinity over caffeine. In addition, the aromatic C8-unit displays a higher deuteration sensitivity over the xanthine part, so when both $-OCH_3$ groups are deuterated the affinity increases by −0.4 kcal mol^{-1}, which surpasses the overall affinity gain of –0.3 kcal mol^{-1} in the perdeuterated d_9-caffeine. Yet, the latter predicts around 1.7-fold potency increase, being relevant for its pharmaceutical implementations, but also those within the coffee and energy drinks production industries. Still, the full potential of our strategy is achieved in d_{19}-istradefylline, whose affinity improves by –0.6 kcal mol^{-1}, indicating a 2.8-fold potency increase that strongly promotes it as a potential synthetic target (Figure 1). This knowledge supports deuterium implementation in the drug design, and while the literature already reports about over 20 deuterated drugs currently in the clinical development, [2] it is easily foreseen that more examples will hit the market in the years to come.

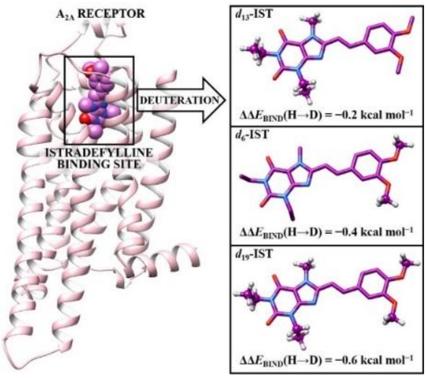

Fig. 1: The effect of selective deuteration on the affinity of istradefylline for the A_{2A} adenosine receptor.

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Chemometric analysis of adaptive titrant addition procedure for spectrophotometric stability constant measurements

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The estimate of parameter uncertainties obtained by regression is a default procedure in the advanced data analysis. [1] Spectrophotometric titrations are routinely used for stability constant determinations of supramolecular complexes in solution due to the commercially available instruments, chromophoric properties of the large number of chemical species and the simplicity of the practical part of the experiment. The volumes of the titrant solution are primarily chosen to cover a specific range of titrant concentrations in cuvette after mixing, with little to some attention to the change of the complex distribution with the titrant concentration. Here we report adaptive titrant addition procedure that selects the titrant volumes with respect to the constant change in the percentage formation of the complex, similar to the work of Tellinghuisen [2] which was focused on the microcalorimetric titrations. The chemometric analysis of the simulated data of both approaches is performed and the results are compared with respect to the parameter values and uncertainties.

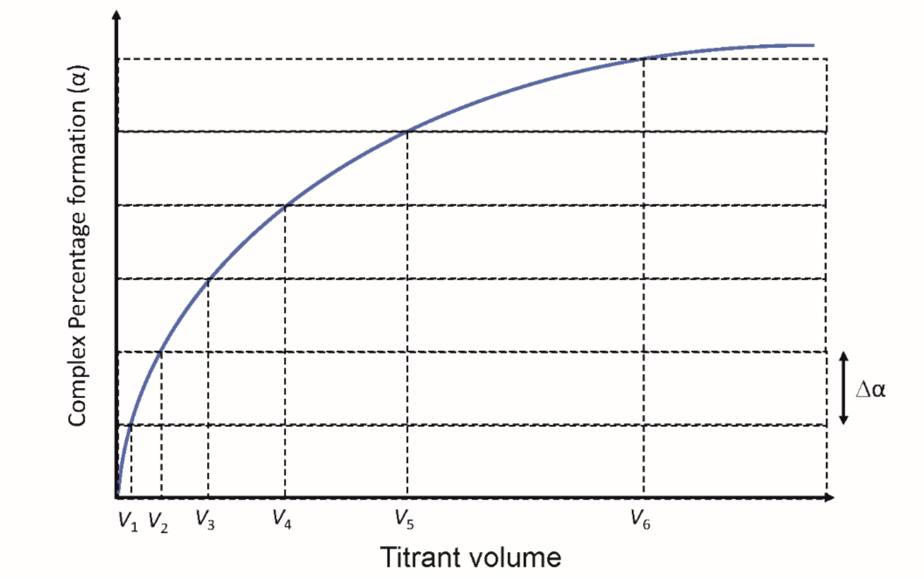

Fig. 1: Adaptive titrant addition

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Development of a planar printed lactate biosensor

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In recent years, the development of personalized and wearable sensing platforms for non-invasive *in situ* monitoring of lactate in sweat has gained importance in sports and medical diagnostics. [1] Amperometric enzymatic sensors are particularly convenient for lactate quantification; because they are relatively inexpensive and have high sensitivity, they are ideal for commercial scale production. Under physiological conditions, lactate can be oxidized by enzymes to pyruvate, producing hydrogen peroxide (H_2O_2) as a byproduct. The sensing mechanism underlying lactate detection follows the physiological pathway and, for first-generation biosensors, is based on the usage of enzyme lactate oxidase (LOx), often coupled with a H_2O_2 electrocatalyst, such as Prussian blue (PB), which mediates current output at mild applied potentials. [2]

This work presents an enzyme sensor fabricated over a glassy carbon electrode (GCE) for measuring lactate in synthetic sweat. To establish a lactate sensing platform, multilayer films were formed by the simple layer-by-layer (LbL) method in the following sequence: (i) PB as a redox mediator; (ii) LOx as an enzyme, and (iii) chitosan as an immobilization matrix and protective outer layer serving as lactate diffusion medium. Since each layer affects the performance of biosensor, each fabrication step is carefully and systematically examined. First, the thickness of the PB layer was optimized by adjusting the concentrations of the precursor solutions to yield maximum current output and high catalytic activity towards H_2O_2. Second, the dynamic amperometric response and the corresponding calibration curves at increasing lactate concentrations in 0.01 M phosphate buffer using the chitosan-LOx-PB/GCE biosensor were provided. The influence of pH and ionic strength were also investigated. The advantages of the presented sensor are its ease of fabrication, including *in situ* chemical synthesis of the PB mediator (avoiding the time- and energy-consuming electrochemical deposition), and the use of the biocompatible chitosan as an enzyme protective layer. Finally, the biosensor design was transferred to printed electrodes, yielding miniaturized planar flexible sensors.

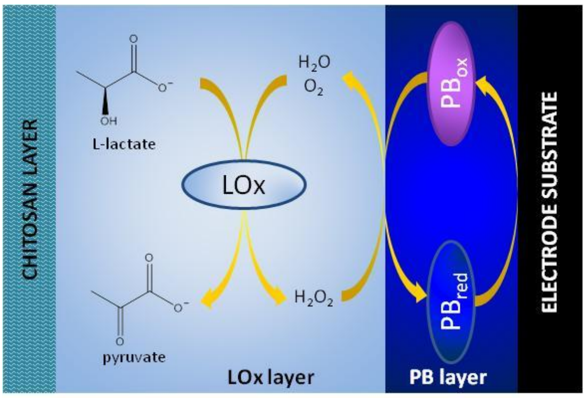

Fig. 1: Schematic presentation of the electrochemical lactate sensing mechanism.

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Computational and experimental study of transcription factors that control manganese homeostasis in bacteria

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Manganese ions (Mn^{2+}) are necessary for basic cellular processes in bacteria such as DNA replication and resistance to oxidative stress. In the same time, manganese ions (Mn^{2+}) are toxic for the cell when their cellular concentration is too high. Therefore, bacteria must have sensitive cellular mechanisms through which manganese homeostasis is regulated. [1] In bacteria, such mechanisms relay on manganese metallosensors – transcription factors that control transcription of proteins involved in transport and storage of Mn^{2+} ions in cell. Since such mechanisms are different between bacteria and eukaryotes, key proteins of such mechanisms in pathogenic bacteria present potential targets for the development of novel antibiotics. Focus of the presented research is on manganese metallosensors of four bacteria: pathogenic bacteria *Mycobacterium tuberculosis* and *Streptococcus mutans*, and nonpathogenic bacteria *Bacillus subtilis* and *Streptococcus gordonii*. A combination of computational and experimental methods was applied with a goal of understanding their molecular mechanisms. Computational methods (molecular dynamics simulations and quantum mechanics calculations) provided an insight into molecular basis of studied mechanisms. Directed mutagenesis, microcalorimetry (ICT and DSC) and circular dichroism spectroscopy were used to validate the computational results.

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Determination of ethylene oxide in botanical dietary supplements used in the treatment of IBD by gas chromatography-tandem mass spectrometry

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The contamination of botanical dietary supplements with pesticide and fungicide ethylene oxide (EO) is well recognized problem worldwide. Contamination of botanicals with pathogenic bacteria is attributed in part to growing conditions and environment, sanitation and hygiene practices among harvest workers, and lack of good agricultural and manufacturing practices within some developing countries. Processing methods for botanicals include fumigation with EO, irradiation, and vacuum-assisted steam. Moreover, capsule shells as the most used delivery system of botanical dietary supplements can be sterilized with EO by manufacturers before releasing to user enterprises. [1,2] Due to its mutagenic and carcinogenic properties, herbal dietary supplements need to comply with the maximum residue level established by regulatory agencies. [3,4] It is important to ensure that the levels of residual EO and its by-product 2-chloroethanol (2-CE) obtained by the reaction of acetaldehyde and chloride ion pose a minimal risk to the patient. The aim of this research was the assessment of EO_{Total} expressed as EO equivalents as the sum of native EO and 2-CE in 53 samples of dietary supplements used in the treatment of inflammatory bowel disease (IBD). 28 samples were obtained from local pharmacies and health food stores and 26 were purchased from the Internet. The dietary supplements analyzed in this work were in multiple oral dosage forms including tablets (6), hard capsules (25), soft capsules (4), powders (16) and liquid extracts (2). The main botanical ingredients included turmeric, Indian frankincense and green chiretta. The samples were analyzed using GC-MS/MS (model TQ8050, Shimadzu). In 25 samples (43%) EO and 2-CE were quantified in the range from 0.02 to 3.29 mg/kg. 2 samples (1 hard capsule and 1 tablet) contained levels higher than 1 mg/kg. This study provide reference for regulatory bodies to routinely control the quality of botanical dietary supplements and to prevent EO residues from jeopardizing patients' health.

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Single-step preparation of mixed metal oxides from heterometallic compounds

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The use of heterometallic complexes containing more than one metal as single source precursors provides a simplified synthetic route through one-step thermal decomposition to form the mixed metal oxides. The advantage of a solid phase transition is the retention of the elemental composition defined by the molecular precursor with only a loss of volatile decomposition products – allowing for excellent stoichiometric control of the intermetallic ratio in the oxide products. It is known that the release of organic gases affects the particle size and porosity of the produced oxide; as the content of organics in the starting materials is increased, the larger porosity and smaller particle sizes in the decomposition products are more pronounced. In addition, the impact of the temperature level and heating rate strongly correlates with the thermal decomposition and prevention of the melting/vaporization of molecular species that can occur by rapid heating. [1]

Mixed metal oxides have attracted much attention in energy conversion and storage applications due to their structural, physical and chemical properties, which can be easily tuned and optimized for the desired applications. To date, there is no photocatalytic oxide material that meets all the practical requirements for successful use in solar water splitting and environmental remediation (*e.g.*, dye degradation), such as high durability, optimal narrow band gap for full utilization of the entire solar spectrum, long lifetime of photogenerated electron–hole pairs, low cost, environmental friendliness, high efficiency and stability. In this sense, it is extremely important to develop a rational design by optimizing the existing synthesis strategies, which may consequently lead to well-organized and visible-light-driven photocatalysts with a long lifetime.

Various heterobimetallic compounds of different dimensionality prepared in our group were used to prepare spinel oxides $CuFe_2O_4$ and Co_2CrO_4 as well as $MnCrO_4$, based on the appropriate metal ratio by thermal treatment. [2] Heterometallic compounds do not always contain the suitable stoichiometry for the formation of the desired single phase mixed metal oxide. Therefore, we tested whether the bimetallic oxide $NiNb_2O_6$ could be prepared by mixing two different precursors in the appropriate ratio prior to thermal decomposition.

The phase formation and structural arrangement of the oxides obtained by a “molecular precursor-to-material” method were studied by a combination of thermal analysis (TGA and DTA) and powder X-ray diffraction, in addition to morphological characterization by scanning electron microscope imaging. The effects of the microstructural and morphological features of these oxide materials, which were studied as efficient photocatalysts for the photodegradation of the dye pollutants Rhodamine B and Methylene Blue, were evaluated by energy band gap calculations from UV-Vis absorption spectra.

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High selectivity of fluorescent (triazole)coumarin peptides to metal cations – fluorimetric and NMR approach

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The basis for the biological functioning of many proteins is the creation of metal complexes, [1] in which metals have structural and functional roles. [2] Our recently published paper shows some interesting nanomolar affinity of FKA(triazole) and KA(triazole) coumarin peptoids towards Cu^{2+} cations in water. [3] This prompted us to continue with further complexation studies using other metal cations. We performed fluorimetric titrations of FKA(triazole) and KA(triazole) analogues (Fig. 1. left) with different metal cations: Cu^{+}, Ag^{+}, Zn^{2+}, Co^{2+}, $Cd^{2+}$and Hg^{+}, experiments yielding micromolar binding constants in aqueous solution. The addition of Cu^{2+}, Cu^{+} and Ag^{+} resulted in pronounced quenching of the emission of KA(triazole) peptoid, compared to other studied metal cations. Using 2D NMR techniques (COSY, HSQC and HMBC), ^{1}H and ^{13}C chemical shifts of KA(triazole) ligand were successfully assigned. [3] In novel NMR spectroscopic study of KA(triazole) ligand complexation with Cu^{2+} in pure D_2O showed evident differences in chemical shifts and shape of some proton signals between KA(triazole) ligand and Cu^{2+}, also supported by the analogous results in the ^{13}C NMR data (significant shift of the triazole carbon C-5' signal). Detailed analysis of NMR data confirmed KA(triazole)/Cu^{2+} complex formation and allowed for the determination of structure of just one dominant type of complex between Cu^{2+} and KA(triazole) ligand (Fig. 1. right).

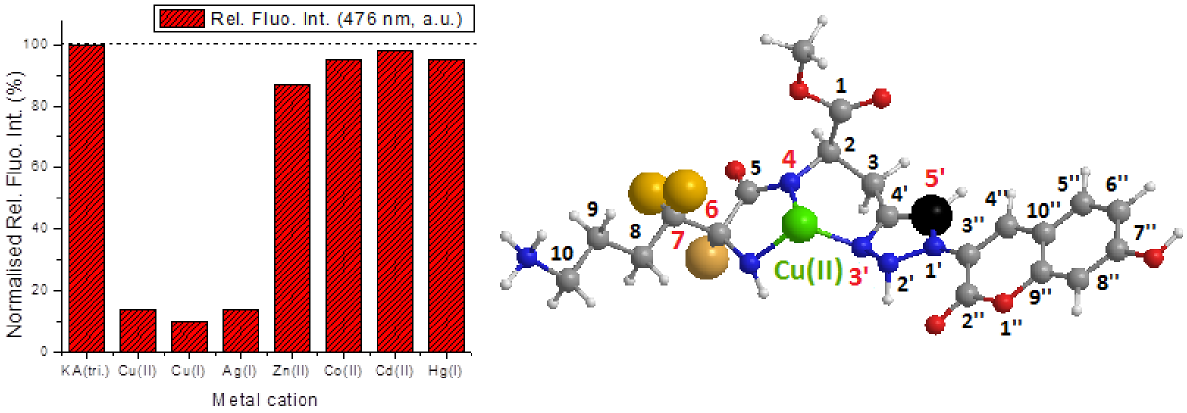

Fig. 1: Left: Comparison of fluorescence emission changes of KA(triazole) ligand (c = 1×10^{-8} M; λ_{exc}= 353 nm, λ_{em}= 476 nm, emission normalised to 100%) upon addition of various transition metal cations in 1000-fold excess (c = 1×10^{-5} M). Done at pH 7, sodium cacodylate buffer, I = 0.05 M. Right: 3D model of KA(triazole) ligand in complex with Cu^{2+} used for NMR data analysis; green: copper; yellow: protons that shift in ^{1}H NMR; black: carbon that shifts in ^{13}C NMR due to coordination of Cu^{2+}.

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Synthesis and antifungal activity of novel 1,2,4-triazolyl coumarins

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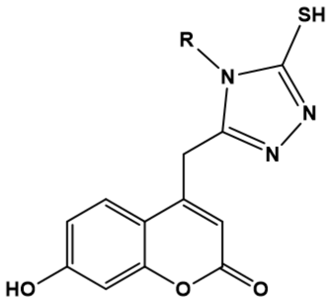
Coumarins and triazoles are two interesting groups of heterocyclic compounds, both exhibiting a wide range of biological activities. The joining of these two scaffolds into a hybrid compound with the improved activities has already been reported. [1] In this research, 11 new hybrid compounds were synthesized, utilizing a deep eutectic solvent as an environmentally sustainable method of organic synthesis. Compounds were obtained in good yields through a one-step reaction of coumarinyl hydrazides and various substituted isothiocyanates, without the use of catalysts. [2]

Since many commercially available fungicides are based on triazole derivatives, antifungal activity of 1,2,4-triazolyl coumarins was evaluated *in vitro* on two pathogenic fungi, *Fusarium oxysporum* and *Fusarium culmorum*. The tested compounds moderately inhibited the mycelial growth of *F. oxysporum* (35.0-57.5%), but were mostly ineffective against *F. culmorum*. Compound **1b**, as the most potent growth inhibitor, was further analyzed computationally. A molecular docking analysis was performed to evaluate the binding mode of compound **1b** with sterol 14 α-demethylase, the target enzyme of triazole based fungicides.



R: CH_3 (**a**); C_2H_5 (**b**); allyl (**c**); C_6H_5 (**d**); $C_6H_5CH_2$ (**e**); *p*-$CH_3C_6H_4$ (**f**); 3-$CH_3OC_6H_4$ (**g**); *p*-$CH_3OC_6H_4$ (**h**); 3-ClC_6H_4 (**i**); *p*-ClC_6H_4 (**j**); *p*-BrC_6H_4 (**k**)

1a-k

Fig. 1: General structure of tested 1,2,4-triazolyl coumarins.

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Exploring the cooper affinity toward the CrdA protein from *Helicobacter pylori*

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Adaptation of *Helicobacter pylori* to the conditions in the gastric mucosa involves acquisition mechanisms that can overcome a temporary lack of essential metal ions. Several proteins are involved in the transport of copper ions and in control of the concentration of free copper ions in the cytoplasm below toxic values. Among them are P-type ATPase CopA, [1] HP1326 (CrdA), HP1327 (CrdB), HP1328, and HP1329. [2] In this research we structurally characterized the CrdA protein from *Helicobacter pylori* (*Hp*CrdA) and we explored its binding affinity toward copper ions. CD measurements confirmed the major contribution of β-sheets in the *Hp*CrdA structure. The modeled *Hp*CrdA structure showed a conserved methionine-rich region, a potential binding site for Cu(I) (Fig. 1), as in the structures of similar copper-binding proteins, CopC and PcoC, from *Pseudomonas syringae* and from *Escherichia coli*, respectively. In contrast to CopC and PcoC, *Hp*CrdA contains two additional methionines and two glutamic acid residues (**M**MX**E**MPGMXX**M**X**E**M) in the conserved amino acid motif but lacks the canonical Cu(II) binding site (two histidine residues). Since the position of the methionine-rich site is in a flexible loop it can adopt different geometries for the two copper oxidation states. Based on the copper affinity studies we concluded that *Hp*CrdA binds copper in both oxidation states (I and II), but with different binding affinities, micromolar was found for Cu(II), and less than nanomolar was proposed for Cu(I).

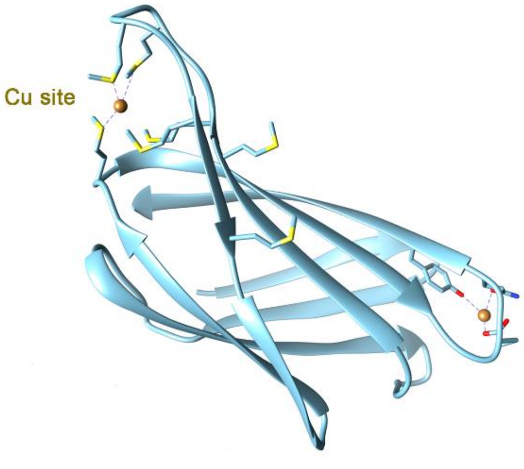

Fig. 1: Model of *Hp*CrdA with the hypothetical position of the Cu(I) and Cu(II) binding sites.

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Enhancement of Raman scattering on gold nanoparticles prepared in HEPES buffer

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Surface-enhanced Raman scattering (SERS) spectroscopy is very sensitive technique in which the intensity of scattered radiation is highly amplified, compared to normal Raman scattering, due to the adsorption of the analyte on rough metal surface. [1] Colloidal metal nanoparticles and nanoparticles immobilized on solid surfaces are most often used as substrates for SERS spectroscopy. Various compounds such as inorganic salts or buffers, used for the preparation of colloidal suspensions, can act not only as reducing agents for metal salts, but also as stabilizing agents, preventing oxidation and aggregation of metal nanoparticles. [2] Other substances, such as polymer molecules, can also be added to the colloids to stabilize the metal nanoparticles. [3]

In this work, the SERS efficiency and stability of gold colloids prepared by reduction of tetrachloroauric(III) acid with 4-(2-hydroxyethyl)piperazine-1-ethanesulfonic acid (HEPES buffer) were investigated using rhodamine 6G (R6G) and (E)-1,2-di(pyridin-4-yl)ethene (BPE) as model molecules. Colloids were synthesized in two ways using the "seedless" method. [4] In the first case, only the metal salt and buffer were mixed, while in the second synthesis, in addition to the metal salt and buffer, silver nitrate was also added. Silver nitrate is commonly used as a shape directing agent in gold nanoparticle synthesis procedures. For both prepared colloidal solutions, the influence of the addition of polyvinylpyrrolidone (PVP) on the stability of the metal nanoparticles and the enhancement of scattering were investigated.

In all prepared gold colloids, the strongest SERS effect was found for the BPE molecules, most likely due to their lack of charge and optimal structural features. Unlike BPE, charged rhodamine 6G molecules were electrostatically repelled from the gold surface by HEPES molecules, which stabilize the nanoparticles, and were located on the metal surface in the form of zwitterion. The addition of silver nitrate during colloid synthesis resulted in a more efficient SERS substrate, probably due to the formation of nanoparticles with different morphology, that scattered radiation more efficiently, compared to the colloid obtained only from metal salt and buffer. By introducing the polymer PVP into the system, a steric barrier was created between the nanoparticles and the analyte, so the obtained spectra of the model molecules showed very weak bands. However, such modified colloidal nanoparticles were more stable over the time, compared to freshly prepared gold colloids.

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Pyridine and amine-based porous organic materials with azo, azoxy and azodioxy linkages for selective CO_2 adsorption

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Global warming is one of the major problems today and has a negative impact on the environment. Compared to other greenhouse gases in the atmosphere, carbon dioxide (CO_2) has an additional side-effect because it also contributes to the acidification of the planet's oceans. Porous organic materials, such as covalent organic frameworks (COFs) and amorphous porous organic polymers have already been proven as versatile CO_2 adsorbents. Different functional and topological properties of the constituting building blocks (connectors) linked by various covalent bonds (linkages) allow for the tailoring of pores and gas adsorption properties of these materials. Recently, we have shown that results from the computational study can guide us in the development of new porous organic materials for selective CO_2 adsorption. [1,2] Among the six trisubstituted benzene and triazine-based connectors with azo, azoxy and azodioxy linkages, the porous systems with azodioxy bonds showed the highest CO_2 adsorption capacity. [1] In this study, we analyzed the effect of trisubstituted pyridine and amine-based connectors by three complementary computational approaches. The grand-canonical Monte Carlo (GCMC) simulations were performed on periodic DFT-optimized geometries of differently stacked layers (Fig. 1) and adsorption isotherms were calculated. These results, together with the calculated binding energies and the electrostatic potential maps, gave us valuable insight into the CO_2 adsorption capacity and CO_2/N_2 selectivity of porous organic materials with azo, azoxy and azodioxy linkages. The computational data were compared with the experimental results obtained for the newly synthesized pyridine-based derivative with azo linkages.

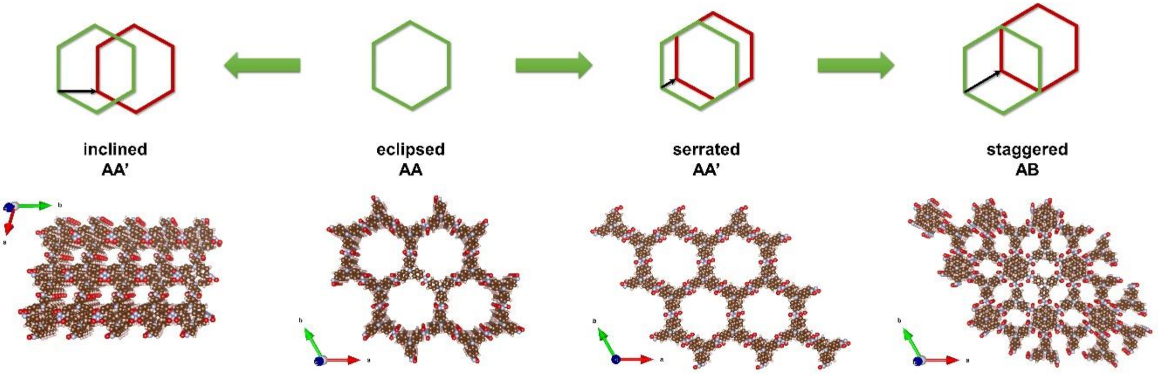

Fig. 1: Different types of stacking in 2D porous organic materials.

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Catalytic conversion of CO_2 into organic cyclic carbonates

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Carbon dioxide (CO_2) gas is considered as an abundant and renewable C1 synthon for the preparation of highly valued chemicals. [1] Catalytic CO_2 capture by propargylic substrates – alcohols or amines – affords α-alkylidene cyclic carbonates or carbamates, respectively. [2] Combination of CO_2 capture with C–C cross-coupling reactions may give direct access to complex products that otherwise require multistep syntheses. [3] Such transformations are particularly desirable because they follow the principles of green chemistry for atom and step economy. We are accordingly presenting, herein, Pd-catalyzed carboxylative intermolecular or intramolecular C–C cross-coupling reactions on various propargylic alcohol substrates (see Fig. 1). Our experiments are supported by calculations based on density functional theory (DFT) method, which show that these reactions are exergonic because of product stabilization through the formation of additional C–C bonds, thus overcoming the thermodynamic and kinetic inertness of CO_2 even under atmospheric pressure. Currently, our efforts are focused on the elucidation of the reaction mechanism.

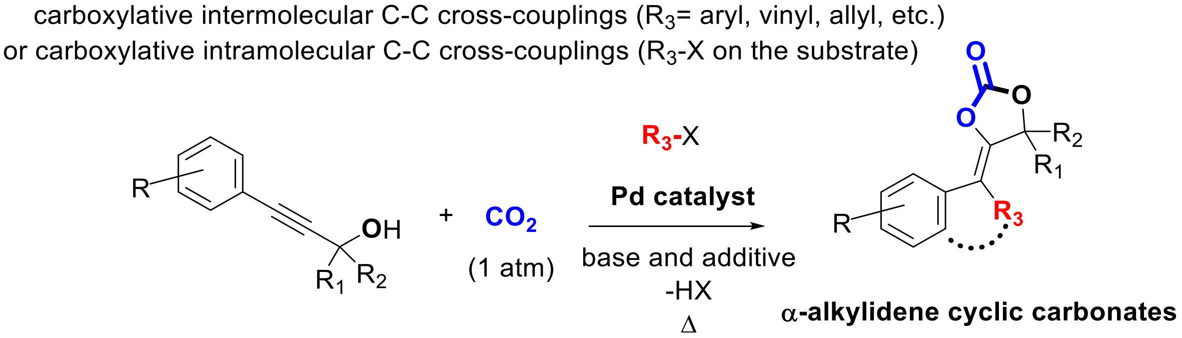
carboxylative intermolecular C-C cross-couplings (R_3= aryl, vinyl, allyl, etc.)
or carboxylative intramolecular C-C cross-couplings (R_3-X on the substrate)

Fig. 1: Catalyzed carboxylative C–C cross-coupling reactions between suitable propargyl alcohols and CO_2.

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Mechanochemical synthesis of quinazolinone Schiff bases in deep eutectic solvents

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The quinazolinone core is widely incorporated into the structure of numerous biologically active compounds. Nowadays, over 200 quinazolinone alkaloids were isolated from plants and microorganisms, but many synthetic routes have been developed. [1] Most of them utilize various organic solvents and catalysts leaving a significant environmental impact. Recently, we reported the synthesis of a series of quinazolinone Schiff bases by green methods in ethanol catalyzed by acetic acid. [2] The use of deep eutectic solvents in the synthesis represents a green media with ever-increasing applications.

In this work, quinazolinone Schiff bases were prepared by mechanochemical synthesis with the addition of choline chloride/malonic acid (1:1) as a solvent for liquid-assisted grinding. Initially, the model reaction was studied to establish the optimal reaction conditions such as reaction time, the volume of solvents and the number of milling balls. A series of Schiff bases was prepared by condensation of substituted 3-amino-2-methylquinazolin-4(3*H*)-ones with aromatic aldehydes (Figure 1). All prepared derivatives were successfully prepared and obtained yields were from 79 to 97%.

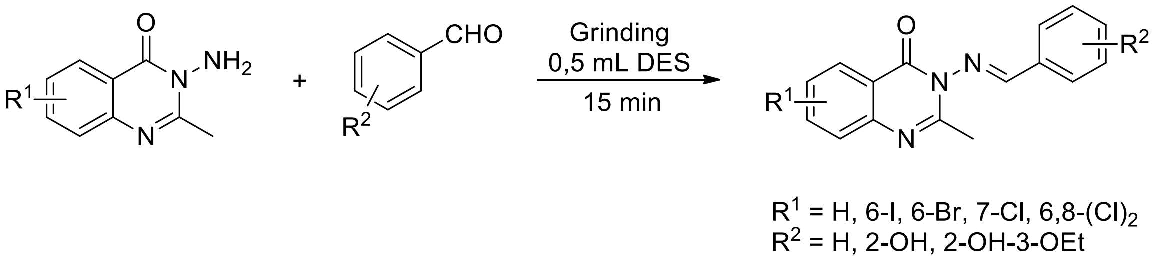

Fig. 1: Mechanochemical synthesis of quinazolinone Schiff bases.

Acknowledgement This work has been supported in part by the Croatian Science Foundation under the project *Green Technologies in Synthesis of Heterocyclic Compounds* (UIP-2017-05-6593).

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Stability of nanoparticles and their interactions with polyelectrolytes

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A very vital issue related to the application of various types of nanoparticles is a requirement for obtaining a stable dispersion. [1] Due to the large specific surface area, nanoparticles tend to agglomerate over time which results in a separation of the dispersed phase from the continuous phase. One of the most promising tools for stabilization of nanoparticles is the adsorption of polyelectrolytes. The influence of polyelectrolytes on the stability of nanoparticles was explored in our study [2] where the interactions of ceria nanoparticles with a strong polyanion, sodium poly(4-styrenesulfonate) were examined. For the interpretation of the experimental results obtained in our study we applied the electrophoretic soft particles model, the so called modified Ohshima model, based on the measurements of mobility of nanoparticles coated with a polyelectrolyte layer. The interpretation of the results leads to the value of the electrophoretic softness (*i.e.* the softness of the polyelectrolyte layer) of $1/\lambda = 3.03$ nm, while the charge density of the polyelectrolyte is equal to $ZeN = -0.032$ mol dm^{-3}. Finally, on the basis of performed experiments and calculations the adsorption density of polyelectrolyte adsorbed on ceria nanoparticles was found to be $\Gamma = (5.42 \pm 2.73)$ mg m^{-2}.
The results obtained for adsorption of polyelectrolytes on flat surfaces could also lead to the better understanding of the polyelectrolyte adsorption on nanoparticles. Therefore, we additionally studied the adsorption of PDADMA cations and PSS anions on Ti/TiO_2 surface and a stable polymeric nanofilm that partially covers the surface was formed, without significant impact on the surface roughness. [3] The obtained corrosion protection effectiveness values indicated that the corrosion properties were greatly enhanced upon polyion adsorption and polyelectrolyte coating formation on the flat TiO_2 surface. The obtained results were additionally confirmed by inner surface potential measurements. The importance of presented adsorption experiments combined with appropriate interpretation lies in possible predictions of the behaviour of nanoparticles in polyelectrolyte solutions. Such findings could enable the preparation of suspensions having satisfactory stability which could lead to the improved applications of nanoparticles in various research fields.

Acknowledgement This research was supported by the Croatian Science Foundation (HRZZ) under the project IP-2020-02-9571.

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Hydrogen bonding patterns in ferrocene tripeptides

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To achieve the desired biological activity of synthetically produced peptides, several properties are important, such as peptide hydrophobicity, net charge, amphipathic nature, and secondary structure. [1] The secondary structure of ferrocene-derived peptidomimetics can be tuned by the number and type of constitutive amino acids, modification of their chirality, and bulkiness of *C*- and *N*-protecting groups, starting from the choice of ferrocene backbone: ferrocene amino acid (Fca) or symmetrically disubstituted ferrocene diacid (−OC−Fn−CO−) and diamine (−NH−Fn−NH−). Our study of ferrocene diamine derived peptides started with Y-Ala-NH-Fn-NH-Ala-Y (**Ia**, Y=Ac, Boc) and was extended by the preparation of their homologues Ac-AA-NH-Fn-NH-AA-Boc (**Ib**, AA=Val, Leu, Phe). [2-5] To find out how the side chain of amino acids affects the pattern of hydrogen bonding, we decided to replace an Ala residue with hydrophobic L- and D-amino acids (Leu, Val and Phe) to generate peptidomimetics **II** (Fig. 1). To investigate whether the dipeptides **II** adopt ordered conformations supported by IHBs in solution, we performed IR, NMR and CD spectroscopic studies.

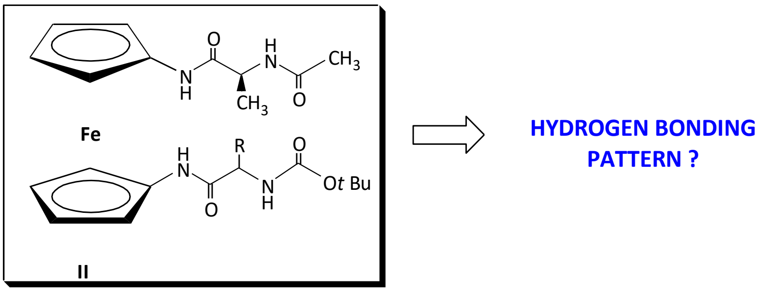

Fig. 1: Ferrocene tripeptides **II** [$R_a = -CH(CH_3)_2$, $R_b = -CH_2CH(CH_3)_2$, $R_c = -CH_2Ph$].

Acknowledgement This work has been fully supported by the Croatian Science Foundation under the project IP-2020-02-9162.

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Chemical proteomics approach for detection of potential off-targets associated with the EGFRi erlotinib

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The process of identifying the protein targets and off-targets of a biologically active compound is of great importance in modern drug discovery. Various chemical proteomics approaches have been established for this purpose. The main advantage of the chemical proteomics approach is the isolation and identification of proteins targets from the cellular environment, in which protein conformations, post-translational modifications and protein complexes are preserved. [1,2] To compare the different approaches, and to understand which method would provide the best results, we have chosen the epidermal growth factor receptor (EGFR) inhibitor erlotinib [3] as an example molecule. Erlotinib derivatives were designed using linkers with motifs, including amino (amidation) and the diazirine group (photo-affinity). Alkyne functionality that was originally present on the molecule was preserved and erlotinib was used as a control molecule. The modified erlotinib analogues were tested *in vitro* to determine their effectiveness in inhibiting the biological target (EGFR) and were subjected to the interaction with the cell lysate with or without UV irradiation depending on the applied chemical proteomic technology. Bound proteins were isolated from cell lysates and identified by mass spectrometry. Experiments have confirmed that chemical proteomics technology can identify the biological target since the identified protein with the modified molecules was EGFR. In addition to these expected results that validate the method, several new proteins were identified that may be potential biological targets for erlotinib. Future work will involve validation of those proteins as new- or off-targets of erlotinib with various biochemical and cellular assays.

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Oral dosage testing of dietary supplements used in the treatment of IBD according to the United States Pharmacopeia

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As the number of patients with inflammatory bowel disease (IBD) that use dietary supplements (DS) continues to increase in many countries, the importance of ensuring product quality is of scientific matter. Regulators, health professionals and manufacturers often disagree on how much quality testing is necessary for DS. This is highlighted by the World Health Organization's Strategy on Traditional Medicines 2014–2023 [1] where quality is seen as a basis of the DS sector. The United States Pharmacopeia (USP) is an independent, nonprofit, science-based organization whose mission is to improve human health through quality standards and tests for DS. [2]

The aim of this research was to perform oral dosage testing based on USP protocols of botanical DS used in the treatment of IBD.

53 samples tested were in multiple oral dosage forms: tablets, hard capsules, soft capsules, powders, and liquid extracts. The following test were performed: Tapped Density <616>, Loss on Drying <731>, Tablet Friability <1216>, Tablet Breaking Force <1217>, Weight Variation <2091>, and Disintegration <2040>. The tests were performed using tapped density testing instrument (PT-DT300), tablet friability test instrument (PTF 100), and tablet disintegration tester (PTZ-S) by Pharma Test (Germany), tablet hardness tester (TBH 125) by Erweka (Germany) and moisture analyser (DBS 60-3) obtained by Kern & Sohn GmbH (Germany).

The lowest tapped density was found for turmeric (CI 25%) and the highest for green chiretta (CI 45%). Tablet breaking force was in the range from 27.7 to 248.5 N. One sample containing black pepper as a botanical ingredient did not meet requirements of loss on drying test (5.2%). All investigated tablets met the requirements of friability test expressed in terms of allowable weight loss (≤0.61%). Investigated tablets and capsules met requirements of the weight variation test expressed in terms of the allowable deviation from the average weight of sample (≤7.7% tablets, ≤9.0% capsule). Only one sample did not meet requirements of disintegration test as none of investigated 6 tablets had not disintegrated under specified conditions.

The challenges in DS science and its regulation provide new opportunities for scientists and regulators to work together both nationally and internationally, and to cooperate to improve public health. Assessments of the quality of DS are needed to provide the scientific information that regulators need.

Acknowledgement This research was funded by the Croatian Science Foundation (UIP-2017-05-3949 and DOK-2021-02-7922), and the European Regional Development Fund (KK.01.1.1.02.0021).

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Novel 7-chloro-4-aminoquinoline-benzimidazole hybrids as inhibitors of cancer cells growth

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Both benzimidazole and quinoline are found in various biologically active compounds. [1,2] As a part of our ongoing efforts [3,4] to prepare novel 7-chloro-4-aminoquinoline hybrid compounds, herein we present synthesis of 23 novel quinoline-benzimidazoles which were evaluated on one non-tumor (MRC-5) and five tumor cell lines (HeLa, CaCo-2, HL-60, THP-1, and HuT78). Results revealed that non-amidine compounds have strong, albeit not selective, antiproliferative activity against all the cell lines, with GI_{50} ranging from 1 to 10 µM. Cyclopentyl-amidine derivatives have shown to be more selective with moderate to strong activity against leukemia and lymphoma tumor cell lines.

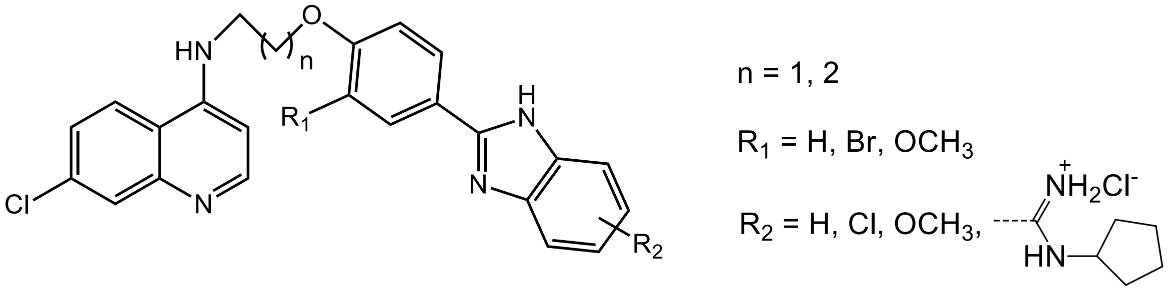

Fig. 1: Novel quinoline benzimidazole hybrids.

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Describing G-quadruplex DNA stability phase space

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We normally associate the DNA molecule with the famous Watson-Crick double helix structure. However, certain G-rich sequences can form quite different non-canonical DNA structures, called G-quadruplexes (G4), which consist of stacked guanine tetrads stabilized by cation coordination. Although G4s were first identified at chromosome ends in telomeric regions, most G-rich DNA sequences occur in the context of double-stranded DNA. G4s form transiently in gene promoter regions and contribute to transcription regulation. G4 formation and thus transcription regulation can be modulated by specific binding of small molecule ligands. Characterization of the binding of G4-directed ligands is therefore of greatest interest. The structural polymorphism of G-quadruplex nucleic acids is an important factor in their recognition by proteins and small-molecule ligands. However, it is not clear why binding of several ligands alters G-quadruplex topology. We addressed this question by following the (un)folding and binding of the human telomeric DNA fragment by calorimetry (DSC, ITC) and spectroscopy (CD). Thermodynamic analysis of the obtained data led to a detailed description of the topological phase space of stability (phase diagram) of the DNA fragment and shows how it changes in the presence of a specific ligand. Various 1:1 and 2:1 ligand-quadruplex complexes were observed. With increasing temperature, the 1:1 complexes transformed into 2:1 complexes, which can be attributed to the preferential binding of the ligand to the folding intermediates. Overall, the dissection of the thermodynamic parameters in combination with molecular modelling clarifies the driving forces of the topological quadruplex transformations in a wide range of ligand concentrations and temperatures. [1-5]

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API cocrystal formation: Evaluation of COSMOtherm predictions

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After 2011, when the Food and Drug Administration (FDA) released guidance concerning regulatory classification of pharmaceutical cocrystals of active pharmaceutical ingredients (APIs), the interest of pharmaceutical companies in cocrystals began to increase exponentially. Accounts of cocrystal investigations in the literature started in earnest in 2003 and patent applications soon followed. [1] Screening of suitable coformers for active pharmaceutical ingredients is the most crucial and challenging step in cocrystal development.

In this work, COSMOtherm software calculations were utilized for selection of appropriate coformers for a chosen API. Although in principle a cocrystal is defined in solid state, it has been shown that the tendency of a given API to form cocrystals with a coformer is strongly correlated with energetic properties of the liquid mixture of the API and coformer. The excess enthalpy, H^{ex} (a major factor for H-bonding interactions) between API and coformer mixture as compared to pure components reflects the tendency of those two compounds to cocrystallize. [2]

Even though cocrystal formation predictions are becoming more accurate, it is still down to their preparation and characterization for definitive proof of the actual solid state chemistry. We have successfully prepared several cocrystals and salts of an API using different methods: mechanochemistry, solution crystallization or slurry (Figure 1).

All prepared cocrystals and salts were characterized using crystallographic, spectroscopic and thermal analysis techniques enabling definitive characterization of prepared compounds. Obtained data allowed for the evaluation of COSMOtherm software predictions.

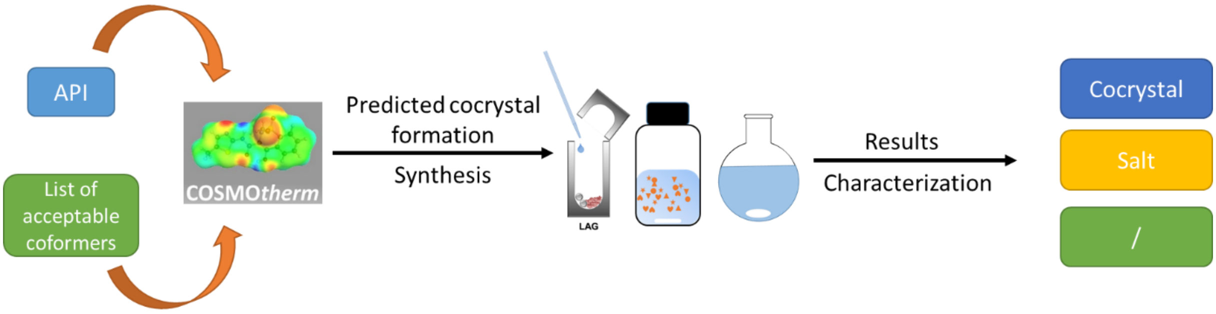

Fig. 1: Flow chart for API cocrystallization experiments.

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Synthesis and biological evaluations of ferrocene-pyrimidine hybrids

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Conjugation of organometallic fragments to a biologically active scaffold has been shown as an excellent strategy for improving the efficacy of drugs and reducing their toxicity. In this regard, ferrocene is a popular choice as bioisosteric group due to its stability and well-understood reactivity and electrochemistry. [1] In the search for bioorganometallic systems with an extended conjugation, our group's previous research has produced new ferrocenyl-nucleobase hybrids with a carbonyl bond between the heterocyclic and organometallic moieties. The synthesis of ferrocenoyl copulates is based on the acylation of nucleobase anions with ferrocenoyl chloride in DMF, where the ferrocenoylation reaction of pyrimidine bases is regiospecific and only the *N*1 product is formed. [2] However, in the case of purine derivatives, the substituents on the exocyclic amino group of adenine were shown to affect the reactivity of the corresponding purine anion and determine the regioselectivity of the reaction, leading to the formation of *N*7 and *N*9 isomers. [3] In continuation of the research, a model reaction with uracil was performed to test the reaction regiospecificity in the formation of ferrocene-pyrimidine copulates (Figure 1). After optimizing the reaction conditions, we will focus on investigating the effects of substituents (electron donor or electron acceptor group) at the C-5 position of uracil on the formation of copulates. The position of the substitution in the products will be explored by spectroscopy methods. In order to evaluate the biological potential of synthesized compounds, their influence on specific immune response in mice was tested. The results suggest that examined compounds enhance the production of antigen-specific antibodies and have potential to be used in immune-mediated diseases.

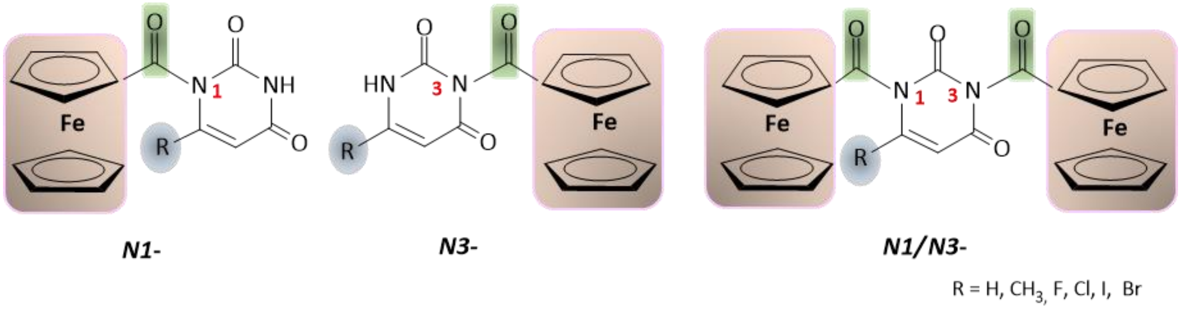

Fig. 1: Structure of *N*1-, *N*3- and *N*1/*N*3- ferrocene-pyrimidine copulates.

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Photoheterolysis reactions of meta-substituted aminonaphthalene photocages

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Photocages are protecting groups that undergo release of a target molecule in a photochemical reaction, activating its function. To date, a scant number of models have been provided that relate the reactivity and structure of photocages undergoing excited-state heterolytic bond cleavage, in contrast to the ground-state reactivity. [1] Winter suggested a hypothesis for the structure-reactivity relationship for the excited state heterolysis, which takes place under conical intersection control. Unstabilized cations favored from photochemical heterolysis were found to have low-energy conical intersections, while stabilized cations from thermal heterolysis have high-energy unfavorable conical intersections. [1]

Based on the *meta*-effect in photochemistry, [2] a series of aniline derivatives were investigated as photocages for carboxylic acids and alcohols. [3] Furthermore, to enable excitation by photons of lower energy, we developed a series of differently substituted aminonaphthalene derivatives as potential photocages for alcohols and carboxylic acids. [4] We found out that *ortho*-derivatives show excellent performance in decaging carboxylic acids; the photorelease from 2,3-substituted photocages takes place more efficiently (acetate elimination, Φ=0.11), than from 1,2-substituted photocages (acetate elimination, Φ=0.01). [4] However, these *ortho*-derivatives did not show good performance as photocages for alcohols. In accordance with the *meta*-effect, [2] it was expected that the *meta*-derivatives would show even better photodeprotection efficiency compared to the *ortho*-derivatives. Herein we present synthesis and photochemistry of 3,1-substituted aminonaphthalene photocages. We have shown excellent performance of the ester derivative in the decaging of carboxylic acids (acetate elimination, Φ=0.22). Furthermore, ethers also undergo photoelimination of alcohols, albeit less efficiently (Figure 1).

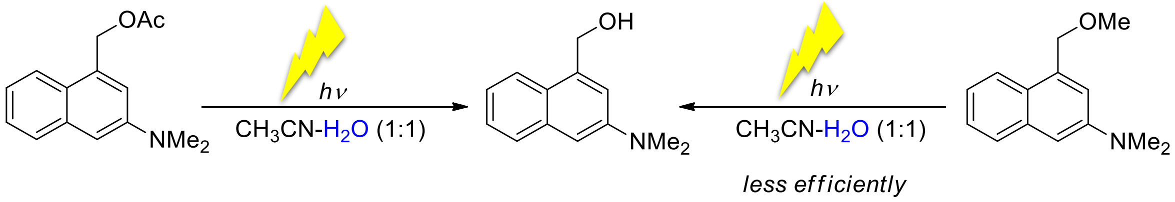

Fig 1: The photolysis of *meta*-substituted aminonaphthalene photocages.

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The signature of inverse hexagonal phase of phosphoethanolamine lipids

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The compositional variations of lipids in the myelin sheath are responsible for nerve conduction failure and neurodegeneration that may ultimately result in demyelinating diseases such as multiple sclerosis (MS). [1] A significant enhancement of phosphoethanolamine (PE) lipids in myelin at pathological conditions is presumably associated with a greater probability that PE lipids, besides forming lamellar (L_β/L_α) structures, can be arranged in nonlamellar inverse hexagonal phase (H_{II}) that structurally resembles to the vacuoles, similar to those caused by demyelination. [2] When 1-palmitoyl-2-oleoyl-*sn*-glycero-3-phosphoethanolamine (POPE), as one of the most common lipids in myelin membrane, is suspended in water, along with L_β/L_α phases POPE can also form H_{II}, distinguished by inverted lipid cylinders with the polar headgroups of lipids facing the water surroundings. The transition from lamellar to nonlamellar phase is a function of temperature, hydration, and the ionic concentration of the aqueous medium. [3] The structural arrangements and phase transition of POPE lipids suspension in a phosphate buffer (pH = 7.4) will be examined with FTIR and UV/Vis spectroscopy along with differential scanning calorimetry (DSC). The differences in the thermotropic behavior of POPE-based unilamellar (LUV) and multilamellar (MLV) liposomes will be analyzed and compared with the additional use of appropriate chemometric tools. [4]

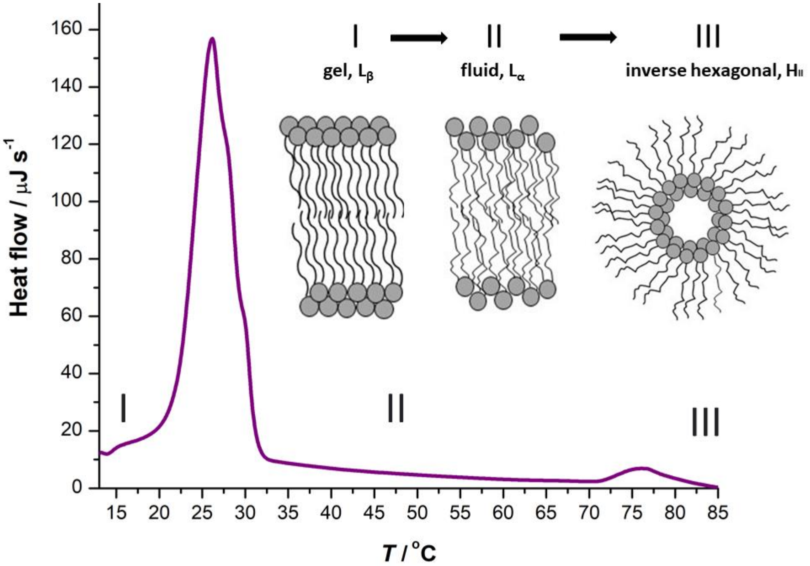

Fig. 1: DSC heating curve of POPE-based multilamellar liposomes (MLV) with indicated phases (L_β –L_α –H_{II}).

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ZnO and CuO nanomaterials for antibacterial application

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In daily life viruses and bacteria pose a serious threat to public health. Their structure allows them to bind on different surfaces and they can be spread by touching the contaminated surfaces. Due to remarkable characteristics and properties, metal nanoparticles (NPs) are recognized as promising agents for battling viruses and bacteria. [1,2] Currently, CuO and ZnO NPs are in research focus for antibacterial and antiviral applications. As microelements in the human body, they are both biocompatible and interesting for daily application.

The overall aim of the research was to prepare CuO and ZnO NPs with different sizes and morphology and to determine their characteristics. As well, the aim was to use the prepared NPs for coating different surfaces (textile materials, Teflon and stainless steel) and to determine the change in the surface properties after the treatment.

The NP synthesis was conducted in an aqueous solution, and the NP composition was determined by FTIR and PXRD analysis. The morphology of the NPs was determined with SEM, while the NP surface charge was determined by a particle charge detector. Contact angles and zeta potential of the textile, Teflon and stainless steel materials with and without nanoparticles were determined. The results showed that nanoparticles with different sizes and morphology (Fig. 1) exhibit different surface properties and change the properties of treated surfaces. As well, they showed promising antibacterial activity.

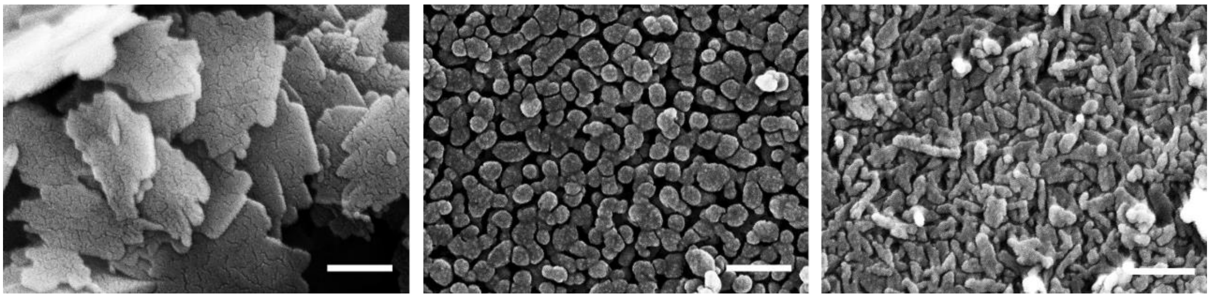

Fig. 1: CuO nanoparticles with different sizes and morphology. The scale bar is 200 nm.

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Organocatalytic synthesis of isoindolinone derivatives containing 3-alkyl tetrasubstituted stereogenic center

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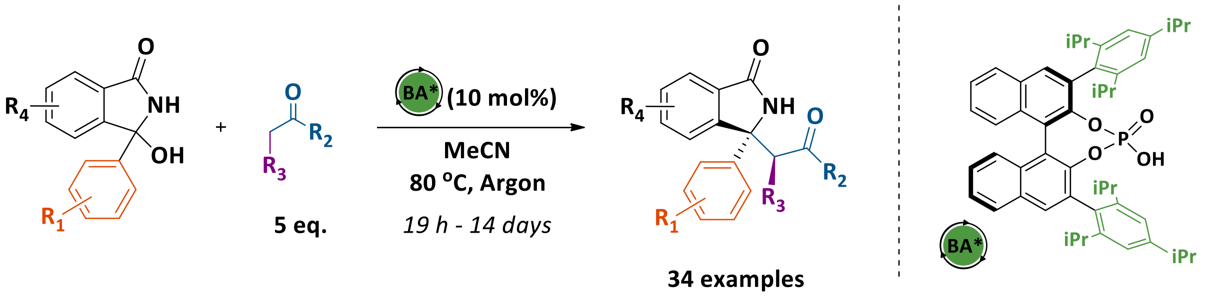
The 3-alkyl isoindolinone structure featuring a tetrasubstituted stereogenic center is a common motif in natural and biologically active molecules. [1] Strategies for the construction of such stereocenters in isoindolinones typically involve addition of non-aromatic carbon nucleophiles – enones [2], *N*-acetyl enamides [3] and difluoroenoxysilanes [4] – in the stereoselective Mannich-type reactions. However, current methods for creating these stereocenters in isoindolinones have limitations, such as difficulty in generating vicinal stereogenic centers and controlling their diastereo- and enantioselectivity.

Herein, we present a chiral phosphoric acid-catalyzed addition of ketone enols to *in situ* generated *N*-acyl ketimines for the construction of 3-alkyl tetrasubstituted stereogenic center in isoindolinones. [5] The developed methodology was also successfully employed for the preparation of compounds with vicinal stereocenters. The transformation is tolerant to a wide range of ketones and ketimines, and products are obtained in high yields and enantioselectivities, as well as high diastereoselectivities (where applicable). The reaction was performed on a larger scale, and selected products successfully underwent post-modification transformations. The mechanism of stereochemical induction is also discussed.



34 examples

35-98% yield
up to >20:1 d.r.
up to >99:1 e.r.

Fig. 1: Stereoselective synthesis of isoindolinone derivatives with a tetrasubstituted 3-alkyl stereocenter.

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Bioprospecting of the Adriatic coral *Eunicella cavolini*

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Eunicella cavolini (Koch, 1887) generally recognized as yellow gorgonian, is a species of colonial soft coral in the family Gorgoniidae. Although it is common in the Mediterranean basin, the evaluation of biological potential of *E. cavolini* from the Adriatic Sea has not been performed yet. Taking this into account, as a part of our Center of excellence for Marine Bioprospecting of Adriatic Sea BioProCro, we have studied the chemical composition and biological activities of this gorgonian. [1] In this contribution, we will discuss the results of screenings of the antiproliferative, antibacterial, antioxidant, and anti-inflammatory activities of organic extracts and corresponding semipurified fractions. Additionally, we will show data concerning antiproliferative activity against four cancer cell lines and one non-transformed cell line, as well as its anti-inflammatory potential concerning the successfully isolated pregnane type steroid by employing dereplication methods.

In final, we will present the synthesis of granulatamide B [2] isolated from the coral species of the *Eunicella* genus and its 12 derivatives by employing Fürstner's Fe-catalyzed C–C coupling reaction. [3] The obtained small compound library of these *N*-acyl tryptamines differing in the number of C-atoms, saturation degree and conjugation of double bonds, were evaluated towards the formation and development of zebrafish *Danio rerio* embryos. [4]

Acknowledgement We would like to thank the Croatian Government and the European Union (European Regional Development Fund—the Competitiveness and Cohesion Operational Program – KK.01.1.1.01) for funding this research through the project *Bioprospecting of the Adriatic Sea* (KK.01.1.1.01.0002) granted to The Scientific Centre of Excellence for Marine Bioprospecting – BioProCro. We also acknowledge the project *Research Infrastructure for Campus-based Laboratories at University of Rijeka*, co-financed by the European Regional Development Fund (ERDF) and the University of Rijeka research grants UNIRI-prirod-18-102 and UNIRI-biomed-18-133. We would like to thank the Croatian Science Foundation program Career Development of Young Researchers-Training of New PhDs' for funding PhD of D. Matulja and research project IP-2019-04-8846.

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Effect of divalent cations on formation and properties of polyelectrolyte nanofilms: Robot side of the story

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Polyelectrolytes are macromolecules consisting of a repeating sequence of subunits that have an electrolyte group that can be charged in solution. According to the charge they are divided into polycations, polyanions and polyampholytes, while according to the degree of dissociation in solution, they are divided into strong and weak polyelectrolytes. Polyelectrolyte multilayers are films formed by alternating adsorption of polycations and polyanions on a surface, most often using the layer-by-layer method. [1] The properties of the film depend on the experimental parameters such as used polyelectrolytes, type of substrate, ionic strength and type of background salt. [2,3] In this study, we investigated how the type of divalent cation present in deposition solutions affects the formation and properties of multilayer prepared from poly(diallyldimethylammonium chloride) and poly(sodium 4-styrenesulfonate). The examined cations were Mg^{2+}, Ca^{2+}, Sr^{2+}, Ni^{2+}, Zn^{2+} and Cu^{2+}. Ellipsometry was used for monitoring the growth of the films up to ten layers, while atomic force microscopy was used to determine morphology and surface roughness. The change in surface wettability during polyelectrolyte adsorption was monitored by tensiometry. The thickness, roughness, and wettability of films prepared in the presence of transition metal cations were not significantly different. In contrast, these properties differed for multilayers prepared in the presence of alkaline earth metal cations.

To examine if the observed conclusions about the ion-specific effect persist for polyelectrolyte multilayers with a greater number of layers, films of 30 layers were prepared with layer-by-layer deposition robot. Again, it was shown that the thickness, roughness and wettability of films prepared by the robot, in the presence of transition metal cations, were not significantly different while these properties varied for multilayers prepared in the presence of alkaline earth metal cations. Therefore, an ion-specific effect was observed for alkaline earth metal cations but not for transition metal cations.

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Resveratrol hybrids as cholinesterase inhibitors and antioxidants: Synthesis, bio-metal chelating capability and computational study

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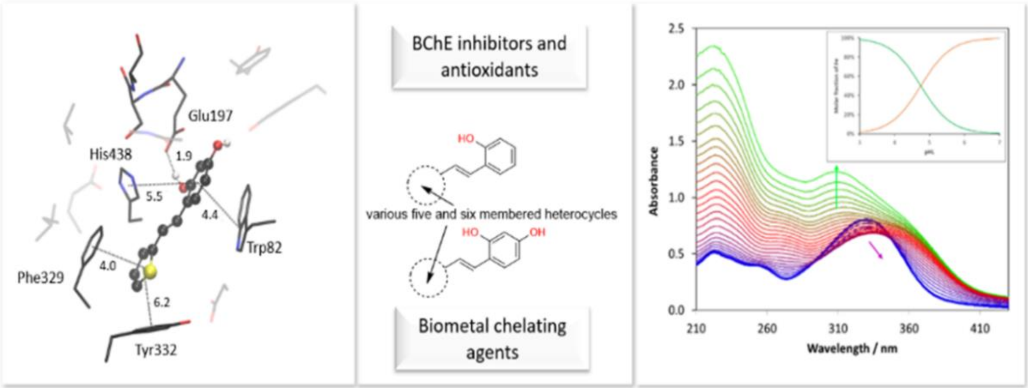
Enzymes acetyl- (AChE) and butyrylcholinesterase (BChE) are pharmacologically relevant targets in neurodegenerative diseases, and today's treatment includes cholinesterase inhibitors such as donepezil, galantamine, *etc*. [1] As antioxidant *trans*-resveratrol plays an important role in neurodegenerative disorders such as Alzheimer's disease, we synthesized resveratrol-thiophene and resveratrol-maltol hybrids and evaluated their antioxidative and inhibitory potential toward cholinesterases. [2] Similar to results obtained by photostability experiments, biological tests also found significant differences in the properties and behavior of thiophene and maltol hybrids. While resveratrol-thiophene hybrids have shown excellent inhibitory and antioxidant properties comparable to the activity of reference drug galantamine, maltols have been proven weaker inhibitors and antioxidants. Structures obtained by molecular docking study showed that thienyl and phenyl present in tested molecules readily participate in π-π stacking interactions with aromatic residues of the active site of both cholinesterases, resulting in stable ligand-enzyme complexes. The maltols that proved to be active cholinesterase inhibitors were able to coordinate Fe^{3+} ion, forming complexes of 1:1 composition. In further research, new heterocyclic resveratrol hybrids are synthesized to improve inhibitory and antioxidant activity and complexation with biometals.



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Optimization of separation of six anticancer drugs by micellar electrokinetic chromatography-tandem mass spectrometry using a volatile surfactant

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Micellar electrokinetic chromatography coupled with tandem mass spectrometry (MEKC-MS/MS) is a powerful technique for various applications due to its ability to analyze a wide range of compounds in a highly efficient and environmentally friendly manner. On the other hand, there is an unmet need for therapeutic drug monitoring of breast cancer drugs. There are some LC-MS/MS methods reported for the simultaneous determination of abemaciclib (ABE), ribociclib (RIB), palbociclib (PAL), anastrozole (ANA), letrozole (LET) and fulvestrant (FUL). [1,2] However, here we report an optimization of separation for these drugs' first-ever MEKC-MS/MS method. Separation was obtained using a volatile, MS-compatible surfactant ammonium perfluorooctanoate (APFO). Optimization of separation was performed by testing APFO concentration (75-150 mM), pH of the running buffer (9.0-10.5), a fraction (20-40%) and type (MeOH, EtOH, AcN, i-PrOH, THF) of organic modifiers in the running buffer, voltage (20-25 kV), capillary temperature (20-30 °C), duration of hydrodynamic injection (5-50 s) and hydrodynamic pressure during the analysis (0-100 mbar). Higher APFO concentrations yielded better resolution until 125 mM after which resolution worsened and the capillary current exceeded the recommended 50 µA. With the increase of pH of the running buffer separation improved. Among the organic modifiers, MeOH was shown to be the best for both separation and peaks' shapes and symmetries. The addition of other organic modifiers resulted in deteriorated separation, possibly due to the interference with micelle formation. Higher hydrodynamic pressure during the analysis shortened each run without the loss of resolution. Voltage and capillary temperature did not affect separation significantly so starting values were chosen as a compromise between run time and capillary current. Optimal separation conditions were thus shown to be 125 mM APFO in 32% methanol with an apparent pH of 10.5, a capillary temperature of 30 °C, separation voltage of 25 kV, hydrodynamic injection of 30 s under 50 mbar and hydrodynamic pressure during the analysis of 100 mbar. Additionally, the sweeping on-line preconcentration of analytes was performed by dissolving the analytes in 32% MeOH, but without the micellar pseudo-stationary phase. With this approach we have achieved that the negatively charged micelles from the running buffer penetrate the sample zone and "sweep" the analytes, thus concentrating them in a narrow band inside the capillary. In further studies, the MS ion source will be optimized for this method and the method will be validated for its intended purpose.

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Affinity of linear and cyclic peptides towards bivalent cations

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During the last few decades there has been a growing interest in studying cyclic peptides due to their metabolic stability and high bioavailability. These compounds also exhibit enhanced binding affinity and selectivity towards substrates compared to their more flexible linear analogs. The main problem in the synthesis of cyclic peptides is the conformational reorganization, that is, the ability of a linear precursor to bring its reactive termini in the close spatial proximity. This reaction step, called macrocyclization step, requires template molecules amongst which the most usually used are cations and anions. Previous papers suggested cations binding to linear peptide to promote cyclization, [1] but our recent work has shown that in the case of smaller peptides not cations but anions bind to linear and cyclic peptides and can induce macrocyclization. [2-4] The larger hexapeptide shows high affinity towards bivalent cations and forms complexes of different stoichiometries. [5] In this work, we determined stability constants of complexes of linear (**L1**) and cyclic (**L2**) phenylalanine derived peptides (Figure 1) with bivalent cations using ^{1}H NMR and fluorescence spectroscopy. In addition, we performed MD simulations to get an insight into the structural characteristics of the complex species.

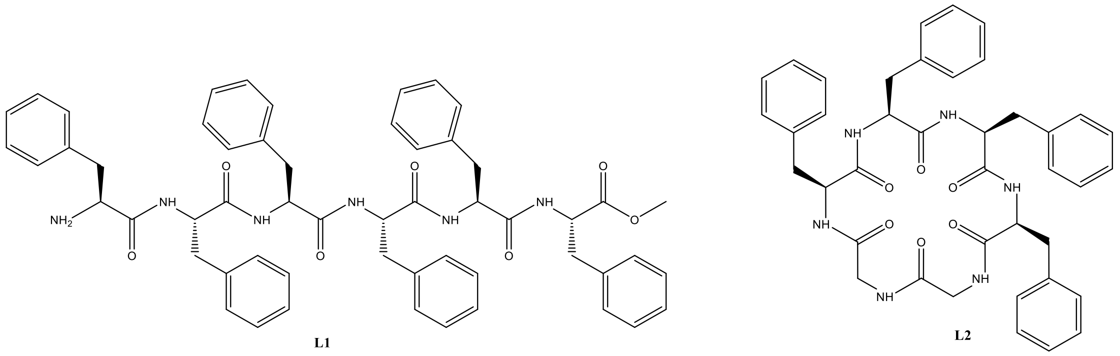

Fig. 1: Structures of peptides **L1** and **L2**.

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Charge transfer between transition metal and quinone through a π-hole interaction

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π-hole interactions involving metal-bound electron donor are studied for the first time on four isomorphous co-crystals of [Cu(terpy)Cl*X*] (terpy = 2,2′:6′,2′′-terpyridine; *X* = Br, I) and perhalogenquinone X'_4Q (*X*' = Cl, Br). Close contact between the halide *X* from [Cu(terpy)Cl*X*] and the quinoid ring (Fig. 1) has a geometry similar to those observed previously for free halides. [1,2] This is a $n \rightarrow \pi^*$ interaction [3] with a partial charge transfer from the halide to the quinone. Therefore, it weakens the Cu–*X* bond: in [Cu(terpy)ClI]·Cl_4Q the length of Cu–I bond is 2.844 Å, which represents an elongation of 0.18 Å.

The extreme elongation indicates charge transfer from the Cu-*X* bond to the quinone, which then has a partial semiquinoid radical character. This is corroborated by EPR spectroscopy: two signals are observed, one corresponding to Cu^{2+} cation (g = 2.0067), the other to a semiquinone radical (g = 2.00263). Their intensities ratio is 50:1, so the degree of charge transfer is estimated to 2%. For comparison, the degree of charge transfer between an uncoordinated iodide and tetrabromoquinone is in the range 8-11%. [3]

A weaker π-hole interaction between Cl atom of the complex and a symmetry-equivalent quinoid ring (Fig. 1) helps forming π-hole-bonded chains parallel to [100]. Since the crystals grow as rods extended along the *a* axis, electric contacts could be attached to a single crystal, allowing for the study of electrical properties by impedance spectroscopy. The compounds are weak semiconductors: room-temperature DC conductivity of [Cu(terpy)ClI]·Cl_4Q is 10^{-7} S cm^{-1}. This is the first documented case of conductivity through a π-hole interaction and shows that it may find use in materials chemistry.

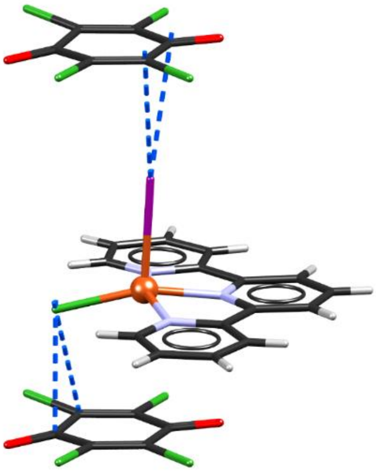

Fig. 1: Short halogen-quinone π-hole contacts in [Cu(terpy)ClI]·Cl_4Q.

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Synthesis and characterization of thioamide pentacyanoferrate(III) complexes

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Cyano complexes have played an important role in the chemistry of coordination compounds since the discovery of Prussian blue in 1704. Mononuclear cyanometallates serve as valuable starting materials in the synthesis of polynuclear complexes in which the cyanide acts as a bridge between two metal centers. In particular, mononuclear heteroleptic cyano complexes of paramagnetic ions were used in the synthesis of heterometallic complexes with interesting magnetic properties. Belonging to the class of thioamide compounds with versatile applications in medicine, thiourea and thiourea based heterocycles were herein investigated as ligands. The reactions of aquapentacyanoferrate(III) with thiourea, 4-imidazoline-2-thione, 1-methyl-4-imidazoline-2-thione or ethyl 3-methyl-2-sulfanylidene-imidazole-1-carboxylate were studied in buffered aqueous media and the produced pentacyano(thioamide)ferrate(III) complexes were characterized by means of UV/Vis and EPR spectroscopy. The wavelength of the ligand-to-metal charge transfer band in the electronic absorption spectra supported the *S*-coordination of thioamides to iron(III). Stability constants of the obtained complexes were evaluated by spectrophotometric mole ratio method. Kinetic studies for the formation and dissociation of $[Fe(CN)_5(thioamide)]^{2-}$ complexes were conducted by spectrophotometric measurements. Isolated salts of pentacyano(thioamide)ferrates(III) were characterized by elemental, thermogravimetric and ESI-MS analysis, IR and ^{57}Fe-Mössbauer spectroscopy as well as by single-crystal X-ray diffraction. The crystal and molecular structure of $(PPh_4)_2[Fe(CN)_5(thiourea)]$ is the first reported structure of a mononuclear pentacyano(ligand)ferrate(III) complex in which the ligand is coordinated through the sulfur.

Preparation of molecularly imprinted polymers for the extraction of fulvestrant from human plasma samples

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In the development of bioanalytical methods, selective sample preparation is of great importance. It is necessary to extract the analytes of interest, which are often present in very low concentrations, from a complex matrix that can both affect the obtained results and damage the analytical instrument. Molecularly imprinted polymers (MIP) show great potential for increasing selectivity in the extraction of different molecules from such complex samples, as they are synthesized with the analyte of interest as a template.

Hormone-positive, human epidermal growth factor receptor-2-negative breast cancer is treated with therapeutic combinations of palbociclib, ribociclib, or abemaciclib with anastrozole, letrozole or fulvestrant. Due to the observed inter-patient variability in plasma concentrations, numerous new bioanalytical methods are currently being developed to determine these drugs in patient samples. [1,2]

Initially, various solid phase extraction (SPE) sorbents were tested for extraction from plasma. It was found that fulvestrant had the lowest extraction recoveries gains with all sorbents tested (<75%). Therefore, different MIPs were synthesized to improve the extraction using 2-hydroxyethyl methacrylate (HEMA), 4-vinylpyridine (VPY) and methacrylic acid (MAA) as different functional monomers. Ethylene glycol dimethacrylate was used for crosslinking, and 2,2'-azobisisobutyronitrile was used as the polymerization initiator. The samples were analyzed using Agilent 1290 UHPLC couple to 6470 triple quadrupole MS detector. A Waters XBridge phenyl column (150 × 4.6 mm, 2.5 µm) was used with methanol, water and formic acid in gradient elution. The obtained extraction recoveries of fulvestrant were greatly increased (75-108%) with the tested MIP sorbents, especially when eluted successively with 2% formic acid in methanol and methanol. Finally, the MIP sorbent synthesized with HEMA monomers was coupled with an HLB sorbent to achieve simultaneous extraction of all six analytes. In this combination, using the same eluents, the recovery of fulvestrant was significantly improved (≈99%) compared with HLB alone (75%).

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Adsorption of polyions on TiO_2 surface

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Strongly and weakly charged polyions like poly(N-ethyl-4-vinylpyridinium) cations (P4VP), poly(allylammonium) cations (PAH) or poly(acrylate) anions (PAA) can adsorb onto the oppositely charged surfaces. [1] The TiO_2 surface was chosen for investigation due to its chemical properties and availability in various well determined forms (nanoparticles, nanotubes, large crystals of crystallographic specific cuts). The adsorbed polyions affect the electric properties of surfaces. [2,3] The effects of adsorption were investigated by measuring the inner surface potential change at single crystal electrodes (SCrE), and by measuring the change of electrokinetic potential of TiO_2 particles by electrophoretic measurements in suspensions. The measurements indicate that adsorption of polyions affects surfaces in more than one way, sometimes making even opposite effect than predicted. These counterintuitive results can be explained by including the changes in the orientation of water molecules at the surfaces, which is less prominent in the case of adsorption of smaller counterions. [4]

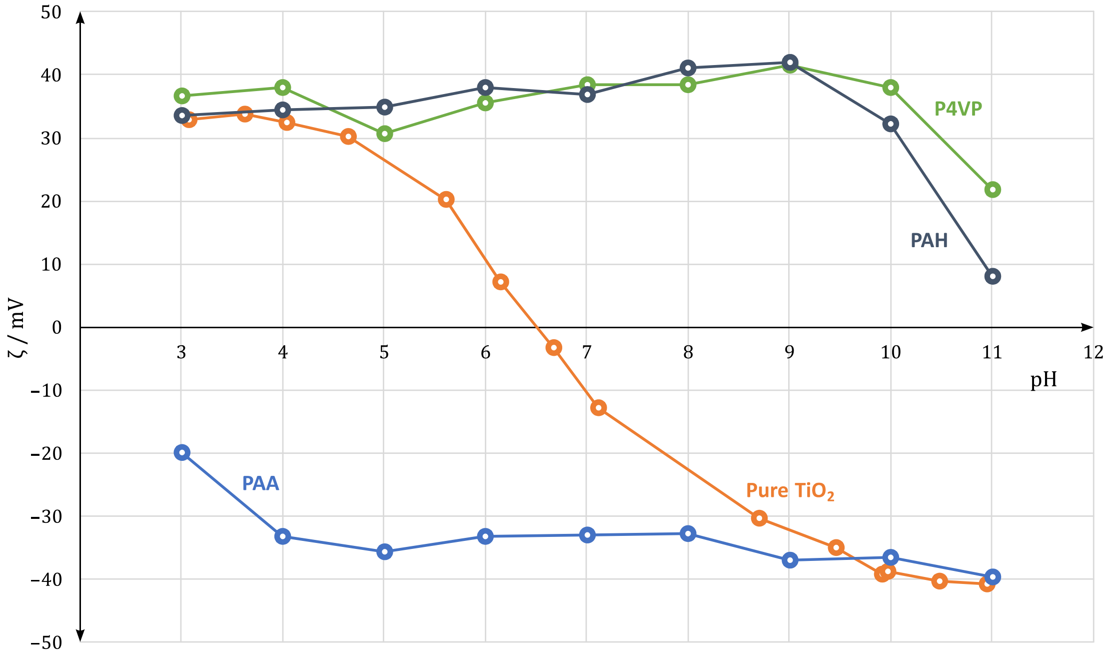

Fig. 1: Effect of polyions adsorption on ζ potential of TiO_2 nanoparticles.

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Synthesis of D-glucose and cholesterol conjugate for targeted delivery of pharmaceuticals by modified liposomes

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Liposomes can serve as drug delivery systems because they can reduce drug's toxicity by its encapsulation. Wider clinical application of liposomes in cancer treatment requires more effective tumor targeting in terms of uptake, controlled drug release and elimination time from the body. Metabolic characteristics of cancer cells are based on higher energy demand and therefore increased glucose uptake, which will be used for the preparation of glucose-modified liposomes (GML), with the aim of ensuring specific tumor targeting via glucose transporters that are overexpressed on tumor cells. [1]

The goal of the research is to investigate the potential of a new system based on glucose-modified liposomes, [2,3] as a stable and effective system for drug delivery in cancer treatment. For this purpose, a conjugate of cholesterol and glucose **1** will be prepared. Due to its structural characteristics, compound **1** will be incorporated into the lipid bilayer of liposomes and that way will cover them with glucose molecules. Glucose transporters on the surface of cancer cells recognize glucose units on the surface of liposomes, and as a result, such a liposome is introduced into the cell, along with a potential drug contained in its internal aqueous part.

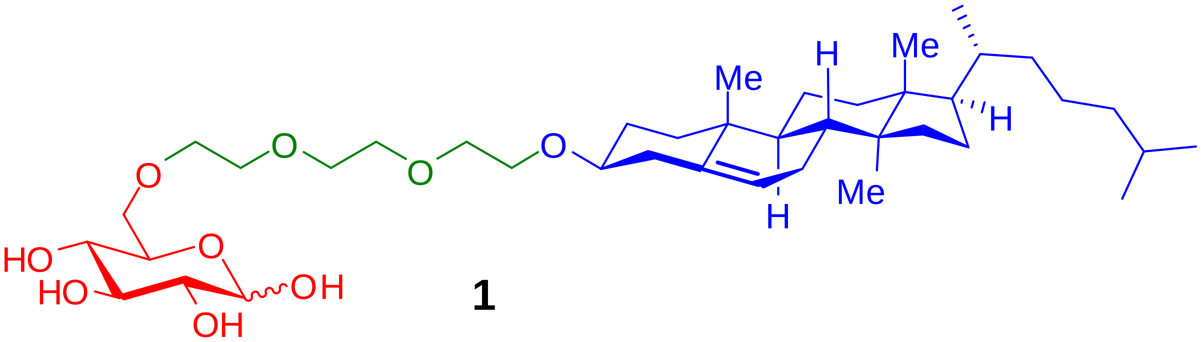

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Fig. 1: Prepared derivative of cholesterol and D-glucose, conjugated by a triethylene glycol linker.

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Solid-state synthesis and catalytic potential of dicyclopalladated azobenzenes

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Selective activation of unreactive C–H bonds using a ligand-directed approach is one of the most popular synthetic protocols for obtaining organometallic compounds. Palladium cyclometallated compounds or palladacycles are common catalysts in cross-coupling reactions and proposed intermediates in metal-catalyzed C–H bond functionalization. [1] In recent years, the strong effect of acidic additives on the pre-activation step of trimeric palladium acetate, $[Pd(OAc)_2]_3$, in C–H bond activation and functionalization was reported. [2] While the synthesis of palladacycles and the mechanism of these reactions are well established in solution, the solid-state approach is still being investigated. [3] In contrast to the reactions carried out in the solution, which are often time-consuming and performed in harmful solvents, the mechanochemical protocols can significantly shorten the reaction times and lead to the almost total omission of solvents. [4]

In this work, we present a simple, fast, and environmentally-friendly mechanochemical procedure for the synthesis of a series of dimeric dicyclopalladated azobenzenes promoted by selected organic acids. Reaction monitoring using *in situ* Raman spectroscopy enabled insight into the reaction dynamics while NMR and IR spectroscopy were used for characterization of dicyclopalladated products. Solid-state Suzuki-Miyaura reaction of 4-bromoazobenzene and phenylboronic acid was used as a model reaction for testing the catalytic potential of the obtained palladacycles.

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Physical-chemical properties of DPPC liposomes in the presence of gold nanoparticles aggregates

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Liposomes are lipid-based spherical structures that are, due to lipid amphiphilic character, arranged as bilayers with lipid hydrophobic tails oriented towards each other and a hydrophilic head towards aqueous surroundings. [1] Because of their nontoxicity and biodegradability they represent powerful and efficient delivery drug systems. [2] Nanoscience is the study of structures and molecules on the scales of nanometers ranging between 1 and 100 nm and represents an expanding and prominent research area. [3] Metal nanoparticles (NPs), particularly those made of gold (Au NPs), attract great interest due to their stability, biocompatibility and unique catalytic activity. The interaction of Au NPs and liposomes came into research focus due to their diverse purpose in application, especially in nano- and biotechnology. [4] Up to now, the understanding the interaction of liposomes and gold nanoparticles has gained great importance due to the possibilities that their combination can be used as potential drug delivery systems. [3] Here, we examined the influence of Au NPS aggregates on thermotropic properties of liposomes prepared from 1,2-dipalmitoyl-*sn*-glycero-3-phosphocholine (DPPC). In order to reach this goal, our experimental work included synthesis of Au NPs, surface enhanced Raman scattering (SERS) measurement (Fig. 1a), confocal microscope imaging (Fig. 1b), temperature-dependent UV-Vis spectroscopy and differential scanning calorimetry (DSC).

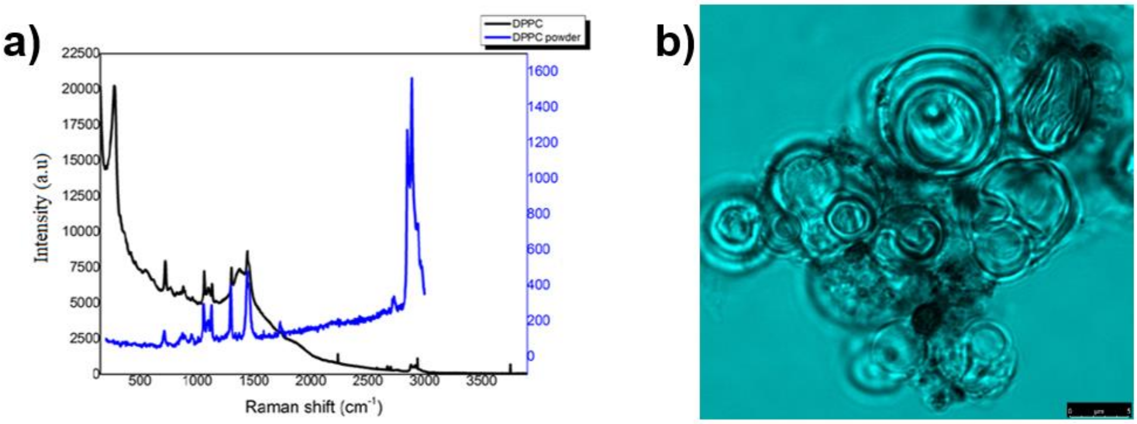

Fig. 1. a) SERS spectra of DPPC powder (blue) and SERS spectra of DPPC with Au NPs (black), b) Confocal microscope image of DPPC liposome with Au NPs aggregates.

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Synthesis and immunostimulating activity of dimannosylated desmuramyl peptide

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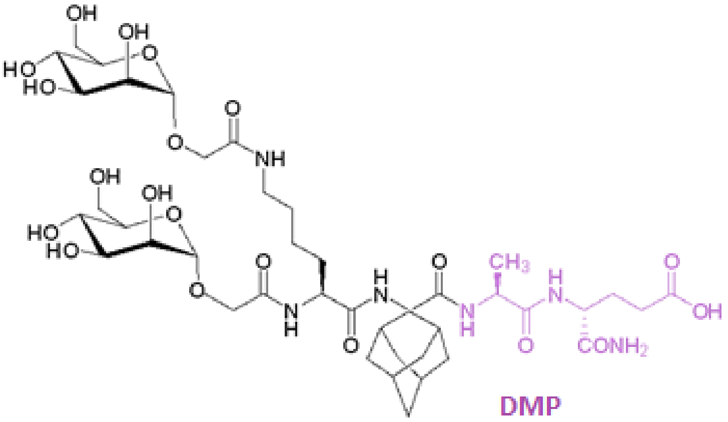
Muramyl dipeptide (MDP, *N*-acetylmuramyl-L-alanyl-D-isoglutamine) is the smallest immunologically active peptidoglycan fragment. [1] Desmuramyl peptides are MDP analogs without *N*-acetylmuramic part. MDP acts as a pathogen-associated molecular pattern and activates the NOD2 (nucleotide binding oligomerization domain containing 2) receptor. Following the activation, NOD2 binds to the protein kinase RIP2 (receptor-interacting protein 2) to coordinate NF-κB (nuclear factor κ B)-mediated cytokine responses. L-Ala-D-isoGln pharmacophore contributes mostly to the NOD2 binding. [2] Mannose receptors present on immunocompetent cells also represent a class of pattern-recognition receptors, as well as NOD2. Therefore, we have designed and synthesized mannosylated desmuramyl peptides with one and two mannose units, in order to explore the contribution of mannosylation to immunostimulation. Immunostimulating properties of synthesized compounds are evaluated *in vivo* in the mouse model using ovalbumin as an antigen and their interactions with the NOD2 receptor were analyzed using computational methods.



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Synthesis and characterization of aromatic trinitroso compounds – potential building blocks for new porous organic polymers

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Porous organic polymers (POPs) incorporating nitrogen-rich functionalities have emerged as promising materials for efficient and highly selective CO_2 capture and separation. We recently reported synthesis and characterization of new two-dimensional (2D) benzene- and triazine-based azo-bridged POPs and identified potential candidates for selective CO_2 adsorption. [1] In the continuation of our work on design and synthesis of promising building blocks for formation of new POPs we focused on the compounds with multiple aromatic C-nitroso groups. It is known that the simplest such compound, 1,4-dinitrosobenzene, forms remarkably stable 1D azodioxy polymer which could be possibly used as organic semiconductor, [2] while polymerization of monomers with tetrahedrally oriented nitroso groups leads to formation of porous three-dimensional (3D) diamondoid azodioxy networks. [3]
In this work, we report the synthesis and characterization of novel aromatic trinitroso compounds and their potential application for the creation of polymeric azodioxy networks. The selected starting compounds (Fig. 1) contain three phenyl rings with a nitroso group in the *para*-position attached to the different central unit: benzene (**1a**), pyridine (**1b**), triazine (**1c**) and nitrogen atom (**2**). Bearing in mind that preparation of aromatic C-nitroso compounds is not simple, different synthetic methods were tested. The prepared compounds were characterized by IR spectroscopy, solution- and solid-state NMR spectroscopy, powder X-ray diffraction and thermogravimetric analysis. The obtained results indicate the formation of oligomers or polymers that contain *E*-azodioxy linkages and show good thermal stability. Preliminary computational study based on the calculation of binding energies and analysis of the electrostatic potential maps allowed us to locate the best binding sites with CO_2 molecules.

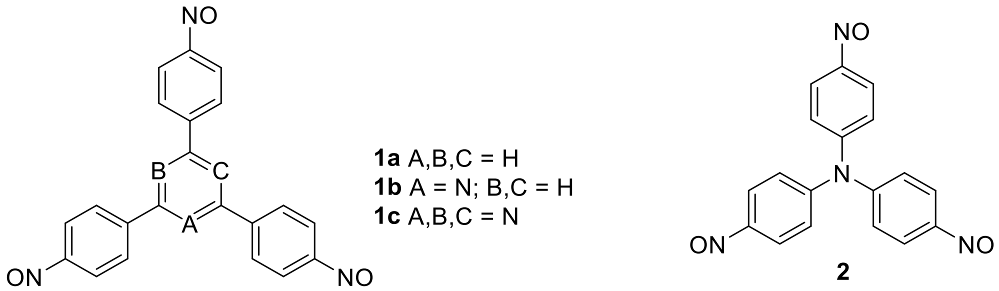

Fig. 1: Selected target aromatic trinitroso compounds for the design of new polymeric azodioxy networks.

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SERS spectra of berberine and papaverine

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Surface-enhanced Raman scattering (SERS) spectroscopy is a powerful analytical technique that allows for detection of molecules at very low concentrations by amplifying the Raman scattering signal due to adsorption or chemical binding of molecules to a nanostructured metal surface. [1] In this study, the enhancement of Raman scattering of two plant alkaloids, berberine and papaverine, was investigated. Alkaloids are natural compounds, mainly secondary metabolites of plants, which have strong pharmacological activity and have been used for centuries in traditional, and nowadays in modern medicine. [2] SERS spectra of berberine and papaverine were obtained using citrate-stabilized silver nanoparticles and a 785 nm laser excitation source. Characteristic vibrational bands of berberine and papaverine were observed and assigned. [3,4] The addition of aggregating agent (0.1 M $MgSO_4$) into the silver colloid resulted in a significant increase of the SERS intensity, allowing for detection of both alkaloids in nanomolar range. Nevertheless, a nonlinear relationship between concentration and SERS intensity was observed in the concentration dependent spectra (5×10^{-9}-1×10^{-4} M) as a result of the surface selection rules. Moreover, the SERS spectra of papaverine in the low concentration range ($<1\times10^{-6}$ M) were similar to the papaverine spectrum (1×10^{-4} M) in the acidic medium (pH = 1.2), indicating that due to electrostatic interactions with the stabilizing citrate anions on the metallic surface only protonated molecules ($pK_a = 6.4$) contributed to the spectra measured at low papaverine concentrations in the neutral colloidal suspension (pH = 7.0). [5] This study demonstrated that the SERS spectroscopy can be successfully used as a sensitive technique for detecting and identifying alkaloids.

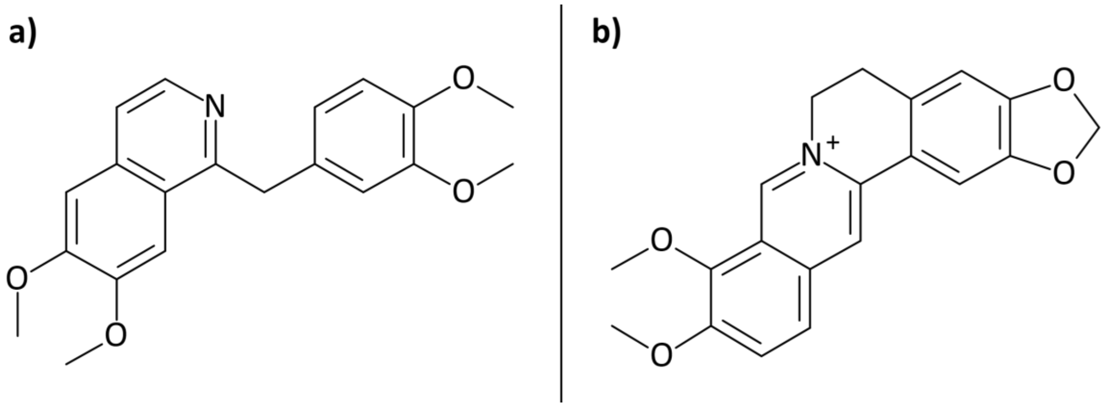

Fig. 1: Structure of a) papaverine and b) berberine.

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Synthesis, characterization and antiproliferative activity of coumarin-based derivatives and their metal complexes

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Cancer is the second leading cause of death worldwide, resulting in around 9 million deaths annually. [1] Among the approved anticancer drugs, around 80% of them are derived from natural compounds. Coumarin derivatives are ubiquitous in nature and can readily interact with a variety of enzymes and receptors such as kinase, telomerase, aromatase, sulfatase, monocarboxylate transporters, and carbonic anhydrase, thereby exhibiting a potential activity against various cancer cell lines including multidrug-resistant cells. [2-4] Thus, the coumarin moiety is a useful template for the development of novel anticancer agents. On the other hand, metal-based drugs have gained attention to address the negative aspects of platinum-based drugs, like high toxicity, resistance to treatment, low specificity for target DNA, and poor absorption. [5] Considering the promising anticancer activity of metal complexes, we designed and synthesized coumarin–pyridine hybrids and their metal complexes with the aim to evaluate their antiproliferative activity (Fig. 1). Herein, we report syntheses, spectroscopic characterization and anticancer activity of coumarin ligands and their Ru(II) and Re(I) complexes.

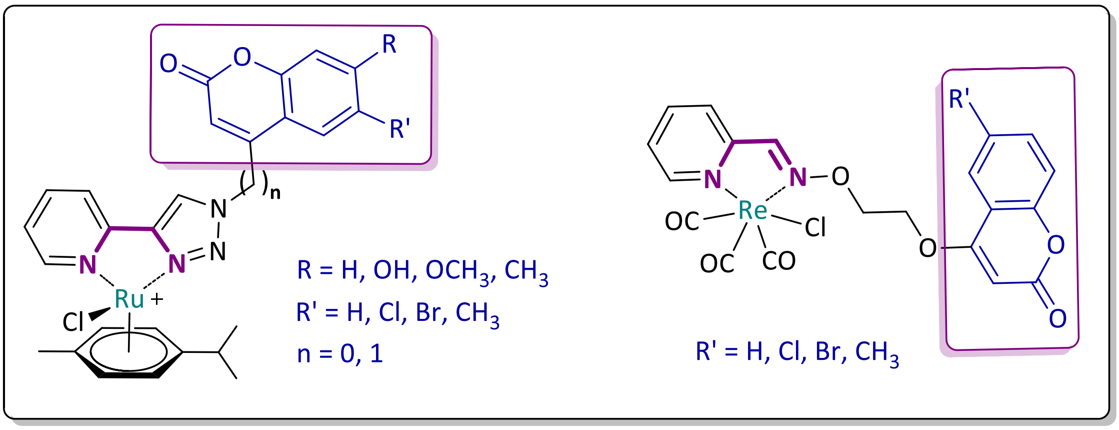

Fig. 1: Structures of coumarin ligands and their Ru(II) and Re(I) complexes.

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Deep reinforcement learning classification model for fragrant compounds based on ATR spectroscopy

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A set of 82 fragrant compounds was initially investigated by attenuated total reflectance (ATR) spectroscopy. The set included six different types of main odor notes of perfumery. [1] The data matrix consisting of ATR spectra was decomposed using the principal component analysis (PCA) and the quality of PCA models was assessed by determining the optimal number of principal components for the representation in the reduced space. Differences among the data points in the reduced space are associated with the total number of aromatic and/or aliphatic functional groups and their structure, reflecting variations in the composition of different odor notes.

To classify fragrant compounds used in perfumery on the basis of their ATR spectra, a deep reinforcement learning protocol implemented in the program ***moonee*** [2] was used. Multi-layer neural network (NN) was trained and utilized for the classification of fragrant compounds. The NN was trained starting with two input samples, and then input space was progressively increased in each step for two additional samples. The backpropagation algorithm was used for network training and classification accuracy was monitored during reinforcement learning. In each step of the learning process, several different neural networks were opposed against each other and the best one was selected. An excellent result of 85% classification accuracy was achieved already on half of the set of compounds.

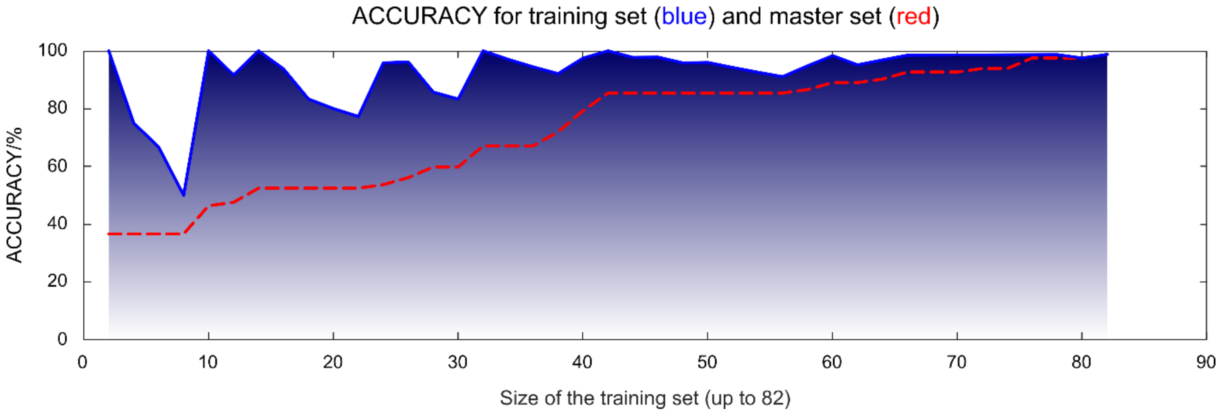

Fig. 1: Accuracy of classification during the deep reinforcement learning protocol for fragrant compounds based on the reduced space of their ATR spectra.

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Stability of water-soluble vitamins in enteral food

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Consumption of enteral formulas for hospitalized, critically ill and home enteral patients has dramatically increased over the past few decades. [1] Enteral foods are used to provide all nutrients for individuals with limited, impaired, or disturbed capacity of taking, digestion, absorption, metabolism and excretion of common food. The stability of vitamins in such formulations can be influenced by various factors, such as the type of packaging and condition of storage (e.g., oxygen exposure, light, humidity and temperatures). [3]

We have developed a sensitive liquid chromatography-mass spectrometry (LC-MS) method in single ion monitoring (SIM) mode for simultaneous stability testing of nine water-soluble vitamins, ascorbic acid (C), thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine hydrochloride (B6), biotin (B7), folic acid (B9) and cyanocobalamin (B12), in different types of formulations. Depending on rheological characteristic of particular formulation, extraction protocol for water-soluble vitamins was optimized. Vitamin content was determined in enteral food formulations and stability tests were performed. The samples were analyzed at the beginning of the storage period and three months after storage of the packaging in temperature chambers at 37 °C and also after storage for six months at 23 °C. The results obtained on seven different formulations were correlated with the results obtained by other methods.

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Influence of Mn^{2+} ion binding on structural changes in metalloregulatory proteins SloR (*S. mutans*) and ScaR (*S. gordonii*)

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Streptococcus gordonii and *Streptococcus mutans* are oral bacteria that grow as a plaque biofilm on the tooth surface. The metabolic production of hydrogen peroxide produced by *S. gordonii* can inhibit the growth of *S. mutans*, the primary causative agent of human dental caries. [1] Manganese ions (Mn^{2+}) are an essential nutrient for pathogenic bacteria and has been linked to virulence in many species. [2] The expression of Mn^{2+}-selective ABC transporters in streptococci is under the regulatory control of a group of homologous metalloregulatory proteins, including ScaR from *S. gordonii*, and SloR from *S. mutans*. [3] To investigate the influence of Mn^{2+} ion binding on structural and dynamical properties of SloR and ScaR, we conducted molecular dynamic simulations of both proteins. The computational results were validated by experimental methods: circular dichrosim (CD) and differential scanning calorimetry (DSC).

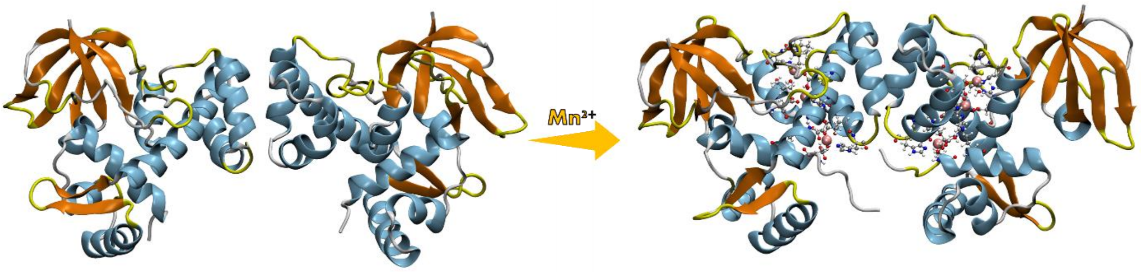

Fig. 1: Structure of ScaR protein with (right) and without (left) bound Mn^{2+} ions obtained by molecular dynamics simulations.

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Antifungal effects of fluorinated pyrazole aldehydes: Biological activity evaluation and molecular docking studies

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Pyrazoline derivatives exhibit a variety of biological activities, such as antifungal, antiviral, and antibacterial. Biological effects depend on the type of substituents and their position in the ring. [1] The aim of this study was to evaluate the inhibitory effects of fluorinated pyrazole aldehydes against plant pathogenic fungi (*Fusarium oxysporum* f. *sp. lycopersici, Fusarium culmorum*, *Macrophomina phaseolina* and *Sclerotinia sclerotiourum*). The compounds demonstrated moderate activity against phytopathogenic fungi. The highest efficiency has shown 2-chlorophenyl derivative (**H9**) against *F. culmorum* (46.75%). In order to determine the binding affinity and interactions of the most active compounds with three enzymes responsible for the fungal growth and the three plant cell wall-degrading enzymes, molecular docking was performed. In order to determine the possible mechanism of action of derivatives against pathogenic fungi, molecular docking study has been performed on three enzymes responsible for the fungal growth: demethylase (sterol 14α-demethylase (CYP51), PDB: 5EAH); chitinase (PDB: 4TXE); transferase (N-myristoyltransferase, PDB: 2P6G); and the three plant cell wall-degrading enzymes: endoglucanase I (PDB: 2OVW); proteinase K (PDB: 2PWB); pectinase (endopolygalacturonase, PDB: 1CZF). The future derivatives should be designed to be more effective against pathogenic fungi without negative effects on beneficial organisms, environment pollution, and human health.

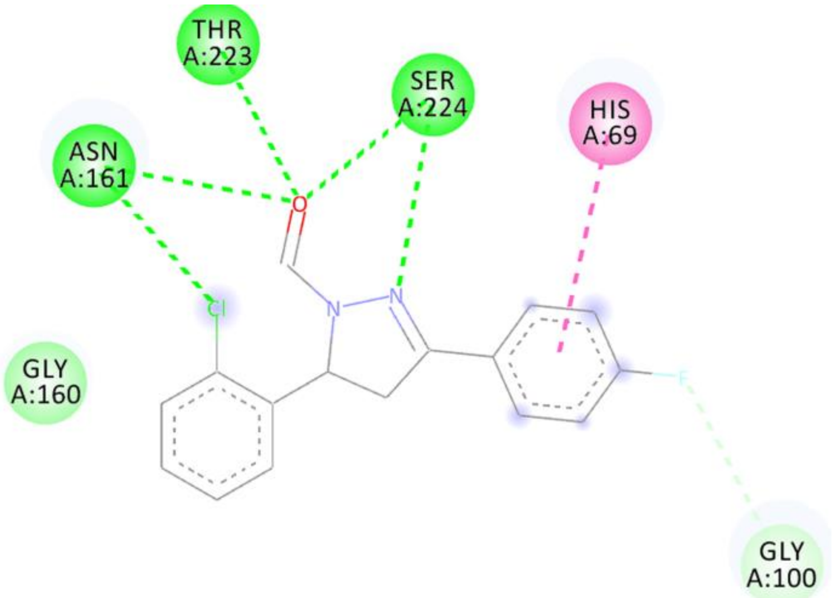

Fig. 1: The main interactions of the compound **H9** with residues in the active site of proteinase K (PDB: 2PWB).

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Synthesis of novel benzothiazole azo dyes and *in vitro* biological evaluation of antibacterial and antitumor activity

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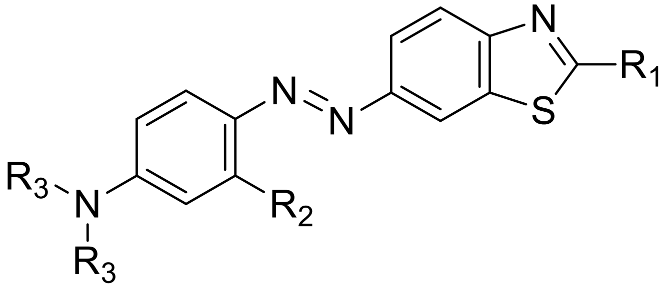
The study of benzothiazole derivatives became a rapidly developing and increasingly active field due to their interesting pharmacological properties. Benzothiazole analogues offer a high degree of structural diversity, which is useful in the search for new therapeutic agents. [1] On the other hand, aromatic and heteroaromatic azo compounds represent the most numerous and diverse group of synthetic dyes used not only as textile dyes but also in many other industrial fields: for dyeing various substrates, in biomedical research, in the field of nonlinear optics and optical data storage. [2]

In conjunction with our previous studies focused on the synthesis and structural investigations of azo-benzothiazole derivatives [3-4], we now turn our attention to the synthesis of novel benzothiazole azo dyes (Figure 1) to evaluate their biological potential. In this work, we presented an efficient method for the synthesis of a small library of 6-azo-substituted benzothiazole molecules by diazotization reactions of 6-amino-substituted benzothiazole derivatives and by copulation of the corresponding diazonium salts with *N,N*-disubstituted aniline derivatives. *In vitro* biological evaluations of antibacterial and antitumor activity were performed for a small library of 12 structurally related compounds.



R_1 = H, CH_3, Cl
R_2 = H, CH_3, Cl, $NHCOCH_3$
R_3 = C_2H_5, C_2H_4OH

Fig. 1: General structures of presented benzothiazole azo dyes.

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The influence of amide group addition on the bioactivity of new soft 3-amidoquinuclidine QACs

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Quaternary ammonium compounds (QACs) are amphiphilic molecules known for their broad-spectrum antibacterial activity. Although they have potent biological potential, they are often highly toxic to living organisms and ecosystems. Recent studies show that the addition of polar groups results in *soft* QACs that are more susceptible to hydrolysis, and therefore less toxic. [1] The aim of this study was to synthesize the new *soft* 3-acetamidoquinuclidine (QAc) and 3-benzamidoquinuclidine (QBn) QACs, both of which contain a naturally-derived quinuclidine backbone. [2,3] The quaternization reactions were carried out using suitable alkyl halide chains of different lengths (12, 14 and 16 C atoms). The antibacterial activity of the new compounds was tested against a panel of Gram-positive and Gram-negative bacteria. We found that the QACs of 3-benzamidoquinuclidine exhibited better antibacterial activity in both bacterial panels (MIC between 3.9 and 62.5 µM) than the QACs of 3-acetamidoquinuclidine, which were active only against Gram-positive bacteria (MIC between 7.8 and 62.5 µM). Because we suspected that the composition of the culture medium might affect the activity of the QACs, we additionally determined the activity in CA-MHB and DMEM media. The MIC values in the cation-adjusted medium, i.e., CA-MHB, decreased 1- to 10-fold, and in the DMEM medium decreased 10- to 20-fold compared with the initial MIC values determined in MHB. These results indicate that the addition of an amide group and the composition of the culture medium strongly influence the antibacterial activity of the synthesized *soft* QACs.

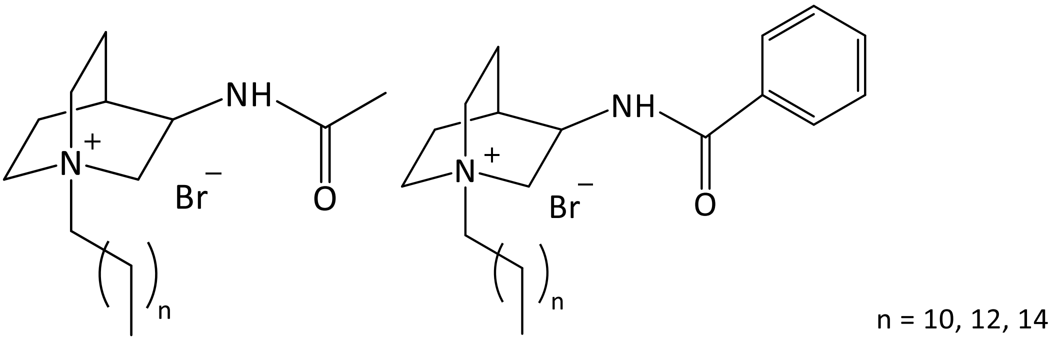

Fig. 1: Representative structures of new synthesized 3-amidoquinuclidine QACs.

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visualEPR: free, online and open-source visualisation and simulation software for fast processing of EPR spectra

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Electron paramagnetic resonance (EPR) techniques are powerful analytical tools in numerous fields, including chemistry, biochemistry, material science, petrochemistry, *etc*. While less popular than nuclear magnetic resonance (NMR), it can give insight into radical stabilities, anti- and pro-oxidizing power, radical rearrangement reactions, analysis of the radical structure, kinetics of redox reactions and much more. After discovery of rare-earth magnets and miniaturisation of EPR apparatus, this technique is becoming more available than before. Currently, only a handful of computer programs are capable of visualising and processing of EPR spectra, with dedicated software for EPR spectra simulation. Most popular suit of programs (Xepr, XSophe, SpinFit, SimFonia and WinEPR) by Bruker is quite expensive, while other plotting programs with additional modules and toolboxes (*e.g.* Matlab with Easyspin) usually have a steep learning curve.

Here a prototype program called visualEPR (http://sw.pharma.hr/EPRSIM/visualEPR.html) is presented; it is a free, online and open-source visualisation and simulation program that runs on modern web-browsers. The main feature of this program is interactive visualisation of EPR spectra from ASCII and BES3T file formats, and subsequent spectra processing, including baseline correction, smoothing/filtering and integration/derivation.

Additionally, this program enables simulation of spectra by user input variables, including simulation of multiple radicals in different ratios, with options of changing line-width, ratio of Lorentzian/Gaussian functions and add/remove multiple nuclei.

After processing and simulation, export options include exporting graph in arbitrary quality in vector (.svg) and raster (.png) picture formats, that are acceptable for publications. Export to comma separated value (.csv) format suitable for additional analysis and handling in other programs is also available.

By allowing researchers all around the world to analyse EPR spectra “on-the-fly” using just web-browser without steep learning curve, we hope that wider audience will notice the benefit of EPR spectroscopy and its usage in their applications.

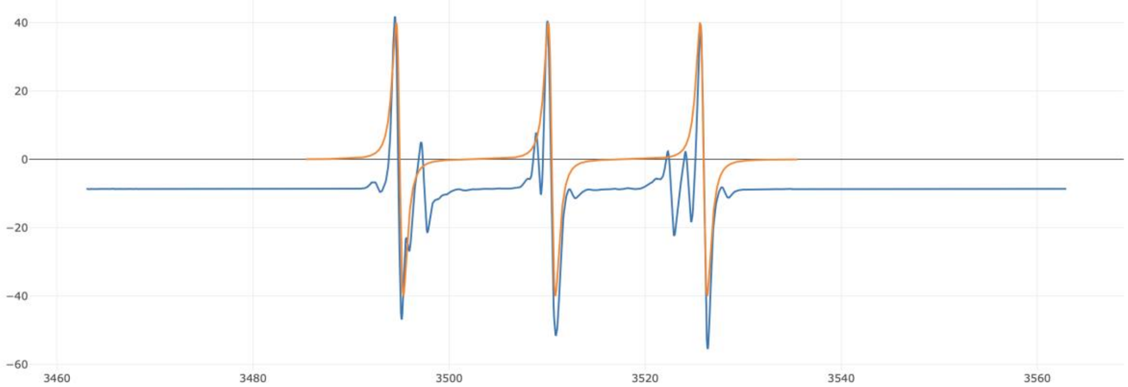

Fig. 1: Example of visualEPR output (blue) with simulation (orange).

Applicability of the new solid-state sensor based on functionalized carbon nanomaterials for promethazine hydrochloride determination

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Promethazine hydrochloride (PM) or *N*,*N*-dimethyl-1-phenothiazin-10-yl-propan-2-amine hydrochloride has antihistaminic, antiemetic, sedative, antipsychotic, and analgesic properties. [1] It is mainly used to prevent motion sickness or to treat mental illness and allergies. [2] However, it can cause serious adverse effects such as breathing and cardiac problems, endocrine disorders, *etc*. [3] Also, in last few decades, its nonmedical abuse has been reported. [4] Considering the wide use of PM, its monitoring is very important. Various analytical methods can be used in that purpose, but many of them require expensive instrumentation, time consuming and complicated procedures, and large amounts of toxic solvents. Potentiometric sensors represent a good alternative considering their selectivity and simplicity.

The new potentiometric solid-state sensor had a liquid membrane contained multi-walled carbon nanotubes functionalized with a sulfate group and PM ions as the sensor material, and 2-nitrophenyl phenyl ether as the plasticizer. The applicability of the new sensor for PM determination in pharmaceutical products was investigated using potentiometric titration with sodium tetraphenylborate as the titrant, and the Gran method. The results obtained using both methods were accurate and precise. With daily measurements, the lifetime of the sensor was at least four months.

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SPRi study of *N*-acetyl glucosamine specific lectin interactions with peptidoglycan monomer functionalized gold biochips

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Peptidoglycan monomer (Glc*N*Ac-Mur*N*Ac-L-Ala-D-*iso*Gln-*meso*DAP(ε-NH_2)-D-Ala-D-Ala, PGM) is a disaccharide pentapeptide isolated from *Brevibacterium divaricatum* that shows immunostimulatory, immunomodulatory, antitumor, and antimetastatic activity. [1] PGM is a fragment of peptidoglycan which is the essential component of the bacterial cell wall and is recognized by the innate immune system through pattern recognition receptors (PRR). Lectins are naturally occurring carbohydrate-binding proteins that are involved in numerous biological processes and some lectins mediate pathogen recognition by binding glycan epitopes on pathogens. Carbohydrate-lectin interactions are extensively studied because of the lectin's potential usage for PRR targeting in the fields of infectious diseases and cancer research. [2] In this study, we were primarily interested in investigating the interaction of peptidoglycan monomer and lectins that specifically recognize the *N*-acetyl glucosamine moiety (e.g. WGA, UEA-II, GS-II) by surface plasmon resonance imaging (SPRi). SPR-based methods are a powerful tool for the investigation of interactions between biomolecules in real-time, enabling quick, label-free characterization of a variety of molecular interactions, such as quantitative measurements of binding kinetics, thermodynamics, concentrations in complex samples, and epitope analysis. Gold biochips were successfully functionalized with PGM and its metal complexes with Cu^{2+} and Zn^{2+} ions, in three steps shown in Figure 1. The results show that PGM was effectively recognized by WGA and that interactions are enhanced when PGM's metal complexes with Cu and Zn were employed.

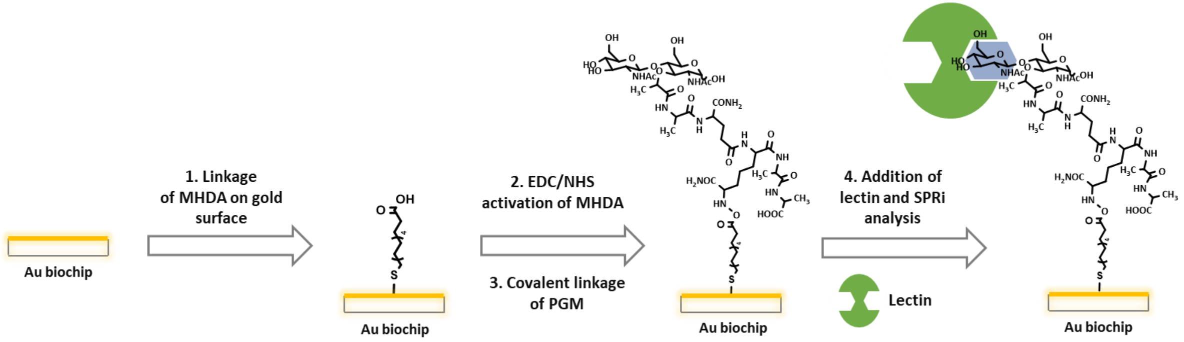

Fig. 1: Schematic representation of PGM functionalization of gold-coated biochip and SPRi analysis of the interaction of peptidoglycan monomer and lectins.

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The reaction between alkenes and maleimides: [2+2] cycloadditions using UVA or visible light

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Throughout the last two decades, the interest in light-promoted transformations has increased significantly, due to the “greener” character of photochemical reactions, as well as the access to novel reactivities. [2+2] Photocycloadditions are a typical example of photochemical reactions, since the corresponding thermal reaction is forbidden. Such a cycloaddition affords a cyclobutane core, which can be found in numerous natural products with potent biological importance or pharmaceuticals. However, the reaction between olefins and maleimides has been limitedly studied and there is only a handful of literature examples. Moreover, the difference in reactivity of *N*-alkyl and *N*-aryl maleimides, which is directly associated with their photophysical properties, has not been discussed in a literature precedent. Our group has experience in the development of methodologies that employ light as the energy source. Based on previous knowledge obtained in our group regarding the [2+2] photocycloaddition between *N*-substituted maleimides and triple bonds, [1] we sought to investigate the feasibility of a [2+2] cycloaddition between maleimides and olefins. Herein, we identify the differences in reactivity between *N*-alkyl and *N*-aryl maleimides and we provide a unified solution for the successful use of substituted maleimides in [2+2] reactions with alkenes. [2]

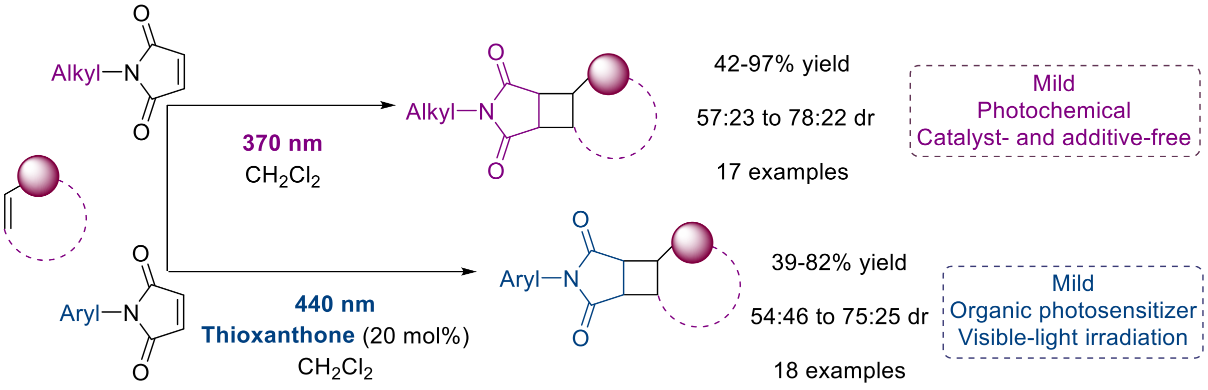

Fig. 1: [2+2] Cycloadditions between alkenes and maleimides using UVA or visible light.

Acknowledgement The authors gratefully acknowledge the Hellenic Foundation for Research and Innovation (HFRI) for financial support through a grant, which is financed by the 1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and the procurement of high-cost research equipment grant (grant number 655).

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Synthesis and antibacterial activity of new hydrazone-bridged benzothiazole derivatives

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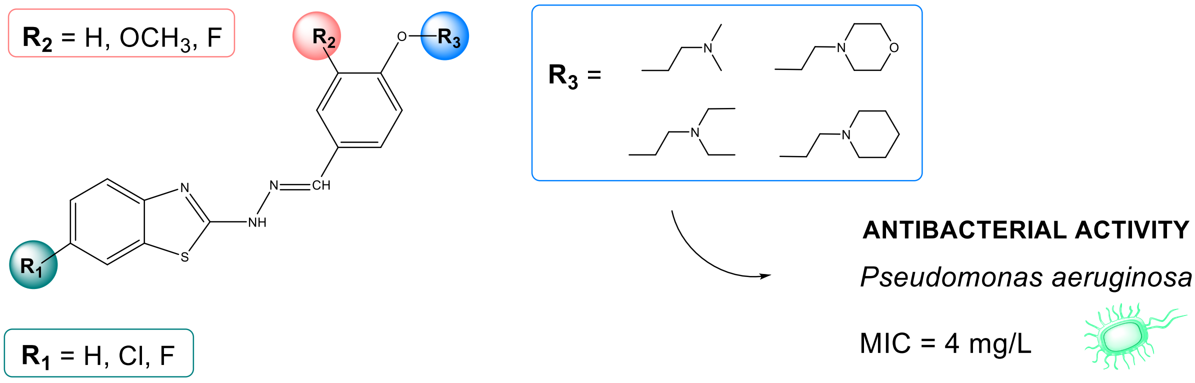
Benzothiazole represents an important class of compounds with a wide spectrum of biological activities such as antimicrobial, antitumor and antituberculostatic activity and possesses special significance in the field of medicinal chemistry. [1,2] Hydrazones show strong therapeutic activity due to the presence of N–N ad C=N bonds [3] and well-known drug with the hydrazone group is levosimendan, which is used in the treatment of acute decompensated congestive heart failure.

This paper describes the solvent-free mechanochemical synthesis of targeted hydrazone-bridged benzothiazole derivatives. 6-substituted 2-hydrazinylbenzo[*d*]thiazoles were prepared by reaction of 2-amino benzothiazole with hydrazine hydrate in the presence of ethylene glycol and hydrochloric acid. Mechanochemical reaction of 2-hydrazinylbenzothiazole with an appropriate aromatic aldehydes gave the target 2-substituted benzothiazole derivatives bridged by hydrazone unit. Structural characterization of all newly prepared benzothiazole derivatives was performed by ^{1}H and ^{13}C-NMR spectroscopy. Furthermore, using the 2D-NOESY technique, it was confirmed that the prepared compounds were obtained in the form of the *E*-isomer. Of all evaluated compounds against bacterial cells of *Escherichia coli, Enterococcus faecalis, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus*, the most pronounced antibacterial activity on bacterial strain *Pseudomonas aeruginosa* was shown by the 6-chloro-benzothiazole derivative with *N,N*-diethyl substituent (MIC = 4 mg/L).



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Mechanical responsiveness of crystals of copper(II) coordination polymers

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For many years, crystals have in general been considered hard and brittle substances that break under the influence of external mechanical force, but recently flexibility of the crystals due to the application of external (light, thermal or mechanical) stimuli has also been described. [1] Exhaustive studies on the mechanically induced behavior of organic crystals revealed the existence of plastically and elastically flexible single crystals. [2] Plastic crystals remain bent even after the removal of the applied external mechanical force (irreversible deformation), while elastic crystals return to their initial position (reversible deformation) upon removing mechanical stimuli. Mechanical flexibility has been reported for a significant number of organic molecular crystals so far, yet it is still relatively rare and much less explored among metal-organic crystalline solids. Recently, we discovered that crystals of coordination polymers of cadmium(II) halides are convenient for studying mechanical flexibility due to their crystal structures having small and systematic differences that can consequently be correlated with a wide range of different flexible responses observed, e.g. elastic, elastic⟶plastic and plastic response. [3-6] It was found that small differences in the strength and directionality of non-covalent interactions can significantly impact the type and degree of mechanical response.

With the aim to further elucidate the relationship between structural characteristics and mechanical properties of polymeric crystalline materials, coordination polymers' crystals of copper(II) halides with 4-cyanopyridine were prepared. Needle-like crystals of sufficient morphology suitable for mechanical properties testing were prepared by a liquid diffusion method and characterized by vibrational spectroscopy, thermal analysis methods (TGA/DSC) and hot plate microscopy. The mechanical responsiveness of acicular crystals to applied external force was investigated *via* modified three-point bending experiments whereas, for the observed elastic mechanical response, the extent of elasticity was quantified. The mechanical properties were analyzed within the context of crystal packing and related to present structural features.

Acknowledgement This work has been fully supported by the Croatian Science Foundation under the project *From form to function: Mechanically flexible crystalline materials with controllable responses* (IP-2019-04-1242).

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Synthesis and gas sensing properties of platinum nanoparticles dispersed on α-Fe_2O_3 and Fe_3O_4 supports

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The α-Fe_2O_3 (hematite) powder samples were synthesized mechanochemically in spherical morphology and hydrothermally in nanotube and nanoring morphologies. Stoichiometric Fe_3O_4 (magnetite) was synthesized by annealing α-Fe_2O_3 samples in a furnace at 360 °C under continuous hydrogen gas flow. The synthesized Fe_3O_4 powders preserved the original morphology of α-Fe_2O_3 nanotubes and nanorings. Platinum was dispersed on the surface of the α-Fe_2O_3 and Fe_3O_4 powders with platinum(II) acetylacetonate dissolved in toluene. Atomic resolution scanning transmission electron microscopy (AR STEM) showed that the platinum was homogeneously dispersed on the α-Fe_2O_3 in the form of small platinum nanoparticles (Fig. 1). The gas sensor properties of the samples were measured by depositing Pt/α-Fe_2O_3 suspensions on glass substrates with interdigitated gold electrodes using the drop casting technique. The changes in electrical resistance of the samples upon exposure to H_2 gas were measured at 433 K, 483 K and 533 K. Fig. 2 shows the response of the synthesized Pt/α-Fe_2O_3 (FePt5 with 5 mol% Pt and FePt10 with 10 mol% Pt) gas sensor as the relative change in electrical resistance, $\Delta R/R_0$, as a function of H_2 concentration. The sensitivity of the samples to hydrogen gas was optimized as a function of platinum dispersion and loading as well as sample morphology (sphere, nanotubes, nanorings) and phase composition (α-Fe_2O_3 versus Fe_3O_4).

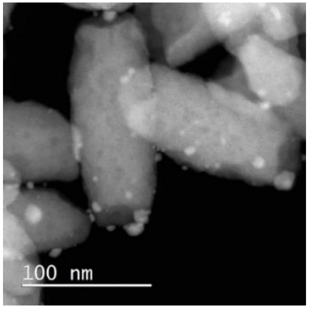

Fig. 1: AR STEM image of small platinum nanoparticles (brighter small dots) dispersed on α-Fe_2O_3.

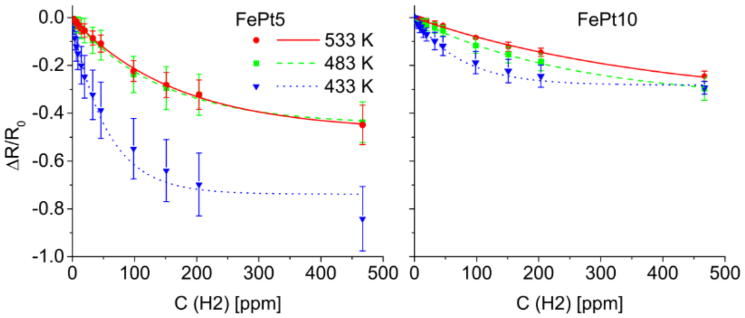

Fig. 2: Response vs. H_2 concentration of FePt5 (left), and FePt10 (right) at different temperatures. Lines show the best fit exponential.

Acknowledgement This work was financially supported by the Croatian Science Foundation under the project IP-2019-04-1195 *Platinum decorated iron tin oxide solid solutions for hydrogen gas sensing* (HydGasSens) and by the Croatian Government and the European Union through the European Regional Development Fund – the Competitiveness and Cohesion Operational Programme (KK.01.1.1.01.0001).

Reactivity of 2,3-dihydro-1-methyl-2*H*-benzimidazole-2-thione towards 1,2-dichloroethane

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As a structural motif, benzimidazole is very common in bioactive molecules, making it an important scaffold for the development of pharmaceuticals and other molecules of biological interest. [1] Not surprisingly, benzimidazole has, over the years, occupied an important place as a pharmacophore in various chemotherapeutic agents. [2] In the past, we have studied the antithyroid drug methimazole (**A**) and its reactivity with 1,2-dichloroethane (DCE). [3] Recently we extended the study towards a structural analogue of **A**, methylbenzimidazole-2-thione (2,3-dihydro-1-methyl-2*H*-benzimidazole-2-thione, **1**) and its stability in DCE. Various alkylation products were isolated and purified from the mixtures resulting from long-term solution stability tests under light and dark conditions, thermal stress, and the influence of various solvents. The obtained products (**2-4**) (Fig. 1) were characterised using chromatographic (HPLC), spectroscopic (NMR, MS) and thermal (DSC) methods. Additionally, the structures were determined by single-crystal X-ray analysis.

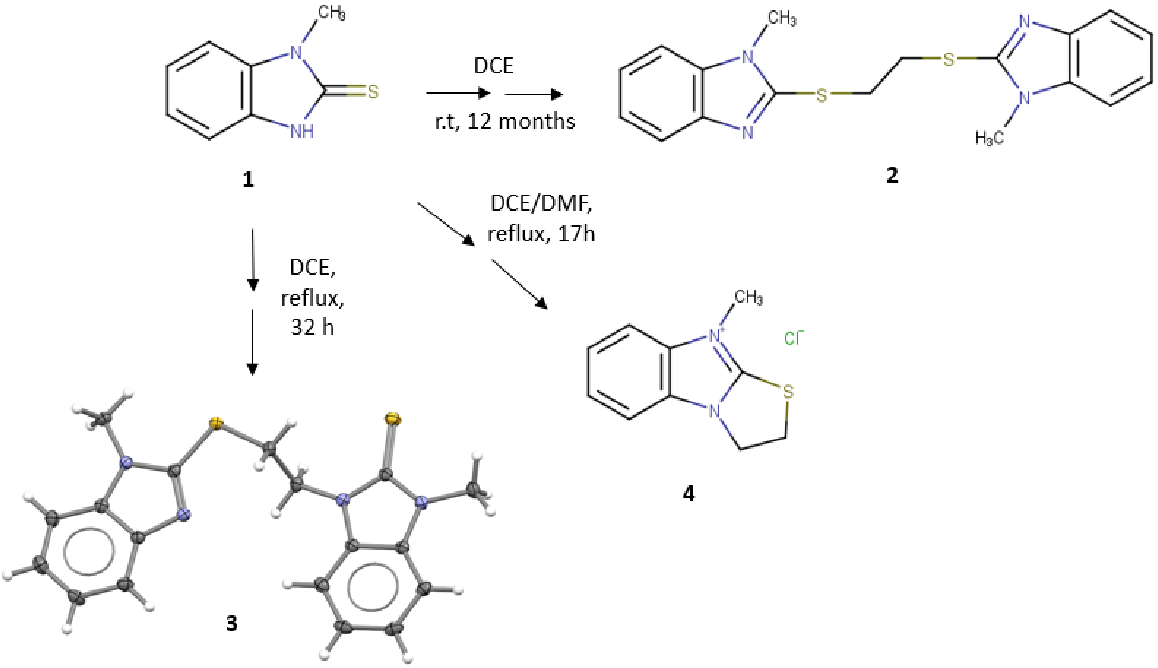

Fig. 1: The structures of studied derivatives of **1**.

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Bio-based solvents for cross-coupling reactions

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Cross-coupling reactions are widely employed in chemical industry. Among them, the Mizoroki-Heck reaction is a useful tool for the formation of olefinic intermediates, essential to produce high-added value products. For such reactions, polar solvents exhibiting high toxicity, such as DMF, are usually employed. The large amount of industrial waste, due to solvents, combined with their non-sustainable character, raise a problem of great significance for both the environment and the human health. Herein, we describe the use of a novel green bio-based solvent, cyrene, [1] as a sustainable medium for the Mizoroki-Heck reaction, examining the scope and limitations. [2] Cyrene is a biodegradable solvent, derived from biomass, which has recently become a very promising alternative for polar aprotic solvents, such as NMP and DMF and it has found use in several cross-coupling reactions such as the Suzuki-Miyaura [3] and the Sonogashira Reaction. [4] We developed a green protocol for the Mizoroki-Heck reaction, employing substituted aryl iodides with various acrylates and using Pd/C as the cheap and sustainable palladium catalyst, triethyl amine as the base and cyrene as the green solvent. A wide variety of substrates bearing different typical functionalities reacted efficiently, leading to high to excellent yields. The developed protocol can also be used for the formation of adducts from the piperlotine family, which have significant biological activities.

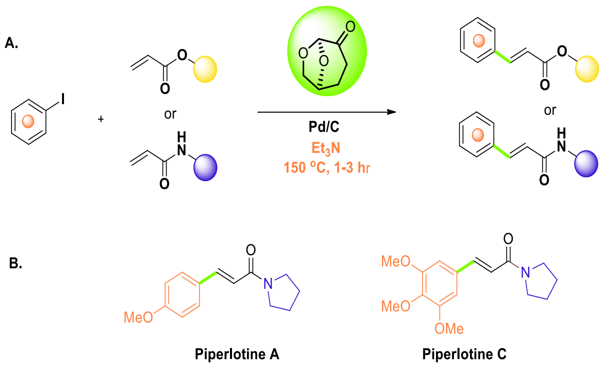

Figure1: A) Green protocol for Heck reactions using cyrene as the solvent.
B) Piperlotine adducts, synthesized using the described protocol.

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Triazole derivatives as potential eco-friendly pesticides – an *in vitro* and *in vivo* study

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The substantial increase in pest’s resistance to commonly used pesticides as well as the concern of growing environmental pollution have been the biggest challenges agricultural industry had to face in recent years. Large efforts have been made to produce a variety of novel and environmentally sustainable compounds to be used as an alternative to commercially available pesticides. [1] A set of 36 newly synthesized triazole derivatives have been assayed as potential acetylcholinesterase inhibitors by utilizing the Ellman’s protocol. [2] The highest inhibition percentages were obtained with compounds 7h (68.32%), KM35 (49.77%), KM16 (48.04%), KM18 (47.82%), and KM19 (39.89%). *In vivo* study was performed on two species of nematodes; *Heterorhabditis bacteriophora* and *Steinernema feltiae.* The nematodes were exposed to aforementioned compounds in the period of 72 h. The highest mortality rate of *Heterorhabditis bacteriophora* species was observed with the compound KM16 with the value of 75.0% after 48 h of incubation, while he highest mortality rate of *Steinernema feltiae* was observed with the compound KM18 with the value of 50.0% after 48 and 72 h of incubation. The inhibition percentages do not seem to correlate with the *in vivo* results, as the compound 7h had one of the lowest mortality rates within the tested group of compounds among the both nematode species.

Acknowledgement Croatian Science Foundation, project UIP-2017-05-6593.

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Methods of enhancing physical properties of active pharmaceutical ingredients

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Crystallization has a wide application in pharmaceutical and chemical industry because it is relatively simple, cost efficient and results in materials of high purity. The type of crystallization process and, of course, crystallization conditions heavily influence physical and chemical properties of active pharmaceutical ingredients and therefore the drug formulation process. One of the ways to enhance and optimize rheological properties of active pharmaceutical ingredients and its formulation processability is to prepare spherical particles. [1] For this purpose, methods like spherical agglomeration (SA), quasi emulsion solvent diffusion (QESD), ammonia diffusion system (ADS) and neutralization (NT) are used. Using the methods listed above, direct transformation of crystalline drug into compact spherical forms is enabled. This leads to improvements in flowability, solubility and compressibility of a crystalline drug. [2] In this paper, the possibility of obtaining spherical crystals suitable for further drug formulation will be examined. Although the methods of gaining spherical particles are not a novelty, finding the adequate solvent system is still based on trial and error. Selecting the adequate solvent, antisolvent and, depending on the method used, additive, binder or emulsifier is key for carrying out a successful process. [3] Spherical crystalline particles can be characterized by means of optical microscopy, scanning electron microscopy (SEM), X-ray powder diffraction (XRPD), low-angle laser light scattering (LALLS), Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy and differential scanning calorimetry (DSC). [2]

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Organocatalytic strategies for the installation of the congested stereogenic centers in isoindolinone structural cores

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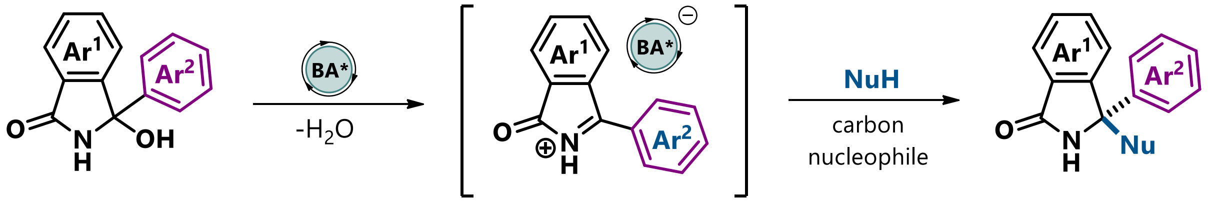
Isoindolinones have attracted much attention among synthetic chemists, as they are integral structural parts of a number of natural products and biologically active compounds. In most cases, only a single enantiomer is effective, or has a better activity profile than the other. Consequently, the synthesis of these structural motifs and the natural products that contain them has been the subject of much elegant and effective research. The most straightforward way to functionalize isoindolinones includes transformations of easily accessible 3-hydroxyisoindolinone precursors. Their ability to form highly reactive species under mild conditions renders them as attractive substrates in various catalytic reactions.

The overview of our recent achievements in the construction of isoindolinone derivatives comprising quaternary stereogenic centers will be presented. The focus will be given on chiral Brønsted acid-catalyzed additions of aromatic and non-aromatic carbon nucleophiles to *in situ* generated isoindolinone-derived ketimines. Generally, transformations proceed smoothly and the corresponding products are isolated predominantly in high yields and enantioselectivities.



- broad substrate scope
- commercially available and easily accessible starting materials
- high yields, and high enantio-, regio-, and diastereoselectivites

Fig. 1: Strategy rationale.

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The influence of antisolvent addition on powder properties of API

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Crystallization is one of the most important processes in pharmaceutical industry. The purpose of a process is to obtain solid material of defined quality and good properties, such as morphology, purity and size distribution. Crystallization process conditions affect the quality of solid material. Morphology and size distribution are important for different post-processes, such as filtration, drying and formulation.

In this work, crystallization with antisolvent addition was performed. Experiments were conducted with three different antisolvents (water, MTBE and *i*-octane) and for different rates of antisolvent addition while maintaining a constant temperature. For selected process conditions, the influence of the cubic cooling profile on the crystallization yield and size distribution was examined. The obtained materials were characterized by XRPD, thermal analysis, microscope and PSD analysis. The best yield of crystallization process and unimodal particle size distribution were obtained using water as antisolvent. Experiments with different addition rate show that the best yield and small crystals were obtained using fast addition rate. Cubic cooling profile affects to better yield, but cause broad particle size distribution.

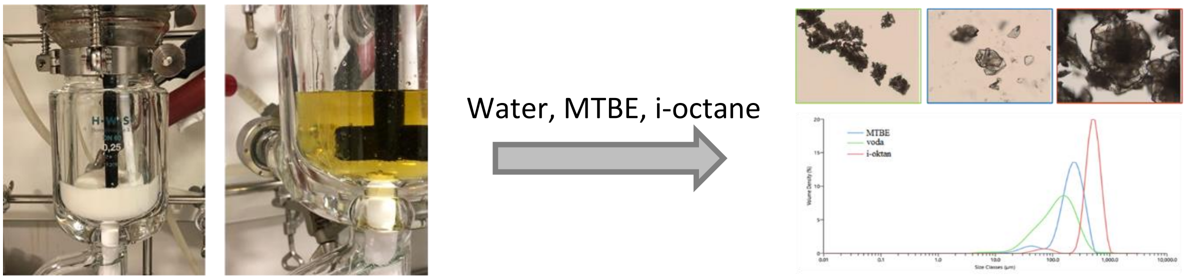

Fig. 1: Scheme of the influence of antisolvent addition on powder properties.

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Evaluation of extraction efficacy and matrix effects for six anticancer drugs in human plasma using different sample preparation techniques with LC-MS

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Determination of matrix effects and extraction recoveries is of high importance in bioanalytical method development. Matrix effects are commonly observed in LC-MS analyses of human plasma samples as signal enhancement or suppression due to co-extracted plasma components. Complicated sample preparation procedures are employed to reduce interferences and selectively extract analytes of interest from complex and variable matrices. [1] Palbociclib (PAL), ribociclib (RIB), abemaciclib (ABE), anastrozole (ANA), letrozole (LET), and fulvestrant (FUL) are anticancer drugs used in combination therapy of breast cancer. They are prone to inter-patient concentration variability and are potential candidates for therapeutic drug monitoring, therefore several LC-MS methods for their quantitation in patient plasma samples have been reported. [2,3] However, little attention has been given to developing a robust sample preparation procedure for the simultaneous extraction of these drugs, which exhibit a wide range of physical-chemical properties that pose a challenge to their successful extraction. The aim of this work was to evaluate extraction efficacy and matrix effects using protein precipitation (PPT), solid phase extraction (SPE) with different sorbents and eluents, phospholipid removal (PLR), and dispersive liquid-liquid microextraction (DLLME). Samples were prepared as pre-extraction and post-extraction spiked plasma and analysed using LC-MS along with standard samples of equal concentrations. Significant matrix effects and low extraction recoveries were observed for the highly lipophilic, weakly acidic FUL in most of the tested conditions. The weakly basic and relatively hydrophilic ABE suffered from extensive matrix effects with C18 sorbents, while PAL and RIB exhibited ion enhancement with mixed-mode cation exchange. Finally, the neutral and moderately lipophilic ANA and LET gave high yields with low matrix effects in most of the tested conditions except for mixed-mode cation exchange. Favourable results in terms of both extraction recoveries and matrix effects for all the analytes were obtained with DLLME using chloroform as extracting and *i*-propanol as dispersing solvent. Extraction recoveries were 67.3-94.9%, with matrix effects 46.6-120.4%. SPE using a C18 sorbent eluted with 5% ammonia in methanol also showed promising results, with extraction recoveries 37.5-100.7%, and matrix effects 88.3-136.4%.

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Trace metal adsorption on plastic pellets and fibers in the marine and estuarine environment

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Plastic materials nowadays are in the focus of research as persistent, relatively inert pollutants of marine [1] and estuarine [2] environment. Plastic debris represents approximately 80% of total aquatic pollutants, with the quantities increasing on daily basis. Trace metals are naturally present in the aquatic environments, and due to industrial, agricultural, and other activities, they can be present in increased concentrations and pose a significant threat to the ecosystems and human health. Thanks to the functional groups found on plastics surface, especially on weathered one, plastic particles interact with trace metals, resulting in their accumulation and synergistic threat for the ecosystems. Hereby, we studied the adsorption of trace metals on two forms of pre-production plastic products ubiquitous in the world oceans. Plastic pellets and fibers were deployed for six months in the estuarine and marine systems and analyzed afterwards. Trace metals (Cd, Cu, Pb, Zn, Ni and Co) were acid-leached [1] from the deployed pellets and fibers and determined by cathodic and anodic stripping voltammetry by Metrohm Autolab modular potentiostat/galvanostat Autolab PGSTAT204, connected with a three-electrode system Metrohm 663 VA STAND. Working electrode used was static mercury drop electrode (SMDE). In general, higher amounts of trace metals were adsorbed on both forms of polymer samples in the marine system when compared to the estuarine, except in the case of Cd, where the highest amount was detected from estuarine pellet samples. Fibrous form collected highest amounts of Zn, Cd, Cu and Ni, while the pellets deployed in estuarine environment adsorbed higher amounts of Pb and Co. The determined mass fractions of trace metals in both systems were similar to the values found in literature and followed the order: Cd < Co < Ni < Zn < Cu.

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Hammett correlation and reaction mechanisms in mechanochemical imine formation

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Solution-based physical organic chemistry was marked by the development of Hammett correlation, which further served as a major tool for deciphering the mechanisms of organic reactions in solution. [1] If applicable to mechanochemical reactions, it will provide support for understanding the reaction mechanisms and expansion of this important synthetic methodology. As a model system to test the validity of the Hammett equation under mechanochemical conditions, we focused on imine formation from an aromatic aldehyde and anilines. [2] Using *in situ* Raman reaction monitoring and kinetic analysis, we find a linear relationship between the reaction probability and Hammett constants indicating that this classical concept of chemical reactivity is valid for reactions conducted by ball milling and could prove useful for optimization of mechanochemical reactions. [3] The Hammett plot showed that the imine formation is sensitive to the nucleophilicity of the aniline partner with the reaction probability increasing with stronger electron donor substituents, as expected. We further explore reaction mechanism of imine formation on a catalysed reaction, in a contrast to the otherwise facile imine preparation by neat grinding. [4]

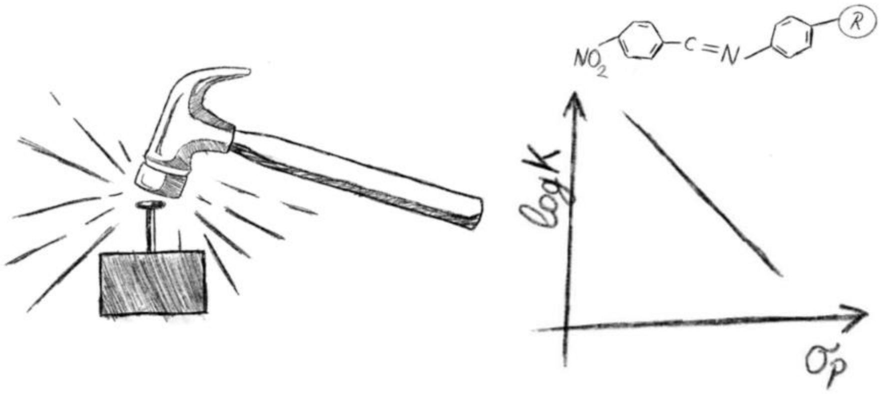

Fig. 1: Application of the Hammett model to imine synthesis in a ball mill.

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Ultrasonic solvent extraction of traditional Croatian cheeses matured in a lamb skin sack

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Cheeses that matured in animal skin sacks belong to traditional cheeses that are strongly connected to the culture and history of the country of their origin. Their main specificity is anaerobic ripening in a sack made from the whole skin of a lamb or goat. [1] The production of cheese in a sack has a long tradition in the Croatian region of Dalmatia. Historically, it dates back to the time of the ancient Illyrians and Thracians, who used lamb skins to store and transport milk from the Dinara mountain to the valley. The cheese was probably created by accident when the rennet in the lining of the skin sack, combined with the heat of the sun, caused the milk to separate into curds and whey. Recently, there has been an increasing interest in the consumption of traditional kinds of cheese, mainly because no additives are used in their production and because they have a positive impact on human health. [2]

In this investigation, cheese extracts were obtained by ultrasonic solvent extraction (USE) and analysed by gas chromatography-mass spectrometry (GC-MS). Fatty acids were predominant volatiles, accounting for 78.2% of the total cow cheese sample, 93.5% of the goat cheese sample, and 97.4% of mixed cow and goat cheese sample. (*Z*)-octadec-9-enoic acid (oleic), hexadecanoic acid (palmitic) and decanoic acid (capric) were the most represented in all samples.

Usually, the main step in GC analysis of fatty acids (especially long-chain ones) is their derivatization into suitable volatile esters (methyl, ethyl and isopropyl esters). [3] In this study, USE in combination with GC-MS analysis is proved to be a simple and fast method for the isolation and identification of long-chain fatty acids without their prior derivatization.

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Application of narrow-gap electrodes for electrochemical determination of antioxidants in high-resistance solvents

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Electrochemical methods for antioxidant determination are preferred due to their short analysis time, high sensitivity, portability, low detection limits, low sample and solvent consumption, and wide working range, and they are more economical than existing traditional analytical methods. [1] The problem with the electrochemical determination of antioxidants in organic samples is a large number of hydrophobic antioxidants and the difficulty of antioxidant sample preparation for electrochemical determination. One of the possibilities for electrochemical determination of water-insoluble antioxidants is direct determination in organic solvents used for their extraction. Low electrical conductivity is the main disadvantage of antioxidant determination in organic solvents. We can address this disadvantage by using narrow-gap electrodes. Electrodes with small inter-electrode gaps (100–250 µm) have already been used in organic electrochemical synthesis. [2] The main advantage of these narrow-gap electrodes is using a small amount or no supporting electrolyte. We report here the preparation and usage of narrow-gap electrodes for antioxidant determination in the organic extract. Two electrode system with a 100 µm or less inter-electrode gap is prepared using 25 µm platinum wire placed in a glass capillary sealed parallel with a second platinum wire inside the outer glass capillary. The system is tested in model solutions by cyclic voltammetry (schematically shown in Fig. 1) and electrochemical impedance spectroscopy and is tested for electrochemical determination of some hydrophobic antioxidants like Trolox and α-tocopherol.

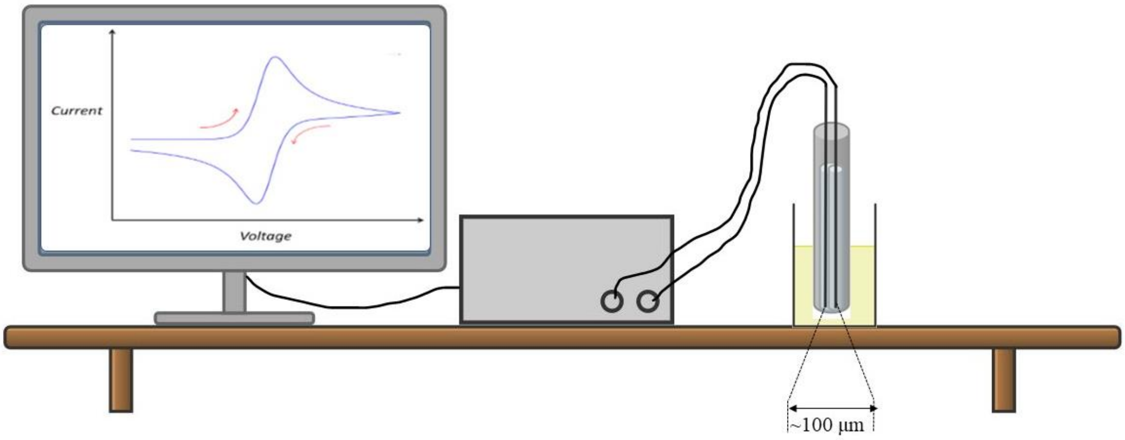

Fig. 1: Schematic representation of the electrochemical determination of antioxidants in the organic solvent.

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Detecting elusive radicals using spin traps. Case study on Hofmann-Löffler-Freytag reaction

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A wide variety of systems are being researched with the goal of functionalizing distant unfunctionalized (alkane) carbons using updated versions of the Hoffmann-Löffler-Freytag (HLF) reaction. [1] The induced cleavage of sulfonamides with iodine and a co-oxidant is one of the more popular methods within the HLF reaction procedures. In such procedures, an N-radical is generated via homolytic cleavage of the N–I bond, when iodosulfonamide, an intermediate product, is photochemically activated. [2] Considering that N radicals are unstable intermediates, the stability of such radicals, which is described in the work done by Šakić and Zipse, [3] determines their concentration and thus the possibility of detection using the electron paramagnetic resonance (EPR) devices. A series of differentially N-substituted amines was prepared in good to excellent yields in order to activate the N–H bond thereby producing the coveted N-radicals which take part in rearrangement as described in the HLF reaction mechanism. The identity of these compounds was confirmed by ^{1}H, ^{13}C NMR and IR measurements. These N-centered radicals have already been detected via EPR measurements and described by the Muñiz group, [4]; however, Khort [5] has done extensive theoretical calculations and therefore has raised some serious doubts regarding this work. Herein, we provide results collected from EPR experiments regarding detection of the N-centered radicals utilizing spin traps, along with theoretical calculations to serve as support and elucidation of the experiments.

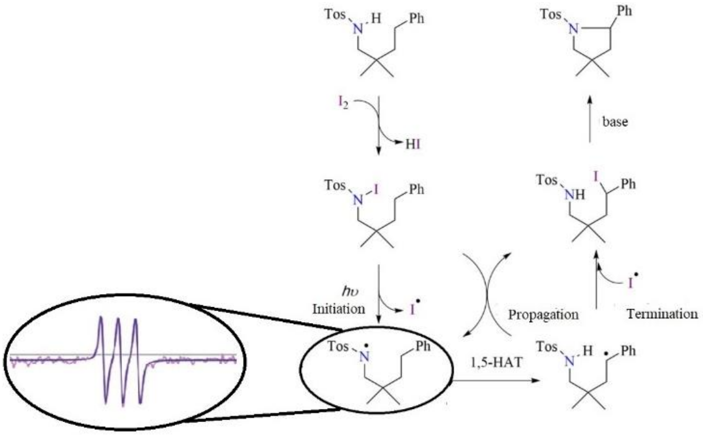

Fig. 1: Mechanism of HLF reaction and EPR signal of the N-centered radical.

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Photophysical and computational study of iminocoumarin and imidazo[4,5-*b*]pyridines conjugates as novel pH sensitive probes

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Design and development of molecules for (chemo)sensing and optoelectronic applications is of great interest in organic chemistry and sensing technology. [1] Benzazoles are among the most privileged heterocyclic subunits in the medicinal chemistry due to a wide range of bioactivities, [2] while iminocoumarins are known for their interesting spectroscopic features. It is no surprise that their conjugates are being explored for pH sensing applications based on their excellent spectroscopic response in correlation with pH value. Here we present the synthesis and spectroscopic characterization of novel iminocoumarin derived imidazo[4,5-*b*]pyridines in several polar and non-polar solvents (Figure 1). The absorption spectra show a strong dependence on iminocoumarin substituents, solvent polarity and pH, which allows for their potential use as sensitive and selective optical sensors in biological, environmental, and chemical processes. [3] To determine their protonation states under different pH conditions, we used the (SMD)/B3LYP/6-31+G(d) model to calculate the matching pK_a values, which are found in very good agreement with experiments. The obtained data reveal that under neutral pH = 7, these systems are present as cations monoprotonated at the exo-imine, while in the pH range 1–13, they exchange between neutral and diprotonated forms, which is responsible for alterations in UV-Vis responses.

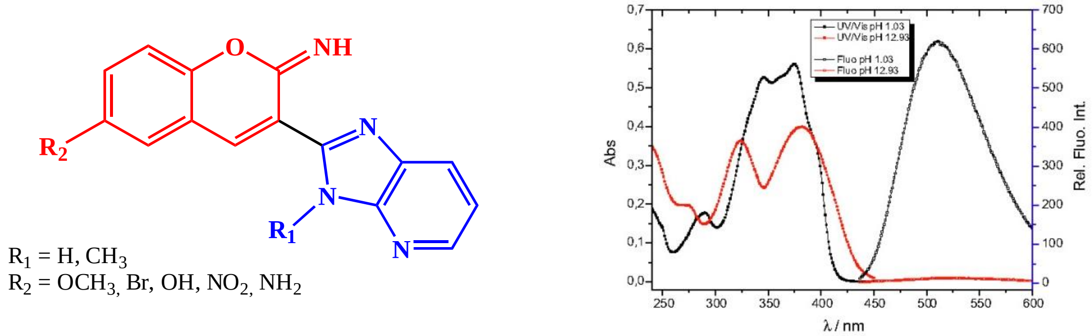

Fig. 1: Structures of investigated systems (left), and a display of typical absorption and fluorescence emission spectra (R_1 = H, R_2 = OCH_3, λ_{exc} = 380 nm) at pH = 1.03 and pH = 12.93 (right).

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Two-stage process for extraction useful metals from a polymetallic ore flotation concentrate: A laboratory study

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Reserves of rich ore, from which it is technologically possible and economically feasible to obtain metals, mainly by pyrometallurgical processes, are reducing from year to year. At the same time, intensive, world-wide development of technology is causing higher metal consumption, which has resulted in multiple increases of metal prices in recent years.

Study of new procedures for usage of low-grade metal ores (*e.g.* Cu and Zn), while also respecting rigorous environmental regulations, are considered current problems of extractive metallurgy in developed countries. Some of these ores are polymetallic ores. Therefore, increasing efforts are being made to develop new hydrometallurgical and biohydrometallurgical procedures that are more selective than conventional ones and which would enable successful processing of this kind of raw material. [1]

The aim of this study was to investigate the possibility of applying *Acidithiobacillus* sp. B2 to obtain copper, zinc and gold from a polymetallic ore flotation concentrate. The study was designed in two phases. The first phase was a classic biooxidation process in which the microorganisms oxidize sulfides, leaching copper and zinc while simultaneously concentrating gold in the ore. In the second phase, after elimination of the sulfide substrate, the rate of gold leaching by potassium cyanide was analyzed.

The leaching was conducted using the shake flask testing technique during a period of 28 days at a temperature of 28 °C. The percentage of copper and zinc leached at the end of this study was 37.63% and 47.95% respectively. The results obtained indicated 6- and 13-fold (for copper and zinc, respectively) higher metal leaching efficiency in the suspension with iron-oxidizing *Acidithiobacillus* sp. B2 than in the control suspension. In the next phase of the study, after elimination of the sulfide substrate, gold was extracted with potassium cyanide from the remaining polymetallic ore concentrate. The results obtained showed that the efficiency of the gold extraction process was 80%.

These results demonstrated that this easily applicable bioleaching method can result in high recoveries of copper, zinc and gold from the polymetallic sulfide ore flotation concentrate.

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Development and optimization of bioflavonoids extraction from ginkgo (*Ginkgo biloba* L.) leaves using deep eutectic solvents

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The plant kingdom is a known reservoir of bioactive natural products. The best-studied group to date is flavonoids, which perform multiple functions in plants and have a major impact on human health. Flavonoids can occur in free form in plants, but are more commonly glycosylated, methylated, acetylated, prenylated, or polymerized, which affects their bioactivity. Flavonoid dimers, known as biflavonoids, which consist of two identical or different flavonoid units, are a less-studied subgroup of flavonoids but have recently been recognized as potential pharmaceutical agents, particularly because of their antiviral, antifungal, and other bioactivities. They are commonly found in plants used in traditional medicine, such as ginkgo (*Ginkgo biloba* L.). The crucial step for the pharmaceutical use of any natural product is its isolation from the natural matrix. This process usually involves the use of various organic solvents, which can be hazardous to the environment and humans. Therefore, natural deep eutectic solvents (NADES) have recently been recognized as environmentally friendly and cheap extraction agents, whose additional advantage is their pronounced flexibility.

To select the best NADES for efficient extraction of biflavonoids from ginkgo, COSMOtherm software was used and 288 NADES were studied. Based on the obtained model predictions, 15 NADES were selected, synthesized and characterized (density, viscosity, pH). After synthesis, the extraction of biflavonoids was performed in a series of batch experiments with the same initial mass of crushed leaves of ginkgo, where the extraction efficiency was defined as a criterion for the selection of the best NADES (Fig. 1). The highest extraction efficiency was obtained with Choline Chloride : Ethylene Glycol (ChCl:EG) 1:2 NADES containing 20% H_2O. Compared to extraction with 70% methanol, 13% higher extraction efficiency was obtained using ChCl:EG 1:2 with 20% H_2O NADES under the same process conditions. The extraction with selected process was further optimized using the experimental Box-Behnken design at three levels with three factors: extraction time, ratio of initial mass of shredded leaves and mass of NADES, and temperature.

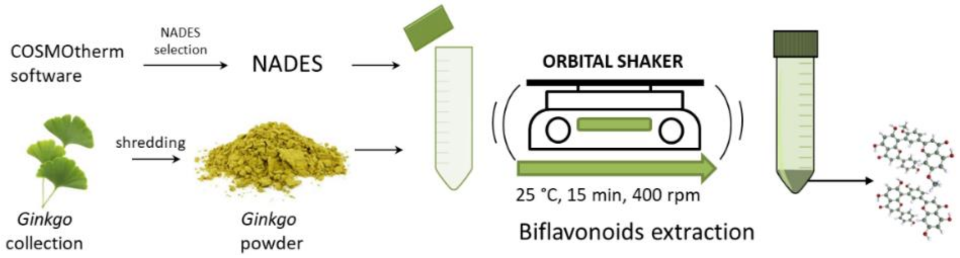

Figure 1. Schematic diagram of bioflavonoids extraction process.

Acknowledgement This work has been supported by Croatian Science Foundation project *Biflavonoids role in plants: Ginkgo biloba L. as a model system* under project no. UIP-2019-04-1018.

The physicochemical characteristics of non-thermally treated fruit juice

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In the last two decades, the increasing demand for fresh-like food products have risen interest in the development and application of non-thermal processes such as sonication, microwaves, pulsed light, radio waves, ultraviolet light (UV-C) treatment, pulsed electric fields and high pressure processes in the food industry. However, the application of UV-C irradiation to liquid foods is a relatively new challenge for beverage manufacturers. Due to certain limitations that UV-C technology has, its application is often combined with other processing techniques to maintain juice quality. In this study, freshly squeezed orange juice was subjected to thermal treatment (at 80 °C/2 min), sonication in an ultrasonic bath (15, 30, and 60 min at 25 °C, 37 kHz frequency), and UV-C treatment (15, 30, and 60 s at 25 °C). In addition, a combination of sonication and UV-C treatment was also performed. The effects of the thermal and non-thermal treatments on pH, total soluble solids (°Brix), and color were evaluated and compared with the untreated juice (control). It was found that the treatments noticeably affected the color properties. The choice of optimal processing conditions is very important to obtain the best physicochemical properties of non-thermally treated juice compared to control and thermally treated juice.

Acknowledgement This work was supported by the project *Increasing the development of new products and services arising from research and development activities – phase II: Development of innovative products to increase food quality* – KK.01.2.1.02.0282.

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Analysis and modelling of a 3D-printed ceramic monolithic reactor for oxidation of aromatic volatile organic compounds

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Recently, more and more attention has been paid to the application of process intensification methodology, and accordingly, the possibility of applying additive manufacturing technology or 3D-printing to the manufacturing of advanced versions of catalysts and chemical reactors using different materials is being studied. Considering that it is possible to create computer-optimized reactors using additive manufacturing techniques, it is easy to see the enormous potential this technique offers, especially on a laboratory scale.

In this research, the analysis and modelling of a 3D-printed ceramic monolithic reactor fabricated by stereolithography was performed, while the deposition of the catalytically active layer was done using the wet impregnation technique. Their effectiveness was tested by the catalytic oxidation of BTEX compounds consisting of benzene (C_6H_6), toluene ($C_6H_5CH_3$), ethylbenzene ($C_6H_5CH_2CH_3$), and xylene ($C_6H_4(CH_3)_2$). BTEX are aromatic hydrocarbons that occur in the environment as compounds naturally found in the oil. However, they are most commonly found in the atmosphere, where they can have harmful effects not only on the environment but also on living organisms and humans.

A one-dimensional (1D) heterogeneous reactor model is proposed to model the reactor, which includes a kinetic model for the first-order reaction. The results obtained with the BTEX mixture and individual BTEX compounds were compared. The evaluation of the acceptability of the proposed model based on the corresponding values of the root of the standard deviation between the experimentally determined and the theoretically predicted values showed that the proposed model successfully describes the experimental results. Considering that the 1D heterogeneous model was derived based on the associated balances for model components in the gas phase and the balance for model components on the surface of the catalytic layer, which corresponds to the physical picture of the process, it was concluded that the proposed model is suitable for describing the catalytic oxidation of BTEX and similar aromatic volatile organic compounds using heterogeneously structured catalysts.

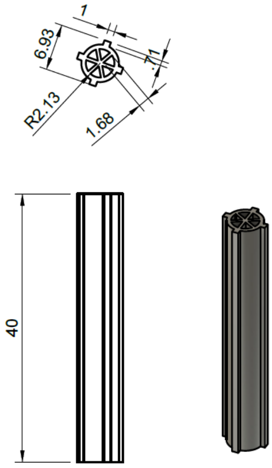

Fig. 1: Design of the tested 3D-printed ceramic monolithic catalyst.

Optimization of the biocatalytic cascade synthesis of (*R*)-3-hydroxy-γ-butyrolactone by means of kinetic modelling

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Biocatalysis can be defined as the use of enzymes or whole cells to speed up synthesis reactions. [1] The newer concept in biocatalysis is the synthesis of valuable chemicals achieved through complex cascades with different enzymes sustainably and efficiently. In comparison with conventional chemical processes, cascade reactions offer many advantages like no need for isolation of intermediate products, mild and controlled reaction conditions, simple and economically profitable reaction system which is composed of one reactor. [2]

3-hydroxy-*γ*-butyrolactone (HBL) is a functional chiral building block with application in the synthesis of different polymers, solvents and pharmaceuticals. With an enzymatic approach, the synthesis of HBL can be economically viable while maintaining the high selectivity of this valuable chemical. [3]

In this work, the kinetic model for the cascade reaction (Fig. 1) was developed. Model validation was done by performing the batch reactor experiments. Simulations were used to optimize reaction conditions and choose the best reactor design.

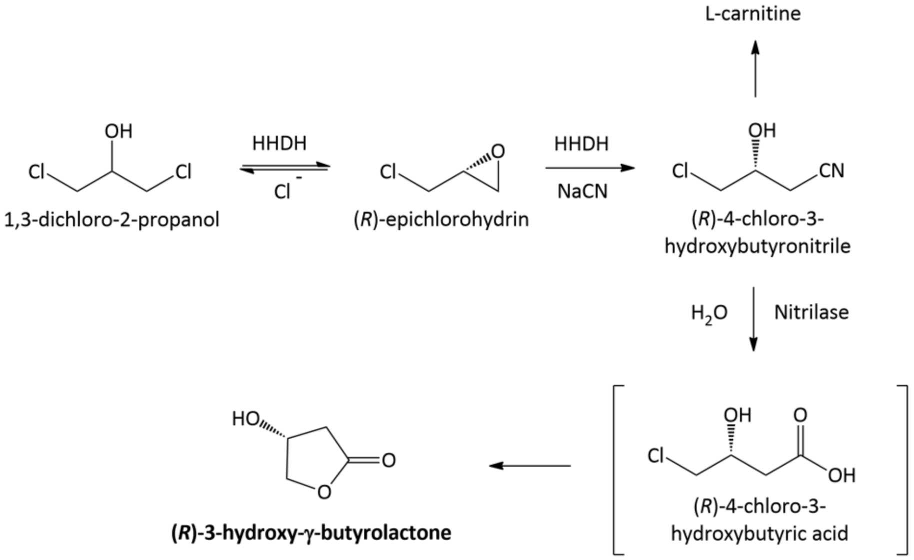

Fig. 1: Chemoenzymatic 4-step cascade for the production of (*R*)-3-hydroxy-γ-butyrolactone (HBL). In the first step, catalyzed by halohydrin dehalogenase (HHDH), 1,3-dichloro-2-propanol (DCP) is converted to (*R*)-epichlorohydrin (ECH), followed by ring-opening with sodium cyanide to (*R*)-4-chloro-3-hydroxybutyronile (CNOH). In the third step catalyzed by nitrilase, CNOH is hydrolyzed to (*R*)-4-chloro-3-hydroxybutyric acid which spontaneously cyclize to HBL.

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Influence of ultrasound amplitude on borax nucleation kinetics in a batch crystallizer at different cooling rates

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The ultrasound irradiation during crystallization (*i.e.* sonocrystallization) is increasingly used due to the numerous advantages that this operation provides. However, for process design and control it is of enormous importance to define the influence of process conditions on nucleation kinetics of particular substance. In this work the influence of ultrasound amplitude on nucleation kinetics of borax decahydrate was systematically investigated in a laboratory scale stirred crystallizer of 2,7 dm^3. The tests were performed at four amplitudes of ultrasonic power, A, in the range of 0 to 30%, and at four cooling rates, b, from 4 to 10 $°C\ h^{-1}$ measuring the metastable zone width and power consumption. The experimental results showed narrowing of the metastable zone width by increasing ultrasound amplitude and decreasing cooling rate. Finally, the functional dependence of the metastable zone width on these variables was derived ($\Delta T_{max} = K\,A^{-0.739}\,b^{0.3525}$). It was found that in all systems the value of the apparent order of nucleation is the same, while the nucleation rate constant increases with the ultrasound amplitude, *i.e.* with the power dissipated to the system. It was also found that the nucleation started by the primary nucleation mechanism at all examined conditions, while its rate is considerably affected by the ultrasound amplitude and the cooling rate. Nevertheless, granulometric properties of crystals obtained at 20% amplitude show close values of mean volume diameter and its standard deviation regardless of the cooling rate. In addition, these values are significantly lower than those obtained in the silent system at 0% amplitude.

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Characterization of microplastics from Zaglav beach on the island of Vis

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In this work, characterization and identification of microplastics waste found in the Zaglav beach sediment on the island of Vis was performed. Sampling and separation of samples was performed by the Institute of Oceanography and Fisheries in Split and 865 specimens of microplastics waste delivered to the Faculty of Chemistry and Technology where they were analyzed. The first step was visual sorting of the specimens into categories according to their shape, as defined by DeFishGear protocol: filaments, films, fragments, granules, pellets and foams. [1] Transparency and color of each individual specimen were also determined as well as their mass. Area and maximum dimension of each specimen were determined using Digimizer free software package for image processing. For the purpose of identification of the type of polymer material FTIR spectroscopy and differential scanning calorimetry (DSC) were used. The results show that the majority of microplastics specimens can be categorized as fragments by shape. Specimens are mostly white, blue, orange, gray and black in color and majority of them are opaque. 59.31% of specimens have dimension smaller than 5 mm in diameter which sorts them in category of microplastics, 40% are in the range 5-25 mm which sorts them in category of mesoplastics while 0.69% are larger than 25 mm which sorts them in category of macroplastics. Analyzed specimens are mostly made of polypropylene (90.52%), followed by high density polyethylene (7.86%) and low density polyethylene (1.62%). Results indicate that microplastic waste at the Zaglav beach on the island of Vis originate from improperly discarded disposable packaging.

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Raman spectroscopy for ceritinib solution concentration and slurry density estimation

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The aim of this work is to investigate the use of *in-situ* Raman spectroscopy for the monitoring of cooling crystallization process. For this purpose, Raman spectroscopy with a focused laser beam was utilized for the estimation of solution concentration and slurry density. The Raman signal depends on many factors, including the composition of the solid and liquid phase, as well as the size and shape of the crystals. [1] Therefore, the use of Raman spectroscopy for quantitative measurements is challenging and requires advanced chemometric methods.

The concentration of an Active Pharmaceutical Ingredient (API), ceritinib was determined experimentally in a solution mixture of 90% acetone and 10% water. The goal was to build a calibration model for the estimation of ceritinib concentration during the crystallization process.

Methods used to build the calibration models include Partial Least Square Regression (PLSR) and an Artificial Neural Network (ANN). During model development, various methods for spectra preprocessing were evaluated. In addition, different hyper parameters for the models were tested by ANN. The prediction performance used to evaluate the developed models was the root mean square error of prediction (RMSE).

The model created with an artificial neural network proved to perform better than the partial least square regression model for the estimation of solution concentration, but were not able to predict slurry density with good accuracy.

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The influence of the reaction parameters and the feedstock type on the synthesis of fatty acid propyl, butyl, isobutyl, pentyl, and isopentyl esters

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Fatty acid alkyl esters (biodiesels) can be synthesized via transesterification reaction from a variety of feedstocks and alcohol isomers, in a presence of a catalyst, influencing the end biodiesel conversion. The use of higher and branched alcohol isomers in biodiesel synthesis is justified through the potential improvement in biodiesel's application properties, e.g. low-temperature properties or cetane number, [1] whereas the implementation of waste feedstock further contributes to the sustainability of the entire process. [2] The presence of the structural branching, as well as the molecular weight of the reactants used dictates the rate and the efficiency of transesterification reactions. In general, the increase in the alcohol chain length and the presence of structural branching in reactants leads to a decrease in the reaction conversion, due to higher steric hindrances. [3] Here, fatty acid propyl, butyl, isobutyl, pentyl, and isopentyl esters were synthesized from corresponding alcohols and a selected feedstock type (sunflower oil, rapeseed oil, coconut oil, animal fat or waste cooking oil), in a presence of potassium hydroxide as a catalyst, at a constant temperature of 60 °C. The influence of the reaction time (up to 120 min), the molar ratio of the reactants (5:1-12:1), and the mass fraction of the catalyst (1-3 wt%) on the reaction conversion was studied. The results showed that the molar ratio of alcohol to oil/fat, and the mass fraction of the catalysts are the most significant reaction parameters, whose increase generally leads to an increase in the reaction conversion.

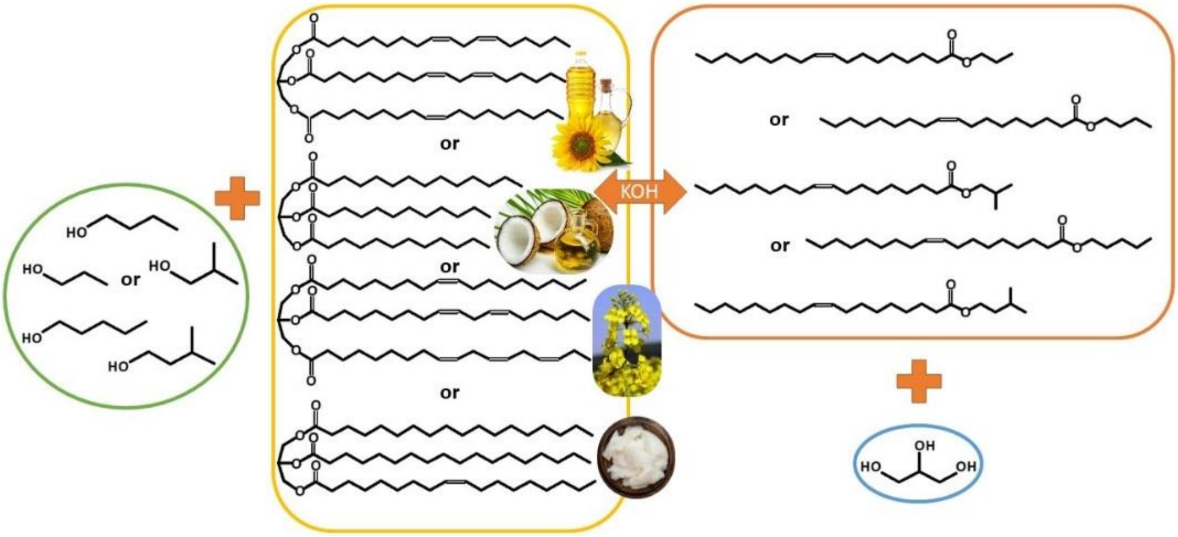

Fig. 1: Biodiesel synthesis from various alcohols and feedstock types.

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Continuous crystallization: Improving product quality and consistency in the pharmaceutical industry

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The crystallization process plays a key role in defining the physical properties of active pharmaceutical ingredients (API) and therefore impacts the formulation process and drug bioavailability. Currently, most crystallization processes in the pharmaceutical industry are carried out in batch mode. Although batch crystallization has been extensively studied, the problem of product quality inconsistency is still present, which is why continuous crystallization is gaining more attention. In comparison to a classical batch process, continuous crystallization has a number of advantages, such as less product quality fluctuations and better process control. [1] As regulatory requirements for API's and FDF's become stricter, there is an increasing need for precise particle size and polymorphic form control during a crystallization process where a switch from batch to continuous manufacturing plays an important role. The two basic types of platforms in which continuous crystallization is carried out and studied are MSMPR (mixed suspension mixed product removal) made up of a single or multiple stirred tank reactors (STR's) operating in continuous mode and continuous tubular reactors. Several modifications of continuous tubular crystallizers have been developed, such as CPFC (continuous plug flow crystallizers), COBC (continuous oscillatory baffled crystallizers) and CSFC (continuous segmented flow crystallizers). [2] There are numerous examples in the literature on how continuous crystallization has proven to be a successful strategy in solving various industrial problems, such as polymorph control, spherical crystallization, cocrystal preparation, and enantiomer separation. [3] This paper provides an overview of different basic and modified continuous crystallizers that have been studied and researched in the last three decades and also of the way they work and the methods of their control.

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Particle size analysis in pharmaceutical suspensions: Use of different methods from active pharmaceutical ingredient to final formulation

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Physicochemical and biopharmaceutical properties of a drug substances and dosage forms can be highly affected by the particle size; thus, it is considered as a critical process parameter in the pharmaceutical production. [1] The suspension dosage form is suited for poorly soluble active ingredients for various therapeutic indications. The advantages of the suspension dosage forms include effective dispensing of hydrophobic drugs, avoidance of the use of cosolvents and incorporation of relatively higher concentration of drugs in the products. [2] When developing a generic drug in form of suspensions, qualitative, quantitative, and microstructural similarity with reference medicinal product (RMP) is essential, therefore the particle size analysis as one of the most critical parameters should be thoroughly assessed. Thus, to enable selection of the most appropriate or optimal sizing technique, cross-correlation between different techniques is required. In this work different techniques for particle size determination used during suspension development, *e.g.* focused beam reflectance measurements (A), laser diffraction (B) and optical microscopy (C) are presented, evaluated and compared. Additionally, an overview of the analytical requirements that unite different techniques is given and it is placed in the context of confirming the pharmaceutical equivalence of the generic product in the form of suspension into the relation to the RMP.

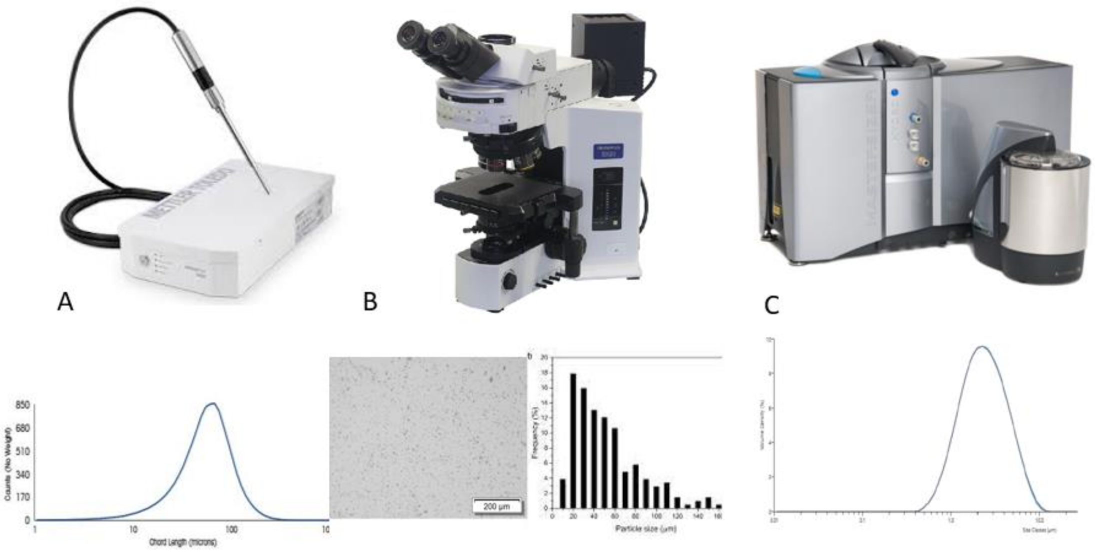

Fig. 1: Different particle size instruments and techniques: (**A**) Particle Track for focused beam reflectance measurements, (**B**) optical microscope for microscopy and (**C**) Mastersizer for laser diffraction with corresponding plots of size distribution.

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Effect of surfactant addition on precipitation of magnesium oxide from sea bittern

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The sea bittern produced in large quantities during the extraction of sea salt is a source for the extraction of valuable minerals. Various methods have been used to extract the valuable mineral, especially $Mg(OH)_2$. Magnesium concentration can reach values of up to 30-40 kg/m^3 of sea bittern, which is 20-30 times that of typical seawater. In this study, saturated limestone water was added to a sea bittern solution to obtain a magnesium hydroxide precipitate. Magnesium oxide was produced by calcination at 950 ^{o}C/5 h.

The aim of this research is to investigate the effect of the surfactant poly(vinyl-alcohol) on the particle size and morphological properties of the obtained magnesium oxide. In the synthesis of magnesium oxide, poly(vinyl-alcohol) was added as a surfactant to prevent agglomeration and affect particle size during synthesis. Poly(vinyl-alcohol) was added in a mass ratio of (1:4) and (1:5) in relation to the mass of magnesium hydroxide obtained by the precipitation process. A characterization of the MgO obtained under these conditions was carried out on the basis of chemical composition, thermogravimetric analysis (TG/DTG), transmission electron microscopy (TEM) and determination of particle size distribution.

The obtained results showed a positive influence of the addition of surfactant, as the microstructure of all samples is uniform and spherical, the particle size is reduced and the accumulation of particles is prevented. However, the formation of agglomerates is not completely prevented. The resulting agglomerates are smaller, due to the smaller particles formed by the presence of poly(vinyl-alcohol) during synthesis. With increasing addition of poly(vinyl-alcohol), the particle size of the resulting magnesium oxide precipitate decreased and agglomerates with an average particle size of 1034.18 nm are obtained.

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Extraction of *Pinus halepensis* essential oil and characterization by IR and UV-Vis spectroscopy

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In the IR spectroscopy analysis, we will focus only on caryophyllene, which is also the chemical component with the largest percentage in wild pine essential oil. Signals in the wave number range 1466-1380 cm^{-1} which appear as two separate peaks belong to the isopropyl or dimethyl groups of caryophyllene. The signals in the range 3000-2800 cm^{-1} belong to the C-H vibrations of the $-CH_3$ groups (symmetric and non-symmetric). At the end of the spectral analysis, we can conclude that the IR spectrum of wild pine essential oil suggests the presence of beta-caryophyllene, which is also the main chemical component of this oil. In organic compounds, four types of electronic transitions are distinguished: $\pi\rightarrow\pi^*$, $n\rightarrow\pi^*$, $\sigma\rightarrow\sigma^*$, and $n\rightarrow\sigma^*$. The last two transitions require very high energy and occur only in the deep UV region (below 200 nm), and therefore during various measurements only the first two transitions: $\pi\rightarrow\pi^*$ and $n\rightarrow\pi^*$ are used, which occur in the 200 nm to 700 nm region. Compounds with conjugated bonds adsorb energy in the UV and Vis region of the electromagnetic spectrum (200-800 nm). The UV-Vis spectrum presented in the figure below presents signals at 200 nm, 230-235 nm and in the range 270-290 nm.

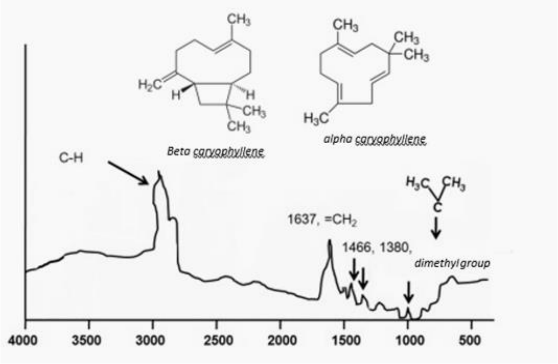

Fig. 1: IR spectrum of *Pinus halepensis* essential oil.

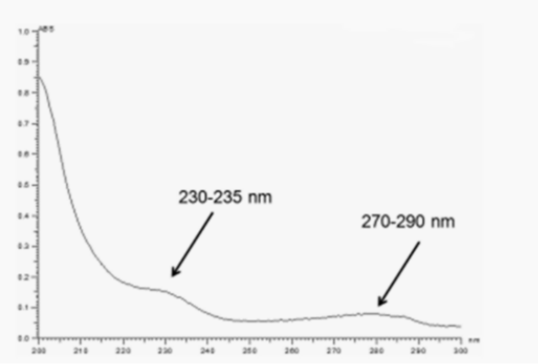

Fig. 2 : UV-Vis spectrum of the extract in hexane solution.

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Synthesis of valuable building block with immobilized biocatalyst in rotating bed reactor

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Halohydrin dehalogenases (HHDHs) are industrially important bacterial enzymes that belong to the group of lyases. On account on their activity, stability, β-regioselectivity and (*R*)-enantioselectivity, HHDHs can be used in the synthesis of optically active epoxides and β-substituted alcohols. Industrial applicability of biocatalysts increases with their stability and reusability, both of which can be improved with the use of different immobilization methods. Some of the most common methods of enzyme immobilization include covalent binding, adsorption, ionic binding, encapsulation, and cross-linking. Apart from enzymes, it is also possible to immobilize whole cells. The method of encapsulating whole cells in alginate beads is a cheap and simple method that enables the use of mild process conditions. Calcium alginate is one of the most commonly used carriers for the immobilization of whole cells. This method of encapsulation has several advantages, good biocompatibility, low cost, it is easily available and simple to prepare. In this work, recombinant *Escherichia coli* cells harboring HheC-ISM4 variant were immobilized in alginate beads and employed in rotating bed reactor (RBR) for the synthesis of (*S*)-2-(4-fluorophenyl)-3-hydroxypropanenitrile, valuable fluorinated building block for uses in fine chemicals industry. Given synthesis resulted in a high product yield and high optical purity of the product. The advantages of the RBR reactor over traditional batch reactor include enhancement of mass transfer, which often represents limitation in immobilized whole-cell synthesis, together with extremely simple recycling of the biocatalyst and its reuse in subsequent reactions.

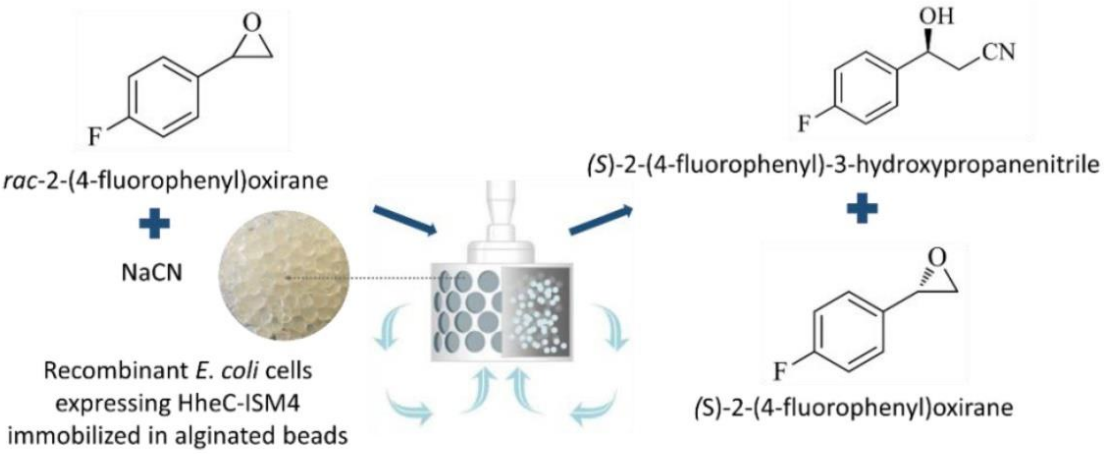

Fig. 1: Biocatalytic synthesis of (*S*)-2-(4-fluorophenyl)-3-hydroxypropanenitrile in rotating bed reactor catalyzed by immobilized *E. coli* cells harboring HheC-ISM4 enzyme variant.

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Structural equation modelling (SCM) and causality of chemical engineering models

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Considered is the concept of causal artificial intelligence (AI), as a part of artificial general intelligence (AGI), and its application for modeling, control, and optimization of chemical engineering processes. Causal models are presented as directed acyclic graphs (DAG) with nodes corresponding to state (process) variables and as exogenous inputs of inflow of mass and energy and control actions. The connections between edges are defined by causal functional relations (probability density distributions, regression or analytical functions, and neural networks or decision trees). Directions (arrows) of the edges represent causal orientation from the cause to the corresponding effect. Chemical engineering knowledge is based on deterministic laws of physics and chemistry. Hence, causal functional relations are defined by the basic principles of mass, energy, and momentum balances. The chemical engineering equations with the signs of equalities, implying reversible relations, are replaced with irreversible causality signs. They are expressed as structural equation models (SEM) with explicit and/or implicit causal relations defined as dependencies between "child" and "parent" nodes. Structural equations for systems with unknown and/or partially known chemical reaction mechanisms can be inferred by statistical tests of conditional independencies based on chemical concentration data. The SEM equations are graphically represented as directed acyclic graphs (DAG) and are Bayes networks with Markovian properties which are the basis of knowledge structural causal models (SCM). [1,2] According to J. Pearl, SCM knowledge models have three basic levels (knowledge hierarchy): 1) association, 2) intervention or doing level, and 3) counterfactual level of individual case hypothetical interventions after observed outcome. In this work, SEM modeling is applied to the case of the continuous nonisothermal reactor with interconnected reaction mechanisms. SCM results are presented in terms of reaction mechanisms identification, accuracy of prediction of unobserved reactants, and responses to process control interventions do(x).

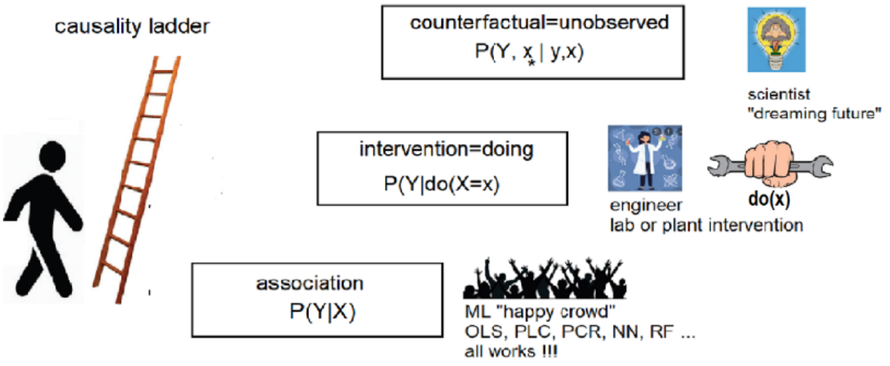

Fig. 1: Pearl's hierarchy of knowledge models

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Optimizing the reaction conditions of enzyme-catalysed betuloside hydrolysis

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Raspberry ketone is a natural phenolic compound found in the red raspberry (*Rubus idaeus*) and is widely used in the food and cosmetic industries. [1] Precisely because of its various market applications, the production of raspberry flavourings is an important trend. The amount of raspberry ketone in the fruit is extremely low, which makes direct isolation of the compound economically unviable. [2] A promising production method is a biocatalytic process that uses as substrate rhododendrol glycosides, e.g. betuloside, precursors found in inner birch bark. Hydrolysis of rhododendrol glycosides results in the (*R*)- and (*S*)-rhododendrol, which can be enzymatically converted to raspberry ketone. [3]

In this study, the reaction of betuloside hydrolysis by β-glucosidase from almonds (Figure 1.) in a batch reactor was studied. The reaction conditions including buffer, pH and temperature were examined. The kinetic parameters were estimated under the optimal conditions of the previously defined parameters. To confirm the developed mathematical model and estimated kinetic parameters, the reaction was carried out in a batch reactor.

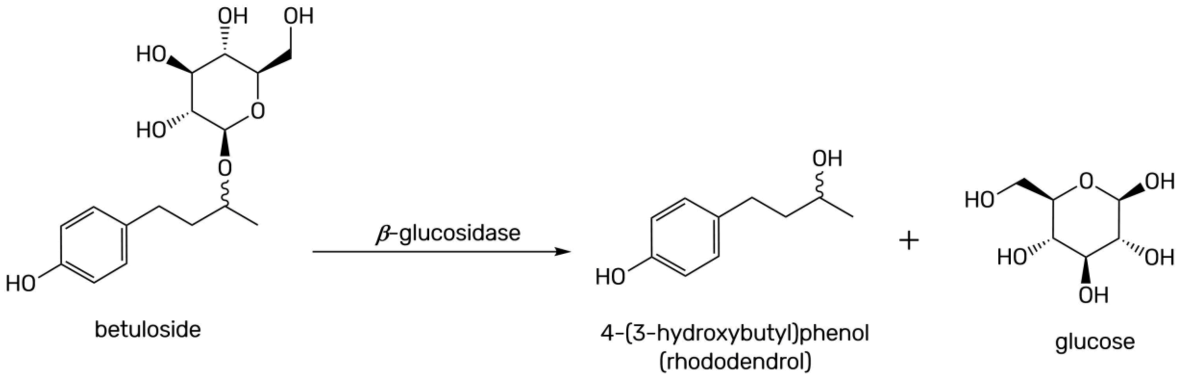

Fig. 1: The reaction scheme.

Acknowledgement This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101000560.

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Dual condenser configuration of a four-product dividing wall column

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Distillation is one of the most energy-intensive separation processes in the chemical process industry. Since it is also the most suitable for application at high capacities and used on largest industrial scale globally, a significant research effort is invested into increasing its sustainability. In the case of multicomponent separations this can be achieved in a cost-effective and compact way if common two or three distillation columns sequences are accommodated accordingly in a single shell in form of a so-called dividing wall column (DWC). Three product DWCs have been successfully implemented in the chemical process industry, their performances meeting, or even exceeding expectations based on theory. Even more benefits could be achieved by extending this technology to four product sequences. This has indeed been proven in theory, but industrial implementation is lagging behind due to concerns related to design, sizing and operability, caused by their complex internal configurations. This contribution is concerned with design and controllability aspects of a four product DWC employing a two condensers based internal configuration, which offers extra degrees of freedom that could enable better control properties, compared to other feasible configurations shown in Fig. 1. [1]

Present study was carried out using established modelling methods and mathematical tools for control system synthesis, but at the same time taking practical limitations and feasibility into consideration. Therefore, a realistic multicomponent feed composition was used, as well as simple but robust, established means of control. Closed-loop performance was evaluated using a series of controlled disturbances. Although the column operation could be successfully kept stable, in certain cases of common process disturbances simple temperature control may prove insufficient in maintaining the desired product composition without active vapor split manipulation. Being still impractical, the latter is an actual burden that needs to be overcome to enable moving dividing wall column technology to a higher level of sophistication.

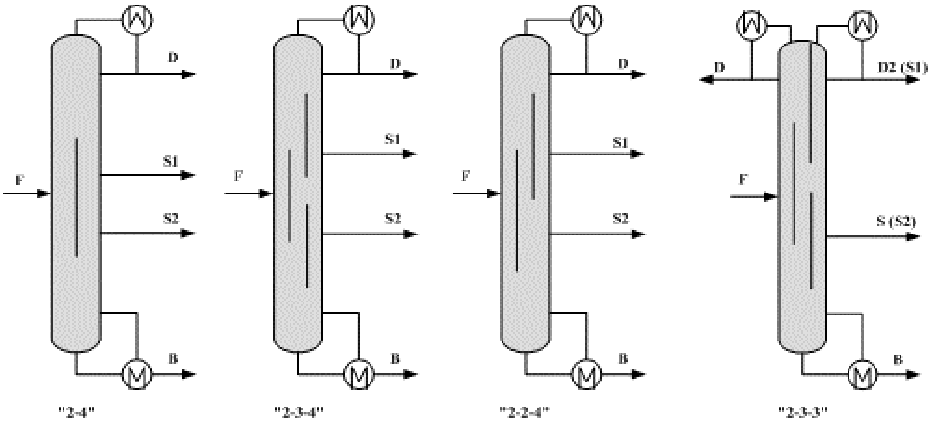

Fig. 1: Four product DWC configurations and their nomenclature.

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Preparation and characterization of litmus-based sensor films

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The objective of this work was to prepare a functional, litmus-based, pH responsive sensor film and use it to coat the 3D printed polyethylene terephthalate glycol-modified (PETG) test plates. The sol-gel method was used to prepare the sensor film. The main goal was to obtain a functional pH sensor film that would exhibit a clear response in real time.

For the sol-gel method, tetraethoxysilane (TEOS) and phenyltrimethoxysilane (FTMS) were used as precursors with water as solvent, the reaction was acid catalyzed with hydrochloric acid, litmus was used as pH indicator and titanium dioxide (TiO_2) was added to enhance the color intensity. In order to be used in 3D printed millireactor channels in future research, the prepared sensor films were tested on 3D printed test plates. The test plates were fabricated using fused filament fabrication (FFF) 3D printing technology. The working range of the immobilized films was tested in acidic and basic solutions with a variation of 1 pH unit.

The test plates with the applied films were examined with a scanning electron microscope (SEM) and Fourier transform infrared spectroscopy (FTIR), and the contact angle was inspected with a goniometer. Tests in pH solutions showed the functionality of the sensor films via color change (Fig. 1) after 10 minutes.

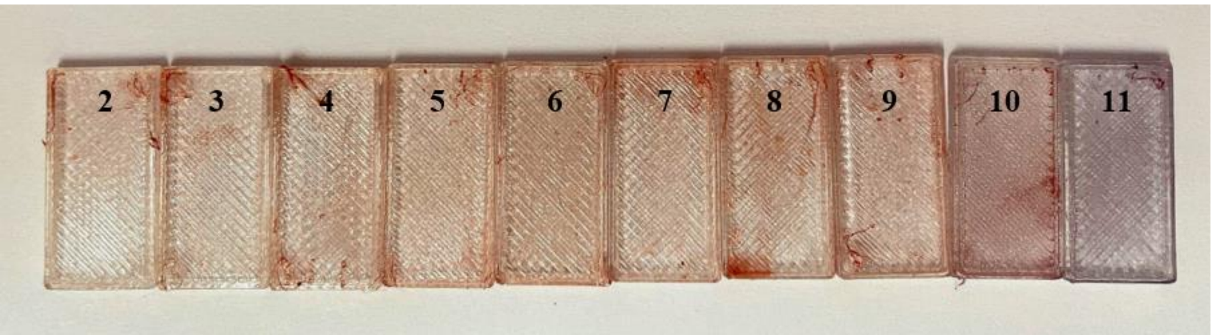

Fig. 1: Test plates with litmus-based sensor films after 10 minutes in pH solutions.

Acknowledgement This work has been supported by the European Regional Development Fund under the project: OS-Mi (KK.01.1.1.04.0006) and by the Croatian Science Foundation under the projects DOK-2020-01-8955 and DOK-2021-02-5999.

Synthesis of galactooligosaccharides in batch and enzyme membrane reactor

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Galactooligosaccharides (GOSs) are nondigestible oligosaccharides composed of a variable number of galactose units (from two to nine) linked by different glycosidic bonds to the terminal glucose. Many health benefits have been claimed for GOSs that are referred both to gut health and immune modulation. [1] The chemical synthesis of GOSs is laboured process, and uneconomical on a commercial scale, which is why the synthesis on a commercial scale is mostly performed using biocatalysis. [2] Traditionally, GOSs are produced in stirred tank reactors, but this setup includes inactivation and subsequent separation of the biocatalyst to achieve enzyme-free GOS products. An alternative to batch processes is the application of enzyme membrane reactor, where the membrane retains the enzyme while lower weight saccharides pass through it. As a result, simultaneous GOS synthesis and biocatalyst separation can be achieved. [3] In this work, transgalactosylation reaction catalysed by β-galactosidase from *Aspergillus oryzae* (Fig 1.) in the batch and enzyme membrane reactor was studied. As substrate, lactose solution in water and 0.9% fat milk were used. Initial concentration of lactose was chosen to be similar to the concentration of lactose in milk. Operational stability of β-galactosidase was measured during the reaction in both reactor modes. Enzyme membrane reactor is known as a convenient way of a continuous production process with enzyme reuse. [3] Once the optimal operational parameters are established, it might serve as a promising alternative to conventional batch-mode reactor.

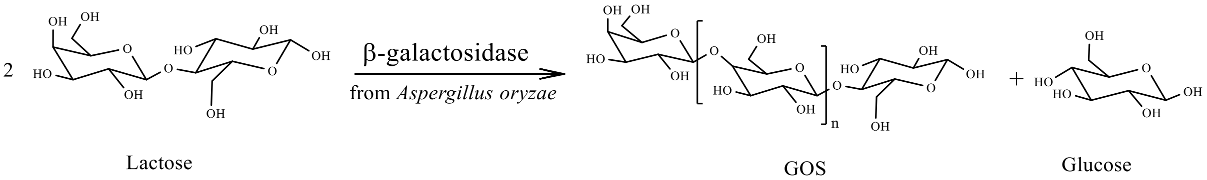

Fig. 1: Reaction scheme.

Acknowledgement This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000560.

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Effect of functionalised groups containing oxygen or nitrogen on lubricity of methacrylate based copolymer solutions in lubricant oil

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In order to reduce friction and thus increase efficiency of mechanical systems, it is important to design lubricants of suitable viscosity for certain operating conditions to minimise hydrodynamic shear and pumping loses. One way to achieve this is to optimise lubricant rheological properties by altering viscosity and composition. The other way is adding friction modifiers in low concentrations. There are few classes of friction modifier additives and one type of them are polymers known as viscosity index improvers. They are utilized to enhance bulk rheological properties of liquid lubricant by contributing to the viscosity of the blend at high rather than at low temperatures. Apart from that, it has been recognised that viscosity modifiers play an important role in reducing friction, not only by their impact on viscosity, but also by interacting with metal surfaces. [1] Alkyl methacrylate copolymers are widely used as viscosity index improvers and they can be further easily functionalised by incorporating comonomers containing nitrogen- or oxygen-based groups thus adding detergent-dispersive properties.

In this work, seven methacrylate-based copolymers were synthesized by radical polymerization. The first one was pristine while the other two sets of three contained oxygen or nitrogen based functional group. Yubase 4 lubricant oil solutions containing 0.5 wt% of polymers were prepared and their influence on wear scar diameter was determined according to HRN EN ISO 12156-1 standard method. Also, the coefficient of friction was measured with four ball geometry of HR30 Rheometer. The solution of copolymer containing hydroxyl functional group and copolymer lacking functional group displayed best lubrication indicated by the lowest wear scar diameter and coefficient of friction.

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The efficiency of organic coating protection of bronze samples exposed to outdoor environment and in simulated laboratory conditions

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The protection of metallic cultural heritage must meet the requirements of the restoration and conservation profession. It should not change the appearance of the protected object, it should be reversible and should have long-term efficiency and easy maintenance. One of the most commonly used protective coatings for archaeological or historical copper alloy objects is the acrylic resin Paraloid B72.

The aim of this work was to compare the corrosion protection efficiency of Paraloid B72 on bronze samples exposed to outdoor environment and samples immersed in simulated acid rain solution in laboratory. The coating was applied to bare and chemically patinated bronze samples, and was also tested in combination with long-chain phosphonic acid (16-phosphonohexadecanoic acid). It is known that long-chain organic acids can form self-assembled monolayers (SAMs) on the surface of oxide-covered metal, resulting in acid-base reaction between metal oxide and acid. This reaction is followed by the self-organization of alkyl chains which creates a very thin and compact film. [1] Such film act as a corrosion inhibitor and should also improve the protective properties of Paraloid B-72.

Protective properties are examined by linear polarization measurements and electrochemical impedance spectroscopy (EIS). The surface of modified samples is also examined by scanning electron microscopy [SEM].

Acknowledgement This work was fully supported and funded by the Croatian Science Foundation under the project IP-2019-04-5030.

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Characterisation and purification of crude glycerol after biodiesel production

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Biodiesel is a renewable fuel made from vegetable oils, animal fats or recycled cooking grease. It is produced through a reaction called transesterification, in which the glycerol component of the feedstock is replaced with an alcohol, most commonly methanol, to form alkyl esters that can be used as a diesel substitute. The main by-product of biodiesel production is glycerol. It is a valuable co-product that can be further processed for various applications such as the production of soap, cosmetics and pharmaceuticals.

After transesterification, the crude glycerol may contain impurities such as water, methanol, free fatty acids, soaps and salt. These impurities can have a negative impact on the quality and performance of glycerol and its derivatives and must therefore be removed in order to produce high-quality glycerol.

Crude glycerol can be characterised by a variety of analytical techniques, including pH measurement, total glycerol content determination and density and viscosity measurement. These techniques provide information on the quality and purity of the crude glycerol and help optimise the purification process. Purification processes usually involve a series of steps such as neutralisation, sedimentation, distillation, crystallisation and evaporation to remove impurities and increase the purity and concentration of the glycerol. Which process is used for purification depends on the desired specifications of the final product and the properties of the crude glycerol to be purified.

This work covers the characterisation and purification of crude glycerol from the production of sunflower oil and waste coffee oil biodiesel. Besides the commonly used purification methods, an alternative method is explored – extraction with hydrophobic deep eutectic solvents.

Optimization of aldolase immobilization on magnetic nanoparticles

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Cardiovascular disease, classified as a group of diseases affecting the heart and blood vessels, is the leading cause of deaths worldwide. [1] A notable example of a commonly prescribed drug for this type of disease is statins. All statins have the same side chain, the precursor of which can be synthesized in a one-step enzymatic reaction. [2] The reaction in question is a double aldol addition catalyzed by the enzyme 2-deoxyribose-5-phosphate aldolase (DERA, EC 4.1.2.4), as shown in Fig. 1. This is one of the most promising routes for the production of statin side-chain precursors, as achiral acetaldehyde and chloroacetaldehyde are cheap and readily available substrates, and it is easier to obtain stereochemically pure product. However, the drawback of DERA is its low tolerance to high concentrations of both substrates, which makes it unsuitable for industrial applications. [3] To potentially overcome this obstacle, DERA can be covalently immobilized, which can increase its reaction stability while maintaining or in some cases even increasing its activity. [2,4]

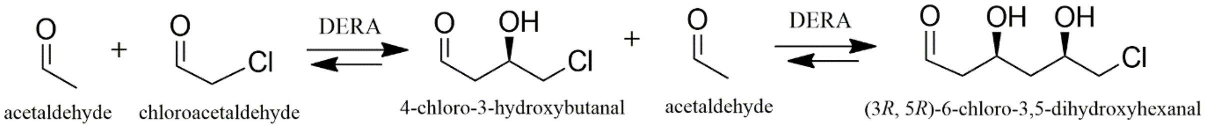

Fig. 1: Aldol addition reaction catalyzed by DERA.

In this work, solvothermally synthesized magnetic nanoparticles (MNP) were used as carriers for immobilization. The MNPs were functionalized with (3-aminopropyl)triethoxysilane (APTES). For carrier activation, three different concentrations of succinic anhydride, *p*-benzoquinone and glutaraldehyde were tested. Enzyme activity measurements were done by initial reaction rate method. The success of immobilization was determined by comparison of three different parameters: retained activity, stability and immobilization efficiency.

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The effect of particle size and morphology on *in vitro* drug release

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Controlling the particle size and morphology of poorly soluble APIs (Active Pharmaceutical Ingredient) is crucial in drug product development since it has a major impact on drug bioavailability. The larger the specific surface area of the particle, the greater the area available for dissolution which results in a faster release rate and, ultimately, greater bioavailability. [1] Additionally, morphology and particle size distribution greatly affect the formulation properties of solid drug products (*e.g.* flowability, compressibility) and stability of pharmaceutical suspensions. [2]

Microscopy is regularly used to evaluate the morphology of particles, with optical microscopy and electron microscopy being the most commonly used techniques. There is a number of methods available for determining the particle size distribution (PSD) of various pharmaceutical products. Among the most frequently used techniques in both industry and academia are those based on the dispersion of monochromatic radiation on the particles, such as DLS (Dynamic Light Scattering) and LALLS (Low-Angle Laser Light Scattering). *In vitro* release testing (IVRT) is performed in all stages of drug product development. Among other things, it is used to detect changes in critical quality attributes such as particle size and shape that could potentially have a significant effect on drug release and bioavailability.

Taking into account the above mentioned, the influence of morphology and particle size distribution on IVRT results will be discussed based on experimental data from different types of drug products such as atovaquone and proguanil HCl tablets, and capsule formulation of celecoxib.

The result shown in this study indicate a strong correlation of particle size and drug release since the release rate was higher for smaller drug particles and vice versa. The results are additionally supported by means of microscopy.

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Thermal and lubricating properties of canola oil nanofluid and corresponding biodiesel-based nanofluid

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With the aim of reducing the impact on the environment and preserving it, the world is turning towards biodegradable, which implies the use in automotive industry as well. One of the examples are vegetable oils which are being considered for their suitability as industrial lubricants. Nanoparticles, which are often added to industrial lubricants, are largely researched due to their effect on base fluid properties such as rheological, tribological, and dielectric properties and thermal conductivity. Also, by the addition of nanoparticles to base fluid the viscosity is increased. Canola oil viscosity ($\nu \approx 35\ \mathrm{mm^2\ s^{-1}}$) would be significantly increased with the addition of nanoparticles. That is why it would be interesting to compare the properties of nanofluids prepared from vegetable oil and corresponding biodiesel considering that biodiesel viscosity is six times lower than that of vegetable oil.

In this work, nanofluids based on biodiesel or canola oil and MWCNT were prepared by an ultrasonic homogenizer in weight fractions from 0.1% to 2.50%. The stability was observed by visual method where canola oil based nanofluid displayed longer stability. Thermal conductivity was measured at 25 °C and the values of canola oil based nanofluids were higher than that of biodiesel based nanofluids. The lubricity measurements indicated that the biodiesel based nanofluid with 0.1 wt% showed the lowest coefficient of friction.

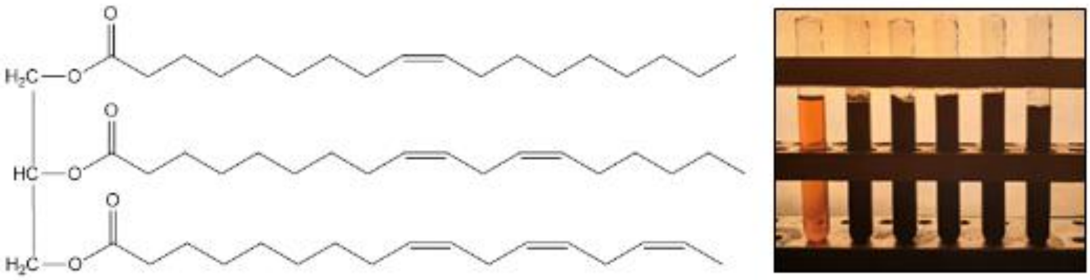

Fig. 1: Triglyceride structure (left) and visual method for stability analysis (right).

Determining solid liquid equilibria in some systems comprising common osmolytes by differential scanning calorimetry

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Osmolytes are low molar mass organic compounds that influence the properties of biological fluids within living cells, such as their viscosity or melting point. These compounds are also capable to interact with other constituents of the cell, *e.g.* water and proteins. In an attempt to fully understand the nature of the interactions of osmolytes in living cells, it might be interesting to test for the possibility of their cooperative action. A good starting point for this is the study of binary solid liquid phase diagrams of systems containing various osmolytes. Among the available experimental methods, differential scanning calorimetry (DSC) seems to be a good option [1,2] due to its simplicity. However, one has to keep in mind that DSC is a dynamic technique. The factors such as the sample mass and heating rate in general affect the obtained transition enthalpies and temperatures, in particular in the multicomponent systems. Thus, one has to be cautious in performing and interpreting the results if they are to be accepted as reliable thermodynamic values. This poster describes the influence of the experimental variables on the shape of obtained phase diagrams in binary systems of sarcosine – guanidine hydrochloride, sarcosine – urea, and trimethylamine *N*-oxide – urea.

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The rapid development of calibration models for supersaturation tracking using *in situ* ATR-FTIR spectroscopy

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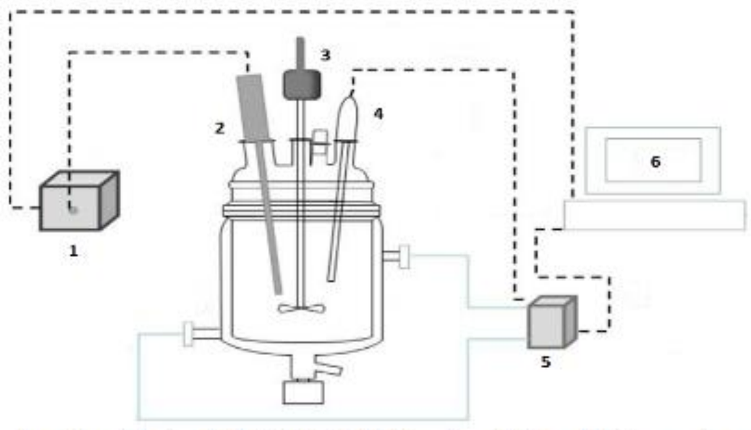
Crystallization is an important unit operation used in many branches of industry because it is an energy efficient way of separating and purifying compounds. [1] It is one of the most important unit operations in the pharmaceutical industry. The industrial control of crystallization is a difficult task because of the stochastic and often unpredictable behavior of the system. With the development of process analytical technology, crystallization control has become possible because it has enabled real-time measurement of critical quality attributes. ATR-FTIR spectroscopy has been used to track the concentration during crystallization [2] but the procedure of developing calibration models is time-consuming. The rapid development of the calibration model is done by slowly heating excess solute in a solvent and collecting temperatures and spectra. It is assumed that for each temperature the solubility equilibrium has been reached and that the spectrum corresponds to the saturated solution concentration. In this work, the excess amount of glycine was heated from 5 °C to 55 °C during the span of 4.5 hours. The amount of glycine was 5% higher than the equilibrium solubility at 55 °C. The particles were grounded with pestle and mortar to achieve a small size of crystals that dissolve quickly. The spectra were recorded every minute together with the temperature. The PLS calibration model relating spectra to saturation temperature was built. The model was tested on an independent dataset obtained by repeating the experiment. The results indicate that the model can predict saturation temperature with relatively good accuracy (RMSEP=0.73).



Experimental set-up: (1) FTIR; (2) ATR-FTIR probe; (3) Stirrer; (4) Temperature sensor; (5) Thermostat; (6) Computer for data aquisition

Fig. 1: Equipment for experiment and data acquisition.

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Utilization of in-line process microscopy in crystallization process development of active pharmaceutical ingredients

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Crystallization is a key unit operation in the production of active pharmaceutical ingredients (APIs). Accurate determination of critical process parameters that influence the products polymorphic form, particle size distribution and its rheological properties is crucial during process development as it enables a successful scale-up of the process and robustness during industrial scale production. *In situ* process analytical technology (PAT) tools like process microscopy, UV, FTIR and Raman spectroscopy are rapidly becoming indispensable aids during process development as they facilitate process understanding and process control through real-time measurement of particle number, shape, size, length distribution, solute concentration and polymorphic form. Such measurements allow for decision making during experimental runs and can provide valuable insight into the crystallization process phenomena like nucleation, growth, attrition, oiling-out and polymorphic transformations and can therefore significantly impact the total development time all the way from initial screening experiments down to process scale-up. [1] The application of a high dynamic range (HRD) in-line process microscope (Blaze 900 by Blaze Metrics Ltd.) in monitoring and control of various API crystallization processes is described. The Blaze 900 system allows for real-time, non-destructive monitoring of crystallization processes. Its single-optical-path technology allows for simultaneous acquisition of HRD microscopic images, HRD turbidity measurements and Raman spectroscopy in a single probe thereby minimizing the impact on hydrodynamic conditions during experimental runs in both batch and continuous crystallization processes. [2] Image analysis algorithm provides particle statistics from the captured images, which makes it superior to other monitoring techniques such as PVM and FBRM. The crystallization processes monitored in this work included seeded cooling crystallizations, anti-solvent crystallizations and solvent mediated polymorphic transformations. One such transformation was monitored in combination with Raman spectroscopy giving additional *in situ* insight into the kinetics of the conversion. In conclusion, the Blaze 900 system proved to be a versatile tool that provides high quality information about crystallization processes and enables shortening of the development time.

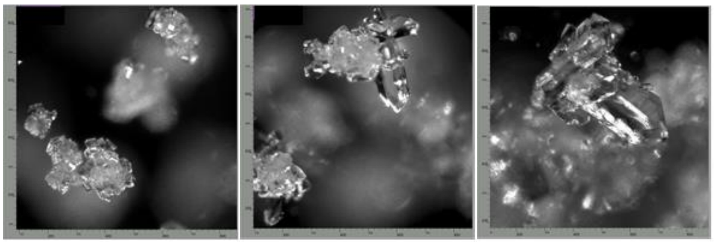

Fig. 1: Blaze 900 microscopic images of a solvent mediated polymorphic transformation.

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Microwave and ultrasound assisted extraction of piperine from different piper species

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Piperine is a major bioactive compound found in the piper species belonging to the Piperaceae family. Piperine is responsible for the pungent taste of pepper and its use as a flavour enhancer in cooking. It also has therapeutic benefits, including antioxidant and anti-inflammatory effects, and has been shown to increase the bioavailability of certain nutrients and drugs. The content of piperine in pepper depends on the plant species, environmental and growing conditions as well as on the preparation methods. This work investigates the influence of particle size, temperature and extraction method on the extraction efficiency of piperine. Two types of pepper (*piper nigrum*: black, white and green; piper *borbonense*: voatsiperifery) were selected. Pepper berries were ground and divided into three fractions. Piperine was extracted by the enhanced microwave and ultrasonic method. Initial concentration of piperine in piper species was determined by Soxhlet extraction with ethanol. Ethanolic extracts were analysed by means of HPLC and UV/Vis methods. Initial content of piperine decreases in the following order: green pepper > black pepper > white pepper > voatsiperifery pepper. Similar extraction efficiencies were obtained for both extraction methods. Extraction efficiency was positively influenced by the increase in temperature and decrease of particle size.

By mechanochemical activation to a drug with an improved solubility and release rate

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The low aqueous solubility of lurasidone hydrochloride, a drug used for the treatment of mental disorders, results in its poor gastrointestinal absorption, low bioavailability, and overall inadequate pharmacological effect. A promising approach to improve its solubility is the mechanochemical preparation of an amorphous solid dispersion with different polymers. In this study, solid dispersions of hydrophobic lurasidone hydrochloride in hydrophilic polymeric carriers, polyvinylpyrrolidone and hydroxypropyl methylcellulose, were made in different drug-to-polymer ratios by mechanochemical activation in a planetary ball mill. The solid dispersions were characterized by XRPD, FTIR and DSC analyses. Tablets with a diameter of 8 mm were successfully prepared using solid dispersions of the drug, *in-situ* fluidized bed melt granulation and traditional tableting. The tablets were analyzed for mass uniformity, disintegration and drug content. *In vitro* release profiles in the presence of McIlvaine buffer (pH = 3.8) showed a significant improvement in the solubility and release rate of lurasidone hydrochloride from tablets containing mechanochemically prepared solid dispersions compared with those containing the crystalline and untreated drug or its physical mixture with the polymer. Tablets containing the polymeric carrier polyvinylpyrrolidone exhibited faster drug release than tablets containing hydroxypropyl methylcellulose, which is used in extended-release oral dosage forms to provide a continuous supply of the drug over a longer period. The results presented confirm that lurasidone hydrochloride can be activated mechanochemically in terms of improving its *in vitro* dissolution and release properties.

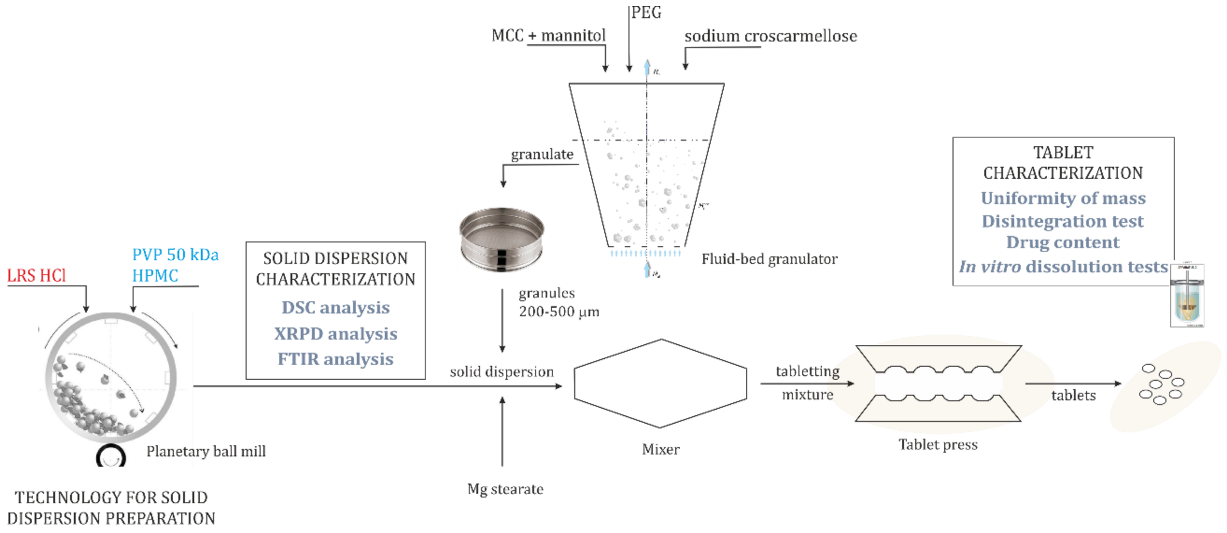

Fig. 1: Scheme of research methodology.

Yersinia enterocolitica proteome profiling after treatment with disinfectants based on quaternary ammonium salts

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Yersinia enterocolitica is a non-spore forming, Gram-negative bacteria. It is a foodborne pathogen that can grow at low, refrigeration temperatures and therefore can often cause food spoilage but also serious health problems. [1] The extensive use of antimicrobial agents based on quaternary ammonium salts (QAC) has resulted in increased antibacterial resistance and reduced potential of these, otherwise very effective disinfectants. [2] In this work, the proteome of *Yersinia enterocolitica* after growth under the inhibition with different, newly synthetized pyridoxal oximes, was investigated. Label-free quantitative proteomic investigations by LC-ESI MS/MS were used to achieve characterization and comparison of proteomes of investigated food pathogen before and after the QAC treatment. [3] The LC-ESI MS/MS analysis revealed up- and down-regulated proteins which were identified using the Uniprot database. Their cellular localizations and functions were determined by gene ontology searching using the web-based tool QuickGo. The most pronounced changes can be observed in down-regulation of ribosomal proteins and proteins which are integral component of membranes after QAC treatment. Accordingly, a decrease in the expression of proteins participating in the translation process was observed. Up-regulation of the enzyme superoxide-dismutase was confirmed using Western blot analysis.

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Application of spectrometric methods in determining the composition of ceramics

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The paper presents the application of energy-dispersive X-ray fluorescence (EDXRF) and Inductively coupled plasma-optical emission spectrometry (ICP-OES) in routine tests to determine the composition of ceramics. The goal is to create a base of local and available materials for making ceramic glazes to create ceramics as an authentic and local product entirely made of local materials and local craftsmen and artists. SiO_2 has the main role in the glaze along with primary (Li_2O, Na_2O, K_2O) and secondary (CaO, MgO, SrO, BaO, ZnO) melting oxides (flux) which are important for achieving the amorphous state. In addition, the ratio between SiO_2 and Al_2O_3 is crucial because it determines the appearance of the surface (glossy, semi-matte, most glossy or matte) and the durability of the glaze. Furthermore, pigments (Fe, Cu, Ni, Mn, Co, Cr) and other elements like Ti, Zr, and Sn are also very important for obtaining glaze quality. The calculations use Seger's method with the correct ratio of elements and an adequate firing temperature for creating high-quality ceramic glaze, which can exist for thousands of years. This study aims to determine and compare the composition of raw materials taken from different locations to make ceramic glazes. Various samples are tested to determine the composition using the EDXRF and ICP-OES methods, well-known techniques for fast, accurate and reliable analysis of the content of individual elements in various samples. The content of P_2O5, Na_2O, K_2O, CaO, MgO, Al_2O_3, TiO_2, Fe_2O_3, SiO_2, MnO_2 and SO_3 is determined with EDXRF, while the content of B, Ba, Co, Cr, Cu, Li, Mn, Mo, Ni, Pb, Sr, V, Zn, Sn and Zr is determined with ICP-OES in different concentration ranges corresponding to the composition of different types of ceramic glazes.

Photo-oxidative degradation of phenol, cyanide and thiocyanate by UV-C/H_2O_2 and UV-C/$S_2O_8^{2-}$ processes

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Contamination of natural water bodies with phenolic compounds, cyanides, and thiocyanates, as a result of inadequately treated wastewater discharge, has recently increased the concern of researchers worldwide due to significant toxicity that aforementioned compounds cause to aquatic organisms, and ultimately to humans. In this work, advanced oxidation processes (AOPs), based on formation of highly reactive radicals (HO· and $SO_4^{-}\cdot$), in a quantity sufficient to oxidize most of the complex compounds present in wastewater, under the influence of energy (UV radiation), were applied. The application of selected AOPs for treatment of model solutions of phenol, cyanide and thiocyanate was investigated with the aim of determination of the optimal UV-C/H_2O_2 and UV-C/$S_2O_8^{2-}$ conditions on decomposition processes as well as the influence of process parameters on kinetics. [1,2] The key process parameters were pH value (4, 7, 10), oxidant concentration (10 mM, 105 mM, and 200 mM), contaminant concentration (1 mM) and reaction time of 1 minute with sampling every 10 s.

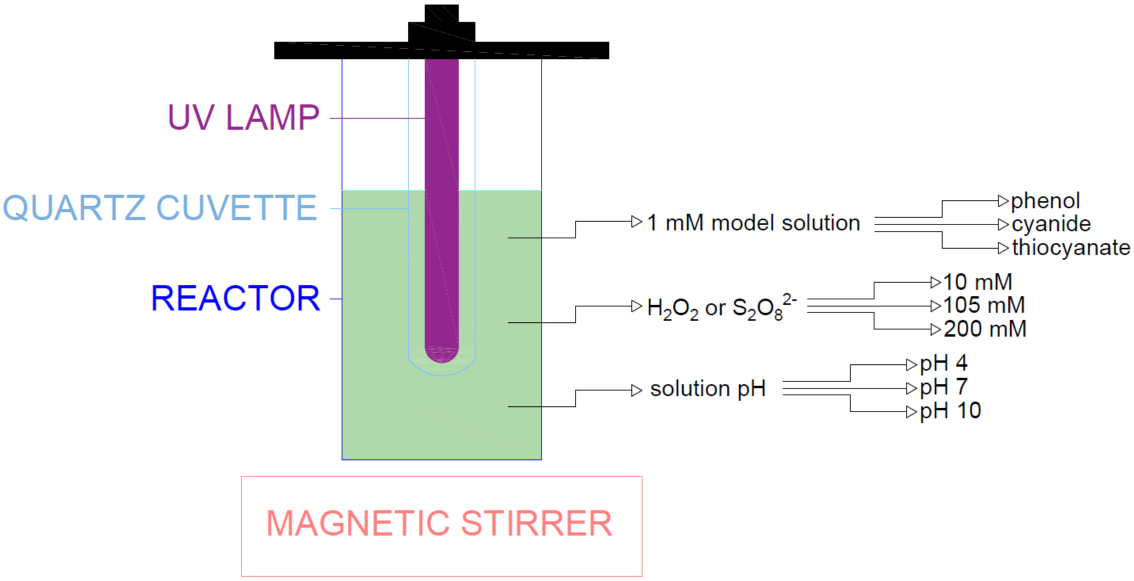

Figure 1. Graphical abstract

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Comparison of NTU and neural network models for fouling monitoring of heat exchangers in the preheat train section of a Crude Distillation Unit

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Monitoring of fouling deposition inside crude distillation unit preheat train is a serious challenge due to the lack of analyzed physicochemical variables of crude oils, unknown mechanisms of deposit formation, and large deviations from designed process conditions. In addition, real plant processes operate under dynamic conditions with frequent changes in the process regime. Fouling, or the formation of deposits in the preheat train of CDU, is an operational problem with serious consequences for oil refineries, with half of the refinery's energy costs attributable to the crude oil preheater. [1]

These unfavorable conditions complicate the development of first-principle models. It has become a common practice in recent years to use data-driven models like neural networks (NN) instead of empirical or fundamental models for fouling detection. [2] However, simpler monitoring should be possible by using design equations, and by following heat exchangers effectiveness and NTU correlations. The NTU parameter summarizes geometric (*via* the transfer area) and hydrodynamic properties (*via* the overall heat transfer coefficient and the sum of fluid flow rate and heat capacity). [3] This property provides a useful basis for the heat exchanger performance model. In this study, a comparison is made between the NTU and NN models for heat exchangers in the preheating train of a crude oil distillation unit. The results show that although the NTU model is less accurate, it indicates a gradual increase in fouling factor during the time from overhaul to process stop, which provides useful information to process engineers about the fouling dynamics and effectiveness of the heat exchanger.

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Cellulose-based hydrogels modified with poly(vinylpyrrolidone)

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When cellulose hydrogels are modified by various functional polymers, the resulting materials are characterized with specific properties. These materials can be used for various purposes, such as the materials for wound dressing, adsorbents or materials for use in wearable electronics, *etc*. [1]

Poly(vinylpyrrolidone) (PVP) is a biocompatible and water-soluble synthetic polymer, which because of its structure tends to form hydrogen bonds and opens up the possibility of chemical reaction and coordination with metal ions.

In this work the grafting of *N*-vinylpyrrolidone/*N*,*N*-methylenebis(acrylamide) onto cellulose backbone by *in situ* free radical polymerization was investigated while preparing cellulose-based hydrogels. Modification of the cellulose was carried out with the three different molar ratio of cellulose to *N*-vinylpyrrolidone (1:1, 1:3, 1:5), while *N,N*-methylenebis(acrylamide) was used for the crosslinking. Furthermore, ionizing radiation with dose 10-100 kGy was used to increase the reaction yield and enhance grafting/crosslinking.

The swelling behavior, viscoelastic properties and morphology of the cellulose-PVP hydrogels was studied. Prepared cellulose-PVP hydrogels showed large equilibrium swelling (1450 to 2200%), while the dynamic viscoelastic measurements revealed that the storage modulus of cellulose-PVP hydrogels was in the range of 7-30 kPa. Finally, aiming at additional functionality, hydrogels themselves were used as reducing agents for the direct reduction of $AgNO_3$ in order to introduce silver particles and thus to improve antibacterial properties of the hydrogel.

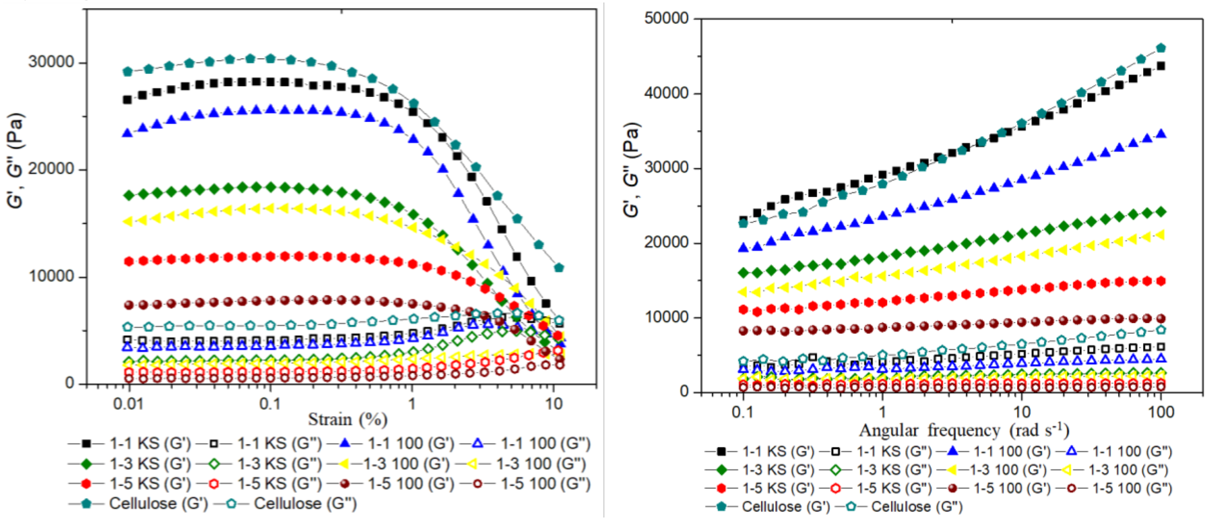

Fig. 1: Viscoelastic properties of prepared hydrogels in: amplitude sweep tests (left) and frequency sweep tests (right).

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Supercritical CO_2 and deep eutectic solvents for sequential extraction of *Lavandula stoechas* L. and attainment of antioxidant and antibacterial agents

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The aim of this work was to investigate the possibility of sequential extraction and more efficient use of *Lavandula stoechas* L. material, by extracting non-polar and polar fractions using green solvents, supercritical CO_2 and natural deep eutectic solvents (NADES). In the first step, supercritical CO_2 extraction (pressure 200 bar, temperature 40 °C, CO_2 flow 20 g/min, and extraction time 3 h) was performed for the extraction of lipophilic components. Moreover, the exhausted material was used in the next step for the extraction of polar compounds using NADES (betaine : ethylene glycol (Bet:EG) (1:3), betaine:glycerol (Bet:Gly) (1:2), and glycerol:glucose (Gly:Glu) (4:1)) and ultrasound-assisted extraction (temperatures 30 and 60 °C, extraction time 30 min). The control extracts were obtained from material that was not used in the CO_2 extraction (non-residue). All extracts were examined in terms of polyphenol composition using high-performance liquid and gas chromatography and their antibacterial and antioxidant potentials were also investigated. In the volatile profile of the supercritical extract, 59 components were identified. Oxygenated terpenes were predominantly present with 72.50%, among which monoterpenes made up 55.69% with fenchone and verbenone being the most dominant. The presence of different classes of components – flavonoids, hydrolysable tannins, derivatives of hydroxycinnamic and hydroxybenzoic acids, and coumarins was identified in NADES extracts. Observing the total sum of identified components, the highest phenolic content was recorded in the extract obtained with Bet:EG (664.19 µg/mL; 60 °C), while the second highest phenolic content was in the extract obtained from non-residue material at 30 °C (555.43 µg/mL). A strong correlation was observed between the content of total identified polyphenols and the antioxidant activity determined by the DPPH assay; therefore, the most potent extracts were Bet:EG. All NADES extracts exhibited a higher antibacterial activity against Gram-positive bacteria (minimal inhibitory concentrations (MIC) 0.781 mg mL^{-1}) compared to the Gram-negative (1.563 mg mL^{-1}). NADES extracts obtained at 60 °C exhibited stronger antibacterial activity than those obtained at 30 °C. Supercritical extract showed weaker activity than NADES extracts, with MIC 3.39 mg mL^{-1} against *E. coli*, *B. subtilis*, and *S. aureus*, and the most resistant being *P. aeruginosa* with MIC 6.775 mg mL^{-1}. It was established that sequential extraction represents a good approach for a more efficient use of materials and obtaining *L. stoechas* extracts that can serve as antioxidant and antibacterial agents.

Acknowledgement This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant agreement No 101003396. The biological activity has been supported by research ID: 3105-12-21.

Betaine:glycerol deep eutectic solvent modified with zinc chloride for extractive gasoline purification

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The development of 'green' technologies in liquid fuels purification implies extraction using deep eutectic solvents (DESs) as one of the alternative approaches. [1-4] The 'green' character of DES is manifested in its low vapor pressure, non-flammability, non-explosiveness, non-toxicity, and biodegradability. The selectivity of DES for desulfurization, denitrification and dearomatization of liquid fuels depends on the choice of DES. DESs are considered as 'designed' solvents because different combinations of their acceptor and donor components, molar ratio and the addition of a third component can directly influence the physico-chemical properties of DES, thus creating DES desirable for a specific application.

This research compares the results of extractive desulfurization and denitrification of model FCC-gasoline obtained by using two DESs based on betaine and glycerol in a molar ratio of 1:4; one with the addition of zinc chloride in a molar ratio of 1:4:0.02. Both DESs showed a higher affinity for the extraction of pyridine (~73%) than thiophene (~20%) from a model FCC-gasoline containing 26% *n*-hexane, 26% *n*-heptane, 26% *i*-octane, 10% toluene, 6% pyridine and 6% thiophene. However, the addition of metal chloride to pure DES did not show an improvement in the extraction efficiency and thus the selectivity. In one-stage extraction with a mass ratio of $m(\mathrm{DES}) : m(\mathrm{model\ gasoline}) = 1.00$, denitrification efficiency of ~73% was achieved, while the same value was achieved through four-stage extraction with four times less mass of the used extraction solvent. During the tested four stages of extraction, the capacity of the extraction solvent decreased, but the vacuum distillation of the extracted components between stages enabled the recovery of DES. The physical properties of both DESa essential for their extraction application were examined: density, viscosity, refractive index, electrical conductivity, thermal conductivity, temperature diffusivity, heat capacity. B:Gly 1:4 and B:Gly:$ZnCl_2$ 1:4:0.02 showed a potential for gasoline denitrification.

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By the principles of green chemistry to a drug with improved properties

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Currently, pharmaceutical industry is facing many challenges. Hazardous solvents are widely used, especially in synthesis of active pharmaceutical ingredients (APIs) and formulation processes. Because of their health, environmental and economic consequences, there is a huge effort nowadays for reducing their use and a strong appeal for using safer solvents. Furthermore, pharmaceutical industry is dealing with the development and production of novel and more effective dosage forms for oral absorption of already existing drugs. Many drugs suffer from the low aqueous solubility leading to inadequate therapeutic effect of drug product. This paper will reveal our vision to use the principles of green chemistry and chemical engineering methodology (Fig. 1) to design a more effective drug product without the use of any solvent.

The ideal API candidate for this, we believe, is drug X with low aqueous solubility and consequently poor gastrointestinal absorption and low bioavailability. It is a relatively new drug on the market indicated for the cancer treatment. For the purpose of drug solubility enhancement, solid dispersions of drug X in the hydrophilic polymer carrier poly(vinyl pyrrolidone) (PVP), are to be made by using the principles of mechanochemistry and properly characterized by the solid state analytics that could explain physically the enhanced dissolution properties (Fig. 1).

Solid dispersions were prepared in different ratios using a high-energy laboratory ball mill with adjustable frequency of up to 30 Hz and characterized properly by differential scanning calorimetry (DSC), X-ray powder diffraction (XRPD) and Fourier-transform infrared spectroscopy (FTIR). The change in phase composition, decreased relative degree of crystallinity and shifts of the absorption bands for the interacting functional groups, might indicate hydrogen interactions between drug X and polymer, thus revealing promising properties of the solid dispersions prepared without the use of solvents. The results presented confirm that this particular drug can be activated mechanochemically in terms of improving its dissolution properties.

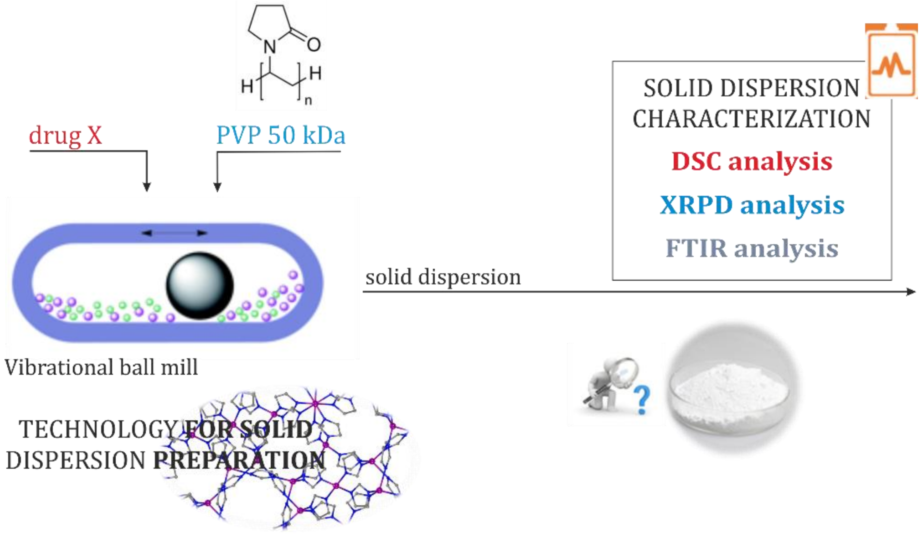

Figure 1: Schematic of research methodology.

Selecting solvent systems for spherical crystallization of API

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Spherical crystallization is a particle formation technique in which fine crystalline particles are directly transformed into a spherical shape by simultaneous agglomeration. It is mainly used for the formation of active pharmaceutical ingredient (API) particles in the pharmaceutical industry. Thus prepared agglomerates have better micrometric properties, flowability and compressibility, which facilitates the process of direct tableting or coating. [1-3] In this paper, the process of selecting a suitable solvent system for spherical crystallization of ceritinib (CRT), and the effect of the addition of polymer on the formation and properties of agglomerates were investigated. The solubility of ceritinib form A (CRT A) in different organic solvents and water has been determined to select ternary solvent systems consisting of solvent, antisolvent and bridging liquid using *Dynochem*. The influence of the mixing rate, the amount of solvent in the ternary system and the retention time on the efficiency of the process was investigated. Spherical agglomeration (SA) was carried out in a double-jacketed crystallizer using the saturated solution of CRT A in tetrahydrofuran (solvent) at 35 °C and a mixture of water (antisolvent) and bridging liquid cooled down to 20 °C. The bridging liquid was mixed with water until visible droplets were formed, after which the CRT A solution was added at a constant flow rate using a syringe pump. Quasi-emulsion solvent diffusion (QESD) was carried out by dropwise addition of the saturated CRT A solution into a solution of polymer dissolved in water. The internal structure and size of resulting agglomerates were determined by X-ray diffraction (XRD), Raman spectroscopy and light microscopy, respectively. The agglomerates prepared by QESD are firmer and larger than those prepared by SA. The addition of polymer has not affected the internal structure of agglomerates.

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Preparation of poly(3-hydroxybutyrate) plasticized with mixture of methyl esters derived from waste edible oils

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Poly(3-hydroxybutyrate) (PHB) is a biodegradable polymer belonging to the poly(hydroxyalkanoate) group. It is a very brittle material that is difficult to process and is also thermally unstable during processing. In theory, an efficient plasticizer would solve most of these problems. The fully biodegradable material must also contain a biodegradable plasticizer. Therefore, PHB was modified by mixing with various amounts of fatty acid methyl esters (FAME) to improve its mechanical and thermal properties for wider commercial application. FAME was synthesized by batch transesterification of waste edible oils with methanol. GC-MS analysis was used to determine the composition of FAME. The major components (94%) are methyl esters of oleic and linoleic fatty acids and the rest are palmitic and stearic esters. PHB/FAME blends with 0, 10, 15, 20, 25 and 30 wt% of FAME were prepared by dissolving both components in chloroform and followed by film casting. The characteristics of phase transitions of PHB in the blends were determined by differential scanning calorimetry (second heating curve). It was found that FAME lowers the glass transition temperature of PHB up to 10 °C (80/20 blend), but increases the degree of crystallinity from 15% up to 60% (75/25 blend).

Thermal conductivity, electrical resistivity and dynamic mechanical analysis of polyester-imide resin/nanocellulose composites

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Nanocellulose is gaining increasing attention as a filler in polymers because it is relatively inexpensive, abundant, biodegradable, and renewable, while significantly improving the mechanical properties and thermal conductivity of polymer composites. [1,2] Polyester-imide resins have acceptable performance as electrically insulating materials, while their other properties can be improved by using fillers, especially in terms of improving their thermal conductivity. In our research we measured the thermal conductivity, electrical resistivity, and dynamic mechanical properties of neat thermoset polyester-imide resin and composites. The composites contain cellulose nanocrystals (CNC) or cellulose nanofibrils (CNF) with a content between 0.5 and 5 wt% and were homogenized in a mixer with high shear rate. The thermal conductivity of the samples was measured by the transient hot bridge method, while the electrical volume resistivity was measured through electrical insulation resistance test. The mechanical properties of the composites were studied by dynamic mechanical analysis using a hybrid rheometer. The largest increase of thermal conductivity of 12.2% compared to neat resin was achieved with 5 wt% CNF, while the largest increase in volume electrical resistivity (22.1% compared to neat resin) was achieved using 1 wt% CNC.

Neat resin and composite samples

Thermal conductivity measurement

Electrical resistivity measurement

Dynamic mechanical analysis

Fig. 1. The figure shows prepared resin samples and instruments used in the measurements.

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Synthesis and characterization of stretchable and conductive PEDOT-*g*-PCL copolymers for wearable electronics

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The good electrical conductivity, thermal and chemical stability, and easy functionalization of poly(3,4-ethylenedioxythiophene) (PEDOT) are a good starting point for the ever-growing search for new conductive materials for the wearable electronics industry. Pristine PEDOT lacks stretchable and self-healing properties, which can be modified using various approaches. One of the approaches used in this work is the synthesis of PEDOT-*g*-PCL copolymers with the aim of achieving stretchability and self-healing properties through hydrogen bonding via polycaprolactone (PCL) branching. Atom transfer radical polymerization (ATRP) is used as a synthetic route to obtain products with desired properties, while controlling molecular weight values and distribution. The PEDOT homopolymer does not have the appropriate functional groups for ATRP, so it must be functionalized first. This is achieved by synthesizing a PEDOT derivative copolymer with 2-(tiophen-3-yl)ethyl-2-bromo-2-methylpropanoate) (ThBr) as the second monomer. This molecule ensures that the conjugated backbone is maintained and active sites for ATRP are added. In addition, PCL must be functionalized to include a double bond functional group to make it suitable for ATRP. This is achieved in two ways by ring-opening polymerization (ROP). The first approach was to use hydroxyethyl methacrylate (HEMA) as an initiator and diphenyl phosphate (DPP) as a catalyst for the ROP of *ε*-caprolactone. The second approach was to use 3-phenyl-1-propanol as initiator for the synthesis of PCL, which was later functionalized with acrylic anhydride to introduce the acrylic functional group. The ROP performed under these conditions shows great control over the molecular weight values and the distribution of the final products. PCL with different molecular weight was synthesized to investigate the influence of the molecular weight of PCL on the final properties of the PEDOT-*g*-PCL copolymers. The last step was ATRP of PEDOT-*g*-PCL products with different ratios and lengths of PCL chains. All the obtained products were characterized by different techniques to confirm their structure, properties and the success of each polymerization.

Improving stability and SERS performance of Au-Ag nanoislands

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The choice of signal-enhancing nanostructures for surface-enhanced Raman spectroscopy (SERS) requires an undesirable tradeoff between performance and stability. Chemically stable Au nanostructures do not provide the best enhancement, while the lack of stability often outweighs the optimal enhancing properties of Ag nanostructures. Combining Au and Ag shows promise in utilizing the desirable properties of both metals and even enhancing the SERS performance by synergistic effects. [1]

With that in mind, we used a straightforward nanofabrication procedure based on galvanic replacement to produce alloy and hybrid nanostructures for SERS. By varying the fabrication conditions, a great degree of tunability for morphological and plasmonic properties was achieved. Au-Ag nanoislands with a SERS performance far better even than that of the pure Ag nanoislands were produced, and showed mechanical, morphological, and chemical stability over the period of several months. Density functional theory (DFT) and electrodynamics calculations helped clarify the reasons for the enhanced stability and performance, providing insights for future sensor design. SERS substrates enabled detection of model molecules in the nanomolar range, even with very low laser power, showing promise for applications in biomedicine. Beyond that, nanostructures that combine stability and good plasmonic properties have a potential for applications in a wide variety of photonic devices.

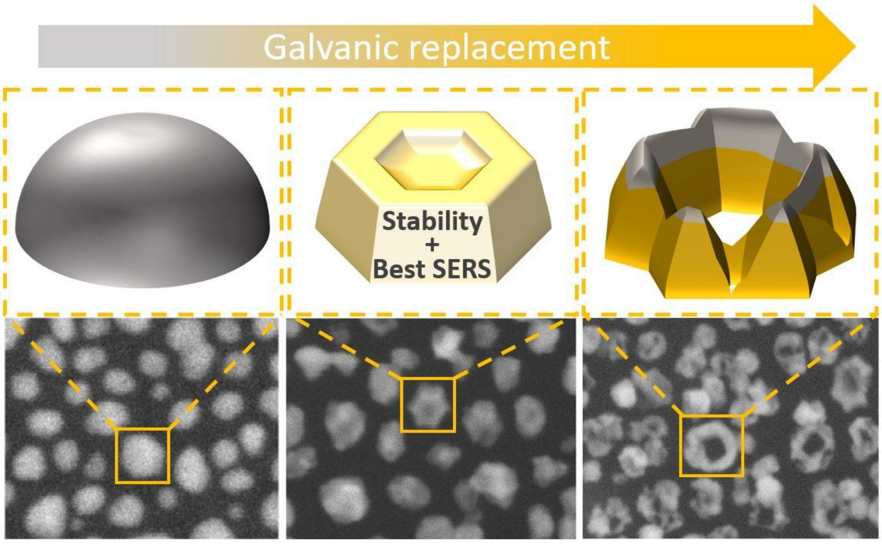

Fig. 1: Progression of nanoparticle morphology changes due to galvanic replacement between Ag and Au^{3+}.

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Porosity – a key parameter of acoustic wood wool cement board

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Wood wool cement board (WWCB) is a porous composite material consisting of Portland cement inorganic binder mixed with wood wool as reinforcement. It is widely used as thermal and acoustic insulator in buildings because of low density, high porosity, good fire resistance and compatibility with other binders and building materials. Majority of composite properties depends on porosity, *e.g.* density, strength, Young modulus, gas permeability, thermal conductivity and thermal diffusivity. Beside density, other properties mentioned, including also sound absorption coefficient depend on pore size distribution. The acoustic properties are related to bulk properties like bulk modulus and effective density which can be used in many acoustic models for porous materials. In this work, two methods for porosity determination are applied and compared on the samples of wood wool cement board from regular production obtained from FRAGMAT H d.o.o., Sv. Križ Začretje, Croatia. Archimedes method is applied for true and apparent density determination of the bulk WWCB, while image analysis of the surface layer and deeper layers accessed by grinding and polishing is used for layer by layer porosity and pore size distribution analysis. The methods are compared in terms of complexity, duration of analysis and type and quality of information obtained.

Fig. 1: Wood wool cement boards (WWCB).

Development of new generation of stretchable conductive polymers for wearable flexible electronics

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Conductive polymers are used as an alternative to conventional materials because of their properties such as electrical conductivity, light weight, and stability. However, their major drawback is their poor mechanical properties, i.e., brittleness, which makes them unsuitable for use in flexible electronics without modification. To improve their mechanical properties, one approach is to introduce chemical species that promote non-covalent dynamic crosslinking in the main chain of the conductive polymer. In this study, the conductive polymer poly(3,4-ethylenedioxythiophene) (PEDOT) was used as the main chain and the side branches of poly(acrylate-urethane) (PAU) were grafted onto it to obtain the grafted copolymer PEDOT-*g*-PAU.

In this way, the main chain of PEDOT retains the property of electrical conductivity without losing conjugation, while the side branches of PAU have the ability to crosslink non-covalently through hydrogen bonds with PAU side branches of neighboring polymer molecules. The presence of hydrogen bonds improves the stretchability and flexibility of the material, and they also have the ability to spontaneously renew after breaking. The obtained graft copolymer PEDOT-*g*-PAU was prepared in the form of conductive ink and printed by inkjet technology on a polyurethane substrate (PU), which is widely used in flexible electronics. The conductivity of the printed layer, its elongation and adhesion were investigated, and possible delamination of the printed polymer layer was also monitored. The results showed that the desired product PEDOT-*g*-PAU copolymer was successfully synthesized and inkjet printing on PU film was successful. The electrical and mechanical properties of the printed material were investigated and found to be suitable for use in flexible electronics.

Problems in stability of the inner surface of glass vials leading to glass leaching and delamination

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Borosilicate glass has high hydrolytic resistance and high thermal shock resistance due to the chemical composition of the glass itself. It is classified as Type I glass. [1] The hydrolytic stability of glass is defined by its resistance to the release of soluble elements into water under specified conditions. The higher the hydrolytic resistance of glass, the lower the risk of glass delamination. [2] Glass delamination may be described as the appearance of thin, flexible flakes of glass (or lamellae) that can range in size from <50 µm to 200 µm in a drug product solution. [3] The inner surface of glass containers may be treated to improve hydrolytic resistance. [1] The manufacturing conditions of vials lead to glass defects resulting in a less chemically resistant surface. [4] The goal of our study was to investigate the effect of solution pH and temperature treatment on different glass types, hydrolytic resistance and glass leaching. In addition, an aggressive condition (potassium hydroxide) was used to evaluate the behavior of different glass sources. The following analytical tools were used: inductively coupled plasma (ICP-OES) to assess the elements released from the glass, scanning electron microscopy to compare the internal surface, and methylene blue staining for visual examination of the glass in its initial state and after contact with the solution.

Fig. 1: Glass vial 10R, colorless, tubular glass, hydrolytic group I, after 3 hours autoclave treatment on 121 °C filled with 0.1 M KOH.

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A study on the influence of waterborne coating application parameters on its protective properties

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It is known that metals are prone to corrosion under the influence of aggressive compounds from the environment, and the coatings are widely used method for metal corrosion protection. The requirement for a good coating is its impermeability to corrosive species, good adhesion, and the absence of cracks and irregularities that can lead to the initiation of corrosion. In the last few decades, waterborne coatings have been developed as a substitute for organic coatings due to the smaller amount of harmful solvents. They consist of a larger proportion of water as a solvent, which presents a challenge in their application. A lower volatility of water, compared to common organic solvents, prolongs the drying time which usually requires the drying at higher temperatures. Inadequate drying conditions may lead to substrate corrosion and result in lower adhesion of the coating. Another important property is the film thickness, which directly affects porosity, stability, quality and level of protection.

The aim of this work is to investigate the influence of different application parameters of a waterborne acrylic coating on the corrosion protection of bronze. The study is conducted by electrochemical impedance spectroscopy (EIS) in terms of continuous immersion in simulated acid rain (pH 5). The emphasis is on examining the curing duration and temperature as well as the coating thickness and number of the layers applied. In addition, the influence of coating dilution and application technique (brush, spraying, knife applicator) are investigated.

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Validation of an adsorption kinetic model for lindane removal by a porous polymer

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Lindane was one of the most commonly used organochlorine pesticides for controlling a wide range of horticultural, agricultural, and public health pests during the second half of the 20th century. [1] Owing to its toxic nature, bioaccumulation capability, and long transportable nature, it belongs to a group of persistent organic pollutants (POPs). [2] Although lindane use has been restricted or even banned, its residues persist and represent a serious environmental problem since lindane residues are still found in water, sediments, soil, plants, and animals. [3] Therefore, there is a growing interest in lindane removal or degradation by various methods. In this context, sorption has received considerable attention as one of the most effective and simplest technological approaches for the removal of lindane. In the present study, we investigated the kinetics of the lindane sorption process onto a porous functionalized copolymer based on glycidyl methacrylate. Five widely used isotherm kinetic models (pseudo-first-order, pseudo-second-order, Elovich, Avrami, and fractional power models) were employed *via* non-linear and linear fitting. The extent of kinetic model compatibility was evaluated through seven error functions. According to the obtained results, the pseudo-second-order model was the best-fitting kinetic model for describing the kinetics of lindane sorption by the investigated sorbent.

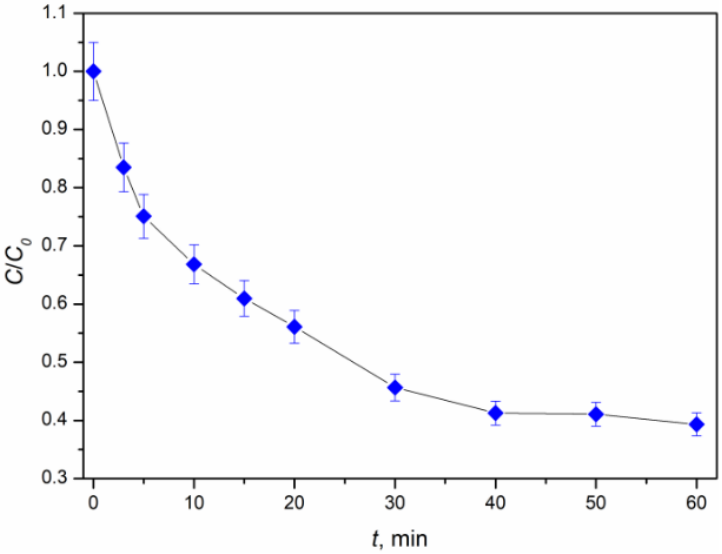

Fig. 1: The plot of the ratio for the lindane concentrations (C/C_0) versus *t*.

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Hydrolytic degradation of poly(lactic acid)/hydroxyapatite composites

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Poly(lactic acid) (PLA), one of the mostly used biodegradable polymers for tissue engineering, is a thermoplastic polymer well suited for additive manufacturing of bone scaffolds due to low melting temperature for melt extrusion. PLA for additive manufacturing usually is a technical-grade filament which is cost-effective; however, this material contains additives that greatly influence biological and degradation properties. We compared technical- and medical-grade polymer properties at accelerated hydrolytic degradation in phosphate-buffered saline (PBS) at 50 °C for 28 days. Technical-grade PLA (4043D, NatureWorks) samples preserved mass and shape throughout the degradation test. Medical-grade PLA (FP158009, Carbosynth) samples went through significant weight loss during simulated degradation, which directed our research towards significantly more expensive medical-grade PLA.

The addition of bioactive ceramics, such as hydroxyapatite (HAp), is one way to tailor the degradation properties of PLA-based scaffolds. Composites of medical-grade PLA with 0, 10 and 20 wt% of hydroxyapatite (PLA-0-HAp, PLA-10-HAp and PLA-20-HAp) were prepared in the form of circular films. The hydrolytic degradation test on prepared composites was carried out according to ISO 13781:2017 (E) norm for 10 weeks in PBS at 37 °C. The results show that PLA-0-HAp weight loss exponentially grows up after 6 weeks, while the addition of HAp stabilises it through the whole degradation process. The visible non-uniform degradation region appears in the thicker middle part of the film, where autocatalytic "bulk erosion" is favoured, and results in the transition of PLA into a rubbery state.

Determined glass transition temperatures (T_g) confirmed the mentioned composite degradation. T_g of composite with the highest amount of HAp remains stable at around 50 °C through 10 weeks. PLA-10-HAp's T_g is stable until week 8, while T_g of PLA-0-HAp starts to decrease towards 30 °C just after 2 weeks. The thicker sample region in the middle of each film is characterized by lower T_g than the thinner outer part. Although the poor distribution of HAp particles, observed by SEM in PLA-20-HAp, can induce sample degradation, it is obvious that a higher amount of HAp slows down sample mass loss and polymer degradation. HAp dissolution process is simultaneous with precipitation and polymer hydrolysis. The results lead to the conclusion that PLA and HAp form good molecular interactions that can inhibit composite degradation.

Synthesis of nanostructured TiO_2 and its application in self-crosslinking water-dispersive acrylic coatings

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Nanostructured titanium dioxide (TiO_2) can be prepared by various synthesis methods as pure minerals anatase, brookite and rutile or their mixtures. The most common application of nanostructured TiO_2 is in photo catalysis, solar cells, environmental pollution treatment, and as a pigment or UV filter in coatings, *etc*. In this work, nanostructured TiO_2 was synthesized by the sol-gel method [1] from the precursor titanium(IV) isopropoxide. The morphology was investigated by scanning electron microscopy (SEM /EDS), while the crystal structure of the nanostructured TiO_2 was investigated by powder X-ray diffraction (PXRD) at room conditions and elevated temperatures. For the purpose of application of the synthesized nanostructured TiO_2 as UV filters in self-crosslinking water-dispersive acrylic coating systems, the surface of the nanoparticles was modified with stearic acid, 3-aminopropyltrimethoxysilane (APTMS) and phenyltrimethoxysilane (PTMS). [1,2] The modification process was confirmed by infrared spectroscopy (FT-IR). Crilat 7829 (Vinavil) as commercially available basic coating was used in the coating system. To improve the coating properties, additives such as preservatives, fungicides, UV stabilizers and viscosity regulators were used. The influence of the TiO_2 additive on the final physicochemical properties of the coating was determined by testing the adhesion to the wood substrate and by testing the hydrophobicity of the coating and its resistance to UV radiation and moisture. The research results show that the amount and type of surfactant used in TiO_2 surface modification significantly affects the UV stability. In addition, hydrophobicity and adhesion depend on the type of wood to which the coating is applied.

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Analysis of chloride penetration in concrete exposed to marine environment

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During its service life, concrete can be found in various types of environments, and one of the most aggressive and complex is the marine environment. Degradation mechanisms in such an environment are numerous, and their intensity and interaction depend on the local specificities of a particular region. Corrosion of reinforcement caused by the action of chlorides is one of the most common factors that adversely affect the service life of reinforced concrete structures in the marine environment. The process of chloride penetration is one of the most important parameters when designing reinforced concrete structures, as well as planning remedial measures and maintenance. [1] The project entitled *Concrete development for sustainable construction in the marine environment* includes tests on reinforced concrete structures of seaports along the Adriatic coast in the territory of the Republic of Croatia. To characterize the concrete of different compositions, sampling was carried out by drilling cores from three characteristic zones of exposure of concrete to the marine environment: the submerged (immersed) zone, the tidal zone, the zone exposed to the atmosphere (air). An analysis of the chloride profiles, i.e., chloride concentrations by depth of the concrete, was performed on the powder grinded from the core samples, using Rapid Chloride Test from German Instruments. This work presents the results of the chloride profiles determined at three characteristic exposure zones of seaport Mandalina-Kuline in Šibenik. Results for all samples show increasing chloride concentration gradient up to the certain depth, where it reaches the maximum in concentration and then decreases constantly. Such a situation where chloride profiles show a maximum in concentration more in the interior of the concrete is produced sometimes in short term tests but is very common in cores drilled from existing structures. [2] The appearance of the maximum in concentration is an indicator of so called ''maximum chloride phenomenon''. This phenomenon may be caused by carbonation, wetting and drying cycles, existence of a ''concrete skin'' layer and elemental changes in the seawater. [2-6] Ultimately, these results show the consequences of long-term exposure of reinforced concrete structures to the marine environment and provide an assessment of their condition, as well as an insight into improvement options.

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Effects of higher alcohol/diesel blends on engine performance

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Bioalcohols are produced from biomass, by direct or indirect fermentation from crops, lignocellulosic residues and food waste. The need to use biofuels stems from legislation and social pressure to preserve the environment. Bioalcohols have already been extensively researched as a biocomponent for blending into gasoline fuels, while other uses have not yet been explored. In order to meet the legal regulations, the demand for biofuels is expected to increase in the future. Alcohols are oxygenated fuels and as such have several advantages in combustion process. Blended with diesel fuel, they can operate at lower fuel-to-air ratios. They have a higher octane rating, which results in delayed ignition, producing more premixed combustion and less soot and smoke.

Goal of this study was to investigate the engine performance of 1-pentanol and 1-octanol diesel blends. The prepared blends ranged from 10 to 30 vol% of alcohol were examined. The alcohols/diesel blends were tested in a compression ignition engine to determine the influence on engine performance and exhaust emissions (NO_x, HC and CO_2). Combustion, performance, and emission characteristics were measured on a single-cylinder, air-cooled engine based on Hatz 1D81 production engine. CO_2 emissions were measured with a non-dispersive infrared analyzer, while HC was measured with flame ionization detector. Concentrations of NO_x and O_2 in the exhaust gas were measured with a ECM NOX 5210 T analyzer.

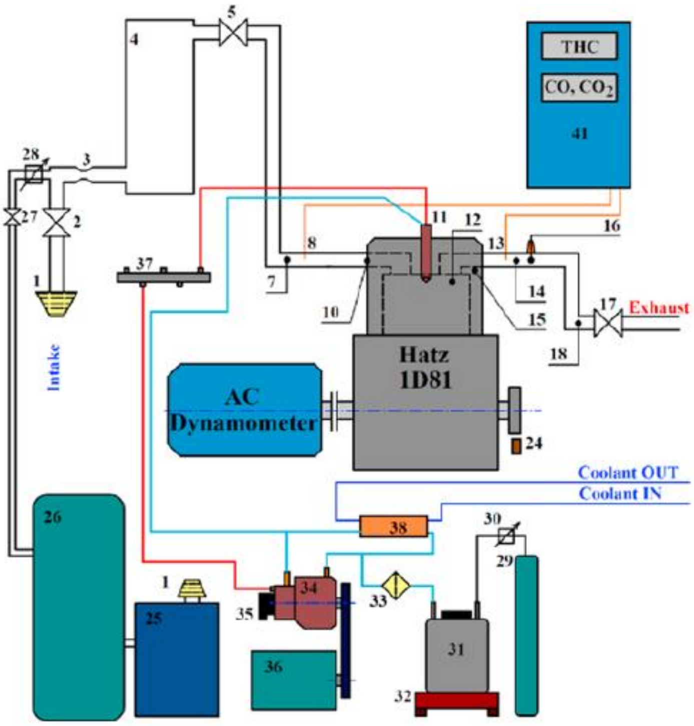

Fig. 1: Scheme of the experimental setup for the evaluation of combustion, performance, and emission characteristics.

Combining hierarchization and cations insertion in mordenite

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Crystalline microporous solids are an important class of inorganic materials with uses in different areas impacting our everyday lives, namely as catalysts, adsorbents, and ion exchangers. Advancements in synthesis have been invaluable in expanding the classical aluminosilicate zeolites to new unique framework types and compositions, motivating innovative developments. However, the inexhaustible post-synthetic options to tailor zeolite properties have been and will continue to be indispensable to realize emerging and to improve conventional applications. [1]

Al-rich zeolite mordenite was obtained from precursor suspensions without template. Hierarchically structured mordenite was obtained by post-synthesis treatment of microporous mordenite with NaOH solution for silicon extraction followed by acid washing with dilute HCl solution in order to eliminate the extra-framework aluminum species, without modifying the framework composition. The sample (MOR-B-A) was modified by wet impregnation (nitrate and acetate salts of Co^{2+}, Ni^{2+} and Cu^{2+}) and consecutive thermal treatment.

All post-synthesis treatments have impact on the crystallinity of the samples, especially desilication/dealumination process with base and acid, which is to be expected. The pores and voids created by these methods are visible on SEM micrographs (Fig. 1). EDS mapping was used to visualize the distribution of transition metals in the hierarchically structured mordenite. UV-Vis spectroscopy was used to identify the metal species. Various post-synthesis treatments, such as wet impregnation with specific metal cations followed by thermal treatment, are powerful tools for fine-tuning the strength of acid sites in many zeolites, including mordenite.

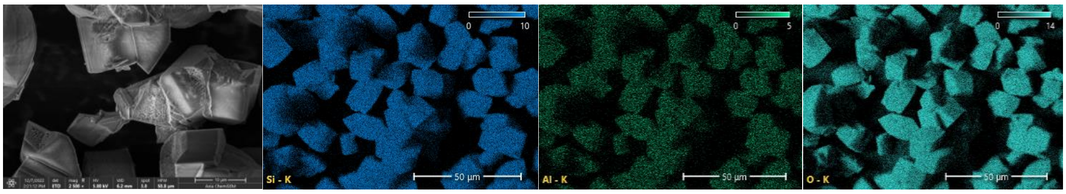

Fig. 1. SEM photo (b/w) and EDS elemental mapping of sample MOR-B-A, for Si (blue), Al (green), and O (cyan).

Acknowledgement Authors are grateful to the Croatian Science Foundation, project IP-2016-06-2214, for financial support.

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Eco-friendly UV-protective polyacrylate/rutile TiO_2 coatings

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Without adequate protection against weathering, wood materials are subject to photochemical reactions that significantly affect the aesthetic appearance and performance (change in colour, gloss, brightness, roughness). For wood protection, polyacrylate-based coatings have advantage due to their transparency and additionally, they can be produced as aqueous emulsions, thus providing an environmentally friendly alternative to organic solvent-based coatings. The aim of this work was to investigate the influence of TiO_2 nanofiller and the method of preparation on the UV protective properties of polyacrylate coatings. Therefore, in this study the influence of different types of TiO_2 (powder form and aqueous dispersions) on the properties of environmentally friendly polyacrylate (PA)/TiO_2 emulsions and on the UV-protective properties of the coating films was investigated. TiO_2 was added in the amount of 1.0 wt% by monomer weight, and emulsions were prepared by *ex situ* and *in situ* polymerization. The results showed that the type of TiO_2 and preparation method significantly affect the particle size distribution and the viscosity of PA/TiO_2 emulsions. Compared with the *ex situ* preparation method, *in situ* polymerization provides better dispersion of TiO_2 nanoparticles in the coating film, as well as a better UV protection effect and greater transparency of the coating films. Better morphology and transparency of nanocoating films were achieved by adding TiO_2 nanofillers as aqueous dispersion compared to the addition of TiO_2 in powder form. An increase in the glass transition temperature during UV exposure associated with cross-linking in the polymer was less pronounced in the *in situ*-prepared coating films, confirming better UV protection, while the photocatalytic effect of TiO_2 was more pronounced in the *ex situ*-prepared coating films. The results indicate that the method of preparation and type of TiO_2 have a significant influence on the properties of the coating films.

Green synthesis of $Ti_3C_2T_x$ MXene

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Transition metal carbides (MXenes) are an emerging family of highly conductive two-dimensional (2D) materials with additional functional properties introduced by surface functionalities. Their general chemical formula is $M_{n+1}X_nT_x$ (n=2-4), where M represents a transition metal, X is carbon and/or nitrogen, and T_x (where x is variable) stands for surface functional groups (–OH, –F, –O). [1] Conventional methods of MXene preparation mostly use wet chemical etching, where A-element atomic layers are etched from the MAX phase using HF or LiF/HCl solutions. [2] Fluoride-based solutions are highly hazardous and therefore, their use is associated with considerable safety and handling concerns that are a major barrier to scaling up MXene production. Therefore, there is an urgent need to explore safe and reliable synthetic methods to prepare MXene.

In this work, we explore mechanochemistry (MC) to prepare MXenes efficiently and in a green way since solvents are not required. This is a viable approach to promote reactions of solids quickly and quantitatively that can be easily scaled-up to manufacturing levels. [3] MXene $Ti_3C_2T_x$ was prepared by mechanochemical ball-milling of Ti_3AlC_2 MAX phase with different salts at room temperature. The obtained material was then ultrasonically treated in HCl, ethanol or TMAOH to complete the delamination process. The prepared MXene has been studied by powder X-ray diffraction (XRD), scanning electron microscopy (SEM), ultraviolet-visible (UV/Vis) spectrophotometry and Fourier-transform infrared spectroscopy.

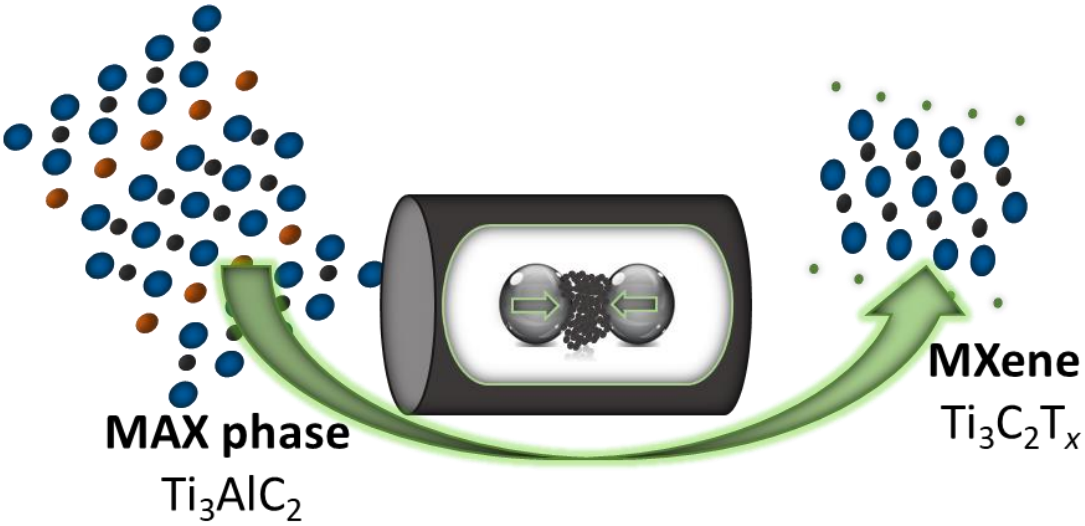

Fig. 1: Schematic illustration of the synthesis procedure to obtain MXene using MC method.

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The impact of reducing CO_2 emissions in the industrial production of Portland cement clinker with increased sulfur content

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The cement industry emits CO_2 at a global level of more than 7%, thus significantly contributing to the increase in greenhouse gasses. For this reason, the cement industry applies various methods to reduce CO_2 emissions. One of the methods to reduce CO_2 emissions is to lower the sintering temperature of the clinker, use more suitable fuels, and add mineralizing agents, which have a direct effect on reducing CO_2 emissions. In this work, an industrial experiment was carried out to produce Portland cement clinker by the dry process in an industrial kiln with four cyclone heat exchangers, using an increased sulfur content in the clinker, natural gypsum as the sulfur source, and petroleum coke as the fuel. The effects of reducing CO_2 emissions, the effects on the formation of sulfur stickers, and the recovery of sulfur with clinker on the production process itself were reviewed. The chemical composition of the produced clinker was determined by X-ray fluorescence method (XRF), and the mineralogical composition was examined using polarized light microscopy, X-ray diffraction on powder materials (PXRD) and scanning electron microscopy (SEM /EDS). The clinker produced was used in an industrial horizontal ball mill in a closed cycle with separators for the production of CEM I 42.5N cement. The Portland cement was further used in cement paste and mortar systems to determine the physical and chemical properties of the produced cement. Compressive and flexural strength tests were performed on the mortars after a hydration period of up to 60 days.

This industrial production confirmed the possibility of producing Portland cement clinker with a significant reduction in CO_2 emissions, without stickers forming in the kiln. The tests carried out on the physico-chemical properties of clinker and cement do not differ from the values obtained in the production with reduced sulfur content.

Indirect evaluation methodology of 1D self-organised charge transfer oxide thin films

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Many photovoltaic systems heavily benefit from configuration reposing on nanostructured charge transfer oxide layers (CTLs). Provided CTLs are achieved homogeneously over large surfaces, they can be responsible for the increase of charge transfer efficiency, and derivatively on the upgrade of the solar cell performance indicators. However, it is demanding to achieve large area homogeneous titania CTLs with the chemical route. The commonly used CTL nanostructured titania (TiO_2) can be prepared in a particularly economic manner via chemical self-organisation route. This investigation tries to demystify the optimisation attempts of electrochemical anodization for preparing nanostructured anatase thin films. We particularly focus on the contribution of the electrolyte composition over broad water contents. Namely, via electrolyte one can influence the equilibrium and the mechanisms behind several competing processes responsible for the formation of nanotubes; these are the titania formation, the growth of the 1D nanotubes via intermediate fluoride phase, and the degradation of all phases. We used broad structural, microstructural, electrochemical, and spectroscopic characterization tools. The characterisation of the electrolyte was found to be particularly useful for shedding more light on the development of the 1D formations in an indirect manner. Water presence facilitated the oxidation of Ti and subsequently faster etching, due to the increase of electron mobility, and also facilitated the dissolution of the intermediate fluoride phase – the only water-soluble phase in the system.

Disproportioning of formation/degradation phenomena occurred at the lowest and highest water contents, resulting in less perfect 1D formations. Luckily, we were able to elucidate the electrolyte composition that allowed for the synergy of formation/degradation, thereby forming the protective titania layer that prevented shunts and enabled the uniform growth of the 1D tubular nanoformations, as well as diminished the formation of residual titanium oxide phases. Consequently, we prepared large-scale homogeneous titania nanotube thin films.

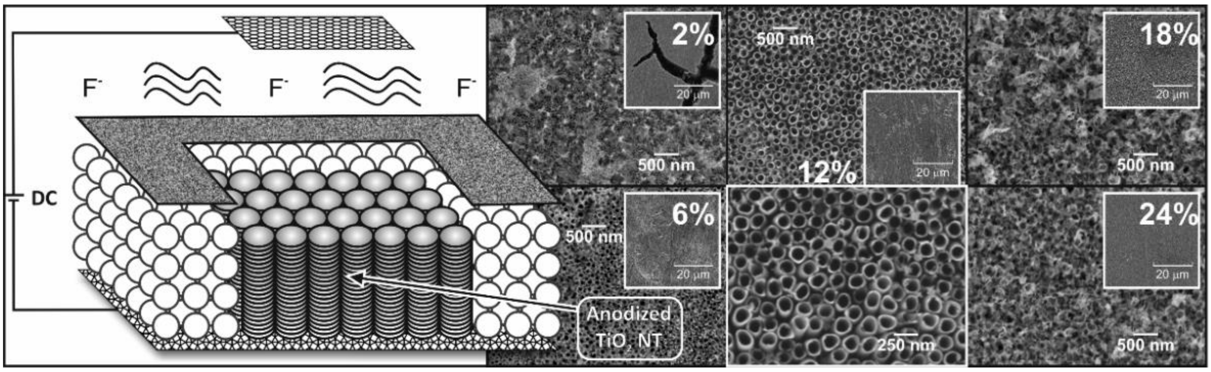

Fig. 1: Anodization scheme and representative electron microscopy of the thin films.

Acknowledgement This work has been funded by the projects UIP-2019-04-2367 and PZS-2019-02-1555 by the Croatian Science Foundation, and KK.01.2.1.02.0316 by the European Regional Development Fund.

Flavin-clay hybrid materials for photodegradation of dye pollutants

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Water pollution is one of the biggest environmental challenges today with direct impact on not only aquatic life but also human health. Major water pollutants are the industrial waste waters, in particular those from textile industry and dye houses. More than 1.3 million tons of dyes and pigments are consumed per year, the most common of which are synthetic azo dyes, many of which are highly toxic. [1,2]

Different strategies to remove dye pollutants from aqueous systems have been explored in the past two decades employing range of nature-inspired and synthetic materials. [3,4] However, most of reported approaches cannot be easily incorporated within large scale water purification systems and are very costly, both from the material and energy use point of view. Herein, we report the design of new photocatalytic material containing synthetic clay laponite functionalised with a flavin derivative riboflavintetraacetate (RTA). Laponite is widely used in cosmetic and paint industry as a rheological additive and provides excellent carrier scaffold for photoactive flavin moiety. The flavin-laponite (flaponite) hybrid can effectively and quickly degrade water soluble azo dyes, amaranth and naphthol blue, in aerated conditions under blue light irradiation. In addition to high degradation efficiency, both building blocks of the hybrid material are biodegradable and safe for use, fulfilling the main requirements for the water remediation agents.

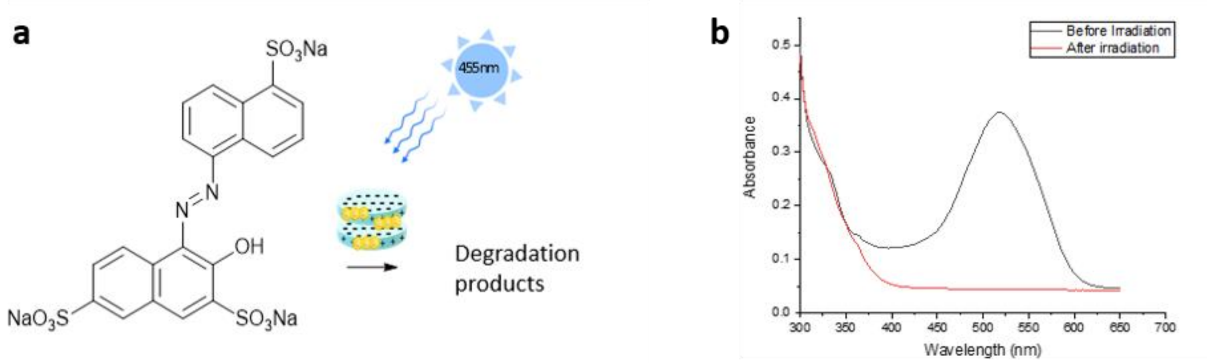

Fig. 1: (a) Amaranth dye degradation scheme; (b) Monitoring of dye degradation with UV-Vis after 5 min of irradiation.

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Charge transfer in bimetallic oxalate-bridged coordination polymer with the $[Fe(C_2O_4)_3]^{3-}$ core induced by light irradiation

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Photochromic materials are able to reversibly change their molecular and electronic structure by light irradiation. It is the reversible transformation of a chemical species between two forms, A and B, with different absorption spectra, induced by the absorption of electromagnetic radiation in one or both directions. The thermodynamically stable form A is converted by irradiation to the less stable form B, which has different absorption spectra and can be returned to form A both thermally or photochemically. The interconversion of two states is usually accompanied by the change of some physical properties, such as the refractive index, dielectric constant, electric conductivity, redox potential, phase state, solubility, viscosity, surface wettability, magnetism, luminescence, or a mechanical effect. These materials have attracted much attention due to their convenient visual monitoring and their real or potential applications in the fields such as optical switches, solar energy conversion, data storage, photomasks, and so forth. In the last decade, a large number of photochromic organic–inorganic hybrids have been investigated and reported.

We have explored compound $\{NH_4[\{Cu(bpy)\}_2(C_2O_4)Fe(C_2O_4)_3]\cdot H_2O\}_n$ (**1**; bpy = 2,2'-bipyridine), which has $[Cu(bpy)(C_2O_4)Cu(bpy)]^{2+}$ cationic species units mutually connected through oxalate groups of $[Fe(C_2O_4)_3]^{3-}$ in a 1D ladder-like coordination polymer, as a new type of photoactive solid state system. [1,2] This heterometallic compound exhibits significant photocoloration after exposure to direct sunlight or UV/Vis irradiation in the solid state (Fig. 1). This was investigated by powder and single-crystal X-ray diffraction, diffuse reflectance, IR and EPR spectroscopy.

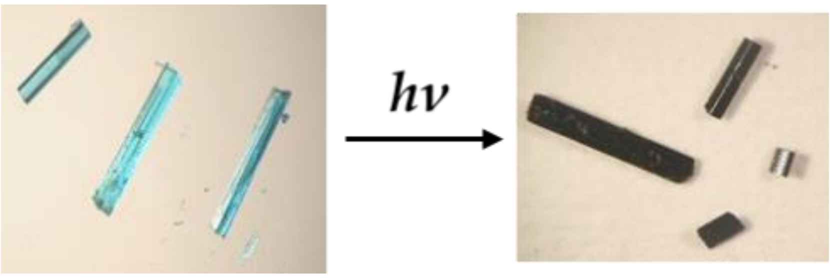

Fig. 1: The photo-induced color change of compound **1** upon continuous irradiation with UV/Vis light

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Alkaline resistance of recycled tyre polymer fibres for cement composites

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Fibres of various types can be added to cementitious composites to reduce their autogenous shrinkage and/or post-cracking. [1] The high strength and modulus of elasticity of fibres limit the propagation of cracks in a brittle cement matrix resulting in longer service life and lower maintenance costs for structures. However, fibre production has a significant negative environmental impact. To meet the EU's transition to a carbon-neutral, resource-efficient, circular and competitive economy, the use of secondary materials is strongly encouraged. For example, waste fibres such as recycled tyre polymer fibres (RTPF) [2] could be used to reinforce cement composites if found resistant enough to highly alkaline environment (pH > 12). To simulate cement matrix conditions and evaluate alkali resistance, RTPFs were exposed to a synthetic pore solution for 90 days. The solution was prepared by dissolving calcium, sodium and potassium hydroxides and calcium sulphate in water (2.2 g/L Ca(OH)2, 3.99 g/L NaOH, 16.83 g/L KOH, 0.34 g/L $CaSO_4 \times H_2O$) so that the pH, ionic composition and strength were adjusted to best simulate cement matrix. [3] The morphology of untreated and treated RTPF was studied by SEM, thermal properties by DSC and TGA and FTIR were used to determine the chemical changes. Partial and limited alkaline hydrolysis was observed in treated RTPF, so it can be suggested that it can be used at least to limit the volume deformation of the cement composite at early age. The reduction in cracking depends on the mechanical properties of the fibres, which could not be evaluated because the RTPFs are too short. This highlights the difficulty of establishing standardized testing protocols for different types of (waste) fibres that could potentially be used to reinforce cement composites.

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Effect of the fatty acid double bond on the properties of crosslinked nanocoatings on metals

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Corrosion causes major financial losses worldwide every year, and due to increasing air pollution, metals such as copper tend to degrade faster. Conventional methods of protecting metals, such as coatings, often contain toxic degradation products, so there is a need to develop a new environmentally friendly method of protecting metals. Fatty acids are non-toxic compounds that have an affinity for metals and self-assembling properties, forming self-assembled monolayers (SAMs) on the metal surface. In addition, SAMs from fatty acids can be crosslinked by gamma radiation, resulting in polymer nanocoatings with improved stability, durability, and other important properties.

The aim of this research was to investigate the influence of double bonds and conformations of fatty acids on the protective properties of the nanocoatings obtained upon crosslinking using gamma irradiation. The influence of double bonds was investigated using two fatty acids: stearic acid, $C_{18}H_{36}O_2$, a saturated fatty acid, and elaidic acid, $C_{18}H_{34}O_2$, an unsaturated trans fatty acid. Two monounsaturated fatty acids with the same number of carbon atoms, $C_{18}H_{34}O_2$: oleic acid, a *cis*-fatty acid, and elaidic acid, a *trans*-fatty acid, were used to study how the conformation of the fatty acids' double bond affects the corrosion protection properties upon crosslinking. The properties of the obtained coatings under simulated atmospheric conditions were investigated using electrochemical impedance spectroscopy and Tafel extrapolation method, while the hydrophobic properties of the coated copper surface were determined using contact angle goniometry. The results showed that the saturated fatty acid (stearic acid) exhibited better protective properties compared to elaidic acid, while oleic acid showed slightly inferior properties compared to elaidic acid.

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Effect of sonication on decellularization of porcine liver with ionic detergent

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Various biomaterials have been developed to obtain a biocompatible and biomimetic scaffold that could be used for tissue engineering. Decellularized extracellular matrix (dECM) appeared as a promising solution for regenerative purposes, as it contains natural components and structures vital for cell survival. Furthermore, since DNA is removed, this method limits the risk of immunogenic reaction, which is among the biggest problems in organ transplantation. Another challenge is to mimic the natural architecture of the tissue. One way to overcome this problem is the use of 3D printing technology. [1]

In order to decellularize liver tissue pieces, an ionic detergent was used: sodium lauryl ether sulfate (SLES). Previous studies indicated that this detergent demonstrates sufficient performance in removing DNA, but involved many protocol steps and took a lot of time, so another method was added to improve the protocol. Researchers also demonstrated that high-power waves could disrupt cell membrane and remove DNA. Therefore, samples were sonicated in detergent solution. [2,3]

After decellularization, light and stereo microscopy was used to compare the morphology of samples. Histochemical staining was used to quantify the remaining DNA, collagen and GAGs. Thus, the protocols were compared to determine possible future use in hydrogel formation.

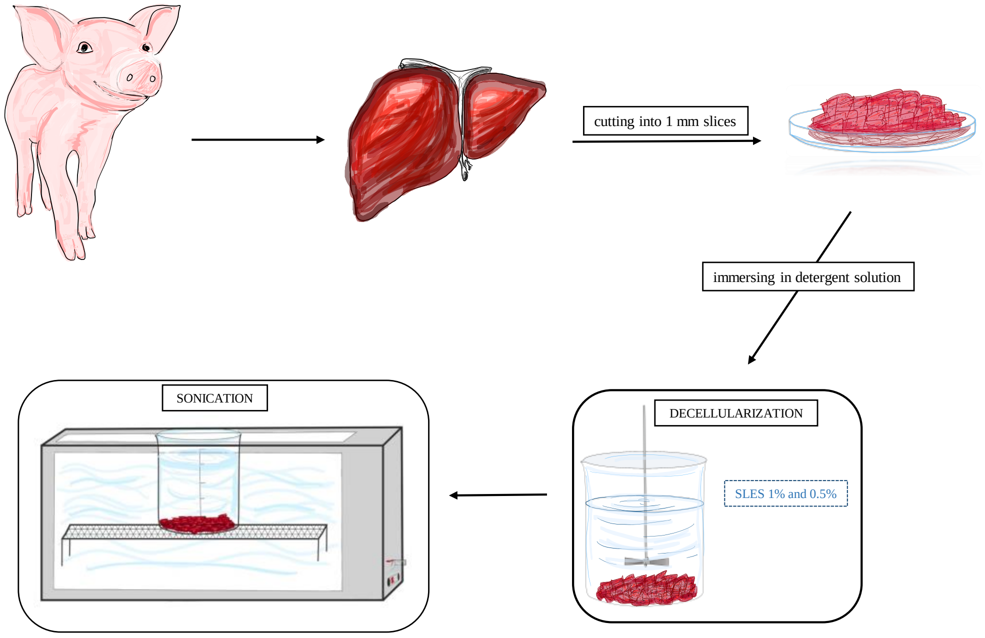

Fig. 1: Scheme of protocol.

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A GISWAXS study on supramolecular assembly of small molecule electron donating photoabsorbers

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Nowadays, organic photovoltaic devices are receiving increased attention due to combination of their comparatively simple and cost effective processing and the ability to derive low weight, flexible thin-film solar cells for both indoor and outdoor application. Exciton generation and charge carrier recombination in such devices are influenced by multiple factors such as donor to acceptor ratio, energy offsets in the active layer (HOMO/LUMO) as well as energy alignment at the electron and hole transport layer interface, and lastly, active layer morphology. A good bulk heterojunction (active layer) needs to fully utilize excitons generated through the absorption of the acceptor and donor blend by converting the charge carrier flux into current at quantum yields as high as possible. Important parameters for this process are electron and hole mobilities, which often depend upon the crystallinity of the material inside the active layer as well as upon the crystal interconnectedness throughout the layer. These factors can be controlled through a variety of approaches out of which the molecular design is deemed to be the most important one nowadays. Here, we dedicated a study to spontaneous supramolecular assembly and thin film crystallization from solution by dropcasting of symmetric and asymmetric aminosquaraine derivatives to investigate the influence of various substituents on π-π stacking, preferential orientation and overall order of crystallinity. The synthesized compounds were characterized through cyclic voltammetry and UV-Vis spectroscopy, while thin films were fabricated for Grazing Incidence Small and Wide Angle X-ray Scattering (GISAXS and GIWAXS) using a 2D detector. The results revealed important information on crystallization suppression regarding volume hindrances caused by the extension of the chain. Moreover, the correlation between planarity of the molecule and quantity of the π-π bonds was discussed.

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The effects of silicon anode thickness on electrochemical characteristics of Li-ion battery

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An important element in the development of Li-ion cells is the electrode configuration. The energy density is directly related to the loading of the active material. Therefore, to achieve higher capacities, the easiest way is to increase the electrode thickness. Here we present a comparative study of the effects of three different thicknesses of Ag decorated Si electrode anode (HCSi) on the electrochemical performances such as the formation of the SEI layer, impedances, and mass capacitances. In this study, we measured in-situ EIS by applying the current signal, galvanostatic electrochemical impedance spectroscopy (GS-EIS), in which a sinusoidal current is superimposed with a fixed charge. To optimize the electrodes, we prepared three different silicon electrode thicknesses: 20, 40 and 60 µm. Using GS-EIS, we investigated the intercalation mechanism of Li^+ ions in detail and found that the thickest electrode, HCSi20, allows for the diffusion of Li^+ ions into the bulk, while thicker layers prevent smooth diffusion into the bulk of the Si electrode due to the increased resistance of the layer. To analyse the anomaly of the frequency dependence of the measured impedance, the Voigt model was used, in which the classical Randles circuit is connected in series with one or two R║C parallel combinations. These two R║C parallel circuits represent processes which have a direct impact on the semi-circular dependence anomaly. One R║C circuit is possible result of the SEI formation, and the second R║C circuit could be the contribution of the Li-electrode impedance. To increase the number of charge and discharge cycles, we improved the electrolyte by adding fluoroethylene carbonate (FEC), which resulted in the capacity fading of the HCSi20 electrode to 50% of the initial capacity (≈3500 mAh g^{-1}) after 60 cycles, while without the addition of FEC the capacity dropped to 20% of the initial capacity after 10 cycles.

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Antimicrobially modified continuous yarns from electrospun fibers

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Common injuries of the musculoskeletal system that require surgical repair have a failure rate of up to 40%, so there is a need for the development of new materials that can be inserted in the place of the injury. In addition, infections caused by antibiotic-resistant bacteria during the hospital care cause more deaths than AIDS, tuberculosis and viral hepatitis together. [1] Therefore, there is a need for development of new antimicrobial implants containing coatings [2] active against Methicillin-resistant *Staphylococcus aureus (MRSA)* and Methicillin-sensitive *Staphylococcus aureus (MSSA),* microorganism strains resistant to antibiotics. The antimicrobial coatings with mixtures of nanoparticles are applied on the surface of materials by sol-gel process and characterized by different spectroscopic, microscopic and chromatographic methods. [3] The combination of the electro-spinning of the yarns and their surface modification can result in antimicrobial materials interesting for medical implants. Therefore, here we propose the functionalization of the continuous yarns from electrospun fibers (Figure 1) with antimicrobial coating containing antimicrobial nanoparticles by dip coating methodology. Since recent biological investigation showed that the biphasic scaffold components are noncytotoxic, and that tendon and bone cells can be grown on the cuff and block, [4] we expect that proposed combination of treatments will result in antimicrobial materials useful in hospital care.

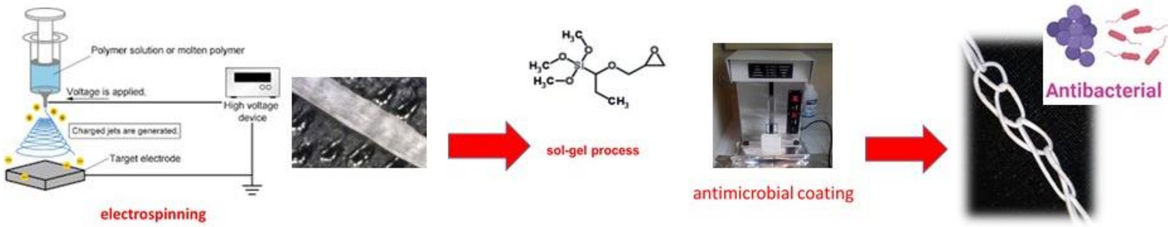

Fig. 1: Antimicrobial functionalization of continuous yarn crochet produced from electrospun fibers.

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Mechanochemical approach for the synthesis of LTA and SOD zeolites from (meta)kaolin

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Due to its high aluminosilicate content, purity, and pozzolanic properties, metakaolin is one of the most commonly used precursors in the synthesis of zeolites. It is obtained by dehydroxylation of the kaolinite structure in the temperature range from 450 to 800 °C. [1] Compared to the common thermal activation of kaolinite, mechanochemical activation is considered as an environmentally friendly alternative for the activation of kaolinite clay avoiding the high-temperature dehydroxylation process. Mechanochemical activation (MCA) is a process that can induce structural disorder – amorphization, through intensive grinding, which increases the chemical reactivity of the processed aluminosilicate material. Also, by using the MCA approach in the synthesis of zeolites, the energy-demanding hydrothermal conditions can be avoided, which is in line with the principles of green chemistry. In this work, the obtained samples were subjected to broad structural, spectroscopic, and morphological characterization. The parameters for zeolite synthesis were set to a molar ratio of 1 mol Na_2O: 1 mol Al_2O_3: 2 mol SiO_2. The amount of water and the temperature for curing the samples were varied. The possibility of MCA of kaolin was investigated by monitoring the degree of dehydroxylation, i.e. the degree of amorphization, as a parameter to monitor the success of conversion of kaolin-into-metakaolin. X-ray diffraction was used to study the degree of amorphization as a function of grinding time. [2] Finally, the study of the proposed mechanochemical activation showed that this route is a viable green approach alternative for the synthesis of zeolites. [3]

Acknowledgement This work has been funded by the projects UIP-2019-04-2367 and PZS-2019-02-1555 by the Croatian Science Foundation, and KK.01.2.1.02.0316 by the European Regional Development Fund.

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Quantum yield optimization of hybrid carbon quantum dots and their application as sensing nanomaterial

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Carbon quantum dots (CQDs), a new type of zero-dimensional carbon-based nanomaterials, represent an emerging class of fluorescent materials for potential applications in biosensing, chemical sensing, and theranostics. Moreover, CQDs have attracted an enormous attention due to their outstanding physico-chemical and tunable optical properties, water dispersibility, high photostability and biocompatibility. In this study, hybrid carbon quantum dots (CQDs@hybrid) have been prepared by a hydrothermal process and the quantum yield was optimized using response surface methodology (RSM). The process was analyzed and optimized using a central composite face-centered design (CCFD) model in a quadratic function consisting of 11 experimental runs with three replicates at the central point. The effects of temperature (160-200 °C; X_1), and preparation time (6-12 h; X_2) were investigated on the quantum yield (y) obtained by CQDs@hybrid sample. The CQDs@hybrid sample obtained under optimal conditions exhibited a high quantum yield of 17.52±0.59%, and was studied in details regarding chemical (solubility, EDS), physical (AFM, FTIR, PXRD), and optical (spectrofluorimetry, UV-Vis spectroscopy) properties. Furthermore, the sample CQDs@hybrid were applied as fluorescent nanoprobe toward Fe^{3+} ion detection in model systems, and also for the detection of Fe^{3+} ions in real samples of well-water, herbs and spices. The presented results indicate a good preparative approach for obtaining highly fluorescent CQDs which have great potential for water monitoring, food analysis and quality control studies.

Acknowledgement This work has been supported by the Croatian Science Foundation under the project *Application of innovative techniques of the extraction of bioactive components from by-products of plant origin* (UIP-2017-05-9909).

Application of EIS and SECM studies for investigation of anticorrosion properties of epoxy coatings

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Cast iron is a material that is commonly used for drainage pipe systems, but when it is exposed to an aggressive medium, it is subject to electrochemical corrosion. [1,2] Appropriate coating systems are used for this purpose. The surface of the coating was analyzed using scanning electron microscopy (SEM) and energy dispersive spectrometry (EDS). Corrosion electrochemical behavior of epoxy coating in 3.5 wt% NaCl solution and tap water were studied by electrochemical impedance spectroscopy (EIS) and with scanning electrochemical microscopy (SECM). The aim of the work is to learn about the working mode of the SECM device by monitoring the corrosion resistance of epoxy coating. EIS measurements were performed in 3.5% NaCl for ten days. SECM has been introduced to evaluate the localized corrosion process, as it provides electrochemical activity and topographic information about the surface reactions at the micrometer scale in aqueous environments. [3] Therefore, two methods of measuring the corrosion resistance of epoxy coatings are compared and the possibilities provided by SECM compared to the classical EIS method are listed. Furthermore, the physical properties such as color, thickness, hardness, and adhesion to the cast iron surface were tested as well. The test results showed that the physical properties of epoxy coatings were satisfactory in the neutral medium, but electrochemical tests showed a reduced corrosion protection.

Acknowledgement This research was funded by *Development of anticorrosion protection system for multipurpose pipe use*, grant number KK.01.1.1.07.0045. This work was supported by the European Regional Development Fund under the Operational Program Competitiveness and Cohesion 2014-2020.

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SEM-EDS analysis of powder from concrete elements exposed to the marine environment

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The influence of seawater on the chemical composition of concrete is complex due to a series of potentially aggressive ions present in seawater, such as chloride, sulfate, magnesium and carbonate ions. The average amount of salt in the Adriatic Sea is 38.3 g/L, which is higher than average compared to other sea waters. [1] In addition to chemical degradation mechanisms, buildings in the marine environment are also exposed to various physical and biological degradation mechanisms, such as changes in wetting and drying cycles, temperature changes, erosion, and the action of microorganisms that develop within the concrete structure. [2,3] When designing concrete structures, designers are expected to define the exposure class and concrete requirements, to ensure that the designed service life is achieved. [4] As part of the project *Concrete development for sustainable construction in the marine environment*, investigative work was carried out on concrete elements from the *Mandalina-Kuline* seaport. Three test samples in the shape of a cylinder were sampled by drilling holes at two different measurement points perpendicular to the direction of the concrete element. Two cylinders were drilled from measurement location 1, from a precast concrete element, in two different zones exposed to the marine environment: the submerged (immersed) zone (XS2) and the tidal zone (XS3). A cylinder was drilled from measurement location 2, from an *in-situ* concrete element, which is located in the zone exposed to the marine environment: the zone exposed to the atmosphere (air) (XS1). After collecting the samples on site, the powders were ground from each cylinder into 11 separate fractions by depth, starting from 0 to 102 cm. Powder samples were then analyzed at SEM-EDS. The device used for the analysis was FE-SEM, Mira II LMU (*Tescan*, *Czech Republic*), equipped with an X-ray detector for elemental analysis (EDS). For each powder sample, the spectrum of chemical elements was analyzed in 20 to 30 points, and the average value from all points was taken as representative. The analysis of chemical elements by sample depth showed that the largest differences in chemical composition occur in the first millimeters of the cylinder. The aim of this work is to compare the representation of chemical elements at different depths for samples of powders from three cylinders that are located in different zones of exposure to the marine environment and have different concrete compositions.

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Physical and chemical properties of differently dried topcoats

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Coating application is the process of covering a surface or substrate with another substance to protect it temporarily or permanently from deterioration due to reaction with the environment or corrosive substances. The main components of coating systems are primers, intermediate coatings, and topcoats. The function of the topcoat is to provide a sealing for the coating system. They must have good adhesion to the primer and high hardness to protect the protected part from scratches. In addition, topcoats provide the desired appearance in terms of color and gloss, so they must be UV resistant.

In this work, solvent-borne topcoats from two different manufacturers were dried under atmospheric conditions and with infrared radiation (IR). Some of the samples dried in an infrared chamber were intentionally overdried, in order to examine the effects of overdrying on the physical and chemical properties of the examined topcoats. For this purpose, the samples were left in the IR chamber two and three times longer than required for their complete drying to simulate the production process. To assess physical properties of tested topcoats, pull-off adhesion and Shore D hardness tests were performed. TGA, DSC and FTIR analyzes were performed to determine the chemical properties of the differently dried topcoats. The examined topcoats achieved satisfactory results regardless of the drying method.

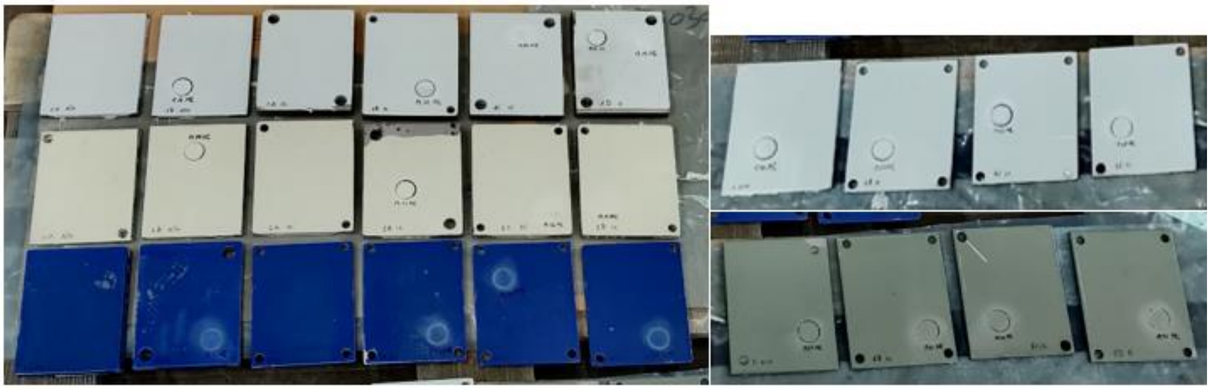

Fig. 1: Five different examined topcoats

Mechanical properties of prepared methacrylate copolymer nanocomposites, synthesized in a green solvent cyrene™

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Green chemistry is an approach to chemical synthesis and manufacturing that aims to reduce or eliminate the use of harmful or toxic chemicals and to promote the use of renewable resources. In the field of polymer production, it can lead to the development of more environmentally friendly and sustainable processes and products. [1,2]

The aim of this research was to demonstrate the potential use of the green solvent cyrene™ for the *in situ* preparation of methacrylate copolymer nanocomposites with cellulose nanocrystals (CNC) as fillers. *In situ* preparation resulted in uniform dispersion of cellulose nanocrystals in the polymerization medium, reducing aggregation and enhancing polymer-cellulose interaction. Tensile strength tests were performed to evaluate the mechanical properties of prepared samples. Size exclusion chromatography was used to determine the molecular weights and dispersity of the synthesized products and to assess the impact of molecular weight size on mechanical properties. The use of cyrene™ as a solvent in the polymerization process resulted in improved mechanical properties of the final materials due to the good dispersion of CNC, high molecular weights and low dispersity. Overall, this study highlights the importance of considering green solvents in polymer synthesis and the potential benefits they can bring to the final properties of the materials.

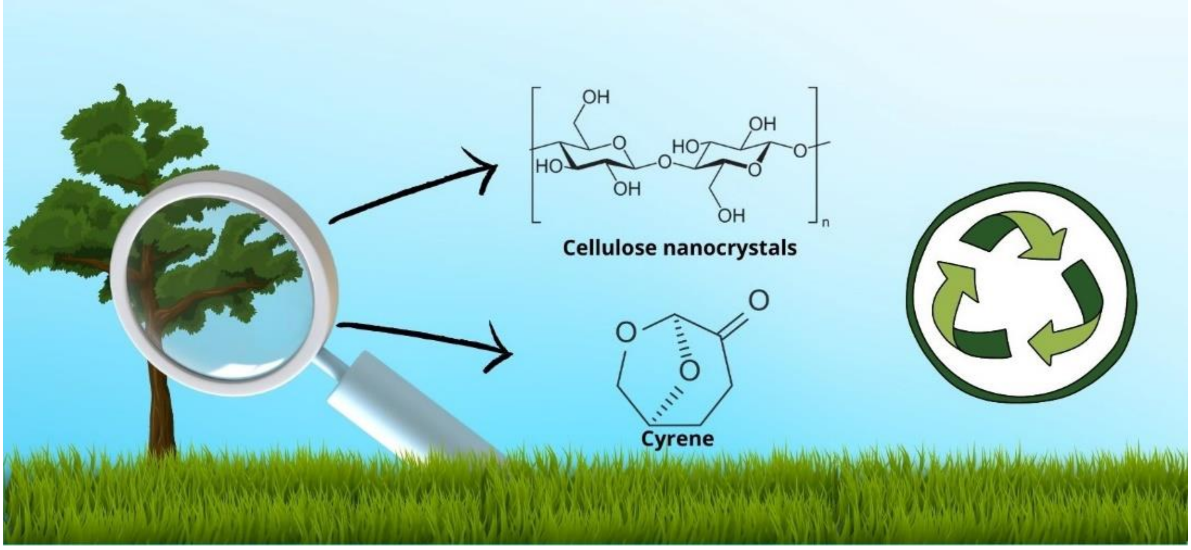

Fig. 1: Green chemistry.

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Dimensionality-dependent magnetic order in hybrid anisidinium tetrachlorocuprates(II)

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Hybrid halometallates materials provide a fertile playground for design of multifunctional materials. [1] The magnetic and electric properties of these materials is dictated by the dimensionality of the inorganic framework, but the relation between dimensionality and choice of building blocks is not well understood. [2]

Tetrachlorocuprate(II) hybrids of the three anisidine isomers were prepared and studied in the solid state via X-ray diffraction and magnetization measurements. Depending on the overall cation geometry, a layered, defective layered and discrete frameworks were obtained for the resulting para-, meta- and ortho-anisidinium hybrids, respectively. In the case of layered and defective layered structures this affords *quasi*-2D layered magnets, demonstrating a complex interplay of strong and weak magnetic interactions that lead to the long-range ferromagnetic order. In the case of the discrete structure, a peculiar antiferromagnetic behavior was revealed. To supplement it, the method for calculation of dimensionality of the inorganic framework as a function of interaction length was developed. The same was used to discriminate between *n*-dimensional and “almost” *n*-dimensional frameworks, to estimate the organic cation geometry limits for layered halometallates, and to provide additional reasoning behind the observed relation between cation geometry and framework dimensionality, as well as their relation to differences in magnetic behavior.

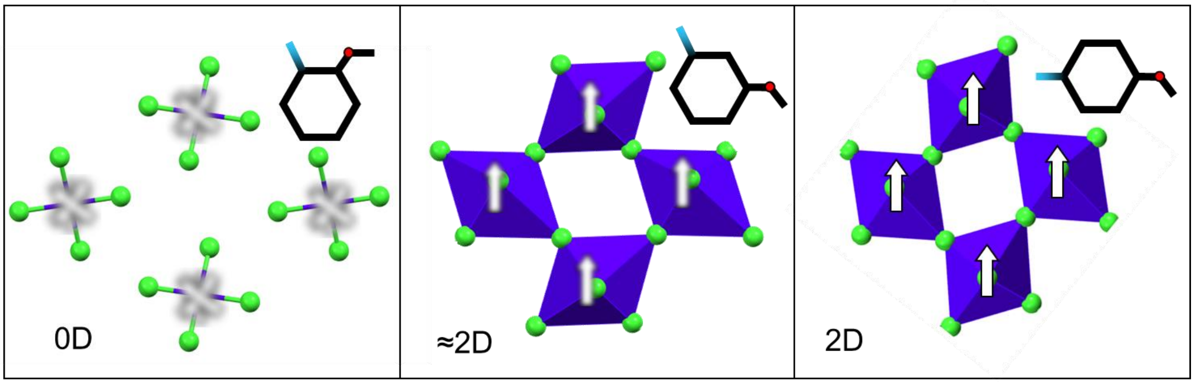

Fig. 1: Magnetic properties of the hybrid materials depend on the dimensionality of the inorganic framework.

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Capturing the pressure driven PXRD features of selected inorganic and hybrid materials

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One of the most important goals and a crucial step in the technologically intensive and competitive search for applicable and first-class materials is a careful planning of the research strategy and the collection of high-quality experimental data to find the optimal combination of their physical and chemical properties that will allow a systematically tailored functionality of the final product. Understanding the synergy of accurate crystal structure, sufficient purity, tunable microstructural parameters, whether it is a purely inorganic or hybrid inorganic-organic material, remains a difficult task.

With these parameters in mind, the use of powder X-ray diffraction (PXRD) and structural evolution with pressure from synchrotron radiation experiments are highlighted independently on the selected inorganic and inorganic-organic examples to emphasize the need for this characterization method, without which it would be impossible to correlate crystal structure with physical properties.

The ability to perform *in situ* synchrotron radiation studies under non-ambient conditions allows for a better understanding of the relationship between structural features and mechanical properties of functional materials.

Thermochromic flexografic prints in paper recycling process

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The production of recycled paper consumes less energy (between 28 and 70%), reduces carbon dioxide emissions and the amount and pollution of wastewater compared to the production of paper from virgin fibers. Paper collected for recycling contains cellulose fibers that must be separated from various impurities such as inks, varnishes, coatings, laminates, staples, *etc*. All of these impurities can have a negative impact on the papermaking process and must be removed to maintain the quality of the recycled paper. Ink removal is the most important process in the production of recycled paper. It depends on the quality of the collected paper for recycling, the type of printing technique, properties of the printing inks, the age of the product and the climatic conditions during its life cycle, as well as the conditions in the deinking itself (the chemicals used). The extraction of printing ink from paper suspension can be carried out by different procedures, with flotation as the most common one. In addition to flotation deinking, research has shown that adsorption deinking can effectively remove printing ink from pulp suspension. The research carried out in this paper describes the possibility of recycling thermochromic flexographic prints. The sample was recycled using different methods to determine the most effective method. Based on the results, it can be concluded that samples printed with thermochromic printing ink are problematic to recycle. Comparison of the optical parameter results shows that the deinking chemicals used, as well as the addition of polymer granules, do not significantly improve the optical properties of the recycled papers. Adsorption deinking with polypropylene as adsorbent and the chemicals used in INGEDE 11 method did not significantly affect the results. The conclusion of this paper is that new methods of recycling thermochromic prints should be further researched, as well as researching new deinking chemicals, optimizing them, and introducing new polymer materials as adsorbents in adsorption deinking, which has proven to be an effective method for recycling digital prints.

Comparative study of socks made of different cellulose fibers

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Socks are knitted garments worn in direct contact with the feet, often covering the ankle and some part of the calf. They have to fulfill high requirements for functionality, comfort, durability and design. Casual socks are usually made of cotton yarns that provide softness and comfort, and are blended with polyamide or Lycra to improve fit, durability and shrink resistance. Today, in addition to cotton, various types of different fibers are used in the production of socks. Man-made artificial fibers from cellulose, such as viscose, modal and lyocell fibers are of particular interest because of their silky handle, exceptional contact comfort and better hydrophilicity than cotton, but their applicability in knitting of socks has been insufficiently researched. [1,2] As the aim of this study is to investigate their applicability, in this paper the comparison of two groups of socks produced with the highest percentage of single ring spun yarns of the same linear density (made of bright staple viscose, modal, lyocell and cotton fibers) in full plating with different polyamide 6.6 yarns was carried out. Therefore, by testing the socks propensity to surface pilling, abrasion resistance, dimensional stability, water vapor absorption and air permeability, all according to the standardized test methods, the evaluation of socks produced from cellulose fibers was performed and the influence of different plating yarns was observed.

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Optimization of thermal and photothermal sintering of inkjet printed amphiphilic silver nanoparticles on glass surfaces

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Inkjet deposition of silver films is widely applied in printed electronics, as well as in architecture and interior design to produce decorative glass surfaces. The printing process can speed up production, save material and minimize the factor of human error. However, to achieve a satisfactory printed material, it is necessary to formulate an ink that, when combined with the substrate, produces a product with desired properties. As part of this experiment, amphiphilic silver nanoparticles (AgNP) suitable for printing on glass were synthesized. To adjust the hydrophilic–lipophilic balance, the AgNPs were first coated with a hydrophilic stabilizer poly(acrylic acid) and then modified with a secondary stabilizer (3-morpholinopropylamine) *via* amide bonding. [1] In order to obtain inkjet-printable conductive ink, the amphiphilic silver nanoparticles were dispersed in a three-component solvent system (water, ethanol and ethylene glycol), followed by printing on glass slides. The necessary sintering process was carried out using an intense pulsed light (IPL) system (λ=190-1100 nm), and the results were compared with samples sintered using the traditional thermal method. A statistical software package (Design-Expert, version 6) was used to assess the importance of the process parameters. Input factors for designing the experiments were source energy and number of flashes for photothermal sintering, and temperature and processing time for thermal sintering. In both cases, the sheet resistance was measured as a response and was found to be lower than 2 Ω/sq for all samples. The obtained simulation models describe the experimental values with an R^2 value larger than 0.9. Sintering using IPL resulted in films with conductivities similar to those obtained with the thermal method, but the optimal duration of the process is significantly shorter (< 1 s). The morphology of the printed films before and after the sintering processes was compared using atomic force microscopy.

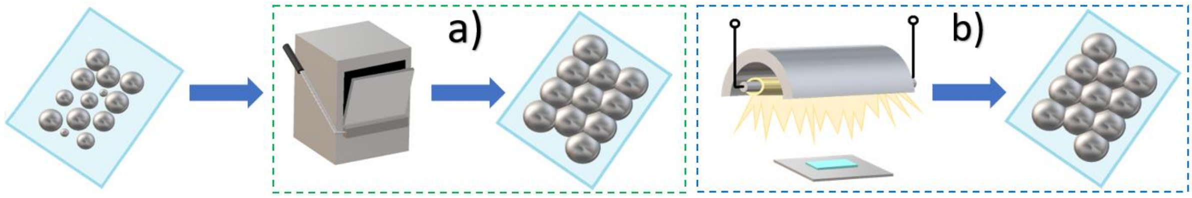

Fig. 1: Schematic representation of a) thermal and b) photothermal sintering of amphiphilic nanosilver inkjet printed on glass.

Acknowledgement This work was supported by the Croatian Science Foundation (projects: UIP-2020-02-9139 and DOK-2021-02-2361) and European Regional and Development Fund for the Industrial Research and Innovation (IRI) Project *Research and development of innovative glass processing techniques* (KK.01.2.1.02.0059).

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Application of simulated solar radiation and hydrogen peroxide to remove xenobiotics from aqueous solutions

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Persistent organic xenobiotics such as pesticides are an environmental problem today. Negative impacts not only on human health, but also on the entire environment are the subject of numerous studies. Precisely with the aim of protecting the environment and the health of living organisms, numerous legal regulations have been passed on the permitted concentrations and monitoring of pesticides, as well as the prohibition of the use of proven toxic components. Nevertheless, developing countries still use some pesticides that are banned in developed countries today, and thus continue to be introduced into the environment. Excessive use of pesticides has a negative impact on the entire ecosystem, so it is important to find a way to remove them from the environment and thus to improve the quality of the biosphere. Each technology has its advantages and disadvantages, and some processes do not achieve the required destruction and removal, but only distribute and stabilize organic substances. [1]

The aim of this work is to investigate the influence of hydrogen peroxide and solar radiation on the degradation of pesticides acetamiprid and thiacloprid. Quantification and detection of pesticides in water samples was carried out by high performance liquid chromatography. The decomposition of the mentioned xenobiotics was tried to be stimulated by mechanical mixing with the presence of hydrogen peroxide, but also with the artificial solar radiation.

By mechanical mixing in the presence of hydrogen peroxide, immediate results were observed, while further mixing did not lead to a shift in the concentration of the mentioned xenobiotics in the solution. By further conducting simulated conditions, the results indicate that solar radiation is necessary for the complete decomposition of any xenobiotic, and the quality and speed of removal depends on other parameters of the solution, such as the pH value and the concentration of hydrogen peroxide.

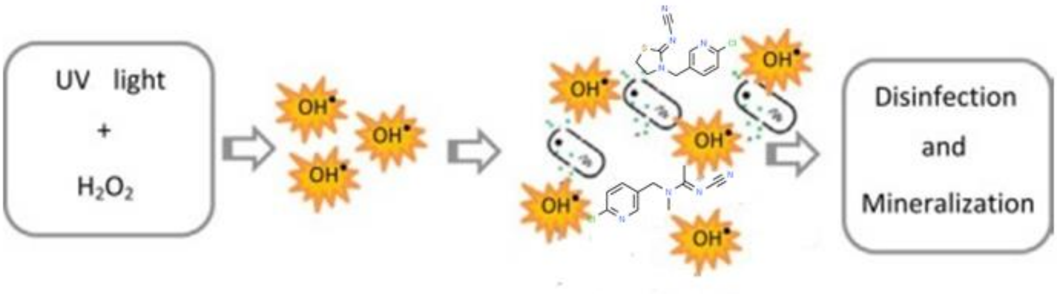

Fig. 1: Procedure for purifying aqueous solutions of pesticides with hydrogen peroxide. [2]

Acknowledgement This paper was prepared as part of the project *Advanced water treatment technologies for microplastics removal* (IP-2019-04-9661, AdWaTMiR) financed by the Croatian Science Foundation.

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Batch biodegradation of xenobiotics

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Nowadays, the use of xenobiotics is more and more common, and thus their occurrence in the environment, including surface water, underground water and soil. The three main sources of xenobiotics into the environment are industry, hospitals and households, whose wastewater reaches wastewater treatment plants (WWTP). [1] The activated sludge treatment method in WWTP is the most common method in wastewater treatment, but the ways of elimination (biodegradation, adsorption, hydrolysis, evaporation) of xenobiotics in the process itself have not been sufficiently investigated. However, many studies have shown that the elimination of xenobiotics in conventional wastewater treatment plants is not complete, and they will eventually enter the environment via wastewater or sludge. Therefore, wastewater treatment plants are one of the dominant point sources of xenobiotic pollution. [1] The aim of this work is to examine the possibilities of removing xenobiotics from wastewater by biodegradation using activated sludge and to examine the hydrolysis and adsorption of xenobiotics on sludge. The possibility of biodegradation of the antiparasitic febantel in 48 hours was determined by high-performance liquid chromatography with monitoring of pH-value, temperature, density, total amount of carbon and the impact on microorganisms. The potential adsorption of the febantel on the sludge was tested after biodegradation by microwave extraction. It was found that the main removal mechanism is the adsorption of febantel on the sludge. The biodegradation of the component itself does occur, which is confirmed by the obtained chromatograms, where the formation of degradation/transformation products that are formed during the biodegradation process is visible.

Fig. 1: Path of xenobiotics into the environment. [2]

Acknowledgement This paper was prepared as part of the project *Advanced water treatment technologies for microplastics removal* (IP-2019-04-9661, AdWaTMiR) financed by the Croatian Science Foundation.

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Evaluation of printability of paper substrates with agro-residues for graphic products

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The overall quality of the graphic product depends largely on the origin of the raw materials for pulp and paper, the type of ink, the technology used to print the product, and the printing conditions. Each printing technology is more or less suitable for a particular type of printing substrate, depending on how the ink is transferred to the substrate. Although the Chinese used other raw materials for papermaking almost 2,000 years ago, wood is now the most important raw material for the production of pulp and paper. As forest areas become smaller and fewer trees are available as raw material for cellulose fibers, the production of paper and graphic products has focused heavily on the use of alternative, non-wood raw materials. Alternative cellulose fibers for papermaking from agro-residues are the most cost-effective and environmentally friendly solution that aims to reduce the consumption of wood raw materials by replacing them with alternative plant biomass. The objective of this study was to evaluate the printability of paper substrates for a specific graphic product where wood fibers are partially replaced by alternative fibers from cereal straw. Papers with a straw fiber content of 30% were produced under laboratory conditions and printed using digital and conventional printing techniques. The evaluation of the printability of paper substrates with agro-residues was based on the determination of the quality of ink acceptance on the previously printed ink, which is the basis for multicolor reproductions in the graphic industry.

Fig. 1: Paper substrate with 30% of triticale fiber.

Acknowledgement This work has been supported in part by the Croatian Science Foundation under the project *Printability, quality and utilization of substrates with non-wood fibres* (UIP-2017-05-2573).

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Application of the prognostic model in the evaluation of the water quality of Lake Blidinje (B&H)

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Lake Blidinje is the largest mountain lake in Bosnia and Herzegovina and lies at 1185 m above sea level. According to the division of Directive 2000/60/EC of the European Parliament and the Council (Directive 2000/60/EC of the European Parliament and the Council on the establishment of a framework for Community action in the field of water policy), Lake Blidinje is placed in the fifth ecoregion for rivers and lakes of the Dinaric Western Balkans. The lake loses 4-5 mm of water per day in the spring, which is about 24,000 m^3 of water outflow per day. The lake serves as a sediment filter and has a 1 mm increment of sediment annually. Lake water contains a large amount of suspended particles that results in a large turbidity. This is significantly reflected in the lake's transparency, which is 15 cm. Large areas of the lake, especially in summer, lose water through evaporation. This lake is the main watering place for the livestock of this and wider region. The type of lake in which the entire water column is frequently mixed is also marked as polymictic. Intense sediment-water interaction and potentially large water impact vegetation makes shallow lakes function in many respects much differently than what is it in deep lakes.

This paper examines the prognostic model obtained by multiple regression analysis of water quality indicators in earlier studies. The multiple regression analysis was performed where the dependence of the concentration of chlorophyll a on concentrations of SO_4^{2-}, Fe, NH_4^+, water temperature, hardness, dissolved reactive phosphorus, N/P ratio (Redfield's) was investigated. The results showed that the relationship between the above indicators was very strong (R=0.849). The coefficient of multiple determination (R^2=0.720) showed that as much as 72% of the variance of chlorophyll a concentration in the measured period was interpreted by the above independent variables. Therefore, this model can be considered representative. In the multiple regression analysis, the dependence of chlorophyll a concentration on water temperature, concentrations of Fe and SiO_2, pH, and TN/TP ratio of filtered water samples showed that the connection between the mentioned indicators was strong (R= 0.705). The coefficient of multiple determination (R^2=0.497) showed that as much as 49.7% of the variance of the concentration of chlorophyll a in the measured period was interpreted by the above-mentioned independent variables. Therefore, this model can be considered representative.

Identification of dominant PAHs sources at three different urban sites: Urban background, urban residential, urban industrial

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Polycyclic aromatic hydrocarbons (PAHs) are recognized as one of the most serious contaminants due to their mutagenic and carcinogenic health effects. They originate from a variety of sources such as forest and peat fires, volcano eruptions, coal combustion and vehicle exhaust emissions. There are several routes of PAH exposure, including water, food and tobacco smoke, but ambient air represents one of the major sources of PAH intake. In this study, PM_{10} particle samples (particulate matter with a diameter <10 µm) were collected at three cities in continental Croatia (urban background, urban residential and urban industrial sites). 24-hour samples were collected on quartz filters from about 55 m^3 of air over two months during winter time. The analysis of the PAHs was performed using an Agilent Infinity 1260 high-performance liquid chromatograph (HPLC) with a fluorescence detector and programmed changes in excitation and emission wavelengths. Samples were analyzed for eleven PAHs: fluoranthene (Flu), pyrene (Pyr), benzo(*a*)anthracene (BaA), chrysene (Chry), benzo(*j*)fluoranthene (BjF), benzo(*b*)fluoranthene (BbF), benzo(*k*)fluoranthene (BkF), benzo(*a*)pyrene (BaP), dibenzo(*a*,*h*)anthracene (DahA), benzo(*ghi*)perylene (BghiP), and indeno(1,2,3-*cd*)pyrene (IP). The average mass concentrations of all of the measured PAHs were highest at the urban industrial and lowest at the urban residential site. The PAHs' diagnostic ratios identified wood and coal combustion as a dominant source at the urban industrial and urban background and liquid fossil fuel at the urban residential site.

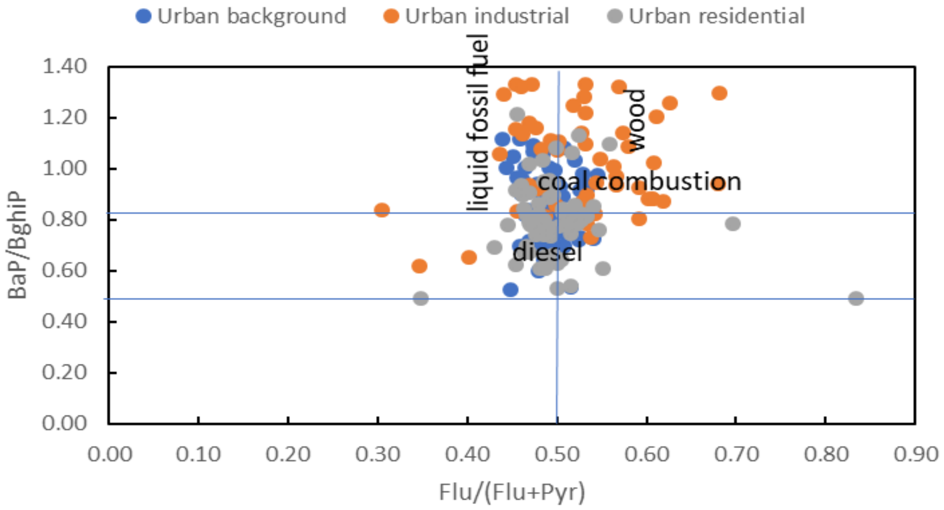

Fig. 1: Diagnostic ratio of individual PAHs.

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Effects of storage conditions on the migration of phthalates from plastic packaging to bottled natural mineral water

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Plastic is the most common type of packaging material on the market today, universally accepted due to characteristics such as low mass, high inertness, low price and good flexibility. Most bottled water and soft drinks are packaged in polyethylene terephthalate (PET) plastic bottles and despite the excellent properties of such packaging, various compounds (e.g. micro and nanoplastics, phthalates, toxic elements) can be used either in the production of plastics or as a result of the mechanical stress to which bottles are exposed in daily use to migrate into beverages.

The aim of this study was to determine the concentrations of different phthalates (dimethyl phthalate – DMP, diethyl phthalate – DEP, dibutyl phthalate – DBP, di-*iso*-butyl phthalate – DiBP, benzyl butyl phthalate – BBP, *bis*(2-ethylhexyl) phthalate – DEHP and di-*n*-octyl phthalate – DOP) in commercially available carbonated (*Jamnica*) and non-carbonated (*Jana*) natural mineral water stored in several types of glass (transparent and green coloured) and PET packaging (virgin or 100% recycled) exposed to elevated temperatures and direct sunlight for 0, 7 and 30 days.

A gas chromatography-mass spectrometry (GC-MS) was developed and validated for simultaneous determination of selected phthalates. Water samples were extracted with dichloromethane, dried by nitrogen and finally, the dried samples dissolved in 0.2 mL of dichloromethane. The concentrations of DMP, BBP and DOP were below the limit of detection in the analysed samples. DEP, DBP, DiBP and DEHP were present in low concentrations in water samples of all tested packaging with tendency of somewhat increasing concentrations after storage for 30 days under the described conditions. The highest concentration of 2.58 µg/L was found for DBP in non-carbonated water sample packaged in 100% recycled PET after 30 days of storage. The concentrations of DEHP (0.31-2.12 µg/L) were well below the recommendations of the World Health Organization [1] for drinking water (<8 µg/L), while the other analysed phthalates have no comparable health guidelines.

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Influence of storage conditions on the migration of metal(loid)s from polyethylene terephthalate (PET) packaging into bottled drinking water

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Over the last 30 years, bottled water has gained significant popularity. Lately, most of this water is sold in polyethylene terephthalate (PET) bottles. The increased use of bottled water has led to concern over human exposure to various metal(loid)-containing compounds used in the production of plastics, which could leach from plastic bottles to beverages. In addition, bottled drinking water is often transported and stored under diverse conditions for several months before consumption. In response to the influence of sunlight and elevated heat, which can be particularly extreme during the summer months when temperatures during transportation can reach over 60 °C, metal(loid)s may be released from packaging at a faster rate.

The aim of this study was to investigate the influence of storage duration (0, 1, 7, 14, 30, 90 and 180 days), temperature and combination of temperature and sunlight (0, 7, 14, 30 days) on the leaching of trace elements from different types of PET packaging (virgin PET of higher and lower density, 100%-recycled PET) of commercially available non-carbonated (*Jana*) and carbonated (*Jamnica*) natural mineral waters produced by Jamnica plus, the largest producer in this part of Europe, using inductively coupled plasma mass spectrometry (ICP-MS).

Antimony (Sb) was the most relevant element leaching from all types of PET bottles under the influence of different storage/transport conditions (sun + temperature > temperature > storage time). Regardless of the experimental conditions, more Sb was released from green colored than from transparent bottles. Mass concentrations of Ba, Co, Li, Mn, Ni and Zn depended on the type of water (carbonated > non-carbonated) and not on the packaging, while the type of water, type of bottle and storage/transport conditions had no influence on the release of Al into the product. In all of the conducted experiments, the measured mass concentrations of metal(loid)s, even in the most extreme experimental conditions, were significantly lower than the maximum allowable levels for trace elements in drinking, mineral and tap waters prescribed by Croatian regulation. [1]

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Bioplastic based on thermoplastic potato starch citrate: Thermal properties

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Packaging waste accounts for a significant portion of municipal solid waste generation, negatively impacting interconnected human-earth systems in a variety of ways and strongly influencing climate change. The dominance of the linear economy (take-use-dispose) is difficult to eliminate. The transition from the dominant linear economy to the circular economy; “5R” (reuse-reduce-recycle-renew-remove) is extremely important, especially with regard to the use of packaging. [1-2] In this paper, potential packaging materials based on polylactic acid (PLA) and thermoplastic potato starch citrate (TPS) are investigated. Potato starch was plasticized with glycerol and citric acid and then compounded with PLA in a laboratory Brabender mixer. The thermal properties of the TPS/PLA bioplastic were characterized using differential scanning calorimetry (DSC), dynamic mechanical analysis (DMA), and thermogravimetric analysis (TGA). According to the DSC results for TPS/PLA bioplastics, the changes in melting and crystallization temperature indicate that there is an interaction between TPS citrate and PLA. The TGA results show that TPS is more thermally stable with the addition of citric acid. The viscoelastic properties were improved by the addition of citric acid. The addition of citric acid has a dual function, primarily as a plasticizer and also as a compatibilizer, *i.e.*, it is a good candidate that can expand the range of achievable properties of TPS/PLA bioplastics.

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Optimization of microplastics polystyrene biodegradation by *Bacillus subtilis* isolated from compost sample

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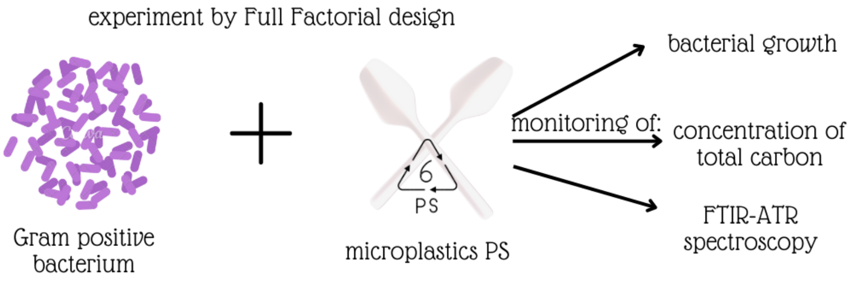
Microplastics (MP) are polymer particles smaller than 5 mm and are divided into primary and secondary. [1] Primary microplastics are formed during industrial production. When macroplastics enters the environment, it breaks down through physical, chemical, and biological processes into smaller particles that form secondary microplastics. The most commonly produced and used polymer types are polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polystyrene (PS). Microplastics pose a problem because they persist in the environment for long periods of time, are insoluble in water, are difficult to decompose, have a complex polymer composition, can transfer hydrophobic pollutants adsorbed to microplastics, have effects on aquatic organisms that can bioaccumulate, enter the food chain, and affect human health. [2] In this context, the biodegradation of secondary MP PS by the bacterium *Bacillus subtilis* which was isolated from compost was studied. The experiment was conducted according to the full factorial design. Three factors (size of PS particles, optical density of bacterial suspension, and speed of rotary shaker) were studied at three levels (minimum, average, and maximum). During the 30-day experiment, the number of live bacterial cells and the concentration of total carbon were monitored. At the end of the experiment, the PS particles were analyzed by FTIR spectroscopy. Optimal conditions were observed at the average values of PS size (300-500 µm) and optical density (0.3), as well as at the maximum value of speed of rotary shaker (200 rpm). According to the obtained results, *Bacillus subtilis* is the suitable choice for biodegradation of PS.



Acknowledgement The authors would like to acknowledge the financial support of the Croatian Science Foundation through project entitled *Advanced water treatment technologies for microplastics removal* (AdWaTMiR, IP-2019-04-9661).

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Assessment of the ecotoxicological effects of microplastics with the study of a bioremediation strategy for its removal from the environment

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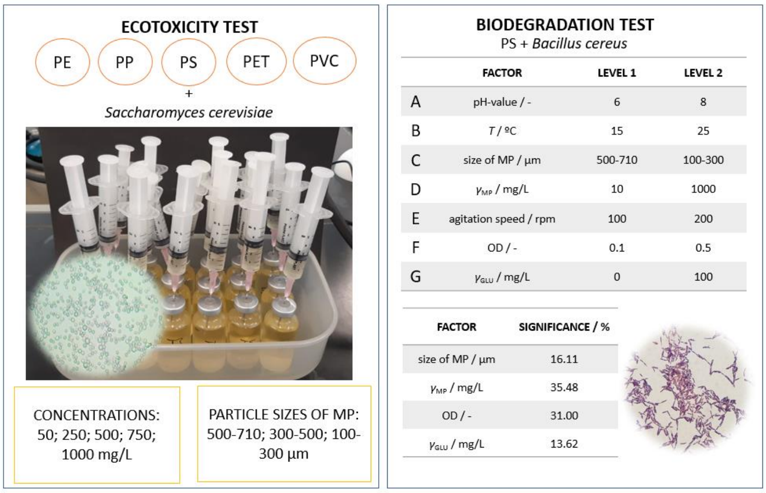
Microplastics (MP) are found in all components of the environment and represent a global problem due to their toxic effects on the environment. For this reason, numerous ecotoxicological studies are being conducted and new methods and technologies are being explored for the removal of MP, including biotic degradation by microorganisms. [1] In this work, ecotoxicological studies were conducted on the effect of MP on the yeast *Saccharomyces cerevisiae*. The yeast was exposed to different concentrations (50; 250; 500; 750 and 1000 mg/L) and particle sizes (100-300; 300-500 and 500-710 µm) of polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET). All types of MP caused growth inhibition at the highest concentration (1000 mg/L) and the smallest particle size (100-300 µm). According to the calculated inhibitions, PS proved to be the most toxic polymer, and the inhibition was 100%. After the ecotoxicological test, the PS biodegradation experiment was performed with the bacterium *Bacillus cereus*. The effect of seven factors was studied according to the Taguchi experimental design: pH, temperature, MP particle size, MP particle concentration (γ_{MP}), agitation speed, optical density (OD) and glucose concentration (γ_{GLU}) at two levels – minimum and maximum. The Design-Expert software was used to determine the significant factors of the process: size of MP, γ_{MP}, OD and γ_{GLU}. According to the obtained percentage of significance, γ_{MP} had the greatest influence on the biodegradation process of PS.



	FACTOR	LEVEL 1	LEVEL 2
A	pH-value / -	6	8
B	T / ºC	15	25
C	size of MP / µm	500-710	100-300
D	γ_{MP} / mg/L	10	1000
E	agitation speed / rpm	100	200
F	OD / -	0.1	0.5
G	γ_{GLU} / mg/L	0	100

FACTOR	SIGNIFICANCE / %
size of MP / µm	16.11
γ_{MP} / mg/L	35.48
OD / -	31.00
γ_{GLU} / mg/L	13.62

Fig. 1. Ecotoxicity test and biodegradation test.

Acknowledgement The authors would like to acknowledge the financial support of the Croatian Science Foundation through project entitled *Advanced water treatment technologies for microplastics removal* (AdWaTMiR) (IP-2019-04-9661).

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Comparison of different yeast cultures in the biodegradation of polyvinyl chloride microplastics

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Polyvinyl chloride (PVC) is a material of concern due to the generation and release of harmful chemicals during the life cycle. The toxicity of PVC increases when is found in the environment in the form of microplastics (MP). MP are plastic particles ranging from 1 µm to 5 mm. [1] To reduce the concentration of MP PVC in the environment, this research examined an economically and ecologically suitable method – biodegradation. [2] Five yeast cultures were tested, *Candida parapsilosis*, *Rhodotorula glutinis*, *Saccharomyces cerevisiae*, *Geotrichum candidum*, and *Trichosporon* sp., in the biodegradation of PVC with a particle size of 25-100 µm. All biodegradation experiments lasted 30 days. During the experiment, the optical density (OG), the number of living yeast cells (CFU), and the concentration of total, organic, and inorganic carbon (TC, TOC, and TIC) were monitored. Before and after biodegradation, the pH value, temperature, and oxygen concentration were determined, with the characterization of MP PVC by FTIR spectroscopy. Finally, the toxicity of the filtrate was determined using *Vibrio fischeri* bacteria. Based on the obtained results, primarily CFU and FTIR, *Candida parapsilosis* was determined as the most effective yeast in the biodegradation of PVC MP.

Acknowledgement The authors would like to acknowledge the financial support of the Croatian Science Foundation through project entitled *Advanced water treatment technologies for microplastics removal* (AdWaTMiR, IP-2019-04-9661).

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Interreg Danube Hazard m^{3}c – key project findings concerning current national policies

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Tackling hazardous substances pollution in the Danube River Basin by Measuring, Modelling-based Management and Capacity building (Danube Hazard m3c) is an Interreg project co-funded by the European Union (ERDF, IPA, ENI). 14 countries of the Danube basin are involved in the project, including Croatia. The main objective of the project is to establish a coherent and comprehensive screening of the water status of the Danube basin. According to the EU Water Framework Directive, pollution by hazardous substances is an important water quality problem in the Danube River Basin that needs to be addressed. This also applies to non-EU member states, which have committed to pursue similar goals under the International Commission for the Protection of the Danube River. The project is based on three elements of water governance: measuring, modelling, and management. Part of the project involves collecting and cataloguing available data on measurements of hazardous substances in the basin and analyzing existing rules and regulations that each country participating in the project adheres to. Conclusions are presented based on analyses of the main aspects of policies related to the management of hazardous substances in water, mainly in the following areas: national legislative frameworks, monitoring of hazardous substances in surface water, management of hazardous substances in groundwater, point source emitters, diffuse polluters, fees, analytical methods, databases and registers, and inventories of emissions of priority substances.

Fig. 1: Countries participants of Danube Hazard m3c project.

Acknowledgement The authors would like to acknowledge financial support through project *Interreg Danube Hazard m3c*.

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Determination of perfluorooctane sulfonic acid (PFOS) by-products after TiO_2 solar photocatalysis over 3D-printed static mixers

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Per- and polyfluoroalkyl substances (PFAS) are an environmentally daunting class of synthetic chemicals of emerging concern that have recently attracted regulatory attention. [1] Perfluorooctane sulfonic acid (PFOS) represents one of the PFAS compounds which has increasingly attracted global concerns in recent years since its global distribution, notable bioaccumulation and potential endangerment to human beings and other animals. [2,3] PFOS is being used directly in surfactants, insecticides, and protective coatings for paper, textiles, carpets, and clothing. [4] TiO_2 photocatalysis is listed as the emerging best available technique (BAT) in the reference document for common wastewater and waste gas treatment/management systems in the chemical sector. TiO_2 as a photocatalyst has the ability to break down and destroy many types of pollutants but outdoor applications of this technology are still developing.

Therefore, in this paper, the application of the photocatalytic oxidation process for the degradation of PFOS is presented as well as the PFOS by-products determined by Q-TOF LC/MS technique. The photocatalytic oxidation was performed in a laboratory compound parabolic collector (CPC) reactor which has been considered as a state-of-the-art of the photocatalytic reactor. As a simulation of sunlight, modular panel with the full spectra solar lamps with the appropriate UVB and UVA irradiation levels were used. A commercially available photocatalyst, titanium dioxide (TiO_2 P25) was immobilized on a PETG carrier (Helix form of static mixer) by the sol-gel method. PETG carriers were obtained by 3D printing.

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Determination and assessment of new-born dietary intake of polychlorinated biphenyls in commercial infant formulae

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Polychlorinated biphenyls (PCBs) are a group of contaminants characterized by their persistence, long-range transport, biomagnification in food chains and bioaccumulation in humans and wildlife. They have been shown to cause cancer in animals as well as a number of serious non-cancer health effects such as effects on the immune, reproductive and endocrine system and other health effects. The international community has responded to the threat from persisting organic pollutants (POPs), including PCBs, by negotiating a global treaty, the Stockholm Convention on POPs, with the objective of protecting human health and the environment from POPs. [1] However, legacy PCBs tend to biomagnify in the food chain and appear at higher concentrations in fat-containing foods. Infant formula plays important role in diet of no breastfeeding newborns. [2] During the period of intensive growth, the infant has 4-7 meals a day. The daily intake of lipids is in the range of 21-35 g, depending on the age of the infant. Although the production standards are very high, in accordance with the Codex Alimentarius, there is no standard control of PCBs present in the products and data on occurrence of legacy contaminants such as PCBs in this important food sources are lacking. In this study, all PCB congeners were analyzed in five commercial infant formulae (stage 1, up to 6 month). First step was extraction of total lipids from infant formulae by Soxhlet method (ISO 8262-1), second step was determination of PCBs in lipid extracts of infant formulae by the method that combines high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The concentration of total PCBs ranged from 14,6 to 51,5 ng/g-lipid. Penta CBs were most prevalent in all infant formulae ranging from 13,6 to 36,6 ng/g-lipid. Average daily intake of PCBs is 88-309 ng PCBs/kg body weight /day for infants 0-month-old, and 73-258 ng PCBs/kg body weight/day for infants 6-month-old. Further investigation should include exposure assessment in order to reveal the exposure significance of PCBs in infant formulae.

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Tackling hazardous substances pollution in the Danube River Basin by Measuring, Modelling-based Management and Capacity building

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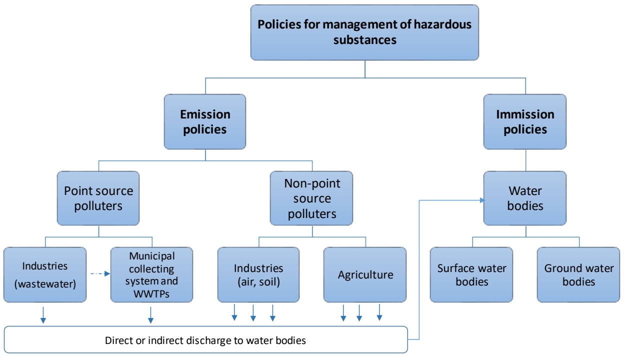
The Faculty of Chemical Engineering and Technology of the University of Zagreb participates in the Interreg project shortly named Danube Hazard m3c. This work represents a critical review of the currently existing national policies of eleven countries in the Danube River Basin for management of the water pollution by hazardous substances and their compliance with the key EU legislative acts in the field. These countries are Austria, Bulgaria, Croatia, Hungary, Moldova, Montenegro, Romania, Serbia, Slovenia, Slovakia and Ukraine. However, the Danube River Protection Convention was signed on June 29 in 1994 by eleven Danube riparian countries (Austria, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Moldova, Romania, Slovakia, Slovenia and Ukraine). It came into force in 1998. Later on, Bosnia and Herzegovina, Montenegro and Serbia have also signed the convention. The Convention establishes the legal framework for the transboundary management of the Danube River Basin, including both surface and ground waters. The scope of monitored hazardous substances includes: priority substances in surface waters, specific substances – the list of these substances is usually established through specific regulations at national level, and priority substances monitored in biota and sediments. As much as 24 priority substances are included in the national monitoring programs in all the countries. In more than half of the studied countries 21 specific hazardous substances are observed. Concerning the monitoring of biota, the regulated priority substances monitored in four countries are: hexachlorobenzene, hexachlorobutadiene, perfluorooctane sulfonic acid and its derivatives and hexabromocyclododecane. Concerning the monitoring of sediments, 16 priority substances are monitored in 3 countries that have submitted the information.



Acknowledgement The authors would like to acknowledge financial support through project *Interreg Danube Hazard m3c*.

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Lead, cadmium and radionuclide caesium (^{137}Cs) in wild growing edible *Boletus* mushrooms from different areas of Croatia

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Fruiting bodies of *Boletus* mushrooms were collected in the season of 2021 in three different areas of Croatia (Central, Northern and Mountainous Croatia). Sampling locations were determined by the highest and lowest (Control area) content of lead (Pb) and cadmium (Cd) in the soil from the Republic of Croatia, categorized according to the Geochemical Atlas of the Republic of Croatia. Inductively coupled plasma mass spectrometry (ICPMS) technique was used to determine the metal content, while the activity concentration of ^{137}Cs in *Boletus* mushrooms was determined by the gamma spectrometric method. The highest Cd content among three areas was found in mushrooms from Northern Croatia where 15% of samples exceeded the maximum level of 5 mg/kg dry mass (dm) set for contaminants in wild fungi. The content of Pb in mushrooms from all three Croatian areas ranged 0.02-3.94 mg/kg dm, which corresponds to levels reported in the literature to reflect unpolluted areas. ^{137}Cs activity concentration in all analysed samples was below the legal threshold for edible products, 600 Bq/kg. Considering that many species of wild edible mushrooms can be harmful to human health because they can accumulate studied metals and radionuclides in excessive amounts, it is of outmost importance to regularly monitor their concentrations.

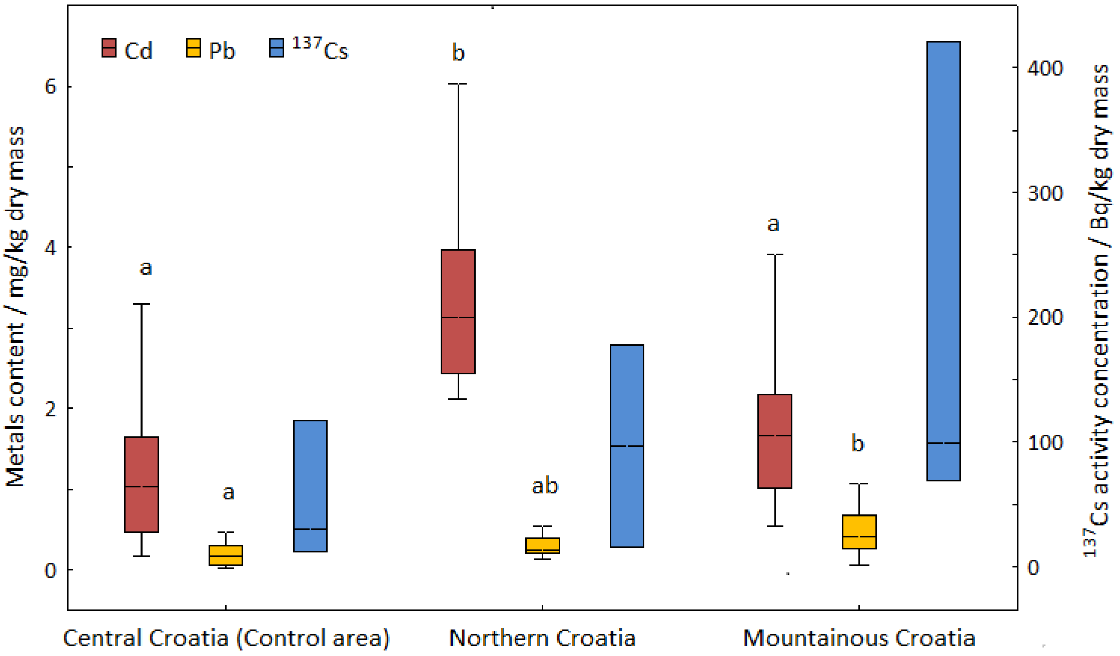

Fig. 1: Cd and Pb content (mg/kg dry mass) and ^{137}Cs activity concentration (Bq/kg dry mass) in *Boletus* mushrooms obtained from different areas of Croatia. Statistically significant differences in concentrations of respective metal or radionuclide between areas were tested by Kruskal-Wallis ANOVA and *post-hoc* multiple comparisons of ranks for all groups (at $p<0.05$) and indicated with different letters. Data are presented by Box-and-Whisker plots where boundaries of box-plots indicate the 25th and 75th percentiles; the line within the box is the median value; whiskers above and below the box indicate non-outlier range.

FTIR analysis of prints on paper substrates with virgin straw fibres

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Over the past decade, the use of recycled paper in the paper and graphic industry worldwide has become increasingly common. However, the recycling process can degrade the properties of the paper, so the recovered cellulose fibres are often blended with a certain amount of virgin fibres to improve the strength and quality of the paper, and thus the quality of the print. Paper as cellulose-based printing substrates can be damaged by photolytic degradation caused by exposure to light and high temperatures. This research has focused on analysing the stability of prints on laboratory paper substrates made with 30% virgin straw fibres. Using FTIR analysis of prints obtained with different printing techniques, an evaluation of the optical stability of the samples after artificial aging treatment was performed. Artificial aging treatment was carried out according to ASTM D 6789-02 standard, in which the samples were exposed to visible and near-ultraviolet electromagnetic radiation ranging from 290 nm to 800 nm in a chamber over two 48-hour cycles. The results of this analysis confirm that the addition of virgin straw fibres to recycled paper pulp results in improved optical stability of prints on paper substrates.

Acknowledgement This work has been supported in part by the Croatian Science Foundation under the project *Printability, quality and utilization of substrates with non-wood fibres* (UIP-2017-05-2573).

Influence of photodeposited silver and iron nanoparticles onto $BiVO_4$ surface on ciprofloxacin photocatalytic degradation mechanism

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Different crystal forms of a photoactive material have different photocatalytic activities, usually represented by differences in band gap energies and affinity to recombination of generated charge carriers. In photocatalytic experiments, monoclinic bismuth vanadate is the most used form of bismuth vanadate. Monoclinic bismuth vanadate is a n-type visible light photocatalyst which means that the majority of charge carriers in this crystal form are electrons. In fact, low mobility of photogenerated holes is one of the main disadvantages of monoclinic $BiVO_4$. Nevertheless, under visible light irradiation this form of $BiVO_4$ can degrade most of organic dyes in a few hours. For degradation of complex molecules modifications of monoclinic $BiVO_4$ are required.

In past studies, bismuth vanadate was first enhanced via morphological change resulting in spherical isotype homojunction $BiVO_4$. Second modification of photocatalytic activity was postdeposition of silver and iron nanoparticles onto its surface. Newly synthesized photocatalysts were immobilized on glass plates. With the use of response surface methodology (RSM), the best conditions (mass of nanoparticles precursor, pH and concentration of hydrogen peroxide) for degradation of 50 μM ciprofloxacin (CIP) under simulated sunlight were examined. In this study, reactive oxygen species (ROS) scavenging under the best conditions for each photo deposited material was performed. The used scavengers were: formic acid for holes, 1,4-benzoquinone as superoxide scavenger and dimethyl sulfoxide (DMSO) as hydroxyl radical scavenger. The obtained results of photocatalytic degradation of CIP under sunlight with hydrogen peroxide show differences in mechanism of activation of hydrogen peroxide with different photodeposited nanoparticles. Those results will be combined with mass spectrometry results and toxicological studies to get the detailed pathway of CIP photodegradation under defined conditions.

An attempt to quantitatively analyse submillimetre microplastics by DSC

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Microplastics (MP) is already a notorious marine pollutant. Its role as a vehicle that transports bacteria and/or various substances including toxic trace metals is less known; thus METALPATH project was conceived to address that problem. To understand the transport properties of MP it is necessary to assess qualitative and quantitative composition of each particular microplastic batch. This may be both challenging and time consuming, particularly for submillimetre particles. Since MP is constituted mostly of semicrystalline polymers, thermal analysis in the form of differential scanning calorimetry (DSC) is already proven as a fast and relatively simple method for identification of polymer composition in submillimetre microplastic collections. [1] In an appropriately selected temperature range DSC is nondestructive so further analysis can be performed on the same sample. However, it is challenging to directly determine masses of particles in a collection of submillimetre MP. A method for quantitative analysis of MP by DSC was proposed by Hajo and Lackner. [2] The authors stated that, since specific heat of a transformation like melting is expected to be constant for a particular polymer kind, the unknown sample mass can be calculated from calibrations based on a linear relationship of melting peak area and the sample mass. The problem is that the authors also proposed that a single calibration using virgin polymer should be valid for all MPs of that polymer kind, irrespective of their origin and state of degradation. The goal of this study was to test that concept by calibrating the melting peak area and sample mass relationship using both virgin polymers and real MP. In the case of two most common constituents of MP, high-density polyethylene (HDPE) and isotactic polypropylene (iPP), we found that linear relationship was valid, but the slopes of calibration curves varied. Variations were significant even between virgin samples of the same composition, as checked by ATR-FTIR. Thus, we conclude that intrinsic polymer characteristics like molecular mass and its distribution and polymer processing affect specific heats of polymers in such a way that proposed calibration may only provide rough estimates of masses. In MP, oxidation and degradation on exposure to environment complicate the problem further so the approach to mass assessment of submillimetre MP batches needs to be revisited.

Acknowledgement This work has been supported in part by the Croatian Science Foundation under the project IP-2019-04-5832. (METALPATH)

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Comparison of the mechanical resistance of prints obtained by different printing techniques on papers containing cereal straw pulp

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Nowadays, the paper industry is facing challenges in providing its main raw material – wood. Deforestation and the lack of reliable sources, as one concern, and transport issues as another, contribute to the rising research into new materials that can be used to partly replace wood as the main source of cellulose fibres needed for paper production. The latest research indicates that cereal straw has great potential as an additional source of cellulose fibres, due to its renewable nature and low cost. Paper substrates with added cereal straw pulp are mainly used for the secondary packaging purposes, and therefore they must show high mechanical resistance. Secondary packaging, almost always, contains printed information about the product that is exposed to various external conditions, and it is important that the print remains unchanged during transport and handling of the packaging. This research focuses on comparison of the mechanical resistance (or rub stability) of prints on papers to which straw pulp of three cereals abundant in Croatia have been added: wheat, barley, and triticale. Prints were made using UV curable inks and four different printing techniques (offset, gravure, flexographic, and digital printing). Mechanical resistance was determined by conducting the rub resistance tests and calculating the Euclidean colour difference based on measured colorimetric values of the prints before and after the tests. A comparison of the results was made to establish the best suited combination of printing technique and paper substrate containing cereal straw pulp that ensures the highest mechanical resistance of the print.

Acknowledgement This work has been supported in part by the Croatian Science Foundation under the project *Printability, quality and utilization of substrates with non-wood fibres* (UIP-2017-05-2573).

Assessment of toxic metal(loid)s content and ^{137}Cs activity concentration in *Boletus* mushrooms obtained from Croatia and Eastern European countries

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Boletus is genus of wild growing mushrooms and preferred delicacy in Croatia and in the world. They concentrate contaminants of anthropogenic and geogenic origin from the soil more efficiently than plants and are thus often used as bioindicators of environmental pollution by As, Cd, Hg, Pb and radionuclide ^{137}Cs. The aim of this study was to determine the toxic metal(loid)s content and ^{137}Cs activity concentration in *Boletus* mushrooms from Croatia (*N*=84, except for ^{137}Cs *N*=8) and those imported to the EU from Eastern European countries (*N*=128). Before stabile metal(loid) analysis by inductively coupled plasma – mass spectrometry (ICP-MS), mushrooms were lyophilized and digested in microwave digestion system. High-resolution gamma-spectrometry was used to determine the activity concentrations of ^{137}Cs. Our results showed significantly lower levels of As, Hg and Pb, but higher Cd level and ^{137}Cs activity concentration in *Boletus* mushrooms from Croatia *vs.* Eastern European countries. Only three samples from Eastern Europe had Cd (34%, range 15-63%) above maximum levels set by European Commission for wild fungi (5 mg/kg dry mass), while eleven samples (31% higher, range 5-63%) from Croatia crossed this legal level, all collected in Northern Croatia. ^{137}Cs activity concentration in all mushrooms were below the maximum permitted levels of radioactive contamination in food products intended for import in the EU.

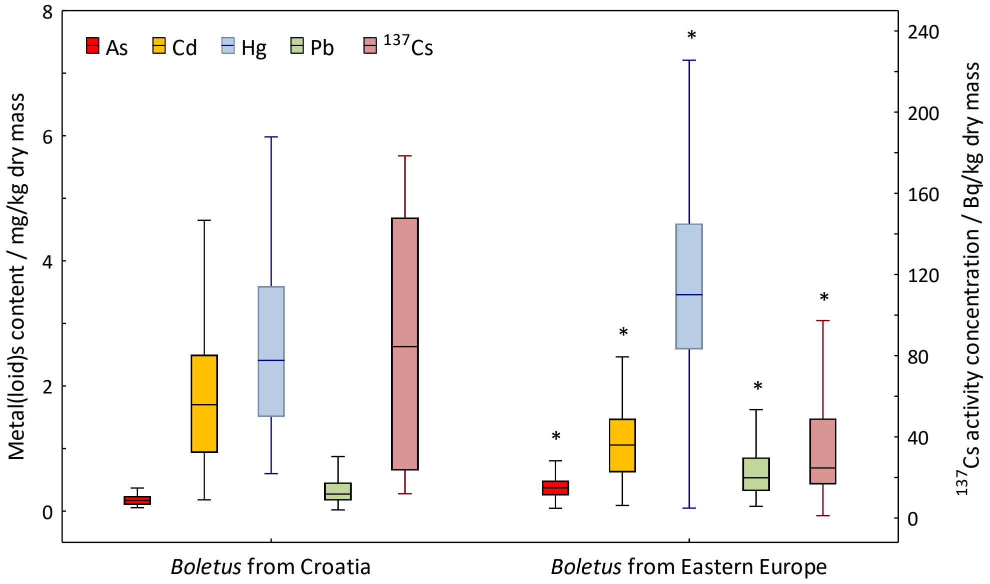

Fig. 1: Toxic metal(loid)s content (mg/kg dry mass) and ^{137}Cs activity concentration (Bq/kg dry mass) in mushrooms of genus *Boletus* from Croatia (*N*=84, except for ^{137}Cs *N*=8) and Eastern Europe (*N*=128). Statistically significant differences in levels of respective metal(loid) between Croatia and Eastern Europe were tested by Mann–Whitney *U* test (at $p<0.05$) and indicated with asterisk. Data are presented by Box-and-Whisker plots where boundaries of box-plots indicate the 25th and 75th percentiles; line inside the box indicate median and whiskers indicate non-outlier range.

Potential of environmental bacterial culture for the biodegradation of xenobiotics

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In recent years, there has been a growing awareness of the negative impact of medicines on the environment. Pharmaceutical products enter the environment at all stages of production, for example through the waste streams of the pharmaceutical industry and as household waste. The biggest problem is the release of antibiotics into the environment, because pathogenic organisms develop resistance to these drugs, so it is difficult to treat them. Such compounds contribute to atmospheric, hydrosphere and lithosphere pollution and undergo various transformations, often producing even more toxic compounds that can negatively affect flora, fauna and humans. Biodegradation is one of the effective degradation processes that uses biological activity to solve such problems and is carried out with the help of indigenous and exogenous microorganisms. The basis of this process is that some microorganisms have the ability to use organic pollutants as a source of nutrients for their growth and development in order to detoxify, mineralize or transform such compounds.

In this work, the removal of the pharmaceutical antibiotic amoxicillin by the process of biodegradation was carried out using bacterium *Pseudomonas aeruginosa* under batch conditions for 12 days. The experiment was conducted in two parallel reactors with initial amoxicillin concentrations of 278 mg/L (Pa-1) and 658 mg/L (Pa-2). During the experiment, the change in amoxicillin concentration was monitored. The results show a process efficiency of 49.6 and 36.2% for Pa-1 and Pa-2, respectively.

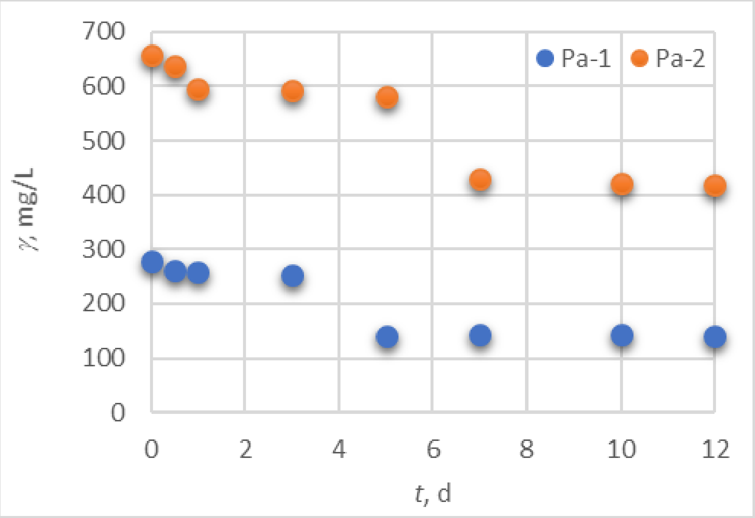

Fig. 1: Change in amoxicillin concentration during biodegradation.

Using nZVI particles and hydrogel incorporated nZVI for amoxicillin removal

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Antibiotics have become a great environmental issue of modern world. Their concentrations are gradually rising in wastewater and ground water where they are imposing a risk for aquatic and terrestrial organisms. Various methods for pharmaceutical wastewater treatment including adsorption, filtration and advanced oxidation processes (AOP) have already been implemented by industries while researchers are working on the improvement of efficiency of those methods. Nano zero-valent iron (nZVI) particles can be used for the removal of amoxicillin (AMX) from water using one of the AOP methods – heterogeneous Fenton-like reaction. [1]

In this work, we conducted two sets of experiments for removal of AMX. First experiments of AMX removal were carried out using bare commercial nZVI particles with different mass concentration (7.5, 12.5 and 25 mg). In the second set of removal experiments two different types of synthetized hydrogels were used. Both of them are copolymers of cellulose and poly(2-(dimethylamino)ethyl methacrylate), molar ratio of 1:3, and contain silica nanofiller. At the same time, they differ because hydrogel 1-3 KSP was not irradiated and 1-3 KSZ was irradiated with gamma radiation of 100 kGy. Finally, those hydrogels were submerged in water dispersions of commercial nZVI particles of different mass concentrations (75, 125 and 250 mg/L).

AMX concentration was determined with UV-visible spectrophotometry and removal efficiency was calculated afterwards. The removal efficiency of AMX by bare nZVI increased with mass load and reached a maximum around 40%. Irradiated hydrogel composites with nZVI particles displayed decreasing removal efficiency with increasing mass load of nZVI particles. Among non-irradiated hydrogels, 1-3 KSP hydrogel with the highest mass load of nZVI showed the highest removal efficiency (around 38%).

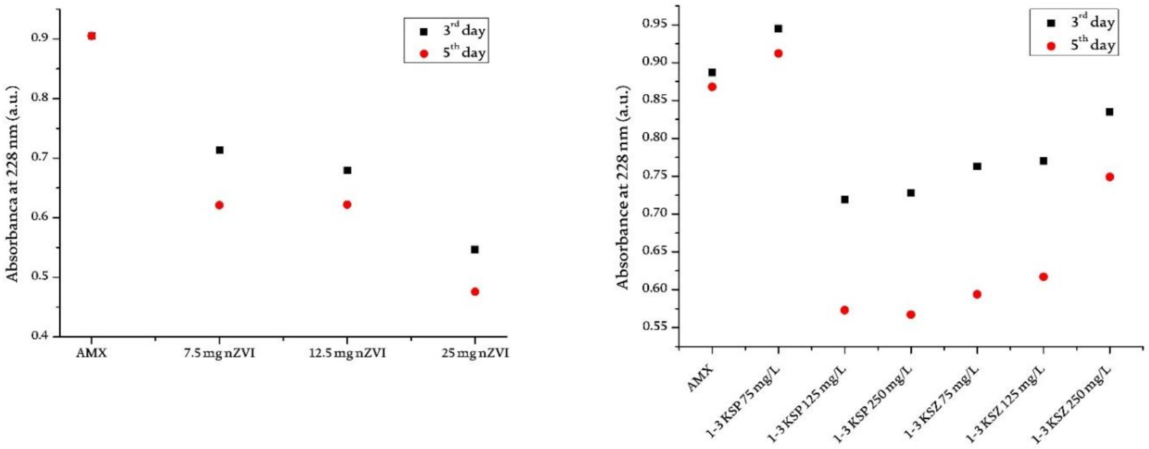

Fig. 1: Absorbance of AMX water samples after 3 and 5 days;
nZVI particles (left); hydrogel incorporated nZVI (right)

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Prediction of environmental microbial biotransformation of azithromycin, its thiosemicarbazone conjugates and their precursors

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Antibiotics and their derivatives are often contaminants of soils and waters, and once released into the environment, they are further degraded by soil and/or aquatic microbes, thus contributing to antimicrobial resistance (AMR). To date, most studies have focused on the parent molecule and paid little attention to the metabolites they produce, the characterization of which is critical as they may also contribute to AMR. [1] In this work, the biotransformation products of azithromycin (AZI) and its thiosemicarbazone conjugates (macrozones) MZ–9a, MZ–4'', and MZ–3 were evaluated using BioTransformer, a web tool for predicting metabolite and degradation products by environmental microbes (www.biotransformer.ca). [2] The results of this study showed that regardless of the position of the thiosemicarbazone moiety (either at 9a, 4'', or 3) in the azithromycin molecule, the predicted sites for biotransformations were at C1, C3, C5, C11, and C13 in the macrolide ring, C2', C3'', and C4'' in sugars, while in the thiosemicarbazone moiety, the amide and C=S functional groups are to be biotransformed. The reactions include oxidation of the secondary alcohol groups at C2', C4'', and C11, hydrolysis of the lactone ring, glycosidic bond at C3 and C5 and amide, and sulfoxidation of S atom in macrozones. The predicted metabolites were evaluated using SwissADME, a free web tool for assessing the pharmacokinetics and drug-likeness of small molecules (www.swissadme.ch). [3] According to the bioavailability radars obtained, that enable a first glance at the drug-likeness of a molecule, those metabolites still consist of a macrolide ring, *i.e.*, the synthetic macrozone precursors 9a-, 4''- or 3-aminopropyl azithromycin, and their 9a–, 4''- or 3-*O*-dealkylated metabolites exhibited the best bioavailability properties.

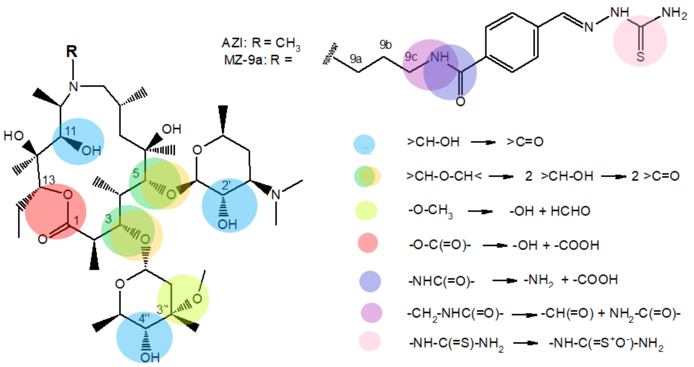

Fig. 1: Predicted sites of environmental microbial biotransformation of azithromycin and its derivative MZ-9a.

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Phthalate esters in polyethylene terephthalate (PET) bottled water stored under common conditions

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Due to the increasing popularity of drinking water stored in polyethylene terephthalate (PET) bottles, the potential health effects of the possible migration of chemical compounds from packaging into the water has become an important issue. Although *ortho*-phthalate esters as plasticizers are generally not used in the manufacturing of PET, several reports suggest that they still may be found in PET bottles and/or in the bottle content. Public health concerns related to the potential leaching of phthalate esters from PET bottles into the water have been raised due to their potential endocrine-disrupting effects.

This study aimed to determine the concentrations of seven phthalate esters (dimethyl phthalate – DMP, diethyl phthalate – DEP), dibutyl phthalate – DBP, di-*iso*-butyl phthalate – DiBP, benzyl butyl phthalate – BBP, *bis*(2-ethylhexyl) phthalate – DEHP and di-*n*-octyl phthalate – DOP) in commercially available carbonated (*Jamnica*) and non-carbonated (*Jana*) natural mineral water. The influence of storage time (0, 7, 30, 90 and 180 days) on the leaching of phthalates from plastic to water was investigated in several types of PET packaging (virgin PET of higher and lower density, 100%-recycled PET) stored at room temperature, representing common storage conditions for consumers.

Phthalates were extracted from water with dichloromethane and analysed using gas chromatography-mass spectrometry. In all of the analysed samples, the concentration of DMP, BBP and DOP was below the limit of detection. After 180 days, somewhat higher concentrations of DEP, DBP and DEHP were measured in non-carbonated water compared to carbonated water. However, phthalate compounds were present in low concentrations (<2.52 µg/L) in all of the analysed samples, even after several month of storage. The measured concentrations of DEHP met the recommendations of the World Health Organization [1] for drinking water (<8 µg/L), but for the other analysed phthalates there are no comparable health guidelines.

Acknowledgement This work was financially supported by the grant *Development of functional beverage in sustainable packaging* – JamINNO+ (KK.01.2.1.02.0305) funded by the European Regional Development Fund within the Operational programme Competitiveness and Cohesion 2014-2020.

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Competitive sorption of imatinib and torasemide on the TiO_2 photocatalyst

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Pollution of the environment by various pollutants from different sources is not an unknown problem. The development of analytical techniques has made it possible to detect and identify various types of micropollutants, which accordingly raises awareness of the need to protect limited water resources. One of the threats to the water and solids environment is pharmaceuticals, whose exposure in the environment can lead to the formation of new unknown degradation products, possibly more toxic than the parent compound. Such small organic molecules are not successfully eliminated by conventional treatments, so one of the many ideas is to implement advanced oxidation processes into classical methods of water treatment. Photocatalysis, as a non-selective degradation process, efficiently removes various types of pollutants from water by the generation of reactive oxidative species. In order to perform photocatalysis, the analyte must have the tendency to sorb on the surface of the photocatalyst.

Therefore, in this study, the sorption affinity of two pharmaceuticals, the cytostatic imatinib and the loop diuretic torasemide, was investigated. The competition of the analytes for active sites on the immobilized TiO_2 photocatalyst was investigated by determining the sorption kinetics, the influence of pH, ionic strength, temperature, and sorbent dosage. The sorption affinity of each pharmaceutical was described by linear, Freundlich, Langmuir, and Dubinin-Radushkevich isotherms. The maximum concentration of the substance sorbed to TiO_2 was determined. If the substance has a good affinity for the sorbent/photocatalyst, the combination of two removal processes such as sorption and photocatalysis can only be beneficial for the removal of pollutants from water, especially since the sorption mechanism does not involve the formation of by-products.

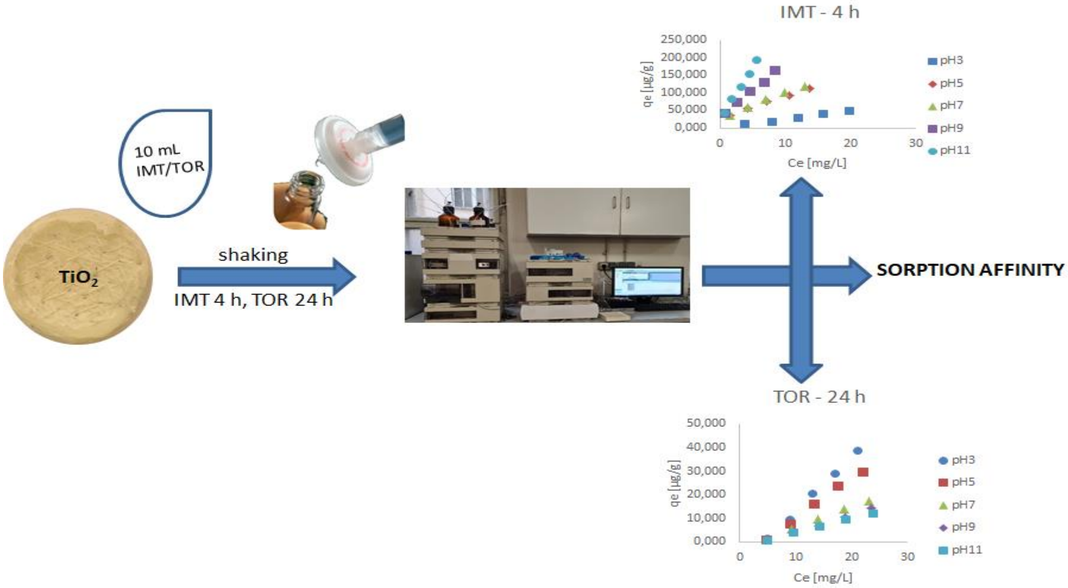

Fig. 1: Description of sorption experiments.

Big data analytics to understand and estimate the risks in drinking water distribution networks

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Water suppliers manage water supply systems and deliver safe water for human consumption to end users. To ensure user satisfaction and preserve public health, water quality is monitored in all steps of the water supply chain, with key indicators of water quality being disinfectant residual, bacteria and turbidity. However, suppliers face numerous challenges because water distribution networks are often large and complex, and, in addition, represent a complex and dynamic environment in which various physical, chemical and microbiological processes occur that can affect the deterioration of the quality of water supplied to end users. All those influences are site-specific and prevent a deterministic modelling approach for estimating failures. The aim of this work is to apply data-driven techniques, including analytics, modelling and visualization, to obtain useful and actionable information from large data sets. The focus is to develop a model that would rank the relative risk of failure of monitored parameters at specific District Management Areas (DMAs), to be able to focus on those DMAs with the highest risk of non-compliance. The mining of the Ponikve data set from 2014-2021 included 11.350 samples with 157.209 observations/analyses of different water quality parameters.

Acknowledgement This work was done within the framework of the IRI 2 *WaterQ – digital transformation of water quality monitoring project*, which was co-financed from the European Fund for Regional Development, approved as part of the Operational Program Competitiveness and Cohesion 2014-2020. (KK.01.2.1.02.0229).

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Robinia pseudoacacia L. – invasive alien species as a source of phytopharmaceuticals

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The phytochemical fingerprint proved to be very important in the invasion ability of alien plants and, therefore, a leading cause of their environmentally harmful effects. [1] On the other side, this phytochemical richness represents a vast, still underutilised potential for isolating active ingredients and their use as phytopharmaceuticals. [2,3] This study provides the first LC-MS phytochemical screening of the black locust (*Robinia pseudoacacia* L.), alien invasive plant species in the Istria region (Croatia). The performed analysis aimed to identify and quantify the phenolic content in leaf and flower extracts and to assess their antioxidant potential as a basis for their potential use as phytopharmaceuticals. Spectrophotometrically determined total phenolic (TP), non-flavonoid (TNF) and flavonoid (TF) content and antioxidant capacity (AC) were higher in leaf than in flower extracts. Higher values of TP and TNF were displayed in 70% ethanolic than in 80% methanolic extracts. In all extracts, a strong correlation between TP, TF and TNF content and AC values determined by ABTS, DPPH and FRAP assays was observed. A total of 60 bioactive compounds were recorded by LC-MS in leaf and 55 in flower extracts. The most commonly detected compounds were catechin, procyanidin, luteolin, apigenin, quercetin, kaempferol, isorhamnetin, vescalagin, and hydroxybenzoic acid, with catechin as dominant (5.907 mg/g DW) in leaf and vescalagin (5.863 mg/g DW) in flower extracts. These compounds have been found to have antioxidant and antimicrobial properties and have been studied for their potential to treat oxidative stress-caused diseases such as cancer and cardiovascular and neurodegenerative diseases. [4,5] The results provided new information on the phytochemical properties of the invasive *R. pseudoacacia* and its potential use as an antioxidant in phytopharmacy.

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The impact of anthropogenic and natural sources on particle-bound metals at the middle Adriatic

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Airborne particulate matter (PM) is a complex mixture of solid or liquid particles dispersed and transported in atmosphere. The current interest in PM is mainly due to its adverse effect on human health, influence on the environment and its potential role in climate change. PM originates from a variety of natural or anthropogenic sources which affects its composition and chemical properties. Within the project "Biochemical responses of oligotrophic Adriatic surface ecosystems to atmospheric deposition inputs" (BiREADI IP-2018-01-3105), funded by the Croatian Science Foundation, influence of metals originating from the atmosphere and their impact on sea surface ecosystems was investigated. This paper presents the results of analyses of metals in PM_{10} particle fraction collected during six-months field campaign, from February to July 2019. Samples were collected continuously at a background coastal station of the Division for Marine and Environmental Research, Ruđer Bošković Institute, in the vicinity of the city of Šibenik. PM_{10} particles were microwave digested with nitric acid and 22 metals were analysed by inductively coupled plasma mass spectrometry (ICPMS). Obtained results were characteristic for sea aerosol but also showed the influence of anthropogenic sources as well as significant input of metals through dust intrusion episode from Sahara and through several open wild fires recorded near the sampling area.

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Studying science through its history – the tale of the Chemical Revolution

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The basic property of science, the one which defines it as science, is the *Scientific method* – the systematic sequence of observation, experiment and logical reasoning which leads from a primary hypothesis to its rejection or (temporary) confirmation. One of the ways the Scientific method can be observed 'in action' is through the history of science, by observing how hypotheses and theories were proposed, adopted, and finally rejected through new discoveries, in various branches of science.

While one might expect the scientific method should always induce a smooth transition from one hypothesis to another, leading to an even and continuous development of science, the true dynamics of exchanging one theory with another is often much more dramatic. Because of this, science does not develop only by slow and calm *evolution*, but also through occasional scientific *revolutions*, when scientific paradigms experience sudden changes.

One of the most famous and most dramatic scientific revolutions occurred in chemistry in the late 18th century when phlogiston theory was abandoned. The phlogiston theory, which explained combustion as release of *phlogiston*, a hypothetical substance supposedly contained in all inflammable bodies was the first scientific theory in chemistry. It dominated development of chemistry since it was first introduced by G. E. Stahl in the late 17th century, until the late 18th century when it was (for the most part) disproven by A. L. Lavoisier, who started questioning its validity in 1770-ies, leading to its (almost complete) abandonment by the mid 1790-ies. Over this quarter of a century, not only the accepted explanations of chemical processes, but the very approach to chemical research experienced drastic changes. Therefore, a detailed look at the discoveries, controversies and misconceptions which have marked this, possibly most dynamic but certainly most dramatic era in the history of chemistry, may help us to see not only how chemistry adopted its current form, but also give us more fundamental insight into the nature of chemistry, as well as science in general.

The history of chemistry teaching in Croatia

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The historical periods of the development of chemistry are inseparable from the history of chemistry teaching. The production processes of some useful items (ceramics, copper...) in ancient times were based only on experience. The masters of these crafts knew the answer to the question '*how*', and science begins with the answer to the question '*why*'. Chemistry teaching as part of science education, and then as a separate subject throughout history, unites both issues in curriculum development. *Why is it important to build chemical knowledge by following the historical development of chemistry?* Students' misunderstandings often arise due to common sense thinking about abstract concepts. A good tool in the construction of scientifically based chemical knowledge can be teaching that includes the historical development of the term. The field of science education, and therefore chemistry, has changed dramatically in the last hundred years. Through wars and geopolitical events, reforms, epistemological, theoretical and methodological revolutions, science education looks significantly different today than it used to. These changes are not limited to the ways in which teaching is done – they also affect the ways in which the future of chemistry education is thought about and talked about. At the same time, certain teaching methods and chemistry content are being 'rediscovered' and re-emphasized by chemistry education 'reformers' through national educational strategies and subject curricula. Sometimes these are significant steps forward, sometimes a few steps back in the development of educational strategies and final outcomes of chemistry teaching. Therefore, the results of educational research throughout history can be of great help in improving chemical education by answering the questions: *What are the key topics of interest throughout the history of chemical education?, How long do educators think, work and discuss topics that are still of interest today?, Have certain topics developed, changed, or experienced renewed interest throughout the history of chemistry development and its teaching, and why?* [1,2]

The aim of this lecture will be to make an overview of chemistry teaching in Croatia through the historical development of chemistry and respecting the development of pedagogical and didactic principles throughout the periods (including J. A. Komenski, 1592-1670). The emphasis will be on the way and sequence of interpretation of terms in textbooks, a review of significant scientists and chemistry teachers that influenced the education of chemistry teachers in our country from the middle of the 19th century until today. Instead of a conclusion: well-educated and versatile chemistry teachers were and will be a 'cornerstone' in the development of chemistry. [3,4]

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Stereochemistry: Configuration and chemistry teaching

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Organic chemistry is the chemistry of carbon compounds in which the carbon atom is tetravalent. Today, a large number of organic compounds are known, and the new ones are constantly being prepared. In the process of synthesis of new compounds there is a possibility of: a) interconnection of different numbers of carbon atoms into chains, straight or branched, or rings and b) formation of single, double and triple carbon-carbon bonds. Based on the above-mentioned possibilities, some of the organic compounds, known as isomers, will be formed. Those compounds have the same molecular formula, but different physical and chemical properties. Isomers are divided into two groups, constitutional isomers and stereoisomers. If the connectivity of the atoms in the two isomers is different, they are constitutional isomers. In the case of stereoisomers, the connectivity of the atoms is the same, the arrangement of atoms in 3D space is different. Stereoisomers are the subject of stereochemistry, the part of chemistry that studies the three-dimensional shape of the molecules. [1-3]

In this lecture, stereoisomers and their configuration will be discussed using selected examples, with an emphasis on the configuration around the carbon-carbon double bond and the chiral carbon atom. These two most common stereogenic units and corresponding configurational descriptors (*cis*/*trans*, *E*/*Z*, *R*/*S*, D/L) are included in the national curriculum in chemistry and are an integral part of high school chemistry teaching.

The aim of this lecture is to improve the competence of primary and secondary school teachers in the field of stereochemistry of organic compounds.

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Teaching Chemistry then and now

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There is a big difference between schools today and in the period when our grandfathers, grandmothers and parents attended them. The first and biggest difference is that in the period of our grandparents, and even in the period of our parents, much fewer children were educated than today. Today, every child has the obligation to go to school and get an education, while this was not the case before. There were schools for boys and schools for girls. Two students were sitting in the wooden benches. Instead of notebooks, they used tiles on which they wrote with a pointed stone or pencil, which leave a white mark like a blackboard. The rules of behavior in former schools were much more rigorous than today. We can boast of progress in this regard as well, because today the rights of students are much more respected than in the past. The teacher was the "commander-in-chief", a concept of the society at that time, and he/she had a certain kind of power over the students. In the 80s of the last century, chemistry textbooks were rather monotonous, black-and-white printing prevailed with some color photographs, and frontal teaching was dominant. The teacher was dominant in the class and the practical works were mainly performed as demonstrations. Teaching aids were the following: slide projector, overhead projector, cinema projector, typewriter and indigo paper, VHS tapes. We are witnessing that the 21st century is a century of progress, both in terms of technology, medicine, society, and education. After all the mentioned similarities and differences, we can conclude that society has progressed in terms of education. Today we have the opportunity to be educated according to the highest standards and qualities, therefore we should and must appreciate everything that has been achieved so that school is truly the most beautiful period of our lives!

The goal of our presentation is to show in more detail the differences in chemistry lessons then and now, the differences in writing preparation for class, the differences in content and outcomes that were taught in the past and are taught today, and the differences in the use of teaching aids. Our work also shows the workshop we did with our students in which we offered them different teaching aids and showed them what a chemistry class looked like twenty years ago.

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Experiment – forever and ever!

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Chemistry is a natural science that we learn through observation, reasoning, and daily use in our life. Based on observing the original reality and performing practical work, it is easier to form conclusions and solve problems. We wanted to emphasize that the experiment has always been and will always be the focus and one of the main components in teaching chemistry. The methods of presenting the experiment, the measures of implementation, the equipment were improved, the types of chemicals changed, the teacher/student as demonstrators, *etc*. "Old school" lecture classes where the teacher is at the center of the work, where the teacher demonstrates experiments and the students observe. Students were mostly passive observers and very often studied without understanding the content of chemistry. Today, some chemical reaction can be viewed in a simulation on a device, but regardless, the best way remains when the students do the experiment themselves and experience the chemical reaction (guided by the teacher's instructions). One of the methods that encourages such a way of working is the Flipped Classroom method and the introduction of ICT as a work aid. Students perform simple experiments at home, make movies and place them on the chosen platforms (Yammer, Webnode…). In such a way, we give students other opportunities, and we direct them even more to the creative creation of their own educational content that they will present to other students and will teach them through the presentation. In this way, the student is the creator of educational contents, presents them to the students and thus teaches them, and ultimately themselves. Students can choose whether to create content in digital form using their mobile devices, the Internet, and computers, and thus use them meaningfully, creatively, and innovatively. The role of the teacher changes to that of a leader and mentor who encourages students to study independently. With the help of ICT and digital tools (through Office 365), work control and mentoring are achieved, to provide students with adequate support during work. (Office 365, Forms, Webnode, Snatchbot, Wordwall, Yammer, various ready-made chemistry applications) Suggested topics in chemistry: Solutions, Determination of the acidity of solutions with red cabbage indicator, Changes in aggregation states of substances (evaporation, condensation, melting).

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Teacher's perception of support in stressful situations

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Being a teacher is extremely responsible and emotionally challenging vocation. Frequent experiences of teachers' negative emotions in relation to students, parents, colleagues or educational system in general as well as feelings of emotional exhaustion (as an important aspect of burnout), can have a negative impact on teachers' psychological well-being and increase the occurrence of psychopathological symptoms, [1] and indirectly on student achievements. [2]

In this empiric research, the role of various origins of stress among teachers was examined, and whether they have support in overcoming the consequences of stress. Also, what kind of support is available for maintaining good mental health. The perception of the teachers regarding the syndrome of burnout at work was examined, and whether they experience support by the educational system that would help them to overcome stress and maintain mental health. The answers received in the survey questionnaire were analyzed according to age, years of service, and gender. The research was conducted on the sample of 92 primary school teachers of mathematics in the City of Zagreb and the Zagreb County, in December 2022.

In this presentation, we will present the conclusions of the research and compare them with research in Croatia and the world. According to the teachers, among the biggest stress origins are the pressure by the parents, classes with too many students, responsibility for the students and their success, and difficulties in maintaining discipline, very similar to the research conducted in 2012 among the chemistry and biology teachers [3] and research results in the world. [4] The teachers also say that they are left on their own and that they very rarely get help when mental health is concerned. Almost 60% of the teachers experienced the syndrome of burnout, and every second teacher, regardless of age, intends to give up work in school.

The research points to the need for an organized support system in the field of mental health among the teachers of STEM subjects, primarily by building up emotional resistance in stressful situations, and by support in overcoming the consequences of stress and burnout at work.

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From raw materials to useful products

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Living in harmony with nature requires our daily engagement in all areas of activity. Piles of discarded wool can often be seen in nature. This way of managing wool creates an exceptional environmental problem (inadequately wool disposal).

The students have researched, based on the chemical composition of wool, how to solve the possibilities of its application in the economy, but also to use the acquired knowledge to create some environmentally useful products. We tried to teach the students the methods of organic farming and make cosmetics based on natural, environmentally acceptable substances, developing social skills and working habits, increase interest in taking care of their own health and hygiene. The students were presented with an eco-story as a starting point for creating a problem situation. Students perform experiments to prove elements X, Y, Z in the composition of natural sheep's wool. Through the aforementioned activities, students have concluded which elements are important in plant nutrition and came to conclusion on the research question of how to use natural wool in agriculture. Those students who failed in solving the problem task were presented a text taken from the scientific work "Possibility of using sheep's wool in agriculture". In further research work, students were encouraged to apply the acquired knowledge in making soap from environmentally friendly raw materials. They used olive oil, coconut butter, various essential oils such as lavender, rosemary, sweet orange *etc*. Then they covered the soaps with natural wool using the felting technique. This technique is based on the ability of fibers to intertwine into a solid structure as a result of mechanical and thermal action, and with the help of soap. Soaps prepared like this are used as peeling to remove dead cells.

With these methods, students are focused on promoting knowledge and skills that can strengthen and improve a healthy lifestyle. Through these activities, we have fulfilled the set goal – to educate students for sustainable development and an appropriate relationship with nature. In addition to developing awareness of proper hygiene and health care, with this way of working, we managed to influence students' environmental awareness and revive the idea of sustainable development as a modern framework for the development of economic and social progress without endangering the environment.

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Chemistry workshops as part of the Synecological STEM EDUCATION project in Klinča

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The Synecological STEM EDUCATION project in Klinča was designed for popularization of science among preschool children, and elementary and high school students from Zagrebačka County and the rest of Croatia. Children and young people sample and analyze samples from the biodiversity garden of Amruševo, monitor data at the meteorological station, and perform experiments in the STEM laboratory. [1] The Eduka organization implements the project in cooperation with scientists from partner organizations (PMF and IRB), experts in the fields of agronomy, meteorology, ecology, mechanical engineering, and informatics. The project is implemented also with the support of educated volunteers.

The important part of the project is chemistry workshops. These workshops are designed to promote interest in science and chemistry among children and young people, appropriate to their age and prior knowledge. [2-4] Preschool children, elementary and high school students learn about laboratory equipment, experimental techniques and safety rules and conduct experiments in the chemical laboratory under the supervision and with help of scientists, volunteers, and coordinators. By performing chemical experiments, preschool children and elementary and high school students learn how to plan an experiment, observe changes, and draw conclusions. They also learn about acidity and alkalinity, gas solubility in water, chemical equilibrium, reaction rate, precipitation, colloidal particles, intermolecular interactions, *etc*. Chemical experiments will be optimized and improved, and new experiments and interactive materials will be introduced (3D models, panel boards) based on the impressions and reactions of preschool and school children participating in the workshops.

Preschool children learn through play; children's curiosity and creativity are stimulated. They are encouraged to observe, discover and explore nature. [5] Elementary and high school students adopt experimental techniques and critical stem thinking by performing experiments. [5]

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Multidisciplinary synthesis of small researchers

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Association EDUKA is implementing the European Social Fund project (Synecological STEM Education in Klinča, UP.04.2.1.10.0061, in the amount of 2.341.515,84 HRK, 29.06.2021. – 29.06.2023.). The project is designed to increase interest in natural sciences and stimulate the interest of children, young people and the general population about the possibilities and application of STEM knowledge in education, everyday life and work. The emphasis is on synecology, a branch of ecology science in which knowledge in chemistry, physics, mathematics and other natural sciences is used. A multidisciplinary team (18 members) of professors and scientists from the University of Zagreb (UniZG) – Faculty of Science, Ruđer Bošković Institute, Croatian Meteorological and Hydrological Service, and UniZG – Faculty of Agriculture educated twenty-three volunteers [nine teachers, professors from primary, secondary schools and extended stay; twelve students (UniZG – Faculty of Chemical Engineering and Technology, Faculty of Science, Faculty of Agriculture, Faculty of Architecture, Faculty of Food Technology and Biotechnology, and Zagreb University of Applied Sciences)] to go through interactive workshops in order to increase the interest of students and preschoolers for experimentation. The workshops are intended for those who want to know more than the school curricula offer and are conducted in the newly equipped laboratory, biodiversity garden Amruševo and 2000 Natura areas: Crna Mlaka, Klinča Sela, Public Institution Nature Park Žumberak – Samoborsko gorje, and Pokupski bazen. Education includes six programs that are adapted for implementation with individual ages (Ref. 1): 1. Water from all scientific angles; 2. The role of ecosystems for individual segments of life; 3. Environment – water, soil and air; 4. WASH program; 5. GLOBE program; 6. Work programme with the gifted. Most of the workshops are multidisciplinary, for example the assignment of plant pigments of a sample of herbaceous leaves from our Amruševo biodiversity garden. Workshop participants are introduced to the basics of chromatography, intermolecular interactions, spectroscopy, cellular structure and the role of plant pigments in the process of photosynthesis. The main idea of the project is the emphasis on applying the acquired knowledge to practice the so-called "hands on" and encouraging research and understanding the importance of natural sciences and their application.

Fig. 1: Small researchers in action as well as professors at workshops (private archive of EDUKA)

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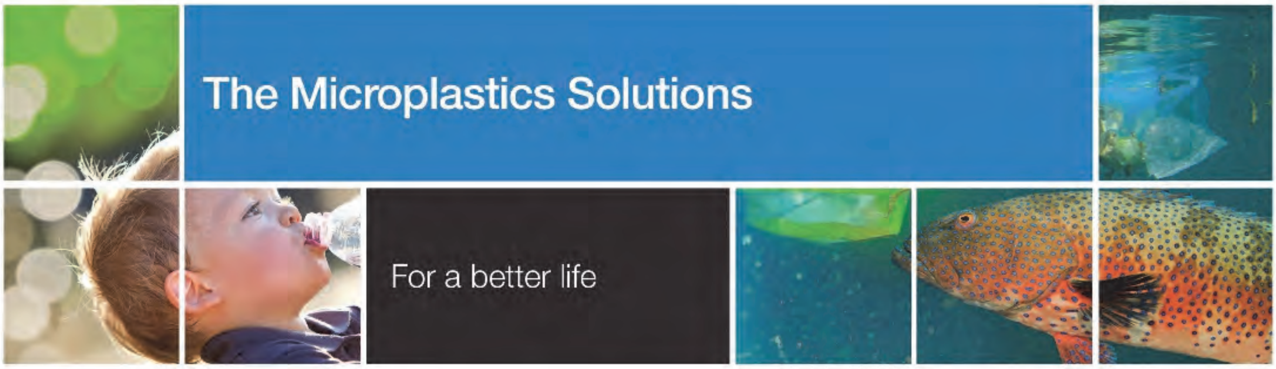
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