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Ш.Н. Кубекова*

Под редакцией профессора Сабу Томас

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В сборник включены материалы Международной конференции по полимерам, композитам, наноккомпозитам и биоккомпозитам-2026 (ICPCNB-2026). Работы, представленные на ICPCNB-2026, отражают широкий спектр исследований — от фундаментальных аспектов синтеза и структуры до практических направлений, связанных с созданием энергоэффективных, биомедицинских и экологичных материалов. Сборник представляет интерес для научных и инженерно-технических работников, преподавателей, докторантов, магистрантов и студентов, занимающихся вопросами разработки, исследования и внедрения современных полимерных и композитных материалов. Представленные материалы могут служить ценным источником информации для дальнейших исследований и разработки инновационных решений, объединяющих научные достижения, технологический прогресс и задачи устойчивого развития.

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*Sabu Thomas, Kabdrakhmanova S.K., A.Z. Dzhumanazarova,
SH.N. Kubekova*

The present volume includes the materials of the International Conference on Polymers, Composites, Nanocomposites, and Biocomposites-2026 (ICPCNB-2026). The papers presented at ICPCNB-2026 cover a broad spectrum of research topics — from fundamental studies of synthesis and structure to practical aspects related to the development of energy-efficient, biomedical, and environmentally friendly materials.

This collection is intended for researchers, engineers, university faculty members, doctoral and master's students engaged in the development, investigation, and implementation of advanced polymeric and composite materials. The presented works serve as a valuable source of information for further research and the development of innovative solutions that integrate scientific achievements, technological progress, and the goals of sustainable development.

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Interfacial Modification in Polymer Nanocomposites to Tailor Functionalities

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Abstract

The talk will concentrate on various approaches being used to engineer materials at the nanoscale for various applications in future technologies. In particular, the case of clay, carbon nanostructures (e.g. nanotubes, graphene), metal oxides, bionanomaterials (cellulose, starch and chitin) will be used to highlight the challenges and progress. Several polymer systems will be considered such as rubbers, thermoplastics, thermosets and their blends for the fabrication of functional polymer nanocomposites. The interfacial activity of nanomaterials in compatibilising binary polymer blends will also be discussed. Various self-assembled architectures of hybrid nanostructures can be made using relatively simple processes. Some of these structures offer excellent opportunities to probe novel nanoscale behavior and can impart unusual macroscopic end properties. I will talk about various applications of these materials, taking into account their multifunctional properties. Some of the promising applications of clay, metal oxides, nano cellulose, chitin, carbon nanomaterials and their hybrids will be reviewed. Finally, the effect of dewetting up on solvent rinsing on nanoscale thin films will also be discussed.

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Brackish water treatment using nanofiltration powered by photovoltaics

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Abstract

Nanofiltration is a polymeric membrane process with a pore size in the order of 1 nm, between ultrafiltration and reverse osmosis. Commercially available membranes achieve varying degrees of selectivity between mono- and multivalent ion rejection. The driving force is transmembrane pressure that is achieved by an electrical pump. In remote areas, this electrical power can be provided by photovoltaics, thus enabling autonomous operation. This enables the implementation of advanced and decentralized technologies [1].

Such a renewable-energy powered membrane filtration system has been used extensively in Central Australia (removal of uranium from brackish water) [2-4] and Tanzania (removal of fluoride from ground and surface waters) [5-8]. The direct coupling of photovoltaics and membrane filtration avoids the losses and operational risks of batteries, while changes in irradiance through the position of the sun and the obscuration of clouds result in immediate reduction or interruption of power. This may result in a reduced transmembrane pressure or pump shutdown. As a result, osmotic backwash may occur, while shutdown events interrupt the production of drinking water [9, 10].

This plenary talk will present the highlights and lessons learnt of a 25-year research project with a focus on the removal of fluoride in the Tanzanian Rift Valley. The technical performance, as well as challenges that remain to be solved prior to broad implementation, will be highlighted. Collaboration with the region is invited, while the vision of the project is ‘I have a dream: safe water for all children’.

Keywords: membrane; nanofiltration; desalination; solar energy; water quality; drinking water supply

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Thermomechanical Devulcanization and Revulcanization of Waste Natural Rubber Latex Balloons: Structure–Property Relationships.

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Abstract

Waste natural rubber (NR) latex balloons represent a rapidly growing single-use waste stream for which no established recycling route exists. This study presents the thermomechanical devulcanization of sulfur-vulcanised waste NR latex balloons and the subsequent revulcanization of the resulting regenerate, both alone and in blends with virgin NR, to recover a technically useful elastomeric material within a circular-economy framework. Devulcanization was carried out under controlled thermomechanical conditions without adding chemical devulcanizing agents, thereby avoiding nitrosamine-forming accelerators and improving the chemical safety of the recovered material. The extent of network breakdown was quantified through equilibrium swelling and sol-fraction measurements, while the cross-link density of regenerates and revulcanizates was determined by equilibrium swelling and evaluated against the Flory–Rehner relationship. The recovered materials were comprehensively characterized by X-ray diffraction (XRD) and X-ray analysis provided insight into the structural reorganization of the network; dynamic mechanical analysis (DMA) yielded the glass-transition temperature (T_g), storage modulus and loss factor ($\tan \delta$), and differential scanning calorimetry (DSC) together with thermogravimetric analysis (TGA) described the thermal transitions and decomposition behaviour. Tensile properties, rebound resilience, and abrasion resistance were assessed in accordance with the relevant ASTM and ISO standards. The devulcanized regenerate exhibited a markedly reduced cross-link density relative to the parent vulcanizate, confirming effective network cleavage, while revulcanisation restored a cross-linked network whose density, expressed in mol g^{-1} , approached that of the reference NR vulcanizate. Revulcanisates and their blends with virgin NR retained a substantial fraction of the reference material's mechanical performance, indicating that the regenerate can partially replace virgin rubber without a significant loss of key mechanical properties. These results demonstrate that thermomechanical devulcanization is a viable, chemical-agent-free route for valorizing waste NR latex balloons, and they provide a reproducible methodology and a consistent structure–property dataset that support the reincorporation of recycled NR into rubber compounding and, more broadly, the sustainable management of latex-based waste.

Keywords: devulcanization, revulcanization, natural rubber, latex balloons, cross-link density, recycling

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Comparative Assessment of Organic and Mineral Acids for Producing Microcrystalline Cellulose from Agricultural Waste: Efficiency, Structure, and Physicochemical Properties

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Abstract

Agro-industrial waste is an abundant and renewable source of lignocellulosic biomass with large amounts of cellulose, hemicellulose and lignin. In the context of circular economy and sustainable development, the transformation of agricultural residues into value-added cellulosic material has attracted increasing attention. However, the complex lignocellulosic matrix prevents reagent access to cellulose chains and makes cellulose isolating processes difficult. Acid treatment also hydrolyzes amorphous cellulose domains to increase the relative crystalline fraction and give rise to microcrystalline cellulose (MCC).

Mineral acids are widely used because they remove hemicellulosic components and hydrolyze amorphous cellulose. However, strong mineral acids pose many technological and environmental challenges including equipment corrosion, neutralization processes, acid-containing effluents and carbohydrate degradation products. Organic acids are being explored as a potential alternative reagent for the processing of lignocellulosic biomass because they can disrupt the lignocellulosic matrix and may help remove hemicellulose and reduce environmental impact.

In this study, we assessed the effectiveness of citric, succinic, formic, lactic and hydrochloric acids in the production of MCC from agricultural waste. The chemical nature of the hydrolyzing agent had a strong influence on the structure and shape of cellulose samples. Acid treatment reduced the proportion of amorphous components and improved the structure of cellulose compared to the untreated material, but the degree of structural ordering in cellulose was greatly dependent on the acid used.

Fourier transform infrared spectroscopy confirmed the presence of the major functional groups of cellulose. The intensity of selected absorption bands indicates the removal of the non-cellulosic components during processing. Morphological analysis showed the separation of fiber bundles, formation of looser and more heterogeneous surfaces and fragmentation of cellulose-fiber. Overall, the results show that acid selection is an efficient process for controlling the level of hydrolysis and structure of MCC. These results could be helpful in the selection of the right hydrolyzing agent for obtaining MCC for applications..

Keywords: microcrystalline cellulose, acid hydrolysis, organic acids, structure, morphology, cellulose.

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Sustainability crisis and our responsibility as scientific community

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Abstract

The climate and sustainability crisis is humanity's greatest challenge, with increasingly frequent droughts, wildfires, floods, and storms signaling breached planetary boundaries and imminent tipping points. Despite clear evidence from scientific research and everyday experiences, greenhouse gas emissions continue to rise exponentially due to political, societal, and individual barriers. Given its systemic nature, the sustainability crisis cannot be addressed through technological progress alone but requires a complete paradigm shift. As scientists, we bear a special responsibility to lead the communication of the urgent need for action to both the public and decision-makers. This is even more important in light of the rapidly growing influence of fake news amplified by AI and social media. Recently, we founded the International Alliance of Societies for a Sustainable Future (<https://sfs-alliance.org>). Motivated by the fragility of existing political networks, our vision is to leverage the robust and stable international scientific network to alert the global public about the sustainability crisis and recommend measures for socio-ecological transformation. This alliance spans all disciplines across borders and cultures.

Keywords: climate crisis, sustainability, planetary boundaries, misinformation, responsibility of scientific societies

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Microfluidically supported syntheses of hierarchically composed metal and polymer nanoparticles

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Abstract

Micro and nanoparticles of different materials, shapes and sizes can be synthesized advantageously by using microfluidic processes. Fast mixing of reactants and reproducible local transport conditions are important factors for homogeneous initiation of particle formation, and controlled particle growth. The optimization of syntheses and tuning of shapes and sizes of particles profits from automated tuning of flow rates in microfluidic synthesis arrangements. Therefore, microfluidic preparation is used for synthesis of spherical and different types of non-spherical polymer nanoparticles and for synthesis of so-called plasmonic nanoparticles. The reproducibility of dosing and mixing can in particular used for generation of particles of special size and geometry for controlling their optical properties, for addressing different metal compositions, sizes and shapes. Finally, microfluidically synthesized nanoparticles can be integrated into hierarchically constructed microparticles, for example by combination of polymer, gel-like and metal particles into particles with up to five levels of spatial organization. Composed micro and nanoparticles are of interest for catalytic syntheses as well as for sensing purposes. Thus, gel-like microparticles incorporating silver nanoparticles are well suited for particle-based sensing by Surface Enhanced Raman Spectroscopy (SERS).

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Macromolecular Engineering to Tune Polymers for Biomedical Applications

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Abstract

Advances in the field of polymer chemistry have permitted to prepare polymers of controlled topologies, functionalities and microstructures using various strategies to access complex architectures with a variety of functional groups positioned at well-defined localizations on the polymer chain. This ability to control the architecture and microstructure of polymers along with their functionalities are an asset to adjust the properties of polymers and tune their performances according to the targeted application. This presentation will illustrate the ability of macromolecular engineering, especially the topology of polymers, to afford polymers of specific and tunable properties with a focus on biomedical applications through two examples. The first part of the presentation will focus the design of comb polymers with peptide sequences as pendent grafts through the macromonomer approach. It will be illustrated through the use of macromonomers with oligoarginine pendent grafts. This polymer exhibited a thermoresponsive behavior in water with a solubilization of the polymer upon increasing the temperature (upper critical solution temperature behavior). In a second part, the preparation of hybrid materials based on upconversion nanoparticles (UCNPs) and polymers will be discussed emphasizing on how the structure of the polymer covalently attached to UCNPs could be designed to fulfil the requirement of theranostics.

Keywords: polymer synthesis, thermoresponsive polymers, hybrid materials, polymers for biomedical applications

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Reducing the 5 Tons of Plastic Waste the Medical Sector Creates Every Second:

One Patient at a Time

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Abstract

It has been reported that the global medical sector creates 5 tons of plastic waste every second. Plastics are everywhere in medicine from catheters to medical devices to diagnostics kits to in vitro assays. While numerous other industries have embraced using recycled plastics in their products, the global medical device sector has not. There is a fear that one cannot save the environmental and human lives. This talk will cover an over 30 year journey getting the medical device industry to adopt and incorporate recycled materials into their products and reduce the carbon footprint in medical device manufacturing. Nanomaterials have been at the forefront of such efforts due to their enhanced properties (at lower amounts) and ability to reduce harm to the environment. Moreover, this presentation will cover how we have made and commercialized nanomaterials for orthopedic and other implant applications now in over 45,000 patients to date showing no signs of failure while reducing their environmental impact. Current orthopedic implants face a failure rate of 5 – 10% and sometimes as high as 60% for bone cancer patients. Further, conventional medical devices lead to a significant impact on the environment with some reports suggesting medical device manufacturing will generate up to 2.8 gigatons of CO₂ and other greenhouse gases by 2050. In summary, this talk will review the use of environmentally-friendly biomaterials in medicine, including nanomaterials now in humans outperforming conventional materials while reducing environmental problems.

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Environmentally Friendly and Strong All-Green Composites Made with Nanocellulose Long Filament and Lignin-based Resins

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Abstract

The bioresource demand for developing high-performance and environmentally friendly composites has recently increased because of net zero emissions and the replacement of petroleum-based materials. Bioresources are attractive candidates for sustainable materials. The enticing hierarchical structure of cellulose has made it possible to fabricate bio-based fibers via wet spinning. Strong and tough nanocellulose filament (NF) has been artificially made by wet spinning the cellulose nanofiber (CNF) suspension. The NF is promising for high-performance and all-green fiber-reinforced polymer composites (AGFRPC) fabricated by developing lignin-based resins with superb physical properties.

A strong, tough, and long filament was made by wet spinning CNF suspension followed by coagulation, washing, drying, and stretching. The CNF suspension was wet spun in a citric acid solution to get NF. To prepare AGFRPC, bio-based high-strength resins were synthesized from low-cost and abundant sustainable resources of starch, citric acid, and lignin. Lignin-based resins are synthesized by directly blending lignin with other additives, and by synthesizing bio-based epoxies using vanillin, a lignin derivative, via esterification. By integrating the resins into NF mats through hand-layup, hot-pressing, and post-curing, all-green composites were conceived with excellent flexural strength and stiffness.

The proposed all-green composite combines the high mechanical strength and stiffness of wet-spun NFs with the rigidity of bio-based resins. Since the developed composites have merits in terms of lightweight, good thermal stability, mechanical and hydrophobic properties, they can be used for automotives, drones, and urban aerial vehicles.

Keywords: nanocellulose, lignin, long filament, resin, all-green composites

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Finding ways to overcome antibiotic resistance

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Abstract

In the context of the global growth of antibiotic resistance among harmful microorganisms, the development of new antimicrobial drugs based on silver nanocomposites (AgNPs) has become a priority in materials science and pharmacology. This article presents the results of the synthesis of silver nanoparticles using plant waste, such as pomegranate, orange, and tangerine peels, tomato and potato tops, as well as two varieties of Jerusalem artichoke, "Nakhodka" and "Interes". The use of plant-derived compounds such as phenolic compounds, flavonoids and alkaloids as reducing and stabilizing agents in the synthesis of AgNPs allows for the production of environmentally friendly nanomaterials with controlled shape. A significant recent breakthrough has been the creation of AgNP-antibiotic hybrid composites that exhibit strong synergistic effects. Application of antibiotics such as cephalosporins to the AgNP surface increases the local concentration of the drug at the site of infection and helps destabilize bacterial resistance mechanisms, especially in *Staphylococcus aureus*. These nanocomposites provide potent antimicrobial effects at lower therapeutic doses while reducing systemic toxicity.

Conclusion. Biosynthesized nanocomposites are a powerful tool in the fight against resistant infections. However, further progress requires moving beyond descriptive in vitro studies to the development of standardized synthesis protocols and a thorough study of composite degradation processes in the environment. A promising direction for future research is the use of encapsulation and fictionalization methods of polymer matrices to ensure controlled release of active ingredients.

Key words: silver nanoparticles, green synthesis, antibacterial composites, antibiotic resistance, bio materials.

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Fabrication of photocatalytic membranes based on atomic-layer-deposited ultra-thin oxide layers onto inorganic membranes for water treatment

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Abstract

The availability of clean drinking water plays – and will continue to play – a crucial role as both humankind and our planet evolve. Considering the demands on fossil fuel resources, a sustainable solution is required to supply the energy required for the purification process, thus enabling a way around the water-energy nexus paradigm. Such solutions are particularly appropriate for the small-scale, decentralized treatment plants that could be deployed in remote areas with minimal infrastructure, such as an electricity and water supply networks. One promising water treatment technology that can address this challenge is photocatalysis, driven by sunlight. While many photocatalytic water treatment concepts have been presented in the past, it is typically observed that they exhibit low overall process efficiencies due to: i) absorbing a limiting range of wavelengths of sunlight; and ii) slow chemical reaction times; while, in addition, iii) many technologies exhibit very limited potential for scale-up. The goal of this work is to address the first two challenges via the realisation of a photocatalytic membrane system that operates under single-pass flow-through conditions using simulated sunlight. Initially, ultra-thin TiO₂ films were deposited onto inorganic membranes using atomic layer deposition (ALD). ALD is chosen as a thin-film deposition technology since it is known to enable conformal coating of even very high aspect ratio structures and the single-pass flow-through filtration demonstrated via the removal of methylene blue (MB). Subsequently, a much wider range of single oxide films – TiO₂, TiO_{2-x}, ZnO and CuO (all 10 – 30 nm thick) – along with thin film heterojunctions thereof – TiO₂/CuO, ZnO/CuO, and TiO₂/ZnO (all ~60 nm thick) – were tested against a wide range of organic dyes using a fast-screening photocatalytic reactor system (FaS-PhoReS) that enables up to 32 photodegradation experiments to be conducted at once. FaS-PhoReS makes the task of selecting the best combination of a photocatalyst to remove an optically-active compound from water, which then greatly reduces the number of lengthy filtration experiments required.

Keywords: solar, photocatalytic membrane, atomic layer deposition (ALD), thin films, photodegradation, high-throughput screening system

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Polymer and Nanocomposite Layers Based on Polymer Brushes as Future Materials

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Abstract

Surface-grafted polymer brushes refer to an assembly of macromolecules attached with one end to a surface and stretched away from it. The stretched conformation of the tethered chains and their conformational freedom leads to unique properties of the brushes and specific applications. Dense polymer brushes can be formed on smooth but also more challenging nanostructured surfaces significantly affecting their properties. Polymer brushes with conjugated chains grafted from surfaces offer unique properties desirable for e.g. organic photovoltaics, thermoelectrics, and molecular electronics enabling directional pathway for charge transport. Formation of mixed brushes, crosslinked or double-stranded chains should further affect the performance of such systems taking advantages of anisotropy offered by the stretched and ordered chains.

The lecture covers the systems containing surface-grafted macromolecules of various structures including single- and double-stranded brushes with e.g. thermoresponsive or conductive properties. Formation of nanocomposite thin layers based on polymers brushes serving as templates for synthesis of magnetic or metallic nanoparticles is also highlighted. Applications of such systems in e.g. photovoltaics, fabrication of surfaces with reversibly changeable hydrophilicity or stimuli-responsive nanovalves on porous surfaces are also envisioned.

Keywords: polymer brushes, nanocomposite coating, smart coatings, conjugated polymers

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Agricultural waste as bio-renewable resources for the green synthesis of silver nanoparticles and fabrication of antibacterial nanocomposites

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The escalating demand for eco-friendly nanomaterials necessitates the exploration of sustainable, low-cost raw materials for nanoparticle synthesis. Agricultural residues, including pomegranate peels, citrus waste (orange and mandarin peels), and herbaceous waste (tomato and potato haulms), represent a rich, underexploited source of bioactive phytochemicals. This study investigates the potential of these biomass types as both reducing and capping agents for the synthesis of silver nanoparticles (AgNPs) and their subsequent integration into polymeric matrices to form functional antibacterial bio-composites.

Aqueous extracts were prepared from dried agricultural wastes. The synthesis of AgNPs was conducted via a green, room-temperature reduction process. The structural, morphological and optical properties of the synthesized nanoparticles were characterized using UV-visible spectroscopy, FTIR spectroscopy, SEM and TEM, and DLS. The study reveals that the varied phytochemical profiles of the selected wastes—ranging from high phenolic content in pomegranate peels to glycoalkaloids and polysaccharides in tomato and potato haulms—significantly influence the size, shape, and stability of the AgNPs.

Furthermore, AgNPs were incorporated into biodegradable polymer matrices (inulin) to assess their antimicrobial efficacy against *Staphylococcus aureus* and *Escherichia coli*.

Keywords: green synthesis, silver nanoparticles, agricultural waste, biocomposites, antimicrobial materials, sustainable nanotechnology.

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Upcycling Post-Consumer Polymers and Agricultural Waste into Advanced Multifunctional and Lightweight Biocomposites

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Abstract

The accumulation of post-consumer plastics and agricultural residue poses significant environmental challenges, driving the need for high-value recycling strategies. This work presents a holistic approach to upcycling post-consumer polyolefin blends of recycled high-density polyethylene and recycled polyethylene terephthalate (rHDPE/rPET) heavily filled with 70 wt% rice husk (RH) into advanced biocomposite systems. Two distinct pathways were explored to tailor material performance: the development of solid hybrid nanocomposites and lightweight biocomposite foams. In the solid biocomposite system, the strategic hybridization of multiwalled carbon nanotubes (MWCNT) and organoclay (TLO) effectively enhanced interfacial bonding, mechanical integrity, thermal stability, and flame retardancy, while mitigating water absorption and accelerating controlled biodegradation. Concurrently, to address weight limitations associated with high filler loadings, structural foaming via chemical blowing agents (ADC) was integrated alongside coupling agent optimization and graphene nanoplatelet (GNP) nucleation. The resulting microcellular biocomposite foams achieved substantial density reduction while simultaneously establishing interconnected conductive networks for functional performance. Microstructural analyses confirmed that fine-tuning processing conditions and nanofiller dispersion are critical to achieving balanced mechanical strength, reduced density, and tailored electrical properties. Overall, this research demonstrates the viable transformation of low-cost waste streams into lightweight, multifunctional, and sustainable materials suitable for high-performance applications such as automotive components and electronic housing.

Keywords: Recycled polymers, Rice husk, Hybrid nanocomposites, Biocomposite foams, Graphene, Waste upcycling

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KS

Selection of extraction modes and creation of a database of experimental data on the chemical composition of polymer composite mixtures -systems for the development of an artificial intelligence-based information system

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Abstract

At present, polymer composite mixing systems are widely used across a broad range of fields: plastic compounds, composites and their derivatives, medical instruments and devices, and a range of building materials. The use of this class of materials makes it possible to optimize manufacturing processes by improving the stability of the composition and the uniformity of the distribution of the components used, selecting a polymer stabilizer matrix, and modifying its properties through the targeted introduction of components with specified properties. In this regard, the selection of component extraction methods for developing a model of the chemical composition of polymer composite blend systems using artificial intelligence is a pressing scientific and practical challenge. Thus, a detailed analysis of the methods for extracting components and their subsequent use in synthesis to produce polymeric mixture systems, an investigation of the conditions for the separation of components from these mixture systems, and an examination of the nature of the polymer matrix, enable an assessment of the factors influencing the efficiency of the synthesis process and subsequent modification. This study has established that temperature, processing time, mixing speed and the concentration of the components have a significant influence on the efficiency of the synthesis of polymer premixes. Humic acids were used as the polymer carrier and were modified using a wide range of filler components. It has been found that varying the experimental conditions (static/dynamic/ageing method) for the separation of components makes it possible to obtain samples characterized by different capacities and compositions. During the synthesis, organic polymeric mixed systems were obtained, in which humic acids—isolated by alkaline extraction from oxidized brown coal from the Kyzyl-Kiya deposit—were used as stabilizers. In this regard, the main objective of this study is to select component extraction methods for the creation of a database of experimental data on the chemical composition of polymer composite mix systems, which is required for training machine learning models and developing an information system based on artificial intelligence. To this end, a comprehensive comparative analysis was carried out of various methods for producing particles (in situ, ex situ, and sediment ageing), including the synthesis of polymer-humic composite systems at different temperatures, pH levels, and concentrations of reagents containing particles of oxides and hydroxides of transition and rare-earth metals (using iron, cobalt, neodymium and gadolinium as examples), as well as the creation of hybrid composite systems based on humic acids. The results obtained were used to create a database of experimental data, which will subsequently be used as a control test sample for training the machine learning algorithms of the information system under development. The use of experimental data when training a machine learning model makes it possible to utilize this data to validate and verify predicted changes in the qualitative and quantitative characteristics of components, as well as to carry out parametric optimization with automatic classification of possible variations in these resources, which are used as test components for modifying the properties of the polymer matrix. It should be noted that the potential applications of artificial intelligence technologies and machine learning algorithms make it possible to explore fundamentally new approaches to monitoring and forecasting possible model series of the chemical composition and properties of polymer composite mix systems. The information system currently under development will be capable of organizing large volumes of heterogeneous data and

processing it in a modular manner in real time, as well as identifying and analyzing parametric apparent patterns and correlations. Furthermore, the development of this information system opens up the possibility of creating a simulation model of the chemical composition of polymer composite blend systems, depending on the nature of the filler components used and the properties of the modified matrix, in order to create digital twins of this process.

Keywords: brown coal, humic acids, hybrid composite systems, polymer composite mixing, simulation model

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Ion-Selective Electrodes of Clay-based Composite Materials in polymer matrix for Chemical Sensor Applications

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Abstract

Clays are layered aluminosilicate materials which are described by presence of two-dimensional sheets, tetrahedral (SiO_4) and octahedral (Al_2O_3). Clay nanocomposites have been widely used as reinforce material for polymer matrix with improved mechanical, thermal, anticorrosive properties and it can be used as adsorbent for the removal of various hazardous substances like heavy metals, dyes, antibiotics etc. Polymer based-Clay nanocomposites have shown a wide range of applications in industrial, biomedical, as well as in the agriculture field. Clay polymer nanocomposites may be synthesized by various methods such as solution-casting, In-situ polymerization, and melt-blending. Innovative synthesis pathways have resulted in clay polymer nanocomposites with improved properties, which successfully incorporated in diverse fields. The small size of the particles and their crystalline structures gives clay material properties like cation exchange capability, catalytic ability, swelling behavior and low permeability. This work aims to describe the contemporary advancements in clay-polymer nanocomposites which have the potential as electroactive material in polymer matrix-based membrane to attract metal ions from solutions and remediate aqueous systems. Therefore, it is significant to fabricate Ion-selective electrode based chemical sensors for the accurate determination of metal ions with high selectivity with the help of these composite materials as ionophores in polymeric membrane.

Keywords: Clay-polymer nanocomposites, Intercalation, Polymeric membrane, Chemical sensor, Ion-selective electrode.

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Molecular Design of Metal-Organic Framework Structures as Precursors of Electrochemical Sensor Materials

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Abstract

Diabetes remains one of the most significant global health issues. The development of high-performance glucose sensors is crucial for the prevention and diagnosis of diabetes. Monitoring the levels of key metabolites that determine a patient's condition in real time requires the use of modern glucose sensors based on continuous glucose monitoring systems, which must have high sensitivity and selectivity and low detection limits. The operating principle of electrochemical sensors of this type is based on the direct electrocatalysis of electrode materials with respect to the analyte using molecularly imprinted polymers, nanomaterials, and other technologies. We conduct systematic studies of metal-organic frameworks (MOFs), including bimetallic derivatives—porous coordination polymers formed through the coordination interaction of metal ions or clusters with polydentate organic ligands [1-3]. The molecular design strategy is based on the use of reticular synthesis approaches using a secondary building block, in the presence of a deprotonating/donor agent or modulator at room temperature and atmospheric pressure in a medium of water and organic solvents or their mixtures, by the solvo- or hydrothermal method; an exchange reaction of a monotopic ligand of pre-synthesized mono- or hetero-metallic polynuclear carboxylate complexes with a polytopic (dicarboxylate) one with the generation of the required structure. A series of isotopic coordination polymers of the MIL-88B type and their composites, including those with carbon materials, as well as Fe₃O₄/γ-Fe₂O₃@Fe₃O-MOF and TiO₂@Fe₃O-MOF with terephthalate, aminoterephthalate, and porphyrinate ligand bridges, and bimetallic CoNi-, CuCo-, CuNi-MOFs and nanocomposite materials based on them, were synthesized and characterized. The composition, structure, specific surface area and porosity, morphology and microstructure of the obtained compounds were studied using IR and UV spectroscopy, X-ray phase analysis, low-temperature nitrogen adsorption-desorption, scanning and transmission electron microscopy. Cyclic voltammetry and chronoamperometry confirmed the electrochemical activity of the obtained materials and demonstrated their electrocatalytic properties with respect to glucose. The obtained results provide a physicochemical basis for the development of electrode materials for electrochemical sensors based on metal-organic coordination polymers and nanocomposite materials based on them.

Keywords: MIL-88B(Fe), metal-organic frameworks, electrocatalytic activity, glucose, electrochemical sensors.

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Chagas disease cardiomyopathy & immunopathology: therapeutic efficacy of a drug combination

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Abstract

Drug combinations and drug repurposing have emerged as promising strategies to develop novel treatments for infectious diseases, including Chagas disease. In this study, we aimed to investigate whether the repurposed drugs chloroquine (CQ) and colchicine (COL), known to inhibit *Trypanosoma cruzi* infection in host cells, could boost the anti-*T. cruzi* effect of the trypanocidal drug benznidazole (BZN), increasing its therapeutic efficacy while reducing the dose needed to eradicate the parasite. The combination of BZN and COL exhibited cytotoxicity to infected cells and low antiparasitic activity. Conversely, a combination of BZN and CQ significantly reduced *T. cruzi* infection *in vitro*, with no apparent cytotoxicity. This effect seemed to be consistent across different cell lines and against both the partially BZN-resistant Y and the highly BZN-resistant Colombiana strains. *In vivo* experiments in an acute murine model showed that the BZN+CQ combination was eight times more effective in reducing *T. cruzi* infection in the acute phase than BZN monotherapy. In summary, our results demonstrate that the concomitant administration of CQ and BZN potentiates the trypanocidal activity of BZN, leading to a reduction in the dose needed to achieve an effective response. In a translational context, it could represent a higher efficacy of treatment while also mitigating the adverse effects of high doses of BZN. Our study also reinforces the relevance of drug combination and repurposing approaches in the field of Chagas disease drug discovery.

Keywords: Chagas disease; *T. cruzi*; invasion; replication; benznidazole; therapeutic efficacy

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From Supercapacitors to Supercapatteries: Charge-Storage Mechanisms, Material Design, and Emerging Hybrid Energy-Storage Devices

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Abstract

Supercapacitors represent an important class of electrochemical energy-storage devices distinguished by their exceptional power capability, rapid charge–discharge response, and long operational lifetime. This presentation will provide a critical overview of electrical double-layer capacitors, pseudocapacitors, and hybrid supercapacitor systems, with particular emphasis on the fundamental distinctions among their charge-storage mechanisms and electrochemical signatures. Special attention will be devoted to differentiating battery-type and pseudocapacitive materials, including their faradaic behaviour, ion-transport characteristics, and implications for capacitance, capacity, rate capability, and cycling durability. The presentation will further examine the emerging concept of the supercapattery, a hybrid device architecture designed to integrate the high-power characteristics of capacitive electrodes with the higher energy-storage capability of battery-type materials. Key considerations in electrode matching, mass balancing, voltage-window optimization, kinetic compatibility, and realistic device-level performance evaluation will be highlighted. The discussion will conclude by outlining opportunities for advanced transition-metal compounds, conductive polymers, porous carbons, and MXene-based hybrid electrodes in the development of next-generation high-performance supercapattery systems.

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Bio-Based Materials for Food Packaging

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Abstract

Edible or water-soluble coating dispersions for fruits and vegetables serve to prolong shelf life by shielding against physical injury and microbial decay while also enhancing visual appeal. These formulations utilize a polymer matrix combined with plasticizers and antimicrobial agents. They function by forming a semi-permeable barrier that moderates respiration rates, minimizes moisture loss, and suppresses microbial proliferation. Key benefits include their edibility or easy removal, straightforward application via spraying or dipping, and the capacity to carry functional compounds such as vitamins and antioxidants. However, challenges remain in their relatively poor mechanical robustness, sensitivity to storage environments, and potential allergenic risks from certain ingredients. Conversely, rigid biodegradable films aim to supplant traditional polyethylene across a broad spectrum of food items. Their composition similarly relies on a polysaccharide base but is fortified with plasticizers, reinforcing fillers, antioxidants, and antimicrobials. To be viable, these films must exhibit adequate tensile strength and flexibility, act as effective barriers against oxygen, carbon dioxide, and water vapor, withstand heat processing, and decompose efficiently in composting facilities. While they are environmentally sound, customizable, and suitable for existing industrial processes, they currently suffer from higher production costs compared to polyethylene, difficulty in balancing strength with barrier performance, and high susceptibility to humidity. Current research in food packaging focuses on advanced polymer films and surface treatments engineered to enhance preservation capabilities, extend product longevity, and minimize ecological impact. The primary areas of investigation center on improving barrier properties, mechanical integrity, and ensuring reliable biodegradability. Researchers are actively assessing how various additives—including antimicrobial substances and structural reinforcements—affect overall material functionality. This work adopts a multidisciplinary strategy, integrating materials synthesis, state-of-the-art analytical characterization, and practical testing under real-world conditions.

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Keywords: polylactic acid, food packaging, biodegradable packaging, polysaccharides

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KS

The Synergic Cell Response to Nanocomposite and Radiofrequency Therapy

Title of the abstract (Bold). Capitalize first letter of each word (12 pt. Times New Roman)

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Abstract

In this plenary talk, it will be explored the use of the Hill model to assess the Benchmark dose (BMD), the lethal dose 50 (LD50), the cooperativity (E) and the dissociation constant (K) while analyzing cell viability data using nanomaterials. The presentation is addressed to discuss the antitumor potential while combining radiofrequency (RF) therapy in and selected nanomaterials. In particular, it will be discussed the use of nanocomposites, for instance comprising graphene oxide (GO) surface functionalized with polyethyleneimine (PEI) and decorated with gold nanoparticles (GO-PEI-Au). Data collected from the cell viability assays using different tumor cell lines (e.g. LLC-WRC-256 and B16-F10) will be presented and discussed. The findings will demonstrate that while the tested nanocomposite (e.g. GO-PEI-Au) may be biocompatible against different cancer cell lines in the absence of radiofrequency (nRF), the application of radiofrequency (RF) enhances the cell toxicity by orders of magnitude, pointing to prospective studies with the tested cell lines using tumor animal models.

Keywords: Hill model; Nanocomposite; Radiofrequency; Cell viability; Synergism

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Next-Generation Osmotic Membranes for Water and Energy Applications: Advances in Support and Active Layer Engineering

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Abstract

Osmotically driven membrane processes, particularly forward osmosis (FO) and pressure-retarded osmosis (PRO), offer significant potential for sustainable desalination, wastewater reuse, resource recovery, and salinity-gradient energy generation. However, their widespread deployment remains constrained by internal concentration polarization (ICP), limited water permeability, reverse solute leakage, and insufficient membrane stability under harsh operating conditions. Overcoming these challenges requires innovative approaches to both support-layer design and active-layer chemistry.

This presentation highlights our recent research in the development of next-generation thin-film composite osmotic membranes through three complementary engineering strategies. The first strategy focuses on modifying the support layer by blending sulfonated polyethersulfone (SPES) with polyethersulfone (PES), resulting in higher porosity, enhanced hydrophilicity, and reduced structural resistance, thereby mitigating ICP. The second strategy involves tailoring the polyamide selective layer by replacing the conventional m-phenylenediamine (MPD) monomer with 2,6-diaminopyridine (DAP), leading to improved permeability, selectivity, and exceptional alkaline stability. The optimized membrane achieved water fluxes up to 16.7 LMH while maintaining low reverse salt flux and long-term stability under highly alkaline conditions. The third strategy employs electrospun nanofibrous supports to create highly porous and interconnected transport pathways with low tortuosity, significantly enhancing water transport while suppressing ICP. Such architectures are attractive for both FO and PRO applications due to their ability to improve mass transfer without sacrificing selectivity.

Collectively, these advances demonstrate how simultaneous engineering of support and active layers can overcome traditional permeability-selectivity-stability trade-offs and accelerate the development of high-performance osmotic membranes for sustainable water and energy applications

Keywords: Osmotic membranes, Forward osmosis, Pressure-retarded osmosis, Electrospinning, Support-layer engineering, Membrane stability

Acknowledgment

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Multi-Dimensional Printing on Polymers and Other Materials

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Abstract

Two dimensional traditional printing processes are well established in textile, paper, plastic and various consumable and non-consumable products. 2D printing refers to the process of reproducing images or text onto a flat surface, typically textile, paper or other substrates. The 2D printing process involves creating a digital file, preparing the image, and using various technologies to reproduce text or images on a flat surface. The technology encompasses various methods since ancient times, namely wooden block, flat and rotary screen, engraved roller printing. In modern days, these methods have been largely substituted by inkjet and recently by laser printing, each with its own operational mechanics.

In recent years, Multi-dimensional printing, namely 3D, 4D, 5D, 6D printing methods are coming into existence and are rapidly penetrating into printing market. 3D printing, also called additive manufacturing, is the process of making a three-dimensional object from a digital file by building it up one thin layer at a time. Instead of cutting or hollowing material away, a 3D printer adds material only where it is needed, each layer a thinly sliced cross-section of the final object, until the whole thing exists. The popular types of 3D printers are Fused deposition modelling (FDM), Stereolithography (SLA), Selective laser sintering (SLS), Multi-Jet Fusion (MJF), Digital Light Processing (DLP), Continuous Liquid Interface Production (CLIP), Material jetting photopolymers (MJ), Binder Jetting, Sheet Lamination, Directed Energy Deposition (DED) etc.

Today, professional, low-cost desktop and bench top 3D printers have accelerated innovation and support businesses in various industries including engineering, manufacturing, dentistry, healthcare, education, entertainment, jewellery and of course, textile manufacturing including smart textiles and innovative garments. 3D printing eliminates many labour-intensive processes from the complete apparel manufacturing cycle, reducing the labour costs. 3D printing offers improved quality, as the occasional human error is eliminated from the manufacturing process.

However, Current 3D printed textiles and garments fail to offer comfort and flexibility that a garment is expected to provide. They do not absorb moisture as the layers of the raw material fuse with each other, leaving no air gaps. 3D printed textiles cannot be sewn into garments like traditional manufacturing.

4D printing relies on the combination of responsive materials with additive manufacturing technologies, enabling the fabrication of smart architectures able to evolve with time in response to external stimuli. Among the external stimuli, solvent, pH, magnetic field and temperature are most exploited till date. Common thermo-responsive polymers include hydrogels, liquid crystalline elastomers and shape memory polymers (SMPs).

While the foundations of 3D printing technology are well-known and widely-utilised, 5D printing is a new technique that offers more versatility and capabilities. The principal difference lies in the way the printers move during production. 5D printers have a moving plateau that allows the print-head to create pieces from five dimensions, including curved layers, whereas 3D printers generally produce flat layers on a fixed plateau. This unique ability to produce curved layers results in more complex, stronger, and versatile parts,

While 3D printing involves the layer-by-layer deposition of material to create physical objects, 6D printing takes this a step further by incorporating smart materials and additional dimensions. 6D printing uses intelligent materials that can adapt and respond to external stimuli, such as light, temperature, and pressure. This innovative approach has rapidly gained attention in various industries, including the food industry.

Keywords: Textile printing methods, smart textiles, 3D printing machines, 4D, 5D and 6D Printing

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Synthesis of Ultrasmall In, Sn and Their Oxides using Pulsed Plasma in Water

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Abstract

Ultrasmall indium (In) and tin (Sn) nanoparticles and their corresponding oxides were synthesized using pulsed plasma in deionized water as a simple, environmentally friendly, and efficient approach. The as-synthesized In and Sn nanoparticles exhibited average particle sizes below 5 nm (approximately 4.5 nm for In) and showed good crystallinity with slightly expanded lattice parameters compared with their bulk counterparts. Thermogravimetric analysis revealed their relatively high thermal stability. Controlled thermal annealing resulted in the oxidation and growth of the metallic nanoparticles, yielding highly crystalline In₂O₃ and SnO₂ nanoparticles. Annealing In nanoparticles at 450 °C produced body-centered cubic In₂O₃ nanoparticles with an average size of approximately 12 nm and semispherical, semihexagonal, and semicubic morphologies. The In₂O₃ nanoparticles exhibited a bandgap energy of 3.63 eV, significantly higher than that of bulk In₂O₃. Similarly, annealing Sn nanoparticles at 800 °C resulted in complete oxidation to the cassiterite phase of SnO₂, with particle sizes increasing to approximately 20–25 nm. The obtained SnO₂ nanoparticles demonstrated photocatalytic activity toward the degradation of organic dyes, including methylene blue and methyl orange. These results demonstrate that pulsed plasma in water provides a facile and environmentally friendly route for producing ultrasmall metallic nanoparticles and their crystalline oxides, while subsequent thermal treatment enables control over their phase composition, morphology, particle size, and functional properties.

Keywords: Indium, tin, nanoparticles, thermal treatment, pulsed plasma in liquid

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**DFT Insights into Electronic Structure and Charge Transfer in Silk Fibroin/Graphene
Oxide Polymer Nanocomposites**

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Abstract

Silk fibroin (SF)/graphene oxide (GO) nanocomposites were fabricated via an eco-friendly solution casting method to develop flexible and conductive biomaterials. SEM and XRD analyses confirmed uniform dispersion of GO within the SF matrix, while FTIR revealed strong interfacial interactions. The nanocomposites exhibited enhanced mechanical strength and significantly improved electrical conductivity, tunable with GO content. Density Functional Theory (DFT) analysis showed a reduced band gap and favorable charge transfer upon GO incorporation, supported by negative binding energy indicating system stability. These findings highlight the potential of SF–GO nanocomposites for applications in flexible electronics and bioelectronic devices.

Keywords: SF-GO NCs, SEM, XRD, XPS, FT-IR, Electrical conductivity.

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Magnetic Iron Oxide Nanostructures for Biomedical Applications: From Rational Design and Machine Learning-Enabled Activity Prediction to Preclinical Validation

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Abstract

A diverse library of over 100 magnetic iron oxide nanostructures, modified with silanes, humic acids, metal organic frameworks, and other agents, has been developed and comprehensively characterized. This representative collection served as a training dataset for machine-learning models aimed at predicting biological activity, including ecotoxicity (EC₅₀) and pro-oxidant potential. Using infrared spectroscopy data and ensemble algorithms, the models achieved high classification accuracy for toxicity groups, while quantitative nanostructure-activity relationship (QNAR) approaches enabled the prediction of biological effects across multiple test organisms (ciliates, microalgae, bacteria, and enzymes). Multifactorial design-of-experiment and sol-gel optimization further guided the fabrication of core-shell carriers with tailored surface properties. A particular focus is placed on mesoporous nanocomposites obtained via template synthesis of magnetite nanoparticles within interpolyelectrolyte complexes of aminoorganosiloxanes and humic acids. These complexes create a well-defined porous architecture and render the materials pH-sensitive, enabling controlled and sustained release of therapeutic agents. The intrinsic biological activity of humic acids, including their ability to inhibit β -lactamase secretion and combat antibiotic resistance, makes these carriers attractive for antimicrobial applications. In this context, the adsorption potential of the nanocomposites toward ciprofloxacin was investigated to enhance its therapeutic efficacy and reduce the risk of resistance development. The resulting pH-responsive, non-toxic nanocarriers demonstrate promising properties for smart antibiotic delivery.

For oncology applications, a new class of ferroptosis-inducing nanocomposites was engineered, combining magnetite nanocrystals (Fe₃O₄) as a magnetic core, a sacrificial MIL-88b(Fe) coordination framework for sustained iron release, and ascorbic acid as a chemosensitizer that amplifies hydroxyl radical production specifically in the acidic tumor microenvironment. For the first time, an “autocatalysis window” was discovered – pH-dependent degradation of the metal-organic polymer at tumour-typical pH values, enabling selective ferroptosis induction while sparing healthy tissues. A representative library of 36 composites established clear correlations between composition, pro-oxidant activity, and magnetic properties, providing a technological platform for adaptation to various neoplasm types.

A mathematical model of magnetic particle capture in simulated blood flow was developed to support the design of magnetotargeting systems and subsequent industrial scaling. In vivo experiments on CT26 adenocarcinoma-bearing mice demonstrated a 42% tumour volume reduction after intravenous administration without an external magnetic field, and up to 55% reduction under simulated magnetotargeting conditions, confirming the feasibility of controlled delivery. Together, these results establish an integrated platform that combines machine-learning-driven prediction, rational materials design, and preclinical validation for both stimuli-responsive antimicrobial carriers and magnetically guidable ferroptosis-based therapies, with strong proof-of-concept for future clinical translation.

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Keywords: iron oxide nanoparticles, machine learning, ferroptosis therapy, drug delivery, structure-activity relationships, preclinical studies

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Stimuli-Responsive Magnetic Nanocomposite Flocculants for Targeted Wastewater Treatment

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Abstract

Industrial wastewater laden with heavy metals, dyes, and microplastics demands advanced, sustainable treatment solutions. Stimuli-responsive magnetic nanocomposite flocculants (SR-MNFs) emerge as a transformative technology, achieving >90% removal efficiency for key contaminants such as Heavy metals: Pb²⁺ (98.5% ± 1.2), Cr(VI) (95.2% ± 1.8), Dyes: Congo red (95% ± 2.8), methylene blue (93.7% ± 2.1) and Microplastics/oils: 92% ± 3.1 (10–100 µm particles). SR-MNFs integrate superparamagnetic cores (Fe₃O₄/γ-Fe₂O₃) with smart polymeric shells (e.g., PNIPAM, chitosan) for programmable pollutant capture via multi-mechanistic flocculation (charge neutralization, bridging, π–π stacking), Stimuli-triggered regeneration (pH, temperature, magnetic fields) and Low-energy recovery. Despite lab-scale success, analysis of several studies (2018–2024) reveals critical gaps, only 5.7% address industrial scalability, and none provide complete lifecycle assessments of nanoparticle leaching or shell degradation. This review presents the first comparative techno-economic analysis, demonstrating SR-MNFs 40% cost advantage over conventional methods (e.g., graphene oxide, biochar) after five reuse cycles, alongside real-world case studies from textile and mining sectors (91–94% efficiency, limited by silica fouling). We identify scalability, core-shell stability, and regulatory hurdles as key barriers and propose hybrid SR-MNF/biochar systems and AI-driven optimization as pathways to industrial adoption. By bridging fundamental research and commercialization challenges, this work outlines a roadmap for deploying SR-MNFs in circular wastewater economies.

Keywords: Stimuli-responsive flocculants; Magnetic nanocomposites; Wastewater remediation; Targeted pollutant removal; Self-regenerating materials; Sustainable treatment technologies

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Herbal Medicines and Herbal Medicinal Products– Quality and Safety

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Abstract

The challenges are innumerable and enormous, making the global medicinal plant/ herbal market unsafe. The talk seeks to enlighten physicians, pharmacists, consumers and stakeholders in medicinal plant industry on the need to establish quality parameters for handling, manufacturing and production of safe herbals as well as employ such parameters in ensuring the safety of the global herbal market that is directly linked to the safety of public health. In the present paper an attempt has been made for a sequential study of the Quality Control and atandardization of Herbal Medicinal Products (HMP) starting from Selection of Medicinal Plants ;Good Agricultural Practices (GAP) Cultivation ;Good Field Collection Practices(GFCP) ; Organized and Unorganized Drugs ;Source and Period of Collection; Identification; Storage ; Chemical Standardisation ; Assay ; Good Manufacturing Practices (GMP) and Pharmacological studies to Clinical Approach , with special reference to ensuring safety of Herbal Medicines. Toxic elements have been identified in a large number of medicinal preparations. e.g. mercury containing skin lightening products are hazardous to health and as a result have been banned in many countries. Different stages, i.e Quality control studies of Raw Medicinal Plants, Controlled Studies of Method of Processing, Quality Control Studies of Finished Product, Standardisation Proceeedures at each stage from birth of the plants up to clinical application of herbal medicine will be dealt with reference to some medicinal herbs. An emphasis have been given on the protocols which are required for Registration of Herbal Medicinal Products (HMP).

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FROM WASTE SILICON WAFER TO SUSTAINABLE CONDUCTIVE Cu/Si MICROSTRUCTURES: TIME-DEPENDENT ULTRASHORT ELECTROLESS AUTOCATALYTIC COPPER DEPOSITION, MORPHOLOGICAL EVOLUTION, AND ELECTRICAL PERFORMANCE

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Abstract

Poor adhesion and interfacial delamination, volume expansion, hydrogen bubble entrapment, metal diffusion, and concerns related to LCA and carbon footprint remain major challenges in Cu/Si conductive materials. In this work, waste silicon (Si) wafers were valorized into sustainable conductive Cu/Si microstructures through a rapid electroless copper deposition process. The surface morphology evolution and electrical conductivity of the resulting Cu/Si structures were systematically investigated as a function of deposition time. Copper deposition was performed by immersing waste Si wafers in a mixed solution of HF and copper (II) nitrate hemi(pentahydrate) for short durations ranging from 10 to 40 s. High-resolution scanning electron microscopy (SEM) revealed that increasing deposition time improved the Cu layer morphology, producing a more homogeneous, continuous, and uniformly distributed coating on the waste Si substrate. The results showed that a 40 s immersion produced the most uniform Cu coverage and the best Cu–Si interfacial coating quality. The enhanced morphology contributed directly to improved electrical conductivity through the formation of a more interconnected conductive network across the substrate surface. The study demonstrates a sustainable waste-to-value approach for transforming discarded silicon wafers into functional Cu/Si microstructures with tunable electrical properties. These findings highlight the potential of rapid electroless copper deposition as a resource-efficient and environmentally sustainable strategy for waste silicon upcycling and the development of conductive materials for future microelectronic applications.

Keywords: Copper, Si wafer, Electroless deposition, Surface morphology, Electrical conductivity.

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Tailored biochar based composited for electromagnetic enhanced composite preparation**Mattia Bartoli^{1,2,3}**¹*Center for Sustainable Future, Italian Institute of Technology, Via Livorno 60, Turin, 10144, Italy, Italian Institute of Technology, Via Livorno 60, Turin, 10144, Italy*²*Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali (INSTM), Via G. Giusti 9, Florence, 50121, Italy*³*Department of Applied Science and Technology, Politecnico d Torino, C.so Duca degli Abruzzi 24, Turin, 10129, Italy***Abstract**

The increasing demand for lightweight, sustainable, and multifunctional materials for electromagnetic interference (EMI) shielding and microwave absorption has stimulated growing interest in biochar-based composites as environmentally benign alternatives to conventional carbonaceous fillers. Tailored biochar, derived from the controlled pyrolysis of biomass, offers a unique combination of hierarchical porosity, tunable electrical conductivity, surface chemistry, and structural disorder, making it a highly promising platform for enhancing electromagnetic properties in polymer, ceramic, and hybrid composites. This work presents a comprehensive overview of the design, tailoring, and application of biochar as an advanced functional filler for the development of composites with enhanced electromagnetic performance. The electromagnetic response of biochar-based composites is strongly governed by the intrinsic physicochemical characteristics of the biochar, which can be precisely engineered through feedstock selection, pyrolysis temperature, heating rate, residence time, and post-treatment strategies. High-temperature pyrolysis promotes graphitization and electrical conductivity, favoring conduction loss mechanisms, while lower temperatures preserve oxygenated functional groups that contribute to dipolar polarization and interfacial loss. Additionally, the development of multiscale porosity and defect-rich microstructures enhances multiple scattering and impedance matching, thereby improving microwave absorption efficiency over broad frequency ranges. Surface functionalization and heteroatom doping further expand the electromagnetic tunability of biochar by modulating charge distribution, dielectric relaxation behavior, and interfacial polarization phenomena. When integrated into polymeric or ceramic matrices, tailored biochar establishes percolated conductive networks and extensive interfacial regions, which synergistically enhance dielectric loss, suppress electromagnetic wave reflection, and improve absorption-dominated shielding effectiveness. Hybridization with magnetic phases, such as ferrites or transition metal nanoparticles, enables the development of biochar-based composites exhibiting combined dielectric–magnetic loss mechanisms, thus achieving superior EMI shielding and radar absorption performance at reduced filler loadings.

Beyond electromagnetic functionality, biochar-based composites offer significant advantages in terms of low density, thermal stability, cost-effectiveness, and environmental sustainability. The utilization of renewable or waste biomass as a carbon source aligns with circular economy principles and contributes to carbon sequestration strategies, positioning tailored biochar as a strategic material for next-generation green electromagnetic composites. Potential applications span aerospace structures, stealth and radar-absorbing materials, flexible electronics, energy devices, and construction materials requiring EMI mitigation. Here, we presented our more recent advancements in the tailoring of biochar for the preparation of electromagnetic enhanced propertiess.

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NANOBUBBLES..a Low Cost Technology With Effective Biomedical Applications

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Abstract

Among the variety of nanosystems applied in the biomedical field either for diagnostics or therapeutics, nanobubbles (NBs) present some peculiar characteristics due to their physico-chemical structure. Their core, containing perfluorocarbons (PFCs), can dissolve a huge quantity of oxygen and other substances, including drugs and natural compounds. Their polysaccharide shell is biocompatible, biodegradable and easily functionalizable with active molecules or nanoparticles.

Moreover, their effectiveness may be enhanced using physical means, such as Ultrasound and Photosensitization.

Some specific applications of NBs will be presented focused on wound healing, curcumin-based NBs and iron chelation in brain.

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Keywords: nanobubbles, oxygen, iron, curcumin.

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Synthesis of Polymer Nanocomposites with Nanocellulose Matrix

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Abstract

The field of Nanotechnology has evolved in the recent past and has become an alternative to several waste remediation strategies. On this forum, we shall discuss the synthesis, characterization and various applications of Polymer nanocomposites with nanocellulose matrix. This nanocellulose can be easily obtained from various agricultural waste. The agricultural waste can be given enzymatic treatment or Chemo-mechanical treatment to get nanocellulose. Biomedical Applications of such nanocomposites include bandaging material, suture material, drug delivery, artificial bones etc. The same nanocomposites are useful for developing newer textile, packaging material for food and beverage industry.

Keywords: Composite, agricultural waste, nanocellulose, Drug Delivery, Polymer

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The Use of Luminous Marine Bacteria for Monitoring the Biological Activity and Biosynthesis of Nano-compounds

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Abstract

We developed the application of luminous marine bacteria in two directions: (1) monitoring the biological activity of nanocompounds (NCs), (2) biosynthesis of nanoparticles. First direction allows application of *Photobacterium phosphoreum* as a classic bioassay system due to its simplicity and high speed of analysis. The luminous bacteria were adapted to monitor bioeffects of NCs – activation and toxic effects, and anti- and pro-oxidant properties. NCs with different structure and surface modification have been studied: (i) humic substances, (ii) fullerenols with different frame sizes, the number of oxygen substituents, and involvement of endohedral or exohedral metals, (iii) iron oxide NPs with different surface modifiers, (iiii) three-component nanocomposites including metal-organic frameworks, iron oxide and modifiers (ascorbic acid or humic substances). The content of reactive oxygen species (ROS) was assessed using the chemiluminescent luminol method. The specific effects of NCs were explained by hydrophobic interactions involving cell membranes, enzymatic processes, electron affinity, and ROS imbalance. The NCs are confirmed and/or revealed to be perspective for balancing radical processes in organisms, cancer therapy, and as contrast MRI agents.

The second area of research is related to the bacterial bioreduction of selenium-polluted water media and biosynthesis of nanoparticles of elementary selenium. Electron microscopy detected NPs in bacteria exposed to Na₂SeO₃. The energy dispersion spectrum revealed a high content of selenium in these NPs. The property of bacteria is important for ecological, biotechnological and medical applications, including the production of food additives and products enriched with selenium.

Funding:

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Development of Heteroatom-Doped g-C₃N₄-Based Nanohybrids for Electrochemical Energy Storage Applications

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Abstract

Graphitic carbon nitride (g-C₃N₄) is a metal-free polymeric semiconductor with a layered structure, high thermal and chemical stability, low cost, and potential applications in electrochemical energy-storage systems. In this study, pristine and heteroatom-doped g-C₃N₄-based materials were developed as electrode candidates for advanced energy-storage applications. Pristine g-C₃N₄ was synthesized from melamine by thermal polymerization, while boron-, sulfur-, and phosphorus-doped g-C₃N₄ samples were prepared using boric acid, thiourea, and ammonium dihydrogen phosphate as dopant sources, respectively. The synthesized materials were initially characterized by Fourier-transform infrared spectroscopy. The characteristic vibrational bands associated with the tri-s-triazine framework and C–N heterocyclic structure confirmed the formation of the g-C₃N₄ framework in both pristine and doped samples. The preliminary results indicated that the characteristic carbon nitride structure was largely preserved after the incorporation of the heteroatom sources. In the next stage of the study, the structural, morphological, surface, and electronic properties of the materials will be investigated using FT-IR, XRD, Raman, SEM spectroscopic methods. Their electrochemical performances will be evaluated by cyclic voltammetry, galvanostatic charge–discharge, and electrochemical impedance spectroscopy measurements. Subsequently, the most promising heteroatom-doped g-C₃N₄ system will be modified with Ag nanoparticles and further integrated with selected phthalocyanine and perovskite derivatives. These multicomponent nanohybrids are expected to provide improved electrical conductivity, enhanced charge-transfer kinetics, and additional redox-active sites. Overall, this work presents a systematic strategy for designing metal-free and Ag-modified g-C₃N₄-based nanohybrids for potential applications in next-generation electrochemical energy-storage devices.

Keywords: g-C₃N₄; heteroatom doping; silver modification; nanohybrids; electrochemical energy storage; supercapacitors

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Green Synthesis of Seaweed-Derived Bioaldehyde–Silver Nanocomposites and Their Anticancer Potential

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Abstract

Marine biopolymers offer a renewable and eco-friendly resource for developing functional nanobiocomposites. This work presents a two-stage research programme based on the chemical transformation of seaweed polysaccharide (agar from *Gracilaria dura*) into a bio-based aldehyde (dialdehyde carboxymethylagar, A~ald~) and its application as a green agent for one-pot synthesis of a solid silver nanocomposite (A~ald~–AgNPs) with potent anticancer activity. In the first stage, carboxymethylagar (CMA) was converted into A~ald~ via controlled periodate oxidation under mild, ambient conditions (pH 5, 30 °C, 4 h), achieving up to 83% aldehyde content and ~81% product yield. Synthesis was confirmed by FTIR, ¹H NMR, XRD, SEM, TGA, DSC, and GPC. Interaction studies with bovine serum albumin (BSA) via fluorescence, circular dichroism, DLS, and UV–vis spectroscopy demonstrated that A~ald~ exhibits reactivity comparable to synthetic formaldehyde, establishing it as a bio-safe cross-linking agent.

In the second stage, A~ald~ served as both reducing and stabilizing agent for rapid microwave-assisted synthesis of solid A~ald~–AgNPs (5 min, 70 °C). TEM and DLS confirmed spherical AgNPs of 30–60 nm uniformly embedded in the biopolymer matrix. In vitro anticancer screening across 49 human cancer cell lines revealed selective cytotoxicity (GI₅₀ < 10 µg/mL) against colon cancer (COLO-205) and myeloid leukemia (HL-60). In vivo xenograft mouse models showed 64%, 51%, and 27.3% tumor volume reduction in ME-180, HL-60, and Colon-26 models, respectively, with 83–100% survival rates. Notably, A~ald~–AgNPs showed no significant toxicity toward normal bone marrow-derived mesenchymal stem cells, confirming selective biocompatibility.

This study demonstrates a sustainable pathway—from marine biopolymer to clinically relevant nanobiocomposite—opening new avenues for seaweed-derived polymers in cancer nanotherapy and antimicrobial applications.

Keywords: Seaweed biopolymer; Bioaldehyde; Silver nanocomposite; Anticancer activity; Green synthesis; Nano-bio composite

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Development of Multifunctional Film Materials Based on PLA/PBAT Mixtures for the Creation of Smart Packaging

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Abstract

The rapid accumulation of non-biodegradable petrochemical plastic waste poses a severe threat to global ecosystems, driving the demand for sustainable alternatives in the packaging sector. Polylactic acid (PLA) is a highly promising biodegradable polymer derived from renewable resources, though its high brittleness and poor thermal stability necessitate blending with flexible, biodegradable polybutylene adipate terephthalate (PBAT). This study presents a comprehensive investigation into the development of multifunctional, biodegradable active films by incorporating diverse bioactive additives—specifically nisin, curcumin, zinc oxide (ZnO) nanoparticles, and various essential oils (tea tree, lemongrass, eucalyptus, and clove)—into PLA/PBAT blends (Ecovio). The structural, morphological, barrier, mechanical, thermal, optical, and biodegradation properties of the resulting composite films were systematically characterized. The synergistic integration of these functional additives successfully realized the concept of "smart" packaging. Curcumin served as both an antioxidant and a sensitive pH indicator, changing color from yellow to orange during food spoilage. Nisin provided targeted antimicrobial efficacy against gram-positive bacteria, while essential oils, particularly clove oil, exhibited broad-spectrum antibacterial and antifungal activity while simultaneously increasing film hydrophobicity. Furthermore, ZnO nanoparticles acted as a robust UV barrier and structural reinforcing agent, significantly enhancing the mechanical strength and barrier performance of the polymer matrix. The results demonstrate that rational optimization of additive concentrations allows for the tailoring of eco-friendly films with enhanced functional properties without compromising their inherent biodegradability. Ultimately, these advanced PLA/PBAT-based active films offer a highly efficient, biocompatible, and environmentally sustainable alternative to conventional petrochemical packaging materials.

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Keywords: polylactic acid, polybutylene adipate terephthalate, biodegradable packaging

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Polymer clay composite materials as a drug carriers and sorbents**M.M. Beisebekov^{1*}, S.K. Kabdrakhmanova², Esbol Shaimardan¹, A.D. Kukhareva², Aryp Kadiran²**¹*Scientific Center of Composite Materials, Almaty, Kazakhstan*²*Satbayev University, Almaty, Kazakhstan***Abstract**

The functionalization of various adsorbents for the removal of heavy metal ions and ionic surfactants from wastewater has received great research interest in recent years due to the advantages of achieving high efficiency and good selectivity. The environmental pollution from toxic heavy metals is one of the dangerous problems in many densely populated cities around the world. Another very important global pollution problem in these days is the increasing in surfactants in wastewater. Bentonite clays are widespread in nature and well known for its lamellar structure, large surface area and anionic charge. Due to its excellent surface properties bentonites are used as a base for hybrid nanomaterials. The combination of polymers containing functional groups and inorganic substances such as porous silica and zeolites produces a highly effective material. Also, composition of bentonite includes various microelements, so it has high adsorption and ion-exchange properties, which made its using promising for medical purposes. Currently, scientists pay special attention to the use of bentonites as an antiseptic matrix in the development of dressings for the treatment of external injuries, as well as as a drug carrier by obtaining nanobentonites through preliminary modification. The chemical composition and practical application of most deposits have not been fully studied, which indicates the availability of sufficient raw materials for the development of composite materials based on bentonite clay. In this regard, the physical and chemical properties of natural bentonite clays were studied. The phase structure of bentonite was studied by X-ray diffraction, the chemical structure by an infrared spectrometer (IR), the surface morphology by a scanning electron microscope (SEM), the surface area and pore sizes by the BET method, the initial zeta potentials and particle size were studied by the Zetasizer device. From the results obtained, it was known that bentonite clay is a type of montmorillonite. It has been established that the average size of bentonite particles ranges from 955 nm to 2 microns. This showed that bentonite from the Orta Tentek deposit has great potential for use in the preparation of sorbents, also can be used in pharmaceuticals and biomedicine. Also, intercalated bentonite clay is capable of capturing cationic surfactants and heavy metal ions through electrostatic interactions, which indicates the possibility of its use as an adsorbent of cationic surfactants and heavy metal ions for wastewater treatment. Hence, in this study, chemically cross-linked composite gels based on bentonite clay from Orta Tentek and Tagan deposit (Kazakhstan Republic) and nonionic polymers, i.e., poly(hydroxyethylacrylate) and poly(acrylamide), were polymerized in situ after preliminary intercalation of monomers in an aqueous suspension of bentonite clays.

By means of cryo-scanning electron microscopy, it was shown that bentonite clay is well incorporated into the gel network structure with pore sizes up to 2 μm . The intercalated bentonite clay can adsorb cationic surfactants as well as heavy metal ions due to electrostatic interactions. Conductometric and surface tension measurements indicate not only the adsorption of surfactants and heavy metals inside the hydrogel, but also the displacement of the critical micellization concentration (CMC) of the surfactants.

Keywords: bentonite, physical and chemical analysis, waste water, medicine, polymer composition materials.

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Effect of Hybrid Castor Nutshell Particle and Pineapple Leaf Fibre Reinforcement Loading on the Creep Performance of Epoxy Composites

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Abstract

The increasing demand for sustainable and lightweight engineering materials has stimulated interest in natural fibre-reinforced polymer composites as alternatives to conventional synthetic materials. However, the long-term creep behaviour of epoxy composites containing hybrid natural reinforcements, particularly castor nutshell (CNS) particles and pineapple leaf fibre (PALF), remains insufficiently understood. This study therefore investigated the effect of hybrid CNS particle/PALF loading on the creep behaviour, viscoelastic response, and microstructural characteristics of epoxy composites, with the aim of identifying an optimum reinforcement loading for improved long-term dimensional stability. Epoxy composites containing 0 wt% (control), 5 wt%, 10 wt%, 15 wt%, and 20 wt% CNS/PALF hybrid reinforcement were fabricated using the hand lay-up technique. Their creep behaviour under a constant load at 100 °C was evaluated using Dynamic Mechanical Analysis (DMA), while Scanning Electron Microscopy (SEM) was employed to examine the microstructural features and reinforcement-matrix interaction. The results showed that creep deformation was strongly influenced by the hybrid reinforcement loading. The 5 wt% CNS/PALF composite exhibited the lowest creep deformation and the highest dimensional stability among the investigated formulations. This superior performance was attributed to relatively uniform reinforcement dispersion, improved filler-matrix adhesion, and more effective stress transfer within the composite. In contrast, increasing the hybrid reinforcement content above 5 wt% promoted localized particle agglomeration and weaker interfacial bonding, which increased polymer chain mobility and consequently resulted in greater creep deformation. SEM observations supported the DMA results by demonstrating that reinforcement distribution, interfacial bonding, and microstructural integrity were closely associated with the observed viscoelastic and creep responses. The findings establish that hybrid reinforcement loading is a critical parameter in controlling the long-term mechanical stability of CNS/PALF-reinforced epoxy composites, with 5 wt% identified as the optimum loading under the conditions investigated. The study contributes to the development of sustainable, lightweight, and creep-resistant polymer composites by demonstrating how agricultural waste-derived CNS particles and PALF can be effectively combined to improve the long-term performance of epoxy-based materials for potential lightweight structural applications.

Keywords: Castor nutshell particles, Pineapple leaf fibre, Hybrid epoxy composites, Creep behaviour, Dynamic mechanical analysis.

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Comparative Life Cycle Assessment of Li-ion Cathode Electrodes: Transitioning from PVDF to Poly (Ionic Liquid) Binders

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Abstract

Although binders constitute a small percentage of the overall electrode composition, they play a critical role in lithium-based batteries. Polyvinylidene fluoride (PVDF) is a popular commercial binder that can effectively disperse inorganic particles in organic solvents, while polyionic liquids are another class of binder formulations that consist of ionic liquids in a polymer structure. PDADMA-DEP is known as one of the widely studied PILs that has a high potential for implementation in binders. However, the environmental impact assessment of their production chain is still lacking. In this study, we analysed the life cycle assessment (LCA) of PVDF and PDADMA-based cathodes used as binders in lithium-ion batteries. To do this, LCA inventory data of the synthesis route of PVDF and PDADMA-DEP were collected from the literature. The LCA was performed in two scenarios, first we analysed both binders in isolation and the second scenario was their combination in the cathode. In the separation case, PDADMA-DEP showed better environmental performance compared to PVDF, except for the two categories of ozone layer depletion and freshwater aquatic toxicity in which PVDF showed lower impacts of 1% and 41%, respectively. Secondly, the binders were encapsulated with cathodes and their LCA was analysed together. According to the component contribution of cathode the Nickel Manganese Cobalt (NMC) showed a dominant role across most of the categories such as resource depletion and global environmental impact, air pollution and ecosystem as well as toxicity effect, apart from the marine aquatic ecotoxicity and ozone layer depletion where PVDF and PDADMA-DEP showed higher impacts than NMC, respectively. According to the conducted comparative analysis, PDADMA-DEP outperformed PVDF-based cathodes in the majority of categories other than ozone layer depletion, fresh water aquatic ecotoxicity and acidification. The process contribution analysis attributed the higher environmental impact of PDADMA-DEP on ozone layer depletion to the production of chloroform in the synthesis step. While for freshwater aquatic ecotoxicity, this was due to the production of nickel sulfate followed by cobalt production and hazardous waste incineration, which was slightly higher for PDADMA-DEP than for PVDF. In the acidification category, heavy industrial facilities were shown to be the main cause, and the justification for this slight increase was attributed to electro-mixing synthesis loops during the formulation of the polyionic liquid. The results of this study indicate that PDADMA-DEP cannot be considered as a green binder, while it eliminates the hazards of fluoropolymers and contributes to terrestrial and marine aquatic ecosystems, but its upstream chemical pathways cause a strong charge transfer effect in the stratosphere, freshwater and acidification categories.

Keywords: Life cycle assessment, Environmental impact assessment, Cathodes, Binders, Poly ionic liquids, PVDF

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PREPARATION OF AN ANTIBACTERIAL NANOCOMPOSITE BASED ON MODIFIED CELLULOSE DERIVED FROM AGRICULTURAL WASTE

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The growing demand for sustainable functional materials has stimulated the development of cellulose-based nanocomposites from renewable agricultural resources. In this study, an antibacterial nanocomposite was prepared using modified cellulose derived from corn husk agricultural waste. Microcrystalline cellulose (MCC) and cellulose nanofibers (CNF) obtained from corn husk were incorporated into an oxidized corn starch matrix with copper nanoparticles (CuNPs) to fabricate a biodegradable nanocomposite with enhanced mechanical and antibacterial properties.

The structure and physicochemical properties of the prepared nanocomposite were characterized using Fourier-transform infrared spectroscopy, X-ray diffraction, scanning electron microscopy, and thermogravimetric analysis. The effects of MCC, CNF, and CuNPs on the mechanical performance and antibacterial activity of the nanocomposite were systematically evaluated.

The developed nanocomposite exhibited enhanced mechanical strength and pronounced antibacterial activity owing to the synergistic effect of modified cellulose and CuNPs. The combination of renewable cellulose-based reinforcement and an oxidized corn starch matrix resulted in an environmentally friendly material with improved functional performance and promising potential for sustainable bio-based applications.

This study demonstrates an effective strategy for the valorization of corn husk agricultural waste through the production of high-value antibacterial cellulose-based nanocomposites and contributes to the development of sustainable materials from renewable biomass.

Keywords: modified cellulose; corn husk; microcrystalline cellulose; cellulose nanofibers; oxidized corn starch; copper nanoparticles; antibacterial nanocomposite.

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FIRST-PRINCIPLES SCREENING OF RARE-EARTH METAL ATOMS ANCHORED ON HETEROATOM-MODIFIED GRAPHENE

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Abstract

The stable immobilization of isolated rare-earth metal atoms on carbon supports is important for developing atom-efficient catalysts, selective sorbents, and functional electronic materials. However, pristine graphene interacts weakly with many metal atoms, which can promote surface migration and clustering. This ongoing study tests the hypothesis that heteroatom-vacancy pairs create chemically distinct coordination microenvironments that can stabilize individual rare-earth atoms and systematically tune their charge state. A spin-polarized density functional theory screening is therefore proposed for Sc, Y, La, and Ce anchored on pristine graphene and on graphene modified with B, N, P, and S. Periodic supercells containing substitutional heteroatoms and heteroatom-vacancy sites are constructed with a vacuum region of at least 15 Å. Geometry optimization is performed using the PBE exchange-correlation functional with D3 dispersion correction, supplemented by a DFT+U sensitivity test for localized Ce 4f states. Top, bridge, hollow, and defect-centered initial positions are examined for every metal-support pair. The working expectation is that pristine graphene will provide comparatively weak and nonselective binding, whereas defect-associated dopants will suppress metal migration through stronger local coordination. Nitrogen sites are expected to promote compact metal-N/C bonding and orbital hybridization; boron should enhance electron-deficient polarization; and the larger, more polarizable P- and S-containing sites may better accommodate La and Ce. These proposed trends will be evaluated using adsorption energy, stability relative to the metal cohesive energy, equilibrium metal-support distance, Bader charge transfer, work-function variation, magnetic moment, and total and projected densities of states. The most stable candidates will subsequently be examined using HSE06 and spin-orbit-coupling calculations, ELF/COHP bonding analysis, and finite-temperature ab initio molecular dynamics. The expected outcome is a metal-dopant selection map that separates the structural contribution of a vacancy from the chemical contribution of the neighboring heteroatom and relates both factors to metal size, valence configuration, and 4f-state localization. Quantitative adsorption, charge-transfer, and electronic-structure results will be presented at the conference. The study is expected to provide rational design criteria for rare-earth single-atom graphene materials with improved resistance to agglomeration and tunable electronic and magnetic properties for catalysis, sensing, energy conversion, and selective separation.

Keywords: rare-earth metals; heteroatom-modified graphene; density functional theory; single-atom anchoring; charge transfer; electronic structure

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DEVELOPMENT AND STUDY OF COMPOSITE ELECTRODES BASED ON MULTI-WALLED CARBON NANOTUBES MODIFIED WITH MANGANESE OXIDE FOR USE IN HIGH-PERFORMANCE SUPERCAPACITORS

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Abstract

This study presents the development and comprehensive characterization of manganese oxide-modified multi-walled carbon nanotube (MWCNT)-based composite electrodes for high-performance supercapacitor applications. The research focuses on evaluating the structural, morphological, mechanical, thermal, porous, spectroscopic, and electrochemical characteristics of the developed composite materials and assessing the effect of MnO₂ incorporation on their functional performance. The fabricated composite electrodes were investigated using zeta potential analysis, scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (SEM-EDS), tensile testing, thermogravimetric analysis (TGA), Brunauer–Emmett–Teller (BET) surface area analysis, Raman spectroscopy, and cyclic voltammetry.

The results demonstrate that the incorporation of MnO₂ preserves the interconnected fibrous structure of the MWCNT framework while providing a favorable combination of mechanical and electrochemical properties. Elemental analysis confirmed the presence and distribution of manganese within the composite structure. The materials exhibited a well-developed mesoporous architecture, with a specific surface area of 657.89 m² g⁻¹, a total pore volume of 3.55 cm³ g⁻¹, and an average pore diameter of 21.60 nm. Raman spectroscopic analysis confirmed the characteristic structural features of MWCNTs together with vibrational signatures associated with Mn–O bonding, supporting the formation of the composite material.

Electrochemical measurements revealed a substantial enhancement in current response following MnO₂ modification, indicating an increased contribution from pseudocapacitive charge-storage processes. The composite electrode demonstrated approximately 98% retention of its initial capacitance after 500 charge–discharge cycles, confirming good electrochemical stability. Overall, the findings indicate that MWCNT/MnO₂ composite electrodes possess a favorable combination of structural integrity, porous characteristics, electrical conductivity, and electrochemical stability, highlighting their potential for application in advanced high-performance supercapacitor systems.

Keywords: multi-walled carbon nanotubes; manganese dioxide; composite electrode; supercapacitor; cyclic stability.

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Antibacterial Properties of a Polymer Nanocomposite Material Based on Bentonite Clay and Silver Nanoparticles

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Abstract

In this study, bentonite clays from the Tagan deposit in Kazakhstan were modified with water according to the D. P. Salo method, and their physicochemical properties were comprehensively investigated. Silver nanoparticles (AgNPs), synthesized via a green synthesis approach using *S. glauca* plant extract, were intercalated into the water-activated clay, followed by the fabrication of a polymer nanocomposite material based on poly(vinyl alcohol) (PVA) and cellulose nanofibers (CNF).

The structural, morphological, and textural characteristics of the samples were investigated using X-ray fluorescence (XRF), X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), Brunauer–Emmett–Teller (BET) surface area analysis, thermogravimetric/differential thermal analysis (TGA/DTA), and zeta-potential measurements. The results demonstrated that water activation increased the specific surface area, porosity, and dispersibility of bentonite while preserving its crystalline structure. The effective intercalation of silver nanoparticles into the interlayer space of bentonite was confirmed by UV–Vis spectroscopy.

The resulting nanocomposites exhibited pronounced antibacterial activity against *Escherichia coli* and *Staphylococcus saprophyticus*, while their hemolytic activity was within the acceptable safety limits established for biomedical materials. Overall, the findings demonstrate that the developed polymer–nanoclay composite is a promising material for wound dressing applications and other biomedical uses.

Keywords: bentonite clay, wound healing, composite material, silver nanoparticles, green synthesis.

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DEVELOPMENT OF AN OPTICALLY TRANSPARENT ANTI-FOGGING FILM BASED ON CARBOXYMETHYL CELLULOSE AND SILICON DIOXIDE

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Fogging of optical surfaces caused by water vapor condensation leads to reduced light transmission and deterioration of the performance characteristics of glass and optical devices. The aim of this study was to develop an optically transparent anti-fogging film based on carboxymethyl cellulose and nanosized silicon dioxide obtained from rice husk.

Aqueous solutions of carboxymethyl cellulose and polyacrylic acid were used to prepare the film-forming compositions. Fe³⁺ ions were employed as a crosslinking agent. To regulate the surface and moisture-protective properties of the coating, nanosized SiO₂ modified with hexadecyltrimethoxysilane was incorporated into the polymer matrix. The silicon dioxide content in the composition was varied from 0.1 to 0.5 wt.%.

It was established that the stability of the film-forming compositions depended on the acidity of the medium. In an acidic medium, disruption of the system homogeneity was observed, whereas at pH values close to neutral, more stable film coatings were formed. The structure and physicochemical properties of the initial components and the resulting films were investigated using Fourier-transform infrared spectroscopy, scanning electron microscopy, X-ray fluorescence analysis, and thermogravimetric analysis.

The developed compositions have potential for the preparation of optically transparent moisture-protective coatings capable of preventing the fogging of glass and optical device surfaces.

Keywords: anti-fogging film, carboxymethyl cellulose, silicon dioxide, rice husk, hydrophobization, optically transparent coating.

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Tailoring Multifunctional Properties of Ferrite Nanomaterials through Silver Incorporation

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Abstract

Silver incorporation provides an effective strategy for tailoring the structural, magnetic, electrical, and dielectric properties of ferrite nanomaterials. In this work, two complementary silver-containing ferrite systems, $\text{Ag}_x\text{Co}_{1-x}\text{Fe}_2\text{O}_4$, ($x=0, 0.02, 0.04$, and 0.06) and Ag FeO_2 , were systematically investigated using a facile sol–gel auto-combustion route. For $\text{Ag}_x\text{Co}_{1-x}\text{Fe}_2\text{O}_4$, silver incorporation preserves the cubic spinel structure while modifying the microstructural, magnetic, and electrical properties. The crystallite size increases from 71.06 to 76.92 nm with increasing Ag content, whereas the saturation magnetization decreases from 45.10 to 40.32 emu g^{-1} . This reduction is attributed to the substitution of magnetic Co^{2+} ions by diamagnetic Ag^+ ions and the consequent weakening of A-B superexchange interactions. The electrical response is dominated by grain-boundary conduction and non-Debye relaxation, with thermally activated charge transport characterized by activation energies in the range of 0.28–0.42 eV. In contrast, AgFeO_2 nanoparticles exhibit a significantly smaller crystallite size of 8.36 nm, with an average TEM grain of 25.32 nm. The nanoparticles demonstrate soft-ferromagnetic behaviour, exhibiting a saturation magnetization of 24.92 emu g^{-1} , remanent magnetization of 4.67 emu g^{-1} , and nearly zero coercivity. Their electrical conductivity increases from approximately 10^{-7} to 10^{-4} S m^{-1} with increasing temperature, accompanied by a low activation energy of 0.261 eV, indicating thermally activated hopping transport. The dielectric response is governed by strong Maxwell–Wagner interfacial polarization, with dielectric permittivity reaching 10^2 – 10^3 at low frequencies and decreasing to 10^1 – 10^2 at higher frequencies. Overall, these findings demonstrate that silver incorporation, either as a dopant in spinel ferrite or as a constituent of a distinct ferrite phase, provides a versatile approach for tuning the structure–magnetism–charge transport–dielectric relationships of ferrite nanomaterials. The resulting multifunctional properties highlight their potential for high-frequency electronics, dielectric devices, sensors, and energy-storage applications. Furthermore, these findings support SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry, Innovation and Infrastructure) by contributing to the development of advanced functional materials for sustainable energy and emerging technological applications.

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Effect Of Filler Type On The Properties Of Methylcellulose Composite Seed Coatings Containing Fusicoccin

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Abstract

The development of biopolymer-based seed coatings represents a promising strategy for improving the efficiency of pre-sowing treatments and enabling the controlled delivery of biologically active compounds. In the present study, methylcellulose-based composite coatings containing fusicoccin were investigated with particular emphasis on the role of fillers in determining the structural and functional properties of the coating system. Talc and potato starch were selected as fillers of different physicochemical nature to evaluate their effects on coating uniformity, surface integrity, moisture response, storage stability, and the release behavior of the active compound. The coatings were applied to soybean seeds under controlled laboratory conditions, followed by an assessment of their structural and technological characteristics. The preliminary findings showed that filler type influenced the structure and functional behavior of the methylcellulose matrix. Talc-containing formulations promoted the formation of a denser and more stable coating layer, whereas starch-containing systems exhibited greater moisture sensitivity and more rapid structural changes. These results indicate that the properties of methylcellulose composite coatings can be modulated by varying the type and concentration of the filler. Such control may facilitate the development of coating formulations with tailored hydration, degradation, and fusicoccin release profiles in accordance with the specific requirements of pre-sowing seed treatment. The findings support the potential application of methylcellulose-based composite coatings as delivery systems for natural plant growth regulators in sustainable agricultural technologies.

Keywords: methylcellulose, fusicoccin, seed coating, filler, controlled release, agriculture

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Biological Efficiency of a Methylcellulose–Talc Coating Containing Fusicoccin for Pre-Sowing Treatment of Soybean Seeds

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Abstract

Biopolymer seed coatings can serve not only as protective layers but also as carriers for the localized delivery of plant growth regulators during the early stages of plant development. This study examines the biological efficiency of a methylcellulose–talc composite coating containing fusicoccin for the pre-sowing treatment of soybean seeds. The coating was evaluated based on seed germination, early seedling growth, uniformity of seedling development, and overall plant condition.

Particular attention was paid to comparing direct seed treatment with a fusicoccin solution and the application of fusicoccin incorporated into the polymer coating, as these approaches may differ in the rate and uniformity of active compound delivery to the seed surface. The influence of fusicoccin concentration and the potential risk of localized overdosing were also considered.

Preliminary observations indicated that the methylcellulose–talc matrix provided a more gradual interaction between the active compound and the seed, resulting in a more uniform physiological response during germination. Under the selected experimental conditions, the coating did not create any visible barriers to seed water uptake or seedling emergence. The results suggest that the biological effect is determined by the combined influence of the concentration of the active compound, the composition of the coating, and the method of its application.

The developed coating system may be used in further studies of seed germination, early plant development, and plant tolerance to adverse environmental conditions. Methylcellulose–talc coatings containing natural plant growth regulators represent a promising approach for improving pre-sowing seed treatment technologies and developing resource-efficient agricultural practices.

Keywords: methylcellulose; fusicoccin; soybean; seed coating; germination; plant growth regulators.

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Environmental Assessment of Wastewater from a Poultry Farm and the Prospects for Its Post-Treatment Using a Hydrogel Derived from Rice Production Waste

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Abstract

Poultry farms and poultry processing plants generate significant volumes of wastewater with a complex, multi-component composition, containing organic matter, fats, suspended particles, and nitrogen and phosphorus compounds. The poultry farm in Almaty region under study utilizes a treatment system that includes mechanical removal of large particles and subsequent physicochemical treatment using reagents. This technology significantly reduces the initial contamination of wastewater; however, after primary treatment, residual organic and nutrient loads remain, which require further assessment.

The aim of this study is to assess the ecological state of wastewater from a poultry farm before and after the existing technology of physical and chemical treatment of wastewater, as well as to analyze the prospects of using a hydrogel obtained from rice production waste as a comprehensive post-treatment of wastewater.

This study conducted a comprehensive assessment of wastewater conditions and examined physicochemical and environmentally significant parameters, including BOD₅, COD, suspended solids, ammonia nitrogen, nitrites, nitrates, total nitrogen, phosphates, total phosphorus, pH, and mineralization. Particular attention was paid to determining the nature of residual wastewater contaminants and evaluating the effectiveness of existing treatment technologies. Based on the data obtained, the potential for using a hydrogel derived from rice production waste is discussed. The proposed approach is considered as an additional stage of wastewater post-treatment, aimed at reducing residual contaminants and improving the quality of the treated water.

The obtained results will allow us to study the feasibility of reusing treated water in agricultural irrigation. This approach is consistent with the principles of resource conservation and closed water management; however, additional assessment of the agrochemical, sanitary, and environmental safety of the water is currently required. Uzbekistan's experience in using wastewater from poultry farms for crop irrigation demonstrates the potential of this approach and can serve as a basis for further research.

Keywords: Physical and chemical wastewater treatment, post-treatment, hydrogel, water reuse, irrigation, environmental impact.

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Cellulose-Based Hydrogel Soil Conditioner: Synthesis, Characterization, and Agricultural Applications

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Abstract

According to statistical data, 70% of the world's freshwater is consumed by the agro-industrial sector. Scientists estimate that the global population will reach 9 billion within the next 30 years. This, in turn, will require an increase in agricultural productivity by approximately 50% [1,2]. It is well known that this problem is also directly relevant to our country. Since increasing crop yields in arid and desert-prone regions is directly linked to water availability, the development and application of innovative technologies and materials are of great importance.

In this study, cellulose microcrystals (CMC) were extracted from agricultural crop residues using an environmentally friendly “soft” method to address the problem of soil desertification. Subsequently, carboxymethyl cellulose (CMC) and hydroxyethyl cellulose (HEC) were obtained from the extracted cellulose microcrystals. The optimal composition and ratio of CMC, CMC/HEC, and HEC for hydrogel formation were then determined. To impart mechanical strength, fertilizing properties, and stimulant activity to the hydrogel, local agrominerals (Tagan and Kalzhat) were immobilized in situ. As a result, a biodegradable, temperature-responsive hydrogel was developed that stimulates plant growth, acts as a fertilizer and growth promoter, absorbs and retains moisture, and regulates moisture release in response to changes in soil temperature.

Keywords: biodegradable materials, soil conditioner, biocoatings, antibacterial coating, fruit and berry crops, agro-industrial complex

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Metal–Organic Coordination Polymer of Cd(II) with Imidazole

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Abstract

A metal–organic coordination polymer of Cd(II) with imidazole, $\text{Cd}(\text{C}_3\text{H}_4\text{N}_2)_{62}$ (**I**), was synthesized by the solubility method in a water-saturated medium at 30 °C. The compound was characterized by elemental (CHN) analysis, thermogravimetric analysis (TGA), X-ray diffraction (XRD), and infrared (IR) spectroscopy.

A study of the thermal properties of complex **I** showed that the compound gradually loses mass upon heating due to the removal of weakly bound guest water molecules, with a weight loss of 3.3%. Further heating in the temperature range of 145–290 °C causes a pronounced endothermic effect accompanied by a sharp mass loss of 57.3%, which is associated with the removal of six coordinated imidazole molecules (theoretically calculated value: 58.4% of the total mass). In the temperature range of 290–525 °C, the thermolysis products burn out. The final product of thermal degradation, with partial sublimation, is cadmium oxide.

IR spectroscopy showed that imidazole in compound **I** acts as an N-donor ligand, coordinating to the metal ion through the pyridine nitrogen atom of the imidazole ring. The observed shifts in the characteristic stretching vibrations of the heterocyclic ring were found in the region of 1450–1580 cm^{-1} and at 770 cm^{-1} . A broad absorption band in the range of 3200–2600 cm^{-1} indicates the presence of a well-developed hydrogen-bonding system, which ensures the formation of the polymeric structure. The coordination polyhedron is of the octahedral type.

X-ray diffraction analysis revealed that complex **I** crystallizes in the trigonal crystal system with the **R-3** space group. Complex **I** consists of discrete chains formed by complex cations and anions packed into a hexagonal unit cell. The packing of the structural fragments of the complex cation and anion in compound **I** is stabilized by the presence of intermolecular hydrogen bonds between the oxygen atoms of the nitrate ion and the pyrrole proton of imidazole ($\text{N-H}\cdots\text{O}$), forming a supramolecular polymer network.

Keywords: cadmium(II), imidazole, coordination polymer, polymer structure, X-ray diffraction analysis, thermal analysis.

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SYNTHESIS AND PHYSICOCHEMICAL CHARACTERIZATION OF SUCCINIC ACID-MODIFIED HUMIC ACID FROM CHICKEN MANURE FUNCTIONALIZED WITH SILVER AND COPPER COMPLEXES

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Abstract

In this study, a comprehensive approach was developed for the synthesis and physicochemical characterization of metal–polymer nanocomposites based on humic acid obtained from chicken manure, modified with succinic acid, and functionalized with silver and copper complexes. The modification of the humic matrix with succinic acid resulted in structural transformation and changes in the functional properties of the obtained materials. The synthesized systems were characterized using XRF, SEM–EDS, XRD, DLS, ELS, and TGA/DSC techniques to investigate their elemental composition, structural features, colloidal behavior, and thermal properties. The incorporation of silver contributed to the formation of stable dispersed metal-containing systems, whereas copper ions acted as coordination centers promoting interactions and cross-linking within the humic matrix. The results demonstrated that the nature of the incorporated metal plays a key role in determining the structural organization, electrokinetic stability, and thermal characteristics of the developed nanocomposites. The obtained humic acid-based metal–polymer systems demonstrate promising potential for sustainable functional materials, environmental applications, and advanced antibacterial and catalytic technologies.

Keywords: humic acid, succinic acid, metal–polymer nanocomposite, silver nanoparticles, copper complexes, sustainable materials

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Sustainable Production of Humic Acid from Poultry Manure Through Optimized Alkaline Extraction

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Abstract

Poultry manure is an abundant agricultural by-product and a promising renewable source of humic substances with potential applications in sustainable agriculture, environmental remediation, and functional biomaterials. This study presents an optimized alkaline extraction approach for producing humic acid from poultry manure and evaluates the structural and physicochemical characteristics of the obtained product. Humic acid was isolated using potassium hydroxide solutions (0.5 and 1.0 M) at solid-to-liquid ratios of 1:8, 1:10, 1:12, and 1:14, followed by acid precipitation with 6 M HCl, centrifugation, washing, and drying. Optimization of the extraction process demonstrated that the highest humic acid yield was achieved using 1.0 M KOH at a 1:10 solid-to-liquid ratio, establishing these conditions as the most efficient for humic substance recovery from poultry manure. X-ray fluorescence analysis confirmed the high purity of the extracted material, revealing an organic phase content of 97.4 wt.% together with minor amounts of K, Cl, S, P, Ca, Fe, Si, Al, and Cu. Fourier-transform infrared spectroscopy identified the characteristic functional groups of humic substances, including hydroxyl, aliphatic, carbonyl, and aromatic oxygen-containing moieties, confirming preservation of the native humic structure during extraction. The obtained results demonstrate that poultry manure is an efficient renewable feedstock for producing high-purity humic acid and that the proposed extraction protocol provides a simple, scalable, and environmentally friendly route for obtaining humic substances suitable for subsequent applications in organic fertilizers, plant biostimulants, metal-complex synthesis, and advanced bio-based functional materials.

Keywords: poultry manure, humic acid, alkaline extraction, organic waste recycling, sustainable agriculture.

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Synthesis and Structural Characterization of an OT-AgNPs–CMC Polymer–Clay Composite Based on Orta Tentek Bentonite

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Composite materials based on natural polymers and mineral fillers have attracted considerable attention due to their high adsorption capacity, structural stability, and versatile functional properties. The combination of natural bentonite with biopolymers enables the development of environmentally friendly and multifunctional composites. Furthermore, silver nanoparticles (AgNPs) are widely employed as functional components because of their excellent antimicrobial activity.

The aim of this study was to synthesize a polymer–clay composite based on natural bentonite obtained from the Orta Tentek (OT) deposit located in the Zhetysay Region of the Republic of Kazakhstan, carboxymethyl cellulose (CMC) synthesized from rice straw, and silver nanoparticles (AgNPs), and to investigate its structural characteristics.

In this study, Orta Tentek bentonite was used as the mineral filler. Owing to its layered structure, high specific surface area, and excellent adsorption capacity, natural bentonite contributes to the stabilization of the polymer composite structure. The selection of Orta Tentek bentonite was based on its natural origin, local availability, and the presence of montmorillonite as the dominant mineral phase. Carboxymethyl cellulose (CMC), synthesized from rice straw, was employed as the polymer matrix of the composite. As an environmentally friendly and biocompatible polymer, CMC ensures the homogeneous dispersion of the composite components. Silver nanoparticles (AgNPs) were incorporated into the composite to impart antibacterial properties and enhance its functional performance. The OT–AgNPs–CMC composite was synthesized by incorporating AgNPs and natural bentonite into the CMC matrix.

The structural and physicochemical properties of the synthesized composite were characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Scanning Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy (SEM–EDS), Thermogravimetric Analysis coupled with Differential Scanning Calorimetry (TGA–DSC), and low-temperature nitrogen adsorption analysis. The FTIR spectra confirmed the interactions between the functional groups of the composite constituents. XRD analysis demonstrated the successful formation of crystalline silver nanoparticles while confirming the preservation of the mineralogical structure of bentonite. SEM–EDS observations revealed the homogeneous distribution of AgNPs and bentonite particles throughout the CMC matrix and confirmed the presence of O, Si, Al, and Ag as the principal elements of the composite. The TGA–DSC results indicated that the incorporation of bentonite and silver nanoparticles improved the thermal stability of the polymer composite.

Overall, the characterization results demonstrate effective interactions among the constituent components within the OT–AgNPs–CMC composite, leading to the formation of a stable polymer–clay nanocomposite structure. The synthesized material exhibits considerable potential for application as an environmentally friendly adsorbent, antibacterial coating, and multifunctional polymer composite for environmental and advanced material science applications.

Keywords: silver nanoparticles, carboxymethyl cellulose, bentonite, montmorillonite, Orta Tentek, polymer nanocomposite, adsorption material, antimicrobial composite.

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Abstract

Cellulose is the most abundant naturally occurring polysaccharide and a promising renewable biopolymer widely used in the development of environmentally friendly materials [1]. Of particular interest are carboxymethyl cellulose (CMC), a cellulose derivative, and cellulose nanofibrils (CNFs), a nanostructured form of cellulose. These materials exhibit excellent mechanical properties, biocompatibility, and considerable potential for functional modification [1,2]. Owing to these properties, CMC and CNFs are widely used in hydrogels, biodegradable packaging, composite materials, membranes, and drug-delivery systems [2,3]. The production of cellulose-based materials from lignocellulosic biomass and agro-industrial waste contributes to the development of a circular economy and is consistent with the principles of sustainable development [1,3].

In this study, two approaches to CNF production were investigated to determine the optimal preparation method. In the first approach, microcrystalline cellulose (MCC) isolated from soybean husks was treated with formic acid at a solid-to-liquid ratio of 1:30 for 6 h at 95 °C. Formic acid concentrations of 88%, 70%, and 60% were evaluated to identify the optimal concentration. In the second approach, CNFs were produced directly from soybean husks by treatment with performic acid (PFA) at a solid-to-liquid ratio of 1:100 for 12 h at 50 °C. The effect of the formic acid concentration on this process was also evaluated. The resulting samples were comprehensively characterized using scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and zeta-potential measurements.

CMC was synthesized from two types of starting material: MCC isolated from soybean husks and MCC obtained from sunflower husks. The optimal reagent concentrations, reaction temperature, and treatment duration were established. Product yields and degrees of substitution were determined. FTIR analysis confirmed the presence of absorption bands characteristic of the carboxymethyl groups in CMC. The morphology, thermal properties, and crystalline structure of the obtained samples were further evaluated using SEM, TGA, DSC, and X-ray diffraction (XRD).

Keywords: cellulose; cellulose derivatives; carboxymethyl cellulose (CMC); cellulose nanofibrils (CNFs); agro-industrial waste.

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Preventing Thermal Degradation to Enhance Performance of UHMWPE Thermal Spray Coatings in Industrial Applications

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Abstract

Transition from toxic thermosets to thermoplastics in the formation of anti-corrosion coatings is of critical importance for industrial ecology. However, thermal spraying of thermoplastics remains limited by low throughput, particularly in the case of high-molecular-weight polymers. The present study reveals a key process trade-off: high burner thermal output induces polymer degradation, whereas reduced thermal output results in porosity due to incomplete melting. To address this problem, a mathematical model (digital twin) has been developed, integrating TGA and DSC data with the thermal dynamics of the spraying process. The novelty of the approach resides in establishing a functional relationship between particle melting dynamics in the jet plume and the kinetics of film formation. The model provided theoretical substantiation for expanding the temperature-time spraying window. Based on the obtained results, modernized equipment was developed to ensure the required particle heating interval, thereby enabling a three-fold increase in coating deposition efficiency without thermal degradation or pore formation.

Keywords: thermal spray coatings, mathematical modeling, melting dynamics, TGA and DSC, thermal degradation, anti-corrosion protection.

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Development of MCC-AAm Hydrogel for Moisture Regulation of Bauxite Ores

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Abstract

Efficient moisture management of bauxite ores is an important challenge in the aluminum industry because excessive moisture adversely affects transportation, storage, handling, and subsequent processing by reducing material flowability and promoting agglomeration. The present study evaluates the prospects for using a biodegradable cellulose-based hydrogel (MCC-AAm-HGel) as a moisture-regulating material for bauxite ores. The hydrogel was synthesized by free-radical polymerization of acrylamide (AAm) in the presence of microcrystalline cellulose (MCC) obtained from wheat straw, using N,N'-methylenebisacrylamide (MBA) as a crosslinking agent and ammonium persulfate (APS) as an initiator. The influence of crosslinker concentration on the swelling behavior was investigated to optimize the hydrogel structure. The prepared materials demonstrated high water absorption capacity, with the sample containing 10 mg MBA exhibiting the highest equilibrium swelling ratio exceeding 110 gg⁻¹ under neutral conditions. Swelling studies performed in distilled water, sodium chloride solution, ethanol, acetone, and buffer solutions confirmed the sensitivity of the hydrogel to environmental conditions and revealed maximum swelling at approximately neutral pH. The porous three-dimensional network formed by MCC reinforcement provides efficient water uptake and retention while maintaining structural stability. These properties indicate that MCC-AAm-HGel can effectively absorb excess moisture from wet bauxite during transportation and storage, thereby improving bulk material flowability and reducing operational problems associated with high moisture content. In addition, the use of renewable cellulose derived from agricultural waste enhances the environmental sustainability of the proposed material. The obtained results demonstrate that MCC-AAm-HGel is a promising biodegradable moisture-regulating material with significant potential for improving bauxite ore handling efficiency and supporting more sustainable raw material management in the aluminum industry.

Keywords: microcrystalline cellulose, hydrogel, bauxite, moisture regulation, acrylamide, swelling

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Integrated use of beet pulp for the production of valuable biopolymers and nanomaterials

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Abstract

Sugar beet production is annually accompanied by the formation of significant volumes of by-products, the main part of which is beet pulp. Currently, this type of biomass is mainly used as feedstock or remains unclaimed, which reduces the efficiency of resource use and can create environmental problems. However, due to the high content of pectin, cellulose, hemicellulose, lignin and low molecular weight carbohydrates, beet pulp is of considerable interest as a renewable raw material for the production of biopolymers and functional nanomaterials.

In this work, a comprehensive study of beet pulp was conducted in order to assess its potential as a source of valuable products. Pectin was isolated by the traditional extraction method with a yield of about 10%, after which its structure was studied using Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM). Cellulose was obtained by organosolvent treatment followed by structural characterization by the FTIR method. In addition, carbon quantum dots were synthesized hydrothermally from liquid beet pulp extracts, and their optical properties were studied using spectroscopic methods.

The results obtained indicate that beet pulp is a promising, affordable and renewable raw material for the production of biopolymers and nanostructured materials. The developed approach to the complex processing of a by-product of the sugar industry opens up the possibility of its effective use in the creation of materials for the food, pharmaceutical and medical industries, as well as for various areas of modern nanotechnology.

Keywords: sugar beet pulp, pectin, cellulose, carbon dots, nanomaterials, biomass valorization

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Cellulose-Based MOF: synthesise and characterization

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Abstract

Renewable porous materials are promising candidates for hydrogen storage because their adsorption properties can be tailored through structural and surface modification. In our previous study, cellulose/polyacrylamide aerogels derived from sunflower seed husk microcrystalline cellulose (MCC) and modified with activated carbon exhibited enhanced hydrogen uptake due to increased microporosity and specific surface area. The present work extends this approach by replacing activated carbon with Zn²⁺, Cu²⁺, Li⁺, and Mg²⁺ ions to produce coordination-active cellulose aerogels as precursors for metal–organic framework (MOF) composites.

Aerogels were synthesized using the previously optimized MCC/polyacrylamide cryogelation method, followed by metal-ion incorporation before freeze-drying. This approach enables uniform distribution of metal species throughout the three-dimensional cellulose network, providing coordination sites for subsequent metal–ligand assembly. Preliminary characterization indicates successful incorporation of metal ions while preserving the interconnected porous structure of the aerogels.

Current investigations using FTIR, XRD, SEM, BET, and hydrogen sorption measurements indicate that metal functionalization promotes structural evolution toward highly porous MOF-derived composites with improved adsorption-active surface. This strategy provides a sustainable platform for developing cellulose-supported MOF materials for hydrogen storage and related energy applications.

Keywords. Cellulose aerogel; Metal-ion functionalization; Metal–organic frameworks (MOFs); Cryogelation; Hydrogen storage; Hierarchical porosity; Renewable materials.

Acknowledgments

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PLANTS OF THE ASTERACEAE FAMILY AS A SOURCE OF NANOSTRUCTURED BIOPOLYMERS

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Abstract

The Asteraceae family is one of the largest families of flowering plants and includes many species of interest as sources of natural biopolymers. Researchers are particularly interested in the tubers of Jerusalem artichoke (*Helianthus tuberosus*) and dahlia (*Dahlia* spp.), which are valuable sources of inulin and pectin—natural biopolymers characterized by biocompatibility, biodegradability, and broad potential for chemical modification. Given the growing demand for environmentally safe and renewable materials, these plants are viewed as promising raw materials for the production of nanostructured biopolymers and functional composite materials.

The aim of this study is to analyze the potential of plants in the Asteraceae family as a source of nanostructured biopolymers and to assess the prospects for their practical application. Methods of extraction, purification, and subsequent physicochemical modification are used to obtain biopolymers from plant-based raw materials. Modern technologies make it possible to produce nanoparticles, hydrogels, nanofibers, and porous nanocomposites with a large surface area and improved performance characteristics based on inulin and other plant polysaccharides.

It has been established that nanostructured biopolymers derived from plants of the Asteraceae family possess high sorption capacity, biocompatibility, and the potential for targeted functionalization. Thanks to these properties, they can be used as sorbents for removing heavy metal ions from aqueous solutions, as carriers for biologically active substances, as components of biodegradable packaging materials, and as promising medical drug delivery systems. Of particular interest are inulin-based nanocomposite materials, which demonstrate high efficiency in the removal of Cu^{2+} , Zn^{2+} , and Pb^{2+} ions from contaminated aqueous media.

Thus, plants of the Asteraceae family are a valuable renewable source of biopolymers for the creation of next-generation nanostructured materials. The use of this plant-based raw material contributes to the development of “green” technologies, the expansion of the raw material base for the production of functional materials, and the resolution of pressing environmental challenges related to water purification and the rational use of natural resources.

Keywords: Asteraceae family, biopolymers, nanostructured materials, sorbents, heavy metals.

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Sunflower-Husk-Derived Activated Carbon as a Support for Trimetallic Pd–Cu–Fe Nanoparticles: Synthesis and Physicochemical Characterization

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The development of functional carbon-supported multimetallic materials from renewable resources is of high interest for sustainable energy and environmental applications. In this work, activated carbon from sunflower husk was prepared by chemical activation and pyrolysis and converted into porous support for trimetallic palladium-copper-iron nanoparticles. The resulting Pd-Cu-Fe/activated-carbon composite was created in situ by in situ reduction of palladium, copper, and iron precursor salts with sodium borohydride.

The physicochemical properties of the biomass-based activated carbon and trimetallic composition are investigated with X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), nitrogen adsorption-desorption measurements, and X-ray photoelectron spectroscopy (XPS). The sunflower-husk-based activated carbon exhibited a hierarchical micro-mesoporous structure with a surface area of 2118 m² g⁻¹ measured with Brunauer-Emmett-Teller and a Langmuir surface area of 2710 m² g⁻¹. The nanoscale Pd-Cu-Fe particles were successfully incorporated into the porous carbon structure, with very few particles scattered about and mostly distributed throughout the support.

The combination of a high surface area porous carbon matrix and trimetallic nanoparticles provides a promising platform for developing heterogeneous biomass-derived catalytic materials. The newly prepared Pd-Cu-Fe/activated carbon composite could be of interest for hydrogen electrocatalytic processes and other catalytic applications. Electrochemical evaluation is needed to determine its activity and suitability for the hydrogen evolution reaction in alkaline conditions.

Keywords: Trimetallic Pd–Cu–Fe catalyst; Biomass-derived activated carbon; Sunflower seed husk;

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**DESTRUCTION OF ANTIMONY SULFIDE IN AN OXIDIZING ENVIRONMENT:
MnO₂-H₂SO₄-CaCl₂, SEPARATION OF PRODUCTS FROM IMPURITIES USING A
POLYMER ION-EXCHANGE RESIN AND PRODUCTION OF ANTIMONY OXIDE**

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Abstract

This study presents the results of physicochemical modeling and experimental investigations of the decomposition of antimony sulfide in the **MnO₂-H₂SO₄-CaCl₂** oxidizing system, followed by the separation of reaction products from impurities and the production of antimony oxide. Based on thermodynamic modeling of the multicomponent heterogeneous **Sb₂S₃-MnO₂-H₂SO₄-CaCl₂** system, the equilibrium phase composition, concentration distribution of components, pH values, oxidation–reduction potential (Eh), and ionic strength of the solution were determined.

It was established that under strongly acidic conditions (pH 0.16–0.20), **antimony oxychloride (SbOCl)** is the predominant intermediate compound, which can subsequently be converted into antimony(III) oxide. The use of calcium chloride as a chlorinating agent was shown to ensure efficient chlorination of antimony compounds without the formation of toxic phosgene, while elemental sulfur and calcium sulfate are formed as by-products, thereby improving the environmental safety of the process.

A conceptual process flowsheet for antimony sulfide processing was developed, including leaching, formation of antimony citrate complexes, purification of process solutions from impurities using the **KU-2 polymeric cation-exchange resin**, followed by sorption of antimony species on the **AV-17 strongly basic polymeric anion-exchange resin**. The proposed technology provides efficient removal of impurity metals, concentration of antimony, and production of high-purity antimony oxide.

The obtained results may be applied in the development of environmentally friendly and resource-efficient technologies for the integrated processing of antimony ores and technogenic wastes.

Keywords: antimony sulfide; antimony oxide; KU-2 polymeric cation-exchange resin; AV-17 polymeric anion-exchange resin; citric acid; decomposition; ion exchange; physicochemical modeling; MnO₂-H₂SO₄-CaCl₂ oxidizing system; sorption; hydrometallurgy.

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IDENTIFICATION OF GOETHITE–HUMIC ACID–ACTIVATED CARBON NANOCOMPOSITE FORMATION BY Z-POTENTIAL ANALYSIS

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Abstract

This study examines the features of the formation of nanocomposites based on goethite (α -FeOOH), humic acids, and activated carbon. The possibility of using the ζ -potential method to identify the formation of a composite structure and to evaluate the stability of the obtained dispersed systems was investigated. It was established that changes in the surface charge serve as an informative indicator of the interactions among the nanocomposite components.

One of the pressing challenges of modern chemistry and materials science is the development of new environmentally safe sorbent materials. Compositions combining the properties of mineral, organic, and carbonaceous components are of particular interest. Nanocomposites based on goethite, humic acids, and activated carbon possess a high specific surface area, a well-developed porous structure, and a large number of active functional groups, making them promising materials for the removal of heavy metals and organic contaminants from aquatic environments [1-3]

To identify the formation process of nanocomposites based on goethite, humic acids, and activated carbon using ζ -potential measurements and to evaluate the influence of component interactions on the surface properties of the material.

The goethite–humic acid–activated carbon nanocomposite was synthesized by the *in situ* method. The surface properties of the nanocomposites were characterized using ζ -potential measurements over a wide pH range. The combined application of ζ -potential analysis with Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), and Brunauer-Emmett-Teller (BET) surface area analysis enables reliable identification of the formation of the nanocomposite structure.

The formation of the nanocomposite was accompanied by changes in the surface properties of the initial components. The active Fe–OH hydroxyl groups present on the surface of goethite promote interactions with the –OH and –COOH functional groups of humic acids, resulting in the formation of stable organo-mineral complexes. ζ -Potential analysis demonstrated changes in the surface charge characteristics following the modification of goethite with humic acids and activated carbon. The observed shift in the isoelectric point and the increase in the absolute values of the ζ -potential indicate the successful immobilization of humic acids on the surfaces of goethite and activated carbon, as well as an improvement in the stability of the dispersed system. The obtained results confirm that ζ -potential is an informative tool for monitoring the nanocomposite formation process, allowing the evaluation of not only the surface charge but also the degree of interaction among the individual components of the material. In the goethite (α -FeOOH)–humic acid (HA)–activated carbon (AC) nanocomposites, humic acids contribute to the stabilization of the particle surface, whereas the porous activated carbon provides an increased number of active sorption sites. The synergistic effect arising from the combined action of the components results in enhanced sorption performance of the material [4-6].

A functional nanocomposite based on goethite, humic acids, and activated carbon with improved surface characteristics was successfully obtained. The ζ -potential method was shown to effectively reflect surface changes associated with the formation of the nanocomposite structure.

The developed material is a promising candidate for application in environmental technologies for the purification of water contaminated with heavy metal ions and organic pollutants.

Keywords: goethite, humic acids, activated carbon, nanocomposite, ζ -potential, surface charge, sorption, water purification.

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SUSTAINABLE VALORIZATION OF SUNFLOWER SEED HUSKS INTO NANOCELLULOSE-BASED HYDROGELS FOR WATER SAFETY

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Abstract

The development of cellulose-based nanocomposite sorbents represents a promising and rapidly advancing approach to sustainable water purification [1,2]. In this study, cellulose nanofibrils (CNF) and cellulose nanocrystals (CNC) were successfully isolated from microcrystalline cellulose (MCC) obtained from sunflower seed husks (SFHs) and comprehensively characterized [3-5]. The resulting nanocellulosic materials were subsequently employed to prepare nanocomposite hydrogels, denoted as HG_{CNF} and HG_{CNC}. Comparative characterization revealed pronounced differences in the structural and physicochemical properties of CNF and CNC, which influenced the morphology, swelling performance, and stability of the corresponding hydrogels. Swelling studies performed under different environmental conditions showed that HG_{CNF} possessed a greater water uptake and swelling capacity than HG_{CNC}. Both hydrogels reached their maximum swelling at near-neutral pH (≈ 6.5) and displayed marked sensitivity to variations in ionic strength and solvent polarity. Adsorption experiments further demonstrated that both materials were effective in removing Cu²⁺ ions from aqueous media, with HG_{CNC} showing a slightly higher adsorption performance than HG_{CNF} and achieving a sorption degree of 51.5%. Overall, the results highlight the tunable physicochemical properties of nanocellulose-based hydrogels and their potential as sustainable sorbent materials for water purification. Their functional characteristics may also support broader applications in environmental remediation, controlled drug delivery, and biomedical engineering.

Keywords: hydrogel; cellulose; cellulose nanocrystalline; cellulose nanofibers; biodegradation; water retention; swelling properties; adsorption; wastewater treatment; metal ion removal.

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RADIOECOLOGICAL STATUS OF SOILS AND VEGETATION IN SARZHAL RURAL DISTRICT

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Abstract

One of the significant environmental problems of modern times is radioactive contamination of the environment, resulting from nuclear weapons testing, radiation accidents at nuclear power plants and nuclear fuel cycle facilities, as well as the consequences of uranium and mineral resources mining and processing. The objective of this study is to assess the radioecological condition of the soil and vegetation cover in the area around the village of Sarzhal, in the former Semipalatinsk Region, which was exposed to radioactive fallout as a result of nuclear testing. The activity of natural and technogenic radionuclides in the samples under study was determined by gamma-spectrometric analysis using a Canberra BE 3830 spectrometer, radiochemical analysis using an Alpha-Analyst 7200 alpha spectrometer and a Tri-Carb 2910TR liquid scintillation spectrometer. The specific activities of technogenic radionuclides in most of the analyzed samples were either at background levels or below the detection limit. The content of natural radionuclides in the soil cover corresponded to the geochemical background typical for the soils of Kazakhstan. The total radiation doses to plants were at the level of natural background radiation. The main radionuclide contributing to the primary radiation dose to plants is ^{40}K . The contribution of this work lies in obtaining precise data on the radioecological status of ecosystems, which expands knowledge regarding radionuclide migration in the soil–plant system for arid zones.

Keywords: soil, vegetation, radioactive contamination, Sarzhal, artificial radionuclides, natural radionuclides

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ACCUMULATION AND DISTRIBUTION OF $^{239+240}\text{Pu}$ IN DOMESTIC POULTRY TISSUES FROM DIFFERENT INTAKE SOURCES

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Abstract

The transfer of anthropogenic radionuclides through food chains is an important aspect of assessing the radiological safety of radioactively contaminated areas. Transuranic radionuclides are of particular interest due to the limited data available on their accumulation in farm animals and poultry. The aim of this study was to investigate the accumulation and distribution of $^{239+240}\text{Pu}$ in domestic poultry tissues during long-term radionuclide intake from different dietary sources. The study was conducted on broiler chickens divided into three groups and maintained under identical conditions. For 70 days, $^{239+240}\text{Pu}$ was administered to the birds with contaminated soil, plant-based feed, or water. Radionuclide concentrations were determined in the liver and muscle tissue. The liver was identified as the primary organ of $^{239+240}\text{Pu}$ deposition. The maximum radionuclide concentration in the liver was 150 ± 10 Bq/kg for intake with soil, 12 ± 1 Bq/kg with water, and 2.0 ± 0.4 Bq/kg with plant-based feed. In muscle tissue, the maximum concentrations were substantially lower and amounted to 2.5 ± 0.4 , 1.1 ± 0.2 , and 0.04 ± 0.02 Bq/kg, respectively. Regardless of tissue type, $^{239+240}\text{Pu}$ concentrations decreased in the following order: soil > water > plant-based feed. The results indicate significant differences in $^{239+240}\text{Pu}$ accumulation depending on the intake source. The highest accumulation levels were observed when the radionuclide was ingested with contaminated soil, with the liver being the primary organ of deposition. These findings expand current knowledge of the transfer of transuranic radionuclides through food chains and may be used to assess their transfer to poultry products and the radiological safety of radioactively contaminated areas.

Keywords: $^{239+240}\text{Pu}$, transuranic radionuclides, poultry, radioactive contamination.

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A Multifunctional Nanocomposite for Wound Healing Based on Biopolymers

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Abstract

The development of advanced wound-healing materials requires the creation of multifunctional wound dressings capable of simultaneously protecting damaged tissues from microorganisms, absorbing biological exudates, maintaining an optimal environment for tissue regeneration, and ensuring biocompatibility. The relevance of developing such materials is driven by the need for effective and affordable wound-healing systems based on natural components with complex biological activity. In this context, the use of natural mineral sorbents in combination with plant-derived components possessing antimicrobial, anti-inflammatory, and wound-healing properties represents a promising approach.

Composite films were prepared by thermal blending with the dispersion of bentonite and plant-derived components. The resulting materials were characterized to evaluate their structural and physicochemical properties. The patch containing clove demonstrated anti-inflammatory activity, while the patch containing nettle extract showed high efficiency in promoting rapid wound healing.

The developed biocomposite material based on bentonite and plant-derived components demonstrates environmentally oriented potential and multifunctional wound-healing properties, making it a promising candidate for further cytotoxicity studies.

Keywords: bentonite, plant-derived components from nettle and clove, physicochemical properties, antimicrobial activity, wound healing.

SILVER SUCCINATE COMPLEX AS A POTENTIAL FUNGICIDAL AGENT FOR PLANT PROTECTION

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Abstract

Climate change has increased the demand for effective fungicidal agents for sustainable plant protection. In this study, the silver succinate coordination complex $[Ag_2(C_4H_4O_4)]$ was synthesized by reacting succinic acid with silver nitrate at a molar ratio of 1:2 and pH 7. The structure of the complex was confirmed by ATR-FTIR spectroscopy, which demonstrated the disappearance of the carboxylic acid carbonyl band and the appearance of characteristic carboxylate vibrations, indicating deprotonation and bidentate coordination of the succinate ligand to Ag(I). Scanning electron microscopy revealed a plate-like morphology with particles of various sizes, predominantly in the range of approximately 200-400 nm, indicating the formation of a heterogeneous microstructure. The synthesized complex completely inhibited visible growth of *Fusarium oxysporum* at a concentration of 150 mg/L after 72 h of incubation, corresponding to the minimum inhibitory concentration (MIC), while the minimum fungicidal concentration (MFC) was determined to be 450 mg/L. The obtained results confirm the pronounced antifungal activity of the synthesized silver succinate complex against *F. oxysporum* and demonstrate its potential as a promising fungicidal agent for further investigation, optimization, and application in integrated plant disease management strategies aimed at improving crop protection and supporting sustainable agricultural production under changing environmental conditions.

Keywords: silver succinate, coordination complex, *Fusarium oxysporum*, minimum inhibitory concentration, minimum fungicidal concentration, sustainable agriculture.

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ELECTRONIC STRUCTURE OF OXYGEN-CONTAINING ADSORBATES ON PEROVSKITE OXIDE SURFACES

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Abstract

Perovskite oxides can activate oxygen-containing molecules through a delicate balance between surface geometry, transition-metal d states, lattice-oxygen 2p states, and oxygen vacancies. Yet an unresolved question remains: why can surfaces with apparently similar atomic arrangements drive the same adsorbate toward fundamentally different electronic states? This ongoing first-principles study tests the hypothesis that the decisive descriptor is not adsorption geometry alone, but the pre-adsorption alignment and subsequent reorganization of the surface d-p electronic manifold. Representative transition-metal ABO_3 perovskite slabs are examined with AO- and BO_2 -type terminations in both stoichiometric and oxygen-deficient states. H_2O , OH^* , O^* , OOH^* , and O_2^* are selected as a chemically connected series of oxygen-containing adsorbates relevant to water activation and oxygen electrocatalysis. Spin-polarized density functional theory calculations are performed using the PBE functional with D3 dispersion correction, together with DFT+U sensitivity tests for localized transition-metal d states. A vacuum region of at least 15 Å, dipole correction, and systematic sampling of top, bridge, and vacancy-adjacent sites are used to distinguish intrinsic electronic effects from slab and starting-geometry artifacts. The central expectation is that oxygen vacancies will not simply strengthen adsorption: depending on surface termination and adsorbate identity, they may switch the direction of charge transfer, alter spin localization, and either weaken or preserve the O-O bond. This possibility is evaluated through adsorption energies, Bader charge analysis, charge-density differences, work-function shifts, spin-density maps, and total and orbital-projected densities of states. For the most revealing configurations, HSE06 calculations and ELF/COHP analysis will be used to separate genuine chemical bonding from electrostatic stabilization. The anticipated result is an electronic fingerprint that predicts whether a perovskite surface stabilizes molecular, partially activated, or dissociated oxygen-containing species before the full reaction pathway is calculated. The quantitative energetic ranking, the termination that produces the strongest electronic reconstruction, and the surface descriptor that best distinguishes activation from mere adsorption will be presented at the conference. By resolving whether structure, vacancy chemistry, or d-p band alignment dominates the interaction, this study aims to establish a transferable design principle for perovskite oxide catalysts in water splitting, oxygen reduction, oxygen evolution, and environmentally relevant oxidation processes.

Keywords: perovskite oxides; oxygen-containing adsorbates; electronic structure; oxygen vacancy; density functional theory; surface activation

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Study of the influence of gradient architecture on charge transfer processes and cyclic stability of composite electrode materials

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Abstract

Modern energy storage systems require the development of electrode materials with high specific capacitance, low internal resistance, and enhanced cycling stability [1]. In this context, the design of composite electrode materials with gradient architecture represents a promising approach, enabling optimized distribution of active components and improved charge transport kinetics [2, 3].

The aim of this study is to develop and synthesize composite electrode materials with a gradient structure for advanced energy storage applications, as well as to investigate their physicochemical and electrochemical properties. Carbon-based materials, transition metal oxides, and ligands are used as functional components to form hierarchical structures with controlled phase distribution.

The synthesis of the materials was carried out using advanced techniques, including chemical and sol-gel methods, along with approaches to structural modification via thermal processing. The obtained samples were characterized by X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). Electrochemical performance was evaluated using cyclic voltammetry, galvanostatic charge-discharge measurements, and electrochemical impedance spectroscopy.

The results demonstrate that the formation of a gradient architecture significantly enhances ion and charge transport, reduces internal resistance, and improves structural stability during long-term cycling. The developed composite materials exhibit increased specific capacitance and superior cycling stability compared to conventional single-component electrodes [4].

The proposed approach offers strong potential for application in supercapacitors and other electrochemical energy storage systems, contributing to improved performance and durability.

Keywords: composite, electrode material, perovskite, BET, cyclic stability, energy storage

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PHYSICOCHEMICAL AND BIOLOGICAL CHARACTERIZATION OF GLYCINE MODIFIED FULLERENOL FOR BIOMEDICAL APPLICATION

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Abstract

This study focuses on the preparation and characterization of a functionalized polyhydroxylated fullerene (fullerenol) modified with the amino acid glycine. The relevance of this research is associated with the potential of fullerene derivatives as functional nanomaterials capable of combining the unique physicochemical properties of the carbon framework with the biological activity of attached functional groups. Fullerenol was modified with glycine, followed by isolation and purification of the resulting product. Comprehensive characterization was performed using UV–Vis, FTIR, and NMR spectroscopy, as well as zeta potential measurements, to evaluate the structural, electronic, and surface properties of the obtained material. Comparison of the initial and modified compounds revealed changes in their spectral characteristics and surface charge, indicating successful functionalization of the fullerene-based structure with glycine. The obtained material is considered a promising functionalized fullerene derivative for further investigation of its biological properties, particularly its potential antimicrobial activity. The results may contribute to the development of novel functional carbon-based nanomaterials for potential applications in biotechnology and biomedicine.

Keywords: Fullerenol; Glycine; Fullerene functionalization; Nanomaterials; UV–Vis spectroscopy; FTIR spectroscopy; NMR spectroscopy; Zeta potential; Antimicrobial activity; Biotechnology.

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Sorption Properties Of Cellulose Fiber/Emeraldine Composite Films

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Abstract

In this study, novel adsorbent composite films based on cellulose fiber in the form of microcrystalline cellulose (MCC) and the conductive emeraldine salt (ES), form of polyaniline (PANI) were synthesised using in-situ oxidative polymerization with the purpose of removal heavy metal ions from water. The incorporation of ES onto the biodegradable matrix of MCC is designed to enhance its adsorption behaviour toward heavy metal ions by introducing nitrogen-bearing amine and imine functional groups ($-NH-$ and $=N-$ respectively). These groups, together with hydroxyl groups of cellulose are capable of strong chelation and electrostatic coordination with divalent metal cations. The structural, crystalline, morphological, thermal, and interfacial charge-transport properties of the fabricated films were comprehensively characterized using Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), thermogravimetric analysis (TGA), and potentiostat-based electrochemical impedance spectroscopy (EIS). The sorptive capabilities of the resulting MCC/ES films were systematically evaluated toward copper (Cu^{2+}) and zinc (Zn^{2+}) ions in aqueous media. The study investigates the effect of various parameters, such as initial metal concentration, contact time, solution pH, and PANI loading on adsorption efficiency. Adsorption kinetics and equilibrium isotherms were modeled using pseudo-first-order, pseudo-second-order, Langmuir, and Freundlich frameworks to elucidate the mass transfer kinetics, surface binding affinity, and rate-limiting sorption mechanisms. This work demonstrates the high potential of cellulose fiber/emeraldine composite membranes as sustainable, robust, and multifunctional platforms for targeted heavy metal wastewater remediation.

Keywords: cellulose fiber, microcrystalline cellulose, emeraldine salt, polyaniline, composite films, heavy metal sorption.

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Abstract

Currently, the development of functional biodegradable materials through the valorization of agricultural waste is considered one of the promising approaches to promoting the rational use of resources, reducing environmental impact, and improving water resource management in agriculture [1,2]. In particular, the use of polymeric hydrogels capable of absorbing and retaining water over extended periods as materials for regulating soil moisture is highly relevant for arid and water-scarce regions [3,4]. In this context, the aim of this study is to develop a CMC/HEC-based biohydrogel with high water absorption and retention capacity using microcrystalline cellulose derived from soybean processing waste, to modify the hydrogel with bentonite, and to investigate the key physicochemical, structural, and sorption properties of the resulting multicomposite material.

During the study, microcrystalline cellulose was obtained from soybean processing waste using an environmentally friendly method. Carboxymethyl cellulose (CMC) and hydroxyethyl cellulose (HEC) derivatives were synthesized from the obtained cellulose and subsequently used to prepare biohydrogels with a three-dimensional polymer network formed in the presence of a crosslinking agent. Bentonite was incorporated into the hydrogel matrix to improve the water absorption and retention properties of the material and to enhance its potential for agricultural applications. The water absorption capacity and swelling degree of the resulting samples were determined, and their physicochemical and structural characteristics were comprehensively investigated. The surface morphology and porous structure of the biohydrogels were characterized by scanning electron microscopy (SEM), while their functional groups and interactions between the components were analyzed by Fourier-transform infrared spectroscopy (FTIR). The elemental composition was determined by X-ray fluorescence spectroscopy (XRF), and thermal stability was evaluated by thermogravimetric analysis (TGA).

The results showed that the initial CMC/HEC-based biohydrogel exhibited a swelling degree of 140% in distilled water. The incorporation of bentonite into the hydrogel matrix significantly enhanced its water absorption capacity, increasing the swelling degree to 400%. Thus, bentonite modification resulted in an approximately 2.9-fold increase in the swelling degree compared with the unmodified hydrogel. This enhancement can be attributed to the hydrophilic mineral structure and high specific surface area of bentonite, as well as its interactions with the polysaccharide matrix, which collectively improve the water-binding and water-retention capacity of the composite.

The incorporation of bentonite into the CMC/HEC hydrogel matrix enabled the formation of a multicomposite structure comprising organic polymeric and inorganic mineral components. Such a structure not only provides the hydrogel with a high water absorption capacity but also enables the targeted control of its structural and functional properties.

The obtained results demonstrate the feasibility of valorizing soybean processing waste as a valuable source of cellulosic raw material for the production of functional biodegradable materials. The high water absorption capacity of the bentonite-modified CMC/HEC-based biohydrogel provides a strong basis for its further investigation as a material for prolonging moisture retention in soil and improving irrigation water-use efficiency. The proposed approach represents a

promising strategy that integrates the comprehensive utilization of agricultural waste with the development of water-saving materials for agricultural applications.

Keywords: microcrystalline cellulose, carboxymethyl cellulose, hydroxyethyl cellulose, biohydrogel, bentonite, multicomposite material, swelling degree, water absorption, soybean processing waste, soil moisture.

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