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Mineral and Energy Economy Research Institute
Polish Academy of Sciences

EUIndTech2025
Industrial technologies and materials for sustainable Europe

9th edition of the Conference

“Innovative ideas of young scientists: Science – Start-up – Industry”

Book of abstracts

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Introduction

On 2–3 June 2025, the 9th edition of the conference *"Innovative Ideas of Young Scientists: Science – Start-up – Industry"* was held in Kraków. The event is dedicated to early-career researchers, doctoral candidates, students, and scientific associations engaged in research in the following areas:

- novel technological and information technology solutions, and
- innovative products and materials that support sustainable and competitive development.

For nearly a decade, the conference has been organized by the Institute – Highway of Technology and Innovation (www.iati.pl), a virtual institute that integrates scientific and research activities conducted by universities, independent research institutes, and enterprises. The event attracted a record number of nearly 120 researchers from across the globe. The presented studies were characterized by a high degree of innovativeness, interdisciplinarity, and collaborative engagement among diverse research institutions.

Although the *Book of Abstracts* does not include full scientific articles, but rather summaries of ongoing research projects, its content provides significant educational and practical value. From an educational standpoint, it constitutes a valuable source of inspiration for young people considering a career in science.

From a practical standpoint, the strong representation of Polish researchers makes the *Book of Abstracts* an important reference point for identifying prospective directions in the development of Polish science over the coming decades. The publication serves as a valuable resource for institutions involved in shaping national science policy, as well as for stakeholders responsible for decisions concerning the allocation of funding for research activities. The research presented herein delineates potential areas in which the Polish economy may achieve future competitive advantage.

The diversity of the submitted studies provided the basis for classifying the abstracts into sixteen thematic areas, which correspond both to the conference sessions and to the chapters of this volume. Within each chapter, the abstracts are arranged alphabetically by the surname of the first author.

Wojciech Piontek

EUIndTech2025 – technologies and materials for sustainable Europe

In the current year, the conference was organized as an accompanying event to EUIndTech2025 (www.indtech2025.eu), the flagship European Union conference held under the Polish Presidency of the Council of the European Union.

EUIndTech2025 was designed to foster international dialogue and the exchange of ideas on European policy. The conference will address key initiatives such as the Clean Industrial Deal, the Omnibus Package, and Polish presidency priorities. As one of the significant in-person events in 2025 under Horizon Europe, the conference provided an excellent exceptional platform for networking, exchanging ideas, and collaborating on future projects. Activities included matchmaking and pitching sessions, discussions on the Horizon Europe Action Plan (2025–2027), and the strategic vision for the next EU research and innovation framework program (2028–2035). Notably, the event coincides with the anticipated opening of new EU funding calls, making it a timely opportunity to explore emerging opportunities. EUIndTech2025 aligns with the EU's strategic goals, emphasizing the need to build competitive, sustainable, and resilient industrial sector for the future of Europe. Key discussions focused on crucial areas such as the utilization of advanced and critical raw materials, the promotion of new technological solutions, the circular economy, and the role of science and innovation in strengthening the EU's industrial resilience and economic security. During EUIntech2025 there were 6 plenary sessions, 20 thematic sessions, 10 study visits, and 8 accompanying events (of which one was *Innovative ideas of young scientists: Science – Start-up – Industry*). The event brought together more than 100 panelists and 824 participants from across Europe.

Conclusions from the Panel Discussion:

1. It is necessary to intensify personal relations between universities and enterprises. To do this it is recommended that business representatives are actively involved in university councils, and that councils of entrepreneurs are created within universities (at the faculty or college level). In addition, the periodic employment (in various forms) of academic researchers in enterprises as well as of enterprise employees in universities should be promoted – both in the areas of research and education.
2. A policy that supports intensive research and development cooperation between science and business, along with the commercialization of its results, is a prerequisite for increasing the efficiency of public R&D expenditure and for engaging in broad international cooperation.
3. The formation of productivity clusters of science-industry consortia organized around the productive use of specific local, regional, or national resources should be considered good practice. These clusters should serve as the foundation for national value creation networks.
4. Public support for foreign investors should be linked to their establishing research and development centers in our country.
5. To foster eco-innovation and sustainability, effective communication needs to be established during cooperation activities. This should be based on a language of benefits and values as each

stakeholder group understands eco-innovation and sustainable growth differently, with public administrations, NGOs, businesses, and consumers each holding different perspectives. Without improving environmental awareness among entrepreneurs and consumers, it will be difficult to successfully implement sustainable growth in Europe. It is necessary to avoid replacing one kind of dependency with another.

6. Two main factors are crucial for the development of a circular and competitive future for European industry. First, the industrial scale of the innovations needs to develop an enabling ecosystem. The required clear and predictable legislation, which plays a vital role in achieving this goal, should not only provide guidance, but also support the development of that future and remove bottlenecks to its achievement using such tools as risk minimization mechanisms, market-based incentives or the recognition of all recycling technologies. Second, it is necessary to create a demand for circular and low carbon innovations because these must be competitive to exist and survive on the market. Incentives need to be provided for circular materials, such as, for example, recycled critical raw materials or recycled plastics, by giving them priority in public procurement.
7. For the triple (digital, energy, social) transition in Europe, industry needs a workforce with new and different skills. Attracting more women is essential to meet the demand. Communicating opportunities in industry, reinforcing skills and encouraging women, and changing company cultures towards a more diverse workforce contributes to reaching this goal.
8. Human-centered skills are the future: As automation increases, emotional intelligence, adaptability, and resilience are becoming just as critical as technical abilities in securing and thriving in high-quality jobs.
9. Wellbeing drives retention and performance: Companies that invest in employee wellness, flexible travel policies, and supportive reskilling environments are better positioned to attract, retain, and empower top talent–especially during transitions.
10. Inclusive access is key: Ensuring equal opportunities for both men and women in upskilling and reskilling programs is essential for building a diverse, competitive, and future-ready European workforce.
11. European funding should not be seen as a transactional mechanism, where specific resources are transferred from public bodies to businesses and/or research institutions, but rather as a platform for institutional learning and for building the capacity to unlock Europe's potential.
12. EU funding should lead to the creation of products, services, and processes that can last far beyond the lifespan of the project itself.
13. Combining global innovation with local relevance is one of the best indicators of the success of European funds.
14. Innovation now develops faster than anticipated within traditional grant cycles. If funding cannot keep pace, scientific discoveries drown in reports instead of reaching users.
15. Europe's challenge is not the amount of available funds, but the strategic use of those resources. To boost global competitiveness, the EU must not only increase the size of its funding but, more importantly, rethink how its funding systems support innovation. EU funding should not only be seen as an investment in science, but also as a catalyst for systemic change – talent development, and translating research into real-world impact. This is how Europe can remain competitive with the USA and China. To achieve this, structural reform is needed. This means combining short-term project grants with long-term core funding for research centers, enabling them to grow sustainably and adapt over time. "EU funds have enormous power, but we must reimagine what success looks like in a world that demands urgent, collective action. Success is not measured by deliverables alone. It's about whether that funding is transformative. Is it creating new e-markets? Is it driving systemic change? Is it building capacity in regions and sectors that need it most?"

16. Guided innovation in the saving of materials and chemicals that are sustainable by design represents an essential element for any future product entering the European market, enabling integration of functional performance, safety, and sustainability. Efforts need to be made to facilitate science-led harmonization of environmental, economic, and societal approaches at early stages in innovation. Such well-balanced approaches require a multidisciplinary collaboration further supported by tailored funding, interconnected on the regional, national and international levels to gain synergies of public investment. Interoperable digitally enabled workflows are needed covering entire value chains serving various sectors. Performance indicators need to be included during the development of digitalization of processes to foster and speed-up the uptake of innovative advanced materials in industrial production. Efforts need to be taken to improve data quality and metadata completeness to increase the reliability of predictions and generate greater acceptance and trust. In implementation, the focus should be on solution-oriented approaches that need to include communication between all stakeholders.
17. Innovation in three extremely important areas is crucial for the EU: broadly defined security, improving the quality and standard of living, and global competitiveness. All these areas are closely interconnected; the loss of competitiveness threatens the standard of living and security, lack of security (including cybersecurity) hinders development and improvements in competitiveness, and so on. Therefore, Europe should focus on innovation in these areas and effectively support it.
18. Europe has enormous talent potential, a rich tradition of innovation, the best cooperation mechanisms in the world, and financial resources – better utilization of this potential is possible. European institutions that manage funds and design future programs are trying to create new frameworks aimed at achieving synergy across multiple levels. Creating these highly desirable frameworks is only possible through close and ongoing collaboration with all stakeholders in the ecosystem – especially entrepreneurs and scientists, research centers, and local government at all levels.
19. Entrepreneurs and experts continuously highlight two main barriers to creating, developing, and, in particular, implementing and commercializing innovations in Europe: a very low risk threshold for innovative projects, and an excessively slow pace of work of public administrations supporting innovators and managing innovation funds, due to still very complex procedures and excessive bureaucracy (more on this can be read in, for example, the well-known report by Mario Draghi). Due to these barriers, many innovators – including in Poland – prefer ecosystems outside the EU, where these barriers are non-existent or significantly smaller, especially the American ecosystem
20. An absolutely screaming challenge for the EU is the unification of the investment market – the single market simply does not work in this strategic area, which harms us all; each country has different regulations, making, for example, Western funds reluctant to invest in CEE countries. Europe needs, an "EU Inc." as a legal form available across the entire EU– so that a startup from Poland can easily secure investment from France or Italy, and vice versa.
21. Security is a fundamental requirement for quality of life –we must at all costs avoid the mistakes of the 20th century. This must be understood in the broadest sense: this is not only tanks but also dual-use technologies, critical infrastructure, and space.
22. One of the key areas is resilient navigation – today, the entire economy relies on GPS/Galileo. These systems can be easily jammed, and their loss could mean damages of around 1 billion dollars daily (for the USA). GNSS is not just maps – it involves transportation, stock exchanges, energy networks, and military operations.
23. Telecommunications and cybersecurity are other strategic fields. Europe needs redundancy, encryption, and European technological solutions.
24. The war in Ukraine shows how important modern dual-use technologies are – drones, GNSS jamming, cyber capabilities. Central and Eastern Europe (CEE) could be a source of such innovations – but this requires investment and regulatory support.

25. Startups are effective because they focus on a single problem and rapidly implement breakthrough solutions. They can act faster than big corporations and accurately meet real customer needs. They take on risks that large companies avoid. This enables them to develop things previously impossible – e.g., new space components, anti-GNSS solutions, or defense technologies. From the ecosystem perspective, the best scenario for most startups is acquisition – investors recover their capital, founders can continue creating, and technology reaches industry.
26. Advanced materials are of paramount importance in fields ranging from the chemical industry, across dual use and defense applications to applications in health. Policies to boost a united European Advanced Materials ecosystem as well as funding instruments tailored to the different stages of the Advanced Materials R,D&I chain are key to achieving Industrial Competitiveness through Advanced Materials.
27. Should the circular economy be designed to serve the wellbeing of people – and not just protect the interests of capital? When we speak of a "wellbeing economy", this isn't just branding. It's a test of political honesty and policy direction. If the circular transition is only about closing loops and minimizing emissions, it risks becoming a technical fix without social purpose. This dilemma is clearly visible in textiles. Around Europe, we see an explosion of thrift shops, repair initiatives, and circular design labs. Young people are rejecting fast fashion – not just for style, but for values. And yet: the flow of cheap imported textiles continues to grow, much of it destined for landfills after minimal use. Moreover many circular models – like clothing rental or take-back – fail not because the ideas are bad, but because the responsibility is misplaced: small startups are forced to absorb the risk, while large brands continue to profit from planned obsolescence.
28. Even a 100% circular economy can be unsustainable if it simply loops high-volume consumption. We need to reclaim the idea of "enough" – not as austerity, but as resilience, dignity, and balance. A sufficiency economy is not about sacrifice, but about designing prosperity within limits. This means moving beyond GDP, as GDP still grows when we sell more cigarettes and alcohol – regardless of the harm caused. That is not progress. That's a failure of accounting.
29. There is the paradox of regulation. Europe is not necessarily over-regulated – but it is badly layered, full of overlapping, outdated, and inconsistent rules. These create friction, not direction. Smart, enabling regulation is needed with clear rules for digital product passports, harmonized definitions of waste and resources, standards for reuse, repairability, and durability, public procurement that leads, not follows. But even the best regulation fails without infrastructure: data systems, logistics, material marketplaces, and legal frameworks for shared responsibility. Circularity is not just a principle – it's a platform.
30. True circularity means more than waste recovery or material efficiency. It means revaluing invisible labor (care, repair, stewardship), building local ownership of value chains, enabling meaningful work, not just green jobs, creating shared infrastructure that supports participation. Application of the rules of the circular economy requires targeted legislation, shared digital infrastructure, value chain transparency, finance for early-stage innovation, cross-border collaboration rooted in place.
31. Knowledge about policy frameworks that enable companies to integrate the principles of the circular economy, resource efficiency, and climate-neutral strategies within European companies has been increasing. However, practical application remains a work in progress. To further support this transition, there is a need for: accessible tools and resources, capacity building and education, collaborative initiatives, policy incentives and support, and measurement and reporting frameworks.
32. Research and innovation play an integral role in advancing next-generation clean technologies and enabling the decarbonization of European manufacturing. In this context, it is essential to consider future expectations for the next EU Framework Programme following Horizon Europe. Particular attention should be paid to the specific capital expenditure (CAPEX) needs of industry to ensure effective deployment and scaling of innovative solutions.

33. Mobilizing private capital to achieve the goals of the triple transformation – ecological, energy, and artificial intelligence. This is especially important in the early stages of innovation, when business risk is particularly high. In this context, the development of the venture capital market plays a key role. The shortage of venture capital in Poland, but also in the EU, results in eco-innovative companies relocating to the United States or Southeast Asia, where funding opportunities for eco-innovation are more accessible. It would therefore be advisable to create a dedicated financing ecosystem for eco-innovation, based among others on mission-oriented finance, which combines public funding with private capital. A more coordinated and efficient activation of both private and public capital is essential to support those transformations.

The conclusions and opinions expressed in this document are those of the individual panellists and do not necessarily reflect the views of the entire panel nor that of the European Commission

Joanna Kulczycka and Agnieszka Nowaczek

Packaging of the Future – Competition Winners Announced at EUIndTech2025

As part of the **EUIndTech2025** conference on dairy industry innovations, a competition titled **"Packaging of the Future – Propose an Innovative Packaging Solution for Dairy Products"** was held by the **Mineral and Energy Economy Research Institute of the Polish Academy of Sciences** in collaboration with **IATI**.

The competition invited students, academic groups, PhD candidates, start-ups, and NGOs to design packaging following **circular economy principles**, including: easy recycling, use of recycled materials, and renewable (bio)materials.

During the conference, the results were announced:

- **1st place:** ReFill Good – "Pij, Napełniaj, Powtarzaj"
- **2nd place:** Grow&Go – "Opakowanie, które wyrasta zamiast zaśmiecać"
- **3rd place:** REBIOPACK
- **Special Mention:** Danokulki

Congratulations to all winners for creating innovative, sustainable packaging solutions for the dairy sector!

Krystian Franczak
AGH University of Krakow

Application of Cu-Sc alloys for cap electrodes in the resistance spot welding process

The aim of the research was to develop new cap electrodes made of Cu-Sc alloys for performing spot welds on galvanized steel sheets. The resistance spot welding process involves the use of cap electrodes made from copper alloys that combine high mechanical and electrical properties. These electrodes serve the purpose of applying pressure to the welded elements and conducting electrical current. Due to the high resistance within the welded elements, heat is generated, which causes local melting of the metals being joined and the formation of a weld nugget. In the case of welding sheets with a zinc coating, difficulties arise due to zinc diffusion into the cap electrodes, leading to faster electrode wear and a decline in the quality of the welds. The addition of scandium to copper reduces the diffusion of zinc into the electrodes, thus increasing their durability in the resistance welding process.

This study presents the results of tests on the quality of spot welds performed with new Cu-Sc alloy cap electrodes compared to the commercial Cu-Zr counterpart. Destructive force tests were conducted on the welded joints.

The new type of cap electrodes will offer an extended service life at a similar cost compared to those currently used, providing a basis for their potential application as a competitive product in automotive industry.

Agnieszka Grabka, Sylwia Szczęśniak
Wroclaw University of Science and Technology

Comparison of air supply control strategies in high-ceiling spaces with respect to the energy consumption and operating cost

In the era of growing environmental awareness and the drive to reduce energy consumption, effective air temperature management in high-ceiling spaces–such as opera houses and performance venues–has become increasingly important. A key challenge in such facilities is maintaining thermal comfort for occupants while minimising the energy demand to do so, requiring a careful balance between performance and operational costs.

This study evaluates control strategies for ventilation systems with heat recovery in high-ceiling rooms characterised by vertical air temperature gradients. The aim was to improve energy efficiency and reduce operational costs. The analysis focused on the ventilation system of the Wroclaw Opera House, comparing two air temperature control strategies: constant setpoint control and adaptive control based on outdoor air temperature.

The study examined two design air indoor temperature differences (8K and 10K), along with the impact of variable thermal loads caused by audience presence. Eight operational scenarios were assessed in total, accounting for vertical temperature stratification and real-time energy demands for heating, cooling, and air transport.

Contrary to typical assumptions, results indicate that constant setpoint control provides better energy performance than adaptive control. Maintaining a fixed indoor air temperature setpoint reduces both thermal and electrical energy consumption and limits heat losses. When combined with heat recovery, this strategy also lowers HVAC (Heating, Ventilation, and Air Conditioning) system loads, leading to significant potential savings in operating costs.

The proposed approach supports the trend toward smart HVAC technologies, contributing to sustainable development and the energy efficiency of public buildings. Optimizing ventilation system operation through detailed performance analysis represents a vital step toward achieving nearly zero-energy buildings (nZEB)–a cornerstone of future sustainable architecture.

Wojciech Jankowski, Mateusz Kuc
AGH University of Krakow

A system for remote monitoring of industrial robot operation and gripper control

Nowadays, modern industry is increasingly relying on the capabilities of industrial robots to streamline production processes, while at the same time posing new challenges in monitoring or controlling them. However, this introduces certain problems, arising from the need for the physical presence of the operator at the robots, which can limit the efficiency, flexibility of operation, and the level of safety of the workers themselves. The answer to these needs is a remote monitoring and control system for grippers, which allows control of the process without the need for direct human contact with the device.

The primary objective of the project is to design and implement a remote supervision system for *Fanuc* (ER-4iA) and *Universal Robots* (UR3) industrial robots, enabling secure and efficient operation via a dedicated web application. The system actively integrates a digital twin and *Intel RealSense* depth cameras. In combination with a mobile application, this setup enhances the platform's functionality by offering clear and versatile visualization of the robotic workspace, as well as accurate, real-time spatial assessment. At its current stage, the project features a fully operational prototype consisting of both hardware and software components. All key system elements–including the grippers, depth cameras, and digital twin–are integrated with the web interface and operate synchronously. The system is presently demonstrating its effectiveness in test environments, offering stable remote communication with the robotics laboratory and providing live visualization of the workstation. The grippers, designed and manufactured by members of the *AGH Focus* student research group, are fully adapted to remote operation and support object manipulation at a distance. These capabilities confirm the viability of creating a comprehensive system for industrial robot supervision and control without the need for physical operator interaction.

Current outcomes indicate the system's broad application potential across various fields. In particular, it is suited for industrial use in remotely managing and monitoring production processes. It is also actively utilized in educational contexts as a tool for learning industrial robot programming, and serves as a research platform for testing innovative technological solutions within a safe, virtual environment.

The project is being carried out by Wojciech Jankowski and Mateusz Kuc, third-year students of Automation Control and Robotics, with ongoing technical and academic guidance from Professor Adam Piłat, PhD, DSc, of the AGH University of Krakow.

The research initiative continues to be actively developed within the *AGH Focus* student research group, in collaboration with the Faculty of Electronics, Automatics, Computer Science, and Biomedical Engineering at the AGH University of Krakow.

Anna Kosman, Piotr Puch
AGH University of Krakow

Optimizing energy sources for sustainable tourist facilities: a comparative analysis

The transition towards sustainable energy systems in the tourism sector presents both an environmental necessity and an economic challenge, particularly in regions of high ecological sensitivity such as Zakopane. In this context, the study addresses the problem of selecting an optimal energy source for a modern, year-round tourist facility that combines low operating costs with compliance to European climate and energy policies. The research objective was to evaluate and compare the feasibility of four heating technologies – natural gas, Podhale geothermal energy, a heat pump supported by photovoltaic (PV) panels and a biomass pellet boiler – under the assumption that renewable-based solutions would ensure the best balance of cost efficiency, ecological responsibility and long-term viability. The analysis was based on a real reference project: a wooden building of 62 m^2 usable area with an annual heat demand of 10,000 kWh.The evaluation considered investment costs (equipment, installation and network connection), annual operating expenses, and CO_2 emissions, while also assessing compliance with EU directives such as the Energy Performance of Buildings Directive (EPBD) and alignment with the United Nations SDGs. Calculations were carried out using current market prices and included the impact of available national subsidy programs such as "Czyste Powietrze," "Moje Ciepło," and "Mój Prąd." The results confirm the hypothesis: renewable-based systems, particularly a heat pump combined with PV and the Podhale geothermal district heating, outperform conventional solutions in both environmental and financial terms. They offer annual operating costs below 500 PLN and nearly zero CO_2 emissions, with public subsidies covering up to 70% of eligible expenses, which significantly enhances their return on investment over a 15-year horizon. In contrast, a gas boiler system, although widespread and easy to install, generates the highest annual costs (around 9,500 PLN) and CO_2 emissions (about 2.5 tons), while also facing increasing regulatory risks due to the upcoming EU ban on fossil-fuel heating in residential buildings from 2030. Pellet boilers represent a transitional option, with moderate investment and operating costs and relative carbon neutrality, but their particulate emissions limit their suitability for mountain tourist areas struggling with air quality issues. Overall, the study concludes that renewable energy-based technologies provide the most future-proof solutions for sustainable tourism infrastructure. Their adoption not only reduces long-term operating costs and environmental impact but also supports regional development strategies aimed at clean energy and air quality improvement.

The authors would like to express their gratitude to the AGH University of Krakow, especially to PhD, DSc, Eng. Marta Sukiennik, who provided essential knowledge and substantive support.

Anastazja Stępień
Ignatianum University in Krakow

Factors increasing the susceptibility of ERP system users to cyber risk

In the face of advancing digitalisation of enterprises and increasing reliance on ERP-class systems, protecting sensitive data from cyberattacks becomes a key challenge. All users of the systems are exposed to risk; however, older individuals are the most vulnerable, as – despite their professional experience – they often exhibit lower technological awareness and higher susceptibility to attacks employing social engineering methods. Psychological manipulation mechanisms may influence the effectiveness of phishing. The aim of the article is to identify factors that increase the susceptibility of ERP system users to phishing. Among all factors, particular attention was given to psychological and demographic factors, with a special focus on the 50+ age group, which influence the effectiveness of information theft. An analysis of phishing methods was conducted from a technical perspective, including minor differences between links, original websites, and their fake copies. An interview with a cybersecurity expert and a statistical analysis of data obtained from a company conducting cybersecurity audits on behalf of external entities allow for a better examination of this phenomenon. The conducted analysis enables the collection of information useful for raising awareness among users of various IT systems. As a result of the research, an answer to the question of why older individuals more frequently fall victim to phishing despite having greater professional experience than younger people has been obtained. The conducted studies are particularly significant for increasing social awareness, creating educational campaigns, and conducting specialised cybersecurity training.

Editorial Advisor: Piotr Musiewicz

Angelika Gancarz, Filip Jęczmiński, Aleksandra Jaśkiewicz, Barbara Duda, Wiktoria Haznar, Dominika Pacułt, Agnieszka Grela, Justyna Pamuła
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Possibilities of removing nutrients in rain gardens

Rain gardens are one of the nature-based methods of stormwater management and should be an essential element of urban space. Through appropriate plants and well-selected substrate, they enable the collection, purification, and infiltration of rainwater. Thanks to their numerous advantages, such as increasing biodiversity and mitigating the urban heat island effect, rain gardens are becoming not only a functional but also an aesthetic element of the urban landscape.

The aim of the study was to determine how activated carbon, as a soil amendment in a rain garden, can affect the removal of nutrients such as nitrates (NO_3^-), ammonium (NH_4^-), and phosphates (PO_4^{3-}). The study was conducted in laboratory conditions, using model columns constructed for this experiment, with synthetic rainfall simulating rainwater in urban areas in terms of the concentrations of selected compounds. Two different types of retention columns, differing in activated carbon content, and a control column were used to compare the results. The influence of activated carbon on changes in pH and specific electrical conductivity (SEC) of rainwater was also analysed.

The obtained results can help in the further development of rain gardens, enhancing their capacity to remove pollutants from rainwater. The use of activated carbon in such systems can be an innovative method of water treatment, contributing to the reduction of concentrations of nutrients entering the aquatic environment, as well as the introduction of more sustainable practices in rainwater management.

The authors would like to thank Dagmara Malina and Michał Łach for their assistance in the laboratory analysis.

This work was funded by the project “Retention, infiltration and purification of rainwater” within the FutureLab PK.

Katarzyna Grąz
The John Paul II Catholic University of Lublin

Structure and composition of the composts

In today's highly urbanized world, more and more waste is being produced. Composting is one form of waste treatment. The aim of this study is to investigate the morphological composition of four types of compost based on the PN-93-Z-15006 standard. Composted grass, backyard compost, soil improver created after composting green waste, and stabilizer – waste created from the mechanical-biological treatment of municipal waste, which was taken from the Mechanical-Biological Treatment of Municipal Waste, were examined successively. Fifty samples of 2000 grams each were taken from each type of compost, respectively. All samples were divided into seven individual fractions: organic waste, plastics, ceramics, paper and cardboard, glass, metal and others.

After the analyses, it can be concluded that it is very difficult to obtain a homogeneous compost, due to the heterogeneity in the input material. The results of the study were analyzed in detail, distinguishing between the different fractions. By weight, grass cuttings contained the most organic matter and stabilizer the least. In addition, it was analyzed that the least amount of plastics was found in domestic compost and the most in stabilizer. New forms of processing stabilization should be sought as a potential form of energy recovery.

Ewa Kopeć, Julia Ulman
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Implementing circular economy principles in the strategy of a clothing enterprise

In the face of global challenges related to environmental pollution, clothing companies are increasingly implementing the principles of the circular economy (CE). These activities are aimed at minimizing the negative impact of business activities on the planet. One of the brands operating on the Polish market, belonging to one of the largest clothing companies in Poland, takes action to optimize production processes, reduce the consumption of raw materials and implement more ecological solutions throughout the life cycle of its products. The aim of the article is to present the principles of CE and assess the impact of their application on the ecological, social and economic efficiency of the selected company. Activities aimed at increasing consumer engagement, including ecological education and promoting conscious purchasing choices, are also discussed. The case study allows for a detailed presentation of initiatives related to fabric recycling, production of clothing from sustainable materials and transparency of the supply chain. The study is based on available qualitative and quantitative data, including the company's strategy and environmental reports. The results of the study can be a significant contribution to the development of the literature on the practical application of CE principles in the industrial sector. Furthermore, they can serve as a reference point for other companies seeking to implement the circular economy concept in their business models.

Editorial Advisor: Piotr Musiewicz

Emilia Mazur, Ewa Kopeć
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Analysis of methods of reducing plastic waste in the activities of enterprises

The aim of the article is to present the actions undertaken by enterprises to reduce plastic waste. The concept of a circular economy includes principles aimed at minimising the natural environmental burden resulting from the economic activities of enterprises. It can be observed that particular importance is attached to actions aimed at reducing waste and promoting the reuse and recycling of materials. In this regard, business responsibility is reduced to implementing solutions that not only minimise the generation of plastic waste but also promote its recycling and efficient life cycle management of products. To meet such requirements, eco-design of products is also significant. The analysis that has been conducted is based on the case studies of companies operating in various industries that implement strategies to reduce the negative impact on the natural environment and introduce innovative solutions within the framework of the circular economy. Based on an interview conducted with an environmental protection expert, the focus was on identifying key areas in which enterprises apply solutions for reducing plastic waste. The study of methods for reusing plastic is a key element in the search for solutions that enable a significant reduction of plastic waste. The obtained results may be valuable for individuals involved in product design, the development of sustainable strategies, and the implementation of innovative solutions, within the context of the principles of the circular economy, which advocates the reuse of all materials in order to minimise the negative impact on the natural environment.

Editorial Advisor: Piotr Musiewicz

Miłosz Struciński
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The role of information and communication technologies in creating green cities

In the present world, there arises a need to reduce greenhouse gas emissions, decrease the amount of waste, reduce natural environment degradation, and improve air quality. The aim of the article is to present the areas in which information and communication technologies (ICT) can support the creation of green cities. Information and communication technologies enable urban space planning in such a way as to optimize resource consumption, minimise pollutant emissions, and increase energy efficiency. The concept of green cities assumes the need for energy production from renewable sources, reducing water wastage, and the application of green technologies. Smart power grids, energy demand management, and the use of renewable energy sources can significantly reduce atmospheric pollution resulting from urbanisation. A review of the literature of the subject and an analysis of case studies allows for the presentation of implemented ICT technologies in the field of urban planning and the indication of further directions for creating green cities possible. An example may be illustrated by cities where buildings are equipped with sensors and AI systems that adjust energy consumption to needs, reducing its wastage. The implementation of smart technologies can contribute to the integration of urban infrastructure with systems for effective environmental management. The conducted research may be useful for local governments, planners, and urbanists striving to create more ecological cities of the future. The implementation of innovative technologies in urban space management allows for better adaptation to contemporary issues related to climate change and the increasing demand for energy. An essential element of future actions may also be effective waste management. In modern green cities, sustainable urban planning, process automation, and the implementation of advanced methods for minimising energy and resource losses can play a particularly important role.

Research Supervisor: Ewa Kopeć
Editorial Advisor: Piotr Musiewicz

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Review of continuous water quality monitoring possibilities in rain gardens

Rain gardens are specially designed areas that support rainwater management by, among other things, preventing excessive runoff or improving water retention in the environment. Their main purpose is to collect rainwater, slow down its runoff and allow it to be gradually absorbed by the soil. Such gardens usually consist of a layer of flood-resistant plants and a specially prepared substrate to ensure proper water flow and allow rainwater collection, treatment and infiltration. Rain gardens are an element of sustainability that supports environmental protection and can also be used in urban spaces to improve water quality and manage rainwater.

The aim of the review was to determine whether and to what extent continuous monitoring of water quantity and quality in rain gardens is possible. Continuous monitoring of rainwater is based on verifying the level of water retention by a rain garden, considering the amount of rainwater flowing into such a garden, and the systematic measurement of various rainwater parameters, e.g. pollutant levels (nutrients – e.g. nitrates, phosphates), pH, temperature, turbidity, specific conductivity, dissolved oxygen concentration. To perform such monitoring, an appropriate measurement infrastructure as well as procedures and tools (both hardware and software) for data collection, analysis and interpretation are required. The review was based on industry scientific publications and the approaches proposed in the review were compared to commonly available and affordable measurement equipment (commercially available sensors, measurement accuracy and frequency, applicability to rain gardens). The results were presented in the form of a tabular overview according to the adopted criteria concerning: accuracy and resolution of measurements taken, disadvantages, advantages, method of data transmission and collection, limitations and price. The aim of the review was to analyse the measurement methods and measurement devices used today with a perspective of applying them to the rain garden being built as part of a co-operative student project.

The results obtained can help in the further development of the rain garden concept by allowing more effective control of rainwater pollution levels and their removal, which can positively affect the introduction of more sustainable rainwater management practices. In addition, the process of constructing a continuous monitoring system itself also provides information on what equipment, in what configuration, can be used so that water quality and retention measurements can be carried out at the lowest possible cost, while still being fully effective.

This work was funded by the project “Retention, infiltration and purification of rainwater” within the FutureLab PK.

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Modern polymeric materials with bioactive additives – characterization of antioxidant properties and release kinetics

The aim of this study is to investigate the effect of silver particles suspended in Arnica montana flower extract on the physicochemical properties and release of bioactive compounds in PVP-based hydrogel systems. Hydrogels were synthesized by photopolymerization, and their properties, such as density, porosity, surface roughness, swelling capacity, and water vapor transmission index, were thoroughly analyzed. The results showed that the addition of silver influenced the structural changes in hydrogels, such as a decrease in density and an increase in porosity, and an improvement in moisture regulation capacity. These changes also affected the release rate of bioactive compounds, suggesting the potential application of these materials in the biomedical field, including wound treatment, where controlled release of moisture and active substances is crucial.

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Transfersomes as deformable drug carriers

Transfersomes are flexible, deformable drug carriers that are an innovative approach to transporting active substances across the skin barrier and biological membranes. Their unique structure, based on phospholipids and the addition of surfactants, gives them a high ability to deform, which allows for deeper penetration into tissues without damaging cells. As a result, transfersomes show great potential in pharmaceutical applications, especially in the delivery of drugs with low bioavailability, such as peptides, proteins or hydrophilic drugs. Compared to traditional liposomes, transfersomes are characterized by greater stability and a better ability to cross the epidermal barrier. This paper aims to present the mechanism of action of transfersomes, their advantages and possibilities of application in modern pharmaceutical therapy, with particular emphasis on skin therapies and delivery of controlled-release drugs.

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4D printing of functional hydrogels with linseed bioink: new directions in biomaterials development

The aim of this research is to develop functional hydrogels using 4D printing technology with flaxseed-based bioink, which is an innovative approach in biomaterials engineering. 4D printing, unlike traditional 3D printing, allows obtaining materials that change their properties in response to external changes, such as humidity, temperature or pH. Flaxseed bioinks used as a printing material are characterized by high biodegradability, biocompatibility and natural anti-inflammatory and antioxidant properties. The obtained hydrogels are expected to demonstrate excellent swelling capacity, moisture regulation and structural adaptation to changing conditions, which will make them promising materials in biomedical applications, including wound care and tissue regeneration. The literature indicates the great potential of flaxseed bioink as a functional material in 4D printing technology, offering new possibilities in the design of intelligent biomaterials with controlled properties.

Materials and sustainable solutions in environmental protection

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A modern approach to terrain permeability analysis based on a Digital Elevation Model (DEM) using SCALGO Live

In the era of rapid climate change and ongoing urbanization, effective water management has become a significant challenge. The aim of this study is to assess the potential of the SCALGO Live platform and high-resolution Digital Elevation Models (DEM) in analyzing land drainage capacity and modeling surface runoff. Special attention was given to the use of these tools in flood prevention and the planning of blue-green infrastructure that promotes rainwater retention.

The research was based on a hydrological analysis conducted using SCALGO Live, which allows for fast interpretation of terrain conditions and their influence on surface runoff. Terrain models enabled the identification of areas at high risk of flooding across various landscape types–urban, suburban, and green spaces. Scenarios involving changes in land use and the potential implementation of retention measures such as detention basins, rain gardens, and green roof systems were compared.

The results indicate a high effectiveness of SCALGO Live as a decision-support tool in spatial planning and environmental protection. For example, the application of retention basins reduced peak flow rates by as much as 30%, with the efficiency of these basins at peak discharge (Qmax) reaching 0.85. Furthermore, the use of hybrid planning models enabled more accurate identification of intervention areas, supporting effective adaptation strategies.

In the analyzed scenarios, the runoff coefficient decreased from 0.75 to 0.52, which reduced the total surface runoff by 27%. Additionally, the capacity of local watercourses increased by approximately 30%, significantly lowering the risk of flooding during heavy rainfall events.

The SCALGO Live platform can be widely used by urban planners, hydrologists, and local governments to support the optimization of drainage systems and catchment area management. Fast access to precise data and interactive visualizations enables informed decision-making regarding flood protection and climate change adaptation.

The presented research confirms that the use of modern digital technologies in water management leads to more effective and sustainable handling of hydrological resources. The ability to forecast and model surface flows in real time creates vast opportunities for spatial planning and the development of smart cities resilient to the impacts of climate change.

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Ecology in business – trend or necessity?

Companies around the world face the challenge of incorporating environmental care, which is becoming a necessity for their long-term success. Ecology not only allows for the protection of nature but is also becoming a trend. Every year, rankings of business leaders actively implementing ecological strategies are created. These include actions such as minimising carbon footprints and investing in environmentally friendly technologies. The aim of the article is to attempt to assess whether ecology in business is a trend, a necessity driven by competitiveness, or an expression of care for the natural environment. It can be observed that the implementation of ecological activities positively impacts the natural environment, but can also be a motive for fulfilling one's own needs, such as building a positive image, increasing customer loyalty, and benefiting from operational cost optimisation. To take a closer look at this issue, three selected companies featured in the latest ranking were analysed. Companies referred to as ecological, consistently develop documents containing strategies mainly concerning climate and natural resources. The case studies of the selected companies show that some enterprises focus on climate neutrality through investments in low-emission technologies. They also concentrate on the use of secondary raw materials, eliminating the use of newly mined precious metals, and integrate ecological solutions throughout the entire life cycle of their products – from design to dismantling. The obtained results show that ecology in business is broadly included in strategic documents. It can be assumed that it is also becoming a trend, however, in many cases, it also stems from increasing regulatory pressure, consumer expectations, and the pursuit of the necessary requirement of sustainable development. The obtained results may be useful for other companies that wish to combine effectively their business goals with the care for the planet, while simultaneously improving their competitiveness, increasing operational efficiency, and building a positive brand image.

Research Supervisor: Ewa Kopeć
Editorial Advisor: Piotr Musiewicz

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The concept of leave no trace environmental ethics – case study

Tourism increasingly impacts the natural environment as mass travel leads to the degradation of nature and often to irreversible damage. In response to this problem, the American organisation Leave No Trace Center for Outdoor Ethics (Leave No Trace – LNT), which promotes responsible and conscious use of nature, was established. Its activities focus on educating tourists about the need to minimise negative environmental impact through proper planning, appropriate behaviour in the field, and reducing waste generation. The aim of the article is to review the principles of Leave No Trace environmental ethics applied in tourism abroad and to demonstrate their implementation in the Gdańsk Region of the Polish Scouting and Guiding Association. The LNT programme is based on seven simple principles that include actions reflecting the assumptions of sustainable tourism. Based on the case study of the Gdańsk Region of the Polish Scouting and Guiding Association – the largest educational organisation in Poland – the practical application of LNT principles in the activities of a non-governmental organisation is discussed. In particular, the establishment of the first and especially significant environmental ethics team, "Nadzieja", in this region was analysed. The team combines the internal document Environmental Ethics of the Polish Scouting and Guiding Association with the Leave No Trace programme, which presents tools and methods for ecological action. Observing the implementation of the Leave No Trace programme, including the case study, may be useful for the development of not only sustainable tourism, but may also contribute to raising awareness of the need to develop measures supporting the introduction of changes in this area within non-governmental organisations, enterprises, and educational institutions.

Editorial Advisor: Piotr Musiewicz

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Feasibility of using geopolymers as materials for CO_2 sequestration

The growing problem of carbon dioxide emissions and the resulting climate change require the development of new, effective methods of CO_2 reduction in the atmosphere. One promising solution is geopolymers – inorganic binder materials whose specific chemical structure allows for permanent storage of carbon dioxide. As part of this research project, a comprehensive analysis of available scientific literature and experimental data was conducted to evaluate the potential application of geopolymers for CO_2 sequestration.

The objective of the study was to determine the capacity of geopolymers to absorb and permanently bind CO_2, both during the material production process and throughout its service life. The hypothesis assumed that proper optimization of raw material composition and curing conditions could significantly enhance the CO_2 uptake capacity of geopolymers. The conducted analysis confirmed these assumptions, highlighting the key role of carbonation reactions and the presence of alkaline components in the geopolymer matrix.

The literature review results indicate that geopolymers can serve a dual function: as durable construction materials and as active media for greenhouse gas emission reduction. Potential applications include capturing CO_2 from flue gases in power plants as well as improving the carbon balance in urban construction. These findings emphasize the need for further detailed experimental studies to fully assess the effectiveness of these solutions on an industrial scale.

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Thermal properties of foamed geopolymers with natural fibers

The growing need for environmentally friendly and energy-efficient construction materials has prompted research into alternative insulation solutions. Traditional insulating materials often have a significant environmental impact, both in terms of raw material use and production emissions. Foamed geopolymers represent an innovative class of inorganic materials characterized by high mechanical strength, chemical resistance, and low environmental footprint. Their porous structure allows for thermal insulation applications. Enhancing geopolymers with natural fibers such as hay, wood fibers, or raffia introduces an additional ecological component and improves the thermal insulation performance by further increasing porosity and reducing thermal conductivity. This combination aims to create a sustainable, lightweight, and highly effective insulation material.

The primary objective of the research is to develop a novel insulation material based on foamed geopolymers enriched with natural fibers, which would be ecological, effective in limiting heat conduction, and structurally durable.

Research hypotheses:

- The addition of natural fibers to foamed geopolymers improves thermal insulation properties by increasing porosity.
- Natural fibers contribute to a lower material density, thereby reducing the weight of the final product.
- The developed composite material will achieve thermal performance comparable or superior to conventional insulation materials, while maintaining a lower carbon footprint.

The thermal conductivity of the developed material was measured using a plate lambdameter, a precise device for determining the thermal conductivity coefficient (λ) under laboratory conditions. The tests confirmed that the addition of natural fibers effectively reduces the thermal conductivity of foamed geopolymers. The presence of fibers led to the formation of a more porous structure, which plays a key role in limiting heat transfer. Moreover, the low density of the resulting composite material suggests its suitability for lightweight construction systems. The achieved insulation parameters position the material as a competitive alternative to traditional insulation solutions, particularly in sustainable construction applications.

The conducted research confirms the high potential of foamed geopolymers with natural fiber additives as innovative insulation materials. They offer a favorable combination of thermal performance, low environmental impact, and structural lightness. The ecological character of the components aligns well with current trends in sustainable and green building. Such composites can be successfully applied in walls, roofs, and floors to reduce energy consumption in buildings. Additionally, potential applications exist in industrial sectors requiring high thermal insulation. Further research is ongoing to optimize the formulation and production process, with the aim of improving insulation efficiency and expanding the material's application scope.

This research was carried out as part of the project titled: "Badania sorpcji i desorpcji CO_2 w geopolimerowych funkcjonalizowanych strukturach porowatych w celu sekwestracji dwutlenku węgla"; SKN/SP/601960/2024: "Studenckie koła naukowe tworzą innowacje".

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Application of locally occurring post-production waste in the synthesis of low-emission geopolymer

With the growing demand for sustainability and lower carbon emissions in the construction industry, low-carbon alkali-activated binders, known as geopolymers, are getting more attention. Geopolymers are a class of amorphous, aluminosilicate inorganic polymers formed by the polycondensation reaction of aluminum-rich raw materials and silicon with alkaline solutions. The aim of the study was to synthesize geopolymer binders from locally available waste materials that had not been considered or had been eliminated due to low reactivity or unsuitable chemical composition. The base materials were analyzed by XRD to determine their phase composition. Laser particle size analysis was also performed. The mixtures of base precursors were activated with a 10M NaOH solution and sodium water glass, and then cured for 24 hours at 60°C. The obtained geopolymers were conditioned for 28 days under laboratory conditions and then subjected to microstructural analysis and strength testing. The highest compressive and flexural strength values were obtained for the mixture based on raw diatomite and fly ash from Bełchatów – 23.7 MPa and 7.62 MPa, respectively. The use of local waste for the production of geopolymer binders is not only environmentally beneficial, but also contributes to the development of a circular economy. In addition, the synthesis of geopolymer binders based on post-industrial waste will reduce the amount of waste in landfills and contribute to its recycling.

This work has been financed under the project "GEOSUMAT – Materials for the circular economy" (M-ERA.NET3/2021/70/GEOSUMAT/2022).

Modern materials and bioenergy: perspectives for sustainable development

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From biomass to bioeconomy: tracking the global growth of bioenergy

Bioenergy constitutes a key element of the energy transition, supporting decarbonization and the development of sustainable energy systems. The aim of this study was to identify the main directions of bioenergy development at the global level, with an emphasis on analysing development scenarios and technologies used in this sector. It was hypothesized that further bioenergy development will be closely linked to technological progress, the increasing importance of waste as a raw material, and the adaptation of regulations in response to local economic and environmental conditions.

The analysis results confirm the dynamic growth of modern bioenergy, understood as the use of biomass in a technologically advanced, efficient, and environmentally friendly manner. The principle of cascade biomass use was presented as a key element in increasing material efficiency. The main trends in biomass utilization for heat and electricity production, as well as the directions of transport biofuels development–taking into account the changing raw material profile (increasing share of waste and organic residues)–were identified. The analysis of biogas market development scenarios in selected countries revealed diverse strategies for its integration with the energy, transport, and industrial sectors.

The study's conclusions emphasize the need for continued support of innovative technological investments and the importance of energy policy instruments promoting sustainable forms of bioenergy.

This analysis constitutes original research conducted by the author as part of the work of the Division of Renewable Energy Sources.

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Modern geopolymer materials for the protection of underwater structures: durability in dilute saline-acidic environments

The protection of critical underwater infrastructure and hazardous shipwrecks poses a growing challenge, especially in harsh and highly polluted environments. Traditional materials often fail due to accelerated corrosion, creating the need for more durable solutions. The issue is particularly urgent where hazardous cargo threatens marine ecosystems. Therefore, the development of advanced, corrosion-resistant materials is essential for long-term structural integrity and environmental protection. The aim of the present study was to evaluate the corrosion resistance of geopolymers immersed in six different chemical environments: a baseline 3% sodium chloride (NaCl) solution and NaCl solutions combined with acid solutions at a concentration of 0.05%, namely: hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), acetic acid (CH_3COOH), and a mixture of the aforementioned acids. The precursors used for geopolymer production included fly ash from the Skawina Combined Heat and Power Plant, coal shale from the Silesia mine, carbon fibers, nanosilica, and an alkaline solution as activator of geopolymerization. After production, the samples were cured for 28 days and subsequently subjected to immersion in aqueous-acidic environments. Compressive strength was evaluated after 7, 28, 180, and 360 days of exposure. Obtained results revealed an increase in compressive strength after one year of immersion in acid-containing environments, while fluctuations in this parameter were observed during shorter immersion periods. The highest compressive strength, amounting to 40 MPa, was recorded for samples immersed in hydrochloric acid solution. The results indicate the potential applicability of the developed geopolymer materials for protecting critical underwater structures, such as pipelines, components of drilling and extraction platforms, port and dock infrastructure, and shipwrecks containing hazardous substances.

Recent research has turned attention toward geopolymer materials as a promising alternative [1, 2]. These aluminosilicate-based binders, activated by alkaline solutions, exhibit superior chemical resistance, particularly against chloride penetration and acid-induced leaching [3]. Unlike traditional cement, geopolymers develop a dense and stable matrix that is less permeable to aggressive ions, enhancing their long-term durability in marine environments [3, 4]. Laboratory and field studies confirm that geopolymers retain mechanical integrity under prolonged exposure to dilute saline-acidic conditions [5]. Incorporation of nanomaterials (e.g., nano-silica or slag), tailored curing protocols, and surface treatments further enhance resistance [6, 7]. In parallel, geopolymer concretes show lower carbon footprints, making them attractive not only for protective underwater infrastructure but also in terms of sustainability [4].

This research was funded by the project titled "Development of geopolymer composites as a material for protection of hazardous wrecks and other critical underwater structures against corrosion" under the

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Multifunctional nano-porous materials

Ordered mesoporous silica is an excellent platform for creating nanocomposites through the introduction of various functional groups on its surface. This strategy enables the modification and control of their physicochemical properties by incorporating a wide range of functionalities. In this work, we present SBA-15 silica functionalized with propyl copper phosphonate groups as a material exhibiting unique optical and biological properties. In this system, the silica acts as a support that anchors the functional groups and ensures their spatial arrangement, while the functional groups themselves impart specific physicochemical features not observed for pristine SBA-15. These include, in particular, nonlinear optical properties which, depending on the concentration of functional groups in the nanocomposite, can be tuned to the needs of the application, as well as remarkable biological properties, especially antimicrobial activity, the extent of which can also be tuned. To elucidate the origin of the observed effects, the material was thoroughly characterized in terms of its chemical composition and molecular structure using a range of experimental techniques. In particular, spectroscopic methods such as Raman spectroscopy and X-ray absorption spectroscopy (XAS) allowed the explanation of the observed structure–property relationships. In conclusion, our research showed that, through the appropriate selection of functional groups and their concentration on the silica surface, it is possible to tune the properties of the obtained nanocomposites.

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Mn-based double perovskite $Sm_{0.9}Ba_{0.9}Mn_{1.8-x}Fe_x(Ni/Co)_{0.2}O_{6-\delta}$ with *in situ* exsolved nanocatalysts as potential electrode materials for intermediate temperature Solid Oxide Cells

In today's rapidly changing world, maintaining a high standard of living depends on access to clean and reliable energy sources. However, conventional energy resources are finite, subject to gradual depletion, and often limit energy independence. Symmetrical Solid Oxide Cell (s-SOC) technology has emerged as a promising solution to these challenges. S-SOCs are highly efficient electrochemical devices capable of both converting and storing energy, depending on system demand. A key challenge, however, lies in the development of suitable electrode materials. Because s-SOCs operate in a symmetrical configuration, their electrodes must simultaneously meet the requirements of both the cathode and the anode. This necessitates materials that exhibit mixed ionic-electronic conductivity, high electrocatalytic activity, and structural stability under both reducing and oxidizing conditions. Therefore, the present work focuses on the development of $Sm_{0.9}Ba_{0.9}Mn_{1.8-x}Fe_x(Co,Ni)_{0.2}O_{6-\delta}$ double perovskite electrodes, further enhanced through *in situ* exsolution of nanocatalysts, as potential high-performance electrode candidates for s-SOC applications. The research work included material synthesis, crystal structure analysis, investigation of thermal expansion properties, characterization of *in situ* nanoparticle exsolution. Finally, electrochemical measurements of selected electrodes were performed in electrolyte-supported s-SOCs. The results indicated that Fe doping in Mn-based perovskite electrodes promotes the *in situ* exsolution process and is beneficial to the overall performance of the s-SOCs. The developed materials exhibit relatively good stability and compatibility with commercially available electrolytes, particularly Gadolinium-Doped Ceria (GDC20). Diffraction studies allowed the symmetry of *in situ* exsolved metallic nanoparticles to be assigned to the $Fm\bar{3}m$ space group, whereas under operating conditions of the air electrode, the nanocatalysts were oxidized to the space $Fd\bar{3}m$ group. Application of these materials as electrodes in s-SOCs revealed stable long-term performance and high power density. Performed systematic investigation indicated that both Fe-doping and *in situ* exsolution are effective strategies for tuning new electrode materials for s-SOCs. The results show that the presented electrodes can accelerate the commercialization of s-SOCs in the coming energy transformation.

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Innovative PVP hydrogels with micrometric silver particles and *arnica montana* extract for applications in the treatment of chronic wounds

The aim of this work was to develop and characterize hydrogels based on polyvinylpyrrolidone (PVP) containing silver particles synthesized using Arnica montana flower extract. The effect of silver suspension content on physicochemical properties and release kinetics of antioxidant compounds was assessed. Hydrogels were prepared by photopolymerization with a constant cross-linking agent (PEGDA), modifying only the amount of Ag suspension. Density, porosity, surface roughness, sorption capacity and water vapor permeability were measured. The results showed that increasing silver content led to a decrease in density (from 0.6669 to 0.2963 g/cm^3), an increase in porosity (from 4% to 11.04%) and an improvement in permeability (WVTR: 65–94 g/m^2·h). Kinetic models confirmed the dependence of antioxidant release on silver concentration. The applied micrometric silver particles combined with bioactive plant extract create a functional material with high stability and therapeutic potential. The obtained systems exhibit properties that predispose them to applications in active dressings – with controlled hydration and delivery of biologically active substances – which may significantly affect the future of chronic wound treatment and the development of modern biomaterials.

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Non-isocyanate polyurethanes (NIPU) based on vegetable oils

Polyurethanes are polymers obtained by the polyaddition of organic isocyanates with compounds containing at least two hydroxyl groups (polyols). Due to their high reactivity, isocyanates are highly irritating and toxic, both during application and in their synthesis, in which phosgene is used as a raw material. An alternative to conventional polyurethanes are non-isocyanate polyurethanes (NIPU), obtained in the reaction of cyclic carbonates based on vegetable oils with polyamines containing primary amino groups. This results in linear, cross-linked poly(hydroxyurethane) (PHU) polymers with a high bio-carbon content. The synthesis of NIPU involves the epoxidation of vegetable oils, the carbonization of epoxidized vegetable oils in their reaction with CO_2, and the synthesis of NIPU in the reaction of cyclic carbonates with selected polyamine compounds.

The key technological challenges associated with the synthesis of PHU polymers were presented, including shortening the synthesis time of cyclic carbonates, accelerating NIPU cross-linking, and obtaining favorable mechanical properties. Current research directions are also presented, as well as potential areas of application as a sustainable alternative to traditional polyurethanes.

A series of carbonization tests were conducted on epoxidized soybean oil using a range of imidazole and choline ionic liquids as catalysts. Using ionic liquids with bromide anions and imidazole cations as catalysts, conversion times comparable to those achieved with ionic salts were obtained. However, the cyclic carbonates obtained were characterized by significantly higher reactivity, which resulted in a reduction in the reaction time with DETA at 100°C to approximately 10 minutes, compared to 25 minutes for standard catalysts.

The effect of a series of polyamines on the PHU synthesis process was investigated. Aliphatic and cycloaliphatic polyamines containing at least two primary amino groups allow for complete cross-linking of cyclic carbonates; aliphatic compounds containing only secondary and tertiary amine groups, as well as only one primary amine group, did not lead to the curing of CSBO; aromatic polyamines with amine groups attached directly to the ring showed no reactivity, while the removal of these groups from the aromatic ring via an aliphatic chain resulted in the ability of these compounds to fully cross-link CSBO.

Ionic liquids with bromide anions and imidazole cations, as catalysts, resulted in the conversion of epoxy groups to cyclic carbonates of >90%, with a yield of 80–95% and selectivity of 85–100%; the best results were achieved with [bmim]BR and [emim]Br. The fastest PHU crosslinking amine identified in this study is the linear triamine DETA with two primary amino groups and one tertiary amino group. Cyclic carbonates obtained with ionic liquids as catalysts resulted in shorter reaction times with polyamines, allowing NIPU foams to be produced using azodicarbonamide (AZO) as a foaming agent, which reduces production costs compared to foams produced using polymer microcapsules. Hot-melt adhesives on wood samples showed strength comparable to commercially available EVA copolymer-based adhesives.

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Efficiency and stability of elemental mercury sorption from the gas phase using activated natural zeolites

Effective removal of elemental mercury (Hg^0) from industrial gas streams remains a significant environmental challenge due to the volatile and persistent nature of mercury species. This study investigates the efficiency and long-term stability of Hg^0 sorption using natural zeolites modified by two activation methods: precursor spraying and ion exchange. The research objective was to determine which modification strategy, precursor type, and loading method most effectively enhances mercury adsorption and its long-term retention. It was hypothesized that ion exchange, particularly using nitrate-based precursors, would result in more uniform precursor incorporation, leading to improved sorption efficiency and mercury immobilization.

Natural zeolites were modified with silver and iron precursors in both nitrate and chloride forms. The materials were characterized using powder X-ray diffraction (PXRD), scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS), and Fourier-transform infrared spectroscopy (FTIR). Mercury adsorption performance was evaluated through six consecutive adsorption cycles in a prototype laboratory-scale installation. Approximately twelve months after initial sorption, the retained mercury and its potential re-emission were assessed using a direct mercury analyzer (DMA).

The results confirmed the hypothesis: ion exchange facilitated more effective incorporation of precursors, especially silver nitrate and iron nitrate, resulting in higher adsorption capacities and enhanced long-term stability. Among all tested samples, the zeolite modified with the highest dose of iron nitrate demonstrated the most promising results in terms of both initial Hg^0 removal and retention over time. In contrast, spraying led to uneven precursor distribution and relatively lower performance, though silver chloride-modified samples still showed appreciable sorption potential. Across all conditions, nitrate-based precursors outperformed their chloride counterparts, indicating their greater suitability for zeolite functionalization and mercury binding durability.In conclusion, the selection of activation method and precursor chemistry plays a critical role in optimizing zeolite-based sorbents for elemental mercury removal. Ion exchange with nitrate precursors emerged as the most effective strategy, offering both high sorption efficiency and long-term mercury stabilization. These findings highlight the potential of tailored zeolitic materials in future industrial applications for mercury control.

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Retention and infiltration of rainwater using pervious concrete

Pervious concrete, also known as permeable concrete, is a mixture of binder and coarse aggregate, with a small amount of fine aggregate and, in some cases, admixtures and additives. The porous structure allows liquids and gases to pass through. Key parameters of pervious concrete include the filtration coefficient and compressive strength. The contact zone between aggregate and cement paste significantly influences the mechanical properties of the concrete.

The experiments used porous concrete with a composition of: C = 3.72 kg/batch, W = 1.12 kg/batch, P = 0.75 kg/batch, G (4/8) = 15 kg/batch and superplasticizer 40 g/batch. Dry ingredients were mixed in a mixer, to which water with dissolved superplasticizer (Viscocrete 6, Sika) was added. The water-cement ratio (w/c) was 0.3. Concrete was made with coarse aggregate of fraction 4/8 mm. Sand was added in an amount of 10% of the coarse aggregate to prevent the setting slurry from flowing down the aggregate during compaction. The concrete was compacted for 3–5 seconds on a vibrating table. The most important parameter is the concrete porosity, which averages 17%.

The experiments conducted so far concerned estimating the value of the filtration coefficient of the tested pervious concretes. Initially, experiments were conducted in a steady state, with a constant pressure ordinate, for a specific flow, using a pervious concrete cube with a thickness of 5.6 cm and dimensions of 25 cm × 25 cm. Experiments were also conducted with pervious concrete in an unsteady state with a known water volume, measuring the water flow time in a pipe 50 cm long, 10 cm in diameter, with a pervious concrete layer 7.2 cm thick. All experiments were performed in triplicate. The filtration coefficient value determined for pervious concrete is in the range of 0.4–0.6 cm/s. Pervious concrete offers promising solutions for water management challenges. For example, in urban agglomerations, increasing permeable surfaces through strategic de-sealing will cause less rainwater to rapidly flow into sewers and rivers, resulting in less loss of water resources and its better use by the urban ecosystem. The greatest advantages of pervious concrete include efficient drainage of rainwater, prevention of sewer overload, reduction of puddle formation, and increased natural water retention.

The authors would like to thank Małgorzata Lenart and Andrzej Mączałowski for their assistance in the laboratory analysis.

This work was funded by the project “Retention, infiltration and purification of rainwater” within the FutureLab PK.

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Cheap, available, safe – halide electrolytes in Na-ion cells

Due to the rising cost and limited availability of lithium resources, alternative energy storage technologies are receiving increasing attention. One of the most promising is Na-ion cells, which use cheap and widely available sodium. Although the commercialization of Na-ion cells with liquid electrolyte is just beginning, the future of this technology is linked to the transition to solid state cells – mainly due to greater safety, higher energy density and better stability. In addition, solid-state Na-ion cells require a revised architecture compared to their liquid counterparts. This opens up new design possibilities, such as the use of composite electrolytes tailored to specific interfaces – for example, an anolyte stable against metallic sodium and a catholyte optimized for stability at high voltages near the cathode. The purpose of this work is to explore the potential of solid halide electrolytes, in particular the material $NaAlCl_4$, in the role of catholyte for solid state sodium batteries.

Material synthesis was carried out using a simple ball milling method, allowing for scalable production. The materials were subjected to structural studies by X-ray diffraction technique, followed by measurements of electrochemical impedance spectroscopy. The effect of oxygen doping on the conductive properties was also studied. Preliminary results showed improved ionic conductivity and potential for further optimization. Further structural and electrochemical studies using advanced techniques are planned.

Halide-based solid electrolytes for sodium cells, such as $NaAlCl_4$, exhibit high conductivity, low interface resistance and good stability during high voltage operation, making them ideal candidates as catholytes in sodium-ion cells. Their composition based on low-cost, widely available elements further enhances their commercial attractiveness. The technology under development could find applications in energy storage systems, especially where low cost and safe use are key.

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Agnieszka Cholewa-Wójcik, Agnieszka Kawecka
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Social determinants of implementing sustainable packaging solutions in the food industry of central Europe

In the face of growing consumer awareness, environmental degradation, and regulatory pressure, the transition toward sustainable packaging has become a central pillar of innovation strategies within the food industry. Packaging is no longer perceived solely as a tool for protection or branding–it increasingly reflects broader ecological and social values. However, the actual consumer readiness to embrace environmentally friendly packaging solutions, especially when these involve higher costs or altered product functionality, remains limited and insufficiently explored in the context of Central Europe.

The objective of the presented study, conducted within the framework of the D4PACK project (Support the Transition of the Central Europe Food Industry Towards Next-Gen Packaging Models), was to assess consumer preferences regarding food packaging and identify social determinants influencing the acceptance of eco-innovations. The research involved a large-scale online survey administered to 1,069 respondents from Poland, the Czech Republic, Northern Italy, Hungary, and Slovenia-regions representing a diverse yet interconnected economic and cultural space within Central Europe.

The results confirm that price, product safety, and packaging functionality remain the dominant criteria in consumer purchasing decisions. While environmental attributes, such as recyclability, biodegradability, or the use of renewable materials are acknowledged as relevant, they seldom lead to a willingness to pay more, suggesting a persistent attitude–behavior gap. Notably, the study reveals that women and older consumers exhibit consistently higher expectations for packaging to fulfill ecological and educational roles, such as providing transparent sustainability information or enabling waste sorting.

These insights indicate that sustainable packaging solutions should not be introduced in isolation but must be aligned with social expectations and economic constraints. Integrating a consumer-centered, socially aware perspective into packaging design is essential for achieving broader acceptance of material innovations. Additionally, communication strategies should be tailored to various demographic groups to effectively bridge the gap between ecological awareness and actual purchasing behavior.

This research was conducted by a multidisciplinary team of authors: Agnieszka Cholewa-Wójcik, Agnieszka Kawecka, Katarzyna Sanak-Kosmowska, and Mariusz Łapczyński.

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Diatomite as a filtration material for the removal of nutrients from stormwater

Progressive urbanization leads to increasing environmental pressures, including the deterioration of stormwater quality entering receiving bodies. Nature-based solutions, such as rain gardens, are being increasingly employed to improve stormwater retention and purification.

This study evaluated the effectiveness of diatomite – a naturally occurring mineral material – as an additive to rain garden substrate in the context of nutrient pollutant removal. Diatomite is a raw material sourced from the only Polish diatomite mine in Jawornik Ruski in the Subcarpathian region, which reduces the transport footprint and enables regional use of the resource.

Laboratory tests were carried out using three retention columns: one without diatomite and two with mixtures of diatomite and sand at weight ratios of 1:4 and 1:2. A simulated rainfall of 32 mm was applied, along with known concentrations of NO_3^-, NH_4^+, and PO_4^{3-} at 15 mg L^{-1}, 5 mg L^{-1}, and 2 mg L^{-1}, respectively.

The presence of diatomite significantly enhanced the removal efficiency of nitrogen load (expressed as the sum of $N\text{-}NO_3^-$ and $N\text{-}NH_4^-$) from 9% to 44%, and phosphorus load in the form of orthophosphates from 38% to 96%. The results confirm that diatomite can be an accessible and environmentally friendly component in modern stormwater management systems, supporting local efforts to protect water resources.

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Hydroprocessing technology for obtaining a sustainable aviation biocomponent

In recent years, intensive research has been carried out on technologies for the production of bio-components for aviation fuel JET A-1, driven by the growing demand for low-emission transport. A major impulse for this development was the revision of ASTM D7566 (2009), which specified the types of hydrocarbon bio-components and set the quality requirements for aviation fuels. Studies have confirmed that fuel containing up to 50% bio-components is equally safe in operation as conventional petrochemical fuels. The lack of appropriate production technologies in Poland creates a deficit in meeting national and EU targets for CO_2 reduction, particularly given the obligation to increase the share of biofuels derived from non-edible raw materials.

The aim of this research was to develop an innovative technology for producing aviation bio-additives from fatty acids. The process consists of two key stages: in the first, hydrodeoxygenation of fatty acids yields bio-n-alkanes, while in the second, hydroisomerization is carried out to improve the physicochemical properties of the fuel, including reducing the freezing point, which is a critical parameter for JET A-1. The hydroisomerization stage was conducted in a three-phase reactor using a heterogeneous catalyst developed at Łukasiewicz – ICSO "Blachownia."

The results confirm that the developed technology enables the efficient conversion of fatty acids into high-quality aviation bio-components. The process provides a sustainable alternative to fossil-based routes and can significantly contribute to increasing the share of renewable aviation fuels, supporting the achievement of decarbonization targets in the aviation sector.

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Technology for the production of pharmaceutical-grade bio-propylene glycol

The production of 1,2-propanediol (propylene glycol) represents a significant challenge for the chemical industry due to the rapidly increasing demand, stringent regulations on CO_2 emission reduction, and the ban on the use of chromium(VI) compounds in catalysts. To date, industrial practice has relied on the energy-intensive hydrolysis of petrochemical propylene oxide, which generates a considerable carbon footprint. An alternative pathway is the hydrogenolysis of glycerol, a by-product of biodiesel production. However, commercially available technologies (e.g., BASF/Air Liquide, ADM) employ catalysts with insufficient selectivity, which increases process costs and complicates product purification.

The aim of this study was to develop an innovative, single-step technology for glycerol hydrogenolysis to propylene glycol using a novel heterogeneous copper-based catalyst. The working hypothesis assumed that the catalyst would enable high selectivity and process stability under continuous operation.

The experiments were conducted in a fixed-bed flow reactor. The process achieved a glycerol conversion of 85% and selectivity above 95% after 1000 hours of operation, confirming both the durability of the catalyst and the stability of the reaction. The technology was successfully scaled up to a quarter-technical level, and the obtained product, after distillation and refining, met the requirements of the Pharmacopeia for pharmaceutical-grade propylene glycol. The conducted research demonstrates that the developed technology constitutes a competitive and sustainable alternative to petrochemical processes, contributing to the reduction of the carbon footprint and the efficient utilization of surplus glycerol from biodiesel production.

This research was carried out within the framework of the INNOCHEM project POIR.01.02.00-00-0041/17 "Technology for the Production of Pharmaceutical-Grade Bio-Propylene Glycol", financed by the National Centre for Research and Development (NCBR).

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Improving methods of color quality control in large-scale printing with hyperspectral imaging

This research analyzes color in multi-color printing, homogeneity, and surface characteristics according to the ISO 12647-2 (International Organization for Standardization), which is appropriate for offset printing. In the printing industry, handheld spectrophotometers are used for precise color characterization and recording spectra of selected graphic fields. Hyperspectral cameras offer new possibilities for quality control of various printing products. However, processing and modelling large spectral data is challenging. The vast potential, high efficiency and accuracy of hyperspectral cameras compared to simple handheld spectrophotometers encourage their wider implementation. It requires constructing models and expert systems, which can ultimately provide accurate evaluation of the entire graphic instead control fields.

The results obtained with basic measurement devices and with a hyperspectral camera correlate with each other, and thus can be used interchangeably for samples with a homogeneous surface. Comparative analysis of data obtained from a spectrophotometer and a hyperspectral camera showed their high correlation. After mathematical transformations of the spectra, the differences resulting from the use of two light sources were corrected.

The color differences calculated for the L*, a*, and b* coordinates for the same samples confirm the agreement of the results according to the CIE (Commission Internationale de l'Eclairage – International Commission on Illumination) model. The proposed hyperspectral approach allows for more efficient and accurate analysis, reduces reliance on color control fields, and decreases raw material consumption.

This research was carried out as part of an Implementation Doctorate at Walstead Kraków sp. z o.o., under contract number DWD/5/0244/2021. The dissertation is entitled "Quality Testing of Printing Products Using Hyperspectral Cameras with Particular Emphasis on Colour". I would like to express my sincere gratitude to the Polish Ministry of Education and Science (MEiN) for the opportunity to carry out this work within the framework of the Implementation PhD Programme. I also extend my heartfelt thanks to Walstead Kraków sp. z o.o. for their invaluable support and for providing the facilities necessary for the successful completion of this research.

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Environmental impact assessment of using a robot for underground mining

The revolution in automation and robotics is a fact today. The ROBOMINERS project is moving in this direction, its aim is the technology of extracting mineral resources. Currently, tests of the robot's movement in the mine have been successfully completed. Since it is generally accepted that replacing humans with robots is economically justified, in the article asks whether there is also a justification for the impact on the environment. For this purpose, a variant environmental impact assessment (EIA) of the use of the robot in a mining environment was carried out. The three variants differed in the degree of development of the facility, geological structure and depth of occurrence. For the evaluation, the matrix method, best for highly hypothetical systems, was used. The environmental impact of raw material extraction using robot technology and an analogy mine was compared. European legislation is included, which is constantly aimed at protecting the heritage that is our planet. The provisions of the laws of the European Union and its selected members were analysed: Czech Republic, Hungary, Poland and Portugal. The assumption is that the robot could replace the construction of an underground mine, which always has a significant impact on the environment. The authors of the study, analysing the conditions of use of the ROBOMINERS for the three proposed cases, concluded that the ROBOMINERS could be used. The project is fundamentally different from conventional extraction from underground deposits, significantly reduces the possibility of negative impact and is a great step towards the rational use of identified mineral resources. The result is very optimistic and at this stage of work it may open new opportunities for sustainable mining in Europe and around the world.

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Nanotechnology in viticulture: field methodologies for grapevine research

The assessment of the effects of nanoparticles on plant growth is becoming increasingly important. Owing to their unique properties, the application of nanoparticles in plant science holds great promise. In recent years, food security has become a key objective of many global agendas, and scientific research on the mechanisms underlying this issue provides the foundation for sustainable agriculture. There is no doubt that the future development of sustainable agriculture will rely on new techniques and innovative solutions, many of which are closely linked to nanotechnology.

Our research included both controlled laboratory studies and field experiments assessing the effects of silicon dioxide nanoparticles (nano-SiO_2) on plant growth, photosynthetic processes, and cellular functions. The environmentally friendly character of silica nanoparticles and their potential to mitigate environmental pollution make them an attractive alternative to conventional agents currently used in agriculture.

A field study was carried out in collaboration with the Wieliczka Vineyard (https://winnicawieliczka.com) which holds organic certification and actively contributes to the development of sustainable viticulture. The study evaluated the effects of foliar applications of silicon dioxide nanoparticles on grapevines.

The results demonstrated that nano-SiO_2 stimulates photosynthetic activity in grapevines and enhances the accumulation of photosynthetic pigments. We observed improved photosynthetic efficiency, an increased rate of carbon dioxide assimilation, and higher values of the normalized difference vegetation index (NDVI) in plants treated with nano-SiO_2 sprays.

These findings highlight the strong potential of SiO_2 nanoparticles as an innovative tool for advancing sustainable agricultural practices.

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Production of green diesel via hydrodeoxygenation of oleic acid over mesoporous carbon supported nickel catalysts

Hydrodeoxygenation (HDO) of vegetable oils to produce so-called green diesel is a promising alternative to the transesterification-based biodiesel. Green diesel is composed mainly of hydrocarbons of C15-C18 range and is supreme to the transesterified biodiesel in terms of oxidative stability and fuel properties, such as cetane number and calorific value. Moreover, it is fully compatible with petrochemical diesel fuel, can be produced in the existing hydrorefining factories and used in current diesel engines without their modifications. A recent focus is on the development of suitable catalytic systems that could produce the green diesel with high activity and selectivity towards C15-C18 hydrocarbons. Metals such as nickel, molybdenum, cobalt and alloys thereof are frequently used over supports including silica, alumina, zeolites and structural carbons. In this work, a HDO process of oleic acid as a model compound was conducted over mesoporous carbon (MC) supported nickel catalysts to produce green diesel range hydrocarbons. The catalysts were synthesized via the incipient wetness impregnation method using 10, 25 and 40 wt.% Ni loading over MC support. The texture and structure of the catalysts was characterized using techniques including N2 physisorption, XRF and XRD. Prior to the catalytic tests, the catalysts were calcined in-situ under 50 bar H2 at 400°C for 3 h. The HDO process was carried in a continuous flow microreactor under H2 pressure of 50 bar at 320°C, using contact times varying from 0.58 to 3.49 s. The influence of different Ni loadings (10, 25 and 40 wt.%) and contact time on the catalytic activity and distribution of HDO products was studied. The catalytic tests revealed high activity of all catalysts towards C15-C18 hydrocarbons, and the conversion exceeded 70%, and the formation of undesired cracking products was below 10% for all catalysts. We believe this research can contribute to a better understanding of the role of Ni-based catalysts in the HDO process, clarify the mechanism of the formation of C15-C18 hydrocarbons, and support the implementation of the green diesel in the fuel industry.

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Circular economy and emerging material technologies in construction and environmental protection

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Post-mining waste dumps as a resource – the potential for metal recovery in a circular economy

Post-mining waste heaps, remnants of historical mining activities, are a lasting feature of Poland's geological landscape, particularly in the Silesian and Lower Silesian regions. For many years, these heaps were regarded as worthless waste. However, they are now gaining recognition as potential secondary sources of mineral raw materials, including critical and strategic metals that are essential for industrial development and the ongoing energy transition.

In the context of increasing global demand for metals and the gradual depletion of easily accessible primary deposits, the recovery of valuable elements from mining waste is becoming a realistic and necessary alternative to traditional mining. This approach aligns with the principles of a circular economy, which emphasizes resource efficiency, recycling, and the reduction of waste.

The aim of this study was to assess the potential of selected post-mining heaps in Poland as sources of recoverable metals. A material sample was taken from a heap located at the former nickel and chrysoprase mine in Szklary. The sample was analyzed using scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS) – morphological analysis and mineral phase identification.

Laboratory results confirmed the presence of hematite and gold, indicating the real possibility of recovering valuable elements from such waste. These findings demonstrate not only economic potential but also environmental benefits – particularly when metal recovery is integrated with the reclamation of degraded post-mining areas.

The presence of such minerals in seemingly depleted heaps suggests that these sites may still contain untapped resources. In the face of limited access to primary raw materials – due to economic, environmental, or geopolitical factors – these secondary sources could play an important role in strengthening national resource security.

Moreover, the utilization of mining waste can reduce environmental pressure by minimizing the need for new mining operations and lowering the volume of waste stored in the landscape. Heaps located in the Sudetes, especially those documented in the Polish Geological Institute's database, show clear potential and merit further research and the development of sustainable recovery technologies.

Adam Hutyra
Krakow University of Technology

Recycled raw materials for concrete 3D printing

Concrete 3D Printing (3DCP) is an innovative construction technology enabling the automated fabrication of structures with complex geometrical features and high material-use efficiency. Despite its technological potential, 3DCP typically relies on conventional cementitious binders and virgin aggregates, which are associated with a significant environmental footprint. A key challenge lies in reducing this disadvantage of 3DCP materials without sacrificing printability or structural performance. This presentation investigates the substitution of standard 3DCP components with recycled materials and industrial byproducts. The working hypothesis states that selected recycled aggregates and supplementary cementitious materials (SCMs) can be effectively integrated into 3DCP mortars while maintaining the performance parameters required for layer-based deposition. Additional objectives include evaluation of the effects of such substitutions on mix rheology and print stability. Experimental trials involved the use of crushed reclaimed concrete, ceramic waste, granulated polymers, glass cullet, fly ash and ground granulated blast furnace slag (GGBFS). Initial results indicate that recycled aggregates introduce variability in flow behavior and mechanical performance, identifying precise control of mix composition as a critical challenge. Additionally, SCMs improve cohesion and extend the open time of 3D printable mortars. The findings support the viability of integrating recycled materials into 3DCP, provided that rheological properties are optimized to ensure process reliability. The presented approach contributes to circular construction practices and aligns with low-carbon development strategies.

The author acknowledges the contribution of Marcin Maroszek (Krakow University of Technology) to the research on the practical implementation of recycled raw materials in the 3DCP process.

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Agnieszka Przybek, Maria Hebdowska-Krupa, Michał Łach
Krakow University of Technology

Sustainable building solutions that reduce greenhouse gas impacts

The construction sector is one of the key sources of greenhouse gas emissions, with Portland cement production accounting for about 8% of global CO_2 emissions. With increasing demands for sustainability and carbon footprint reduction, the search for alternative construction materials has become a priority for modern materials engineering. Geopolymers, which are products of alkaline activation of silicon- and aluminum-rich raw materials such as fly ash, blast furnace slag and metakaolin, are a promising alternative to traditional cementitious binders. The process of their synthesis is characterized by lower CO_2 emissions, reaching reductions of up to 80%, and also allows for the management of industrial waste, which contributes to the implementation of the principles of a closed-loop economy. Geopolymer materials show high mechanical strength, good resistance to aggressive chemical environments and improved thermal stability compared to traditional Portland cement-based concretes. Their physicochemical properties make them applicable in infrastructure elements, prefabricated construction, as well as in the production of insulation and refractory materials. Despite their numerous advantages, widespread implementation of geopolymer technologies faces challenges in optimizing synthesis processes, ensuring reproducibility of material properties, and the lack of standardized technical standards. Large-scale implementation of geopolymers could significantly contribute to reducing greenhouse gas emissions in the construction industry, supporting global decarbonization and sustainable development goals.

Elwira Rusinek, Michał Łach, Kinga Korniejenko, Agnieszka Grela, Kacper Oliwa
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Possibilities of using diatomites in water treatment processes and producing synthetic zeolites based on them

Diatomites are sedimentary rocks rich in silica (SiO_2), formed from the accumulation of fossilized shells of diatoms (unicellular algae). These lightweight, highly porous materials have a wide range of applications. They are commonly used in filtration, the prevention of eutrophication, and the sorption of petroleum-derived substances. Additionally, diatomites can be transformed into synthetic zeolites with diverse properties, which are particularly useful in water purification processes. The goal of this study was to check if diatomite can be used instead of fly ash to produce zeolites in a more environmentally friendly way. The synthesis has been performed at low temperatures (below 40°C) and in a weak sodium hydroxide (NaOH) solution (2 and 3 M) to reduce CO_2 emissions and energy use.

The research done shows potential for synthesizing zeolites from diatomites found in Poland. It also explores the feasibility of using these materials in water treatment and purification, as well as in the removal of various pollutants from liquids. Although Polish diatomites may not be of the highest purity, they show significant promise for use in environmental engineering, especially in applications aimed at removing contaminants from water and other media. In conclusion, our results show that diatomite is a good alternative to fly ash for making zeolites. This method is simpler, uses less energy, and fits well with the idea of greener and more circular production processes.

Michał Sadzikowski
AGH University of Krakow

Evaluation of the potential use of selected scrap grades in producing new copper alloys

Modern technologies for the production of copper alloys are increasingly facing shortages of primary raw materials and significant fluctuations in their prices. As a result, there is a growing trend to use waste in the form of scrap as an input material. Until now, such materials have primarily been recycled through metallurgical processes, where no stringent standards have been applied for selecting scrap types based on their chemical composition. This situation contrasts sharply with the production of new copper alloys from scrap, particularly those designed for applications involving mechanical-electrical functions, where even trace amounts of foreign elements can disrupt functional properties, notably leading to a decrease in electrical conductivity. As part of the conducted research, an analysis of copper scrap contamination from railway networks was carried out. The study revealed that the contamination is limited to the surface of the material (copper scraps), with the primary impurities–aside from atmospheric corrosion products–being iron (Fe) and silicon (Si). To eliminate these contaminants, a surface cleaning technique for copper scrap was developed. The implementation of the proposed method enabled the recovery of high-purity copper from the scrap material. The findings clearly confirm that selected, high-quality copper scrap can be directly recycled into the production processes of new alloys. This aligns with the principles of a circular economy, demonstrating the substantial potential of these research results for improving the sustainability of copper alloy production.

Valentina Baruzzi
RINA Consulting S.p.A.

The ZeroWasteLIFE project, transforming composite manufacturing by achieving zero waste

Composite materials find their greatest potential in applications where weight reduction is required without compromising rigidity and resistance of the material, particularly in automotive and aerospace sectors. Despite the high performance of these materials, their sustainability is still a major concern.

The project ZeroWasteLIFE aims at revolutionizing composite manufacturing through innovative processes and modular design, by reducing waste of material to nearly zero, improving efficiency, reducing costs, and enhancing reusability. The project employs High Volume Tailored Fiber Placement (HV-TFP) technology, patented by Nobrak, which involves stitching multiple filaments onto flat patterns, then shaping 2D shapes (textile preforms) into 3D structures and consolidating them by autoclaving or hot pressing through the development of specific moulds. A key aspect of the ZeroWasteLIFE approach is topological optimization, ensuring that the material is used efficiently by placing reinforcements only where they are structurally required. This optimization process involves creating mathematical models to determine the optimal distribution of fibers within the composite material, maximizing strength while minimizing weight.

Project outcomes will include drastic reduction in composite material waste, from 40% to nearly zero, energy consumption and CO_2 emissions reduction by 15%, time and costs reduction and improved rate of reusability for the final products. Results will be validated through one automotive and one aerospace demo products and assessed through environmental, social, and economic sustainability analysis.

ZeroWasteLIFE innovative approach is applicable to various industries, particularly automotive and aerospace, where lightweight and high-performance materials are critical. The project will validate its outcomes through two demo products, highlighting the benefits in both sectors. The project's success will pave the way for its application in additional sectors, such as wind energy and marine applications, further increasing its applicability and impact.

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Information about the research project: ZeroWasteLIFE is a 3-year EU co-funded project started in July 2023. The pilot location is in Varano de' Melegari (PR). The total budget of the project is 3 M€ at 60% funding rate. The consortium is composed by Bercella S.p.A. (coordinator), Nobrak and RINA Consulting S.p.A.

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Social aspects in innovative mining technology – the case of ROBOMINERS project

The ROBOMINERS project has a resolute goal to revolutionize the extraction of raw materials, including strategically vital metals crucial for the ongoing energy transition, from domestic (and primary) sources within the EU. The bio-inspired design makes it possible to make the robot much smaller, lighter, and more flexible than conventional mining machines. An EU-funded initiative qeuips robots with novel locomotive capacities, sensors and tools able to identify and mine targeted ores as well as geological modelling capabilities, making mining a more ecofriendly and sustainability industry also within social aspects.

The aim of work was to provide a social analysis of the opportunities and risks associated with adopting the ROBOMINERS technologies. ROBOMINERS offer a new and innovative solution in extractive process. Unmanned nature and the ability to develop an invisible mine distinguish it from other robotic solutions in mining.

The assessment of social aspects in the new ROBOMINERS technology was carried out based on three case studies:

- Sulmierzyce Północ Cu-Ag ore deposit (Poland, ultra-deep deposit),
- Recsk-Lejtakna Cu-Au ore deposit (Hungary, small deposit, uneconomic for traditional mining) and
- Neves Corvo (Portugal exploited or abandoned deposit with known remaining non-economic resources).

They were the basis for drawing conclusions and formulating recommendations in the area of Social Licence to Operate (SLO). The detailed analysis aimed to identify all stakeholder groups that could potentially be involved in the mining project. It was assumed that they came from country, regional and local level and represents among others: policymakers, future employees, mining and environmental authority, as well as raw materials users and governments. In the next stage, the roles they would perform in the process (policymaker, beneficiary, expert and affected public) , were also indicated. It was the basis for creating the stakeholder matrix for each case study.

The most common cause of social conflicts are fears about environmental degradation and deterioration of living conditions. The minimally invasive ROBOMINERS technology has a great chance of gaining social acceptance even in locations with complex social and environmental conditions. Without a doubt, the low environmental footprint of the technology will be the basis in negotiation with potential local stakeholders.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 820971.

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TOOL4LIFE PROJECT – TOOLing materials, design, and process engineering, leading to improved sustainability and wider applications for the composites of tomorrow

Composite materials find their greatest potential in applications requiring low weight, high mechanical performance and near-net-shape production. However, the difficult recycling of thermosetting resins, frequently used in their production, poses a challenge to their sustainability. Currently, moulds for composite parts manufacturing are produced by subtractive machining of polyurethane boards, being non-recyclable and typically landfilled after a single use.

In this context, the purpose of TOOL4LIFE, an EU-funded project, is to revolutionize tooling production in the automotive sector towards sustainability. A novel methodology, i.e. a hybrid process that combines Additive Manufacturing (AM) and milling, will enable the production of tooling using thermoplastic materials that can be fully recycled at the end of their life in subsequent AM processes. This process is further improved through topological optimization of the printed tooling, while thermal, rheological, 3D-printability, and recyclability properties of candidate thermoplastics are evaluated. Water-based sealants, release agents, and in-mould coatings are also developed.

This circular process will allow up to 80% savings in polymer material thanks to the recycling of the thermoplastic mould, uses around 30% less energy avoiding long machining of the tooling, and generates about 10% of CO_2 equivalent emissions if compared to State-of-the-Art production. Furthermore, it avoids the use of toxic chemicals (e.g., isocyanates) normally used to produce polyurethanes.

By combining additive manufacturing with milling, and by using recyclable thermoplastic materials, the project offers a circular, energy-efficient, and lower-emission alternative to current tooling practices, transforming the ordinary linear value-chain into a fully circular process. Beyond the automotive sector, the developed methodology has the potential to be scaled and adapted across a wide range of industries where composites are used (e.g., sporting goods, aeronautics, space, wind turbines, boats, etc.), contributing to broader sustainability goals and fostering a more responsible use of resources in advanced manufacturing.

TOOL4LIFE is a 3-year EU co-funded project started in August 2022. The pilot location is in Varano de' Melegari (PR). The total budget of the project is 3.5 M€. The consortium is composed by BERCELLA S.p.A. (coordinator), RINA Consulting S.p.A., CENTRE SCIENTIFIQUE & TECHNIQUE DEL'INDUSTRIE TEXTILE BELGE ASBLL, MARBO ITALIA srl.

This project has received funding from the European Union's Programme for Environment and Climate Action (LIFE) under grant agreement N° 101074299-TOOL4LIFE- LIFE-2021-SAP-ENV. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

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Gendered innovation living labs for inclusive technological futures

Innovation ecosystems across Europe face the dual challenge of addressing urgent societal transitions while ensuring inclusivity and diversity in innovation processes. Too often, gender perspectives are overlooked, limiting both the scope and impact of solutions. This gap hinders the EU's ambitions in advanced technologies, circular economy, and sustainable resource use.

The Gendered Innovation Living Labs (GILL) project was established to investigate how gender-responsive approaches can foster more inclusive, sustainable, and impactful innovation across different sectors. The central hypothesis is that embedding gender and equality dynamics in real-world experimentation enhances innovation outcomes, supports cultural change, and broadens participation in key industrial and societal transitions. Through fifteen Action-Oriented Experimentations (AOEs) in eight European countries, GILL used the Living Lab methodology to create testbeds for co-developing new solutions. Our poster features some among the most successful AOEs, which have promising results in the three vertical domains addressed by the GILL project:

- Digital Transformation (Heilbronn University): increased awareness of gender inclusion in tech education and retention.
- Green Transition (Coventry University): gender-responsive transport research influencing safety, accessibility, and sustainability.
- Health & Resilience (Devices for Dignity): inclusion of gender perspectives in medical device design, improving usability and equity. Across domains, AOEs demonstrated that gender-sensitive methods enhance idea generation, improve user acceptance, and support long-term cultural change.

The GILL Living Lab approach validates the importance of integrating gender-responsive practices in innovation. Living Labs are open innovation ecosystems where citizens, public authorities, private actors, and research institutions collaborate (Quadruple Helix model) to co-design, test, and validate new products, services, and systems, in real life-environments and addressing real user's needs. By linking research to real-life test environments, practical solutions are developed while advancing academic understanding of open and user-driven innovation. The creation of the GILL Hub ensures long-term access to tools, methods, and networks, extending the project's impact beyond its duration.

GILL is funded under the European Union's Horizon Europe programme. It brings together 15 partners to operationalize inclusive innovation and develops Gender Responsive Smart Innovation and Entrepreneurship (GRSIE). We thank all project partners, Living Lab participants, and the EU Horizon Europe programme for supporting this work, and invite colleagues to join the newly established Gender in Innovation Working Group through the GILL Hub.

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Responsible supply of REEs through environmental impact minimization: towards zero waste European mineral extraction

Weaning the economy off fossil fuels and switching to a green and digital future is a metal and mineral-intensive undertaking. In this context, rare earth elements (REEs) are critical materials of strategic importance in a wide range of high-tech sectors. The project Unlocking the Supply of Rare Earth Elements in Europe Through Responsible, Sustainable and Decarbonised Innovative Technologies (REESOURCE), funded within the European Union's Horizon Europe framework programme, proposes to develop innovative technologies for extracting REEs in Europe to secure the continent's self-supply and the resilience of the European REE value chains. In work package 5, the greener beneficiation of minerals from Fen deposit in Norway for REEs extraction is developed. Different mineral processing approaches and identification of innovative flotation formulations and operation conditions were developed and tested, with special emphasis on the water recirculation, in order to reduce both the water consumption and the produced wastewaters.

This work was supported by the European Union's Horizon Europe Research and Innovation Program through the project REESOURCE Project under Grant Agreement number 101138460.

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Novel taxane drug carriers: a protein-based strategy against chemo-resistant cancers

Cancers remain one of the greatest challenges in modern medicine. According to the World Health Organization (WHO), one in five people will develop cancer during their lifetime, with nearly 20 million new cases reported globally in 2022. The most frequently diagnosed types include lung, breast, and colorectal cancer. A major challenge in cancer therapy is the development of resistance to standard chemotherapeutics, which has led to the use of second-generation agents such as cabazitaxel (CAB), designed to overcome multidrug resistance mechanisms.

The aim of this study was to develop stable lysozyme-based protein nanoparticles as a delivery system for CAB, a second-generation taxane used in the treatment of drug-resistant cancers, e.g. advanced prostate cancer. Due to its poor aqueous solubility and dose-limiting toxicity, CAB requires an effective carrier system to enhance its bioavailability and therapeutic index. Therefore, in this work nanoparticles were formulated using a dialysis-based nanoprecipitation approach, where an aqueous solution of lysozyme was combined with an ethanolic CAB solution, promoting controlled self-assembly of protein matrices. The resulting suspension was subjected to dialysis against deionized water to remove the organic solvent and unbound drug.

Nanoparticles were characterized using Dynamic Light Scattering (DLS), Atomic Force Microscopy (AFM), and Fourier Transform Infrared Spectroscopy (FT-IR). The optimal lysozyme-to-ethanol ratio of 1:3 yielded particles averaging 250 nm in diameter with a zeta potential of –17 mV, indicating stability. Biological in vitro activity of prepared particles was assessed on colorectal cancer cells. Effects on the cell cycle, induction of cell death pathways, and cellular damage were evaluated using flow cytometry and confocal imaging. The results confirmed that CAB-loaded lysozyme nanoparticles are stable, non-toxic, and effectively internalized, showing promising anticancer potential. Thus, this research opens new perspectives for the development of innovative drug delivery systems that could significantly improve the efficacy of cancer therapies while reducing their side effects.

Work within the framework of an implementation doctorate 7 funded by the Ministry of Science and Higher Education "Enhancing Peritoneal Retention of Taxanes through the Use of Hydrogel-Based Drug Delivery Systems" no. DWD/7/0183/2023.

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Preparation of iron oxide nanoparticles and verification of their application in the catalytic graphitization process

Iron, the fourth most abundant element in the Earth's crust, plays a key role as a structural foundation of modern technologies and various rapidly developing industries. Compared to other metals with catalytic properties, such as nickel, cobalt, or zinc–iron stands out for its low toxicity, wide availability, and relatively low environmental impact. In recent years, particular attention has been paid to iron-based nanomaterials due to their promising magnetic, catalytic, and sorption properties.

The main objective of this research was to develop and evaluate the catalytic properties of iron oxide nanoparticles (Fe_2O_3) in the graphitization process of amorphous carbon. We hypothesized that the use of Fe_2O_3 nanoparticles could significantly reduce the temperature required for the transformation of amorphous carbon into electrically conductive graphite structures. The nanoparticles were synthesized via hydrothermal methods–both microwave-assisted and conventional furnace-based.

Characterization of the obtained materials was conducted using scanning electron microscopy (SEM) and X-ray diffraction (XRD). The catalytic graphitization process was carried out in a tubular furnace under inert gas atmosphere, with a focus on optimizing key parameters: temperature, heating rate, duration, and catalyst concentration.

The results confirmed the effectiveness of Fe_2O_3 nanoparticles in lowering the graphitization temperature and improving the conductivity of the resulting carbon structures. This suggests potential for developing more sustainable and energy-efficient methods for producing advanced carbon nanomaterials.

Project affiliation: This study is part of the doctoral research project carried out at the Faculty of Chemical Engineering and Technology, Krakow University of Technology.

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Chitosan films of the future – dual function of DES with tomato leaf extract

The growing demand for environmentally friendly and sustainable food packaging highlights the need to develop alternatives to traditional packaging materials. The aim of the conducted research was to develop innovative, eco-friendly chitosan films modified with deep eutectic solvents (DES) and tomato leaf extracts obtained using DES-based extraction. The research hypothesis assumed that the use of plant extracts obtained in DES would improve the mechanical and antibacterial properties of chitosan films, eliminating the need for additional modifiers.

The novel approach involved the simultaneous use of DES and plant extracts as plasticizers and antibacterial agents, allowing the elimination of additional substances typically used in conventional packaging materials. For the film production, DES composed of choline chloride, glycerol, and lactic acid was used. Chitosan films were then prepared with tomato leaf extracts obtained through extraction with DES. Mechanical, barrier, and antibacterial analyses showed that the films enriched with extracts exhibited improved physicochemical and antibacterial properties compared to films containing only glycerol or those modified solely with pure DES.

The best results were obtained for the film containing tomato leaf extract in DES based on choline chloride and lactic acid. This film demonstrated a tensile strength of 47 MPa and an elongation at break of 29%. The obtained results confirm that chitosan films modified with plant extracts in DES represent a promising and eco-friendly alternative to conventional packaging materials. Due to their enhanced physicochemical properties and effective antibacterial protection, they offer a modern solution for dairy product packaging, addressing the growing market demand for sustainable and innovative packaging materials.

The research was carried out as part of the project conducted within the Student Scientific Circle of Chemists: "Innovative biodegradable films – the use of DES as plasticizers and antibacterial and antioxidant agents". The study was funded by the Ministry of Education and Science under project no. SKN/SP/569054/2023 and partially supported by the Silesian University of Technology under project no. 31/010/SDU20/0006-10.

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Analysis of the influence of gold modification of thin ZnO layers on their morphology and optical properties

The aim of this study was to analyze the effect of gold modification of zinc oxide (ZnO) thin films on their morphology and optical properties. This modification aims to improve the functional properties of ZnO layers, which is crucial in the context of advanced applications in nanotechnology, such as optoelectronics, chemical sensors, and photovoltaic devices. The ZnO layers were produced using the sol-gel method, which allows for precise control of the synthesis parameters. The process included the preparation of solutions containing precursors of the appropriate metals, application of the sol to the substrate surface using the dip-coating technique, and calcination under controlled conditions. The layers were modified with gold by introducing the gold precursor into the sol-gel solution before the deposition process. The work included a detailed characterization of the structure and morphology of the produced coatings using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The electro-optical properties of the materials were studied using spectroscopic ellipsometry.

The obtained results indicate that modification of ZnO layers with gold leads to significant changes in the morphology of the material. Reduction of surface roughness and improvement of the homogeneity of the layers are some of the main effects of this modification. Spectroscopic analysis of the produced materials showed that gold modification affects the optical properties of ZnO layers, such as the refractive index and absorption. It was observed that an increase in the concentration of the modifier leads to a decrease in the energy gap. The sample containing 10% of gold addition shows a value of the energy gap slightly higher than the sample with 5% addition. In the case of the refractive index, increasing the amount of gold results in its decrease. These changes may be beneficial in the context of applications in photocatalysis, where high homogeneity and appropriate optical properties are crucial for the efficiency of photocatalytic processes.

Additionally, modified ZnO layers show potential for applications in high-sensitivity gas sensors. Reducing surface roughness can lead to an increase in the active surface, which is important for gas detection. Optical properties, such as changes in absorption, can be used to monitor chemical reactions occurring on the sensor surface.

In summary, modification of ZnO thin films with gold leads to significant changes in their morphology and optical properties, which makes these materials promising candidates for advanced applications in nanotechnology. The research results indicate the possibility of improving the functionality of ZnO films by appropriate modification, which opens new perspectives for their use in various fields of technology.

Anna Piasek, Marcin Banach, Jolanta Pulit-Prociak
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Composite PVA films enriched with carbon nanodots – synthesis, characterization and potential applications

The increasing need for environmentally friendly and biocompatible materials in medicine, sensors, and environmental monitoring has driven research on polymer composites enhanced with carbon nanostructures. One of the current challenges is the integration of sustainable, low-cost nanomaterials into functional films for biomedical applications, especially those related to skin-contact diagnostics. The present study addresses this problem by utilizing barley bran – a rich lignocellulosic biomass as a renewable carbon source for the synthesis of carbon quantum dots (CQDs).

The objective of the research was to develop an effective synthesis process of CQDs using the hydrothermal-microwave method and to incorporate these nanostructures into a polyvinyl alcohol (PVA)-based composite film, aiming to obtain a biodegradable, flexible, and fluorescent material suitable for diagnostic and therapeutic use. The study tested the following hypotheses:

- barley bran-derived CQDs can be synthesized with strong photoluminescent properties using more eco-friendly methods,
- the resulting CQDs can be successfully embedded into a PVA film, retaining their fluorescence and enhancing the material's mechanical and chemical functionality.

The results showed that the CQDs obtained exhibited a strong fluorescence emission at around 460 nm under 380 nm excitation and characteristic UV-Vis absorbance around 280 nm. The average particle diameter was about 8 nm, with clear lattice fringes observed by TEM, indicating a degree of crystallinity. FTIR and XRD analyses confirmed the presence of functional groups and structural features typical of carbon nanodots. The CQDs were embedded in a PVA matrix enriched with glycerol (plasticizer), chitosan (antimicrobial agent), and hydroxyethyl cellulose (structural stabilizer). The resulting composite film showed desirable mechanical strength, optical activity, and flexibility, as well as biodegradability, which is crucial for single-use medical applications.

In conclusion, the developed films provide an attractive platform for applications such as fluorescent wound dressings, transdermal biosensors or controlled drug release systems. In the non-medical field, they can also be useful in environmental protection to control pollution levels or in the form of films in food packaging to control the freshness of products. This research underscores the potential of biomass as a raw material even in areas such as nanotechnology and supports the development of a circular bio economy in advanced materials science.

The study was conducted by Anna Piasek, Marcin Banach, and Jolanta Pulit-Prociak at the Krakow University of Technology, Faculty of Chemical Engineering and Technology, Department of Chemical Technology and Environmental Analytics.

The research was carried out as part of the research for the PhD thesis "PVA-based films doped with carbon nanodots as non-enzymatic sensors" conducted at the Krakow University of Technology, Faculty of Chemical Engineering and Technology.

Innovations in waste recycling for sustainable development

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The potential of extractive waste in a circular economy framework

The extractive industry is a major pillar of economic growth and social progress through the provision of raw materials to a wide range of sectors. Despite the economic importance, mining operations generate substantial volumes of extractive waste, presenting both environmental challenges and opportunities for resources recovery. These wastes often contain valuable minerals and critical raw materials that have the potential to be valorized in key sectors, including construction, chemical, metallurgical industry and energy sectors. Their proper handling and processing can have positive environmental impacts, such as the contribution to sustainable resource management, the reduction of the dependency on primary raw material sources and the diversification of the supply. Moreover, the recovery and valorization of these materials is in line with EU policies and approaches, such as the Circular Economy Action Plan, which emphasizes the economic significance of critical raw materials and acknowledges the potential risk of supply interruptions. In this context, the ValorWaste project proposes a comprehensive approach to the reprocessing of extractive waste and promotes sustainable practices in a circular economy framework for the extractive industries.

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Extractive waste valorization and integration into construction materials

One of the most important waste streams is generated by the extractive industry. Depending on their composition and processing, these wastes may become an environmental burden or an important resource for critical raw materials. The VALORWASTE project, proposes to identify valorization routes for extractive waste by recovering critical elements through hydrometallurgy. The project also aims to design construction materials and chemicals that can integrate extractive waste in their composition. The environmental impact of the valorization routes will be identified by life cycle assessment, hot spot analysis, and risk identification. Machine learning algorithms will assist in the optimization of the valorization processes and developed products. In the first phase of the project questionnaires were used to select the study case wastes. A total of six waste types were selected for analysis and subsequent characterization.

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Eco-Innovation in fiber technology: extracting and modifying palm leaf sheath fibers using industrial waste materials

This study explores a sustainable approach to processing palm leaf sheath waste in the UAE by employing carbide lime waste (CLW) as an alternative to the traditional sodium hydroxide (NaOH) treatment. The treatment aims to enhance the mechanical and physical properties of the derived fibers. Results indicate that CLW provides enhanced treatments, significantly improving fiber characteristics such as tensile strength, elongation at break, and moisture absorption. The distinct morphological changes observed in the treated fibers, particularly under scanning electron microscopy, underscore the substantial impact of CLW in improving key fiber characteristics. Utilizing CLW not only conserves chemical resources but also repurposes an industrial by-product, thereby offering a more environmentally friendly, promising and cost-effective solution. Moreover, the incorporation of carbide lime waste into the treatment regimen showcased significant enhancements in the properties of the fibers, further emphasizing its viability as a sustainable alternative. This approach aligns with circular economy principles by promoting efficient resource use and minimizing waste, ultimately reducing environmental impact while enhancing the utility of the fibers for potential applications.

The authors would like to express their gratitude to Zayed University for giving them the space and resources they needed to complete this research. Special thanks to the lab. technicians and staff for their invaluable assistance in the analysis.

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HEPHAESTUS – heavy and extractive industry wastes PHAsing out through ESg tailings upcycling synergy

In the EU27, every year around 140 M tons of steel are manufactured. This volume can be raised by an additional 40 M tons of steel manufactured in the EU associated countries. 40% of the overall produced steel (i.e., around 70 M tons) is manufactured via Electric Arc Furnace (EAF), leaving behind an overall volume of about 1.1 to 1.5 M tons (1.5 to 2% w/w) fine hazardous dust. The EAF dust, catalogued as special waste, due to the extremely pyrophoric and unstable nature of the metal dusts requires proper handling and disposal, and withhold a remarkable hidden value, currently being not directly recyclable by the steel industry. In some countries, EAF dust landfilling is banned and technologies for a proper recycling are not yet profitable and/or sustainable (respectively, mostly due to the costly briquetting pre-process and to the volume and toxicity of some by-products, like dioxins).

The EU funded HEPHAESTUS project (GA 101058696) aims at developing a set of scalable operative units, featuring the capacity to treat multiple process wastes deriving from mineral and metallurgical (primary and secondary) streams. The project targets small-scale applications to cope with the typically fragmented European process size. The units include a Clean-Tech electric furnace transforming multiple steelmaking process wastes into reusable metal alloy; the EZINEX process unit to extract the residual zinc present in the furnace dusts; a Fibre drawing unit for mineral wool manufacturing out of the process slag; a catalytic conversion unit of CO_2 gas into methanol, feed by the CO_2 contained in the Clean-Tech flue gases; and finally an Ammonia-ammonium carbonate (AAC) hydrometallurgical process, producing a recyclable Fe-rich residue also recovering metals from EAF dusts. The project ambition is

to demonstrate with Pilots plants in Italy and Greece, the feasibility of diverting dangerous EAF fine dust from landfilling, recovering iron alloy, Zinc metal, and producing mineral wool and methanol.

HEPHAESTUS is 54 months project and is still in progress. Up to now the feeding material has been characterised and thermodynamic simulations has been conducted on different types of feed to processed, with the synthesis of mineral wool taken as a representative parameter to assess such feed. Globally the process reduces 0.8 MWh energy consumption and 3 tons of CO_2 emissions per ton of processed dust. The results exploitation includes the development of business models to provide service to the steel industry, transforming wastes into new added-value products, achieving circularity in metallurgy at European scale.

Elizabeth Addae
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Effects of ZnO on the performance of dye-sensitized solar cells

Fossil fuel air pollution is estimated to cause around 8.7 million deaths globally each year, with exposure to fine particulate matter from burning fossil fuels being a major contributor. According to a worldwide energy analysis, global fossil fuel use reached an alarming new high in 2024, pushing emissions to over 40 gigatons of carbon dioxide for the first time. Renewable energy comes from natural sources like sunlight and wind that replenish quickly. A study by the U.S. Department of Energy's NREL found that widespread solar energy use could significantly reduce harmful emissions like sulfur dioxide, nitrogen oxides, and particulate matter. However, silicon solar cells are costly due to the energy-intensive process of producing ultra-pure silicon. Dye-sensitized solar cells (DSSCs) offer a cheaper alternative, but their lower efficiency (7–11%) and limited long-term stability make them less commonly used than traditional silicon-based cells.

The aim of this research work is to use Atomic Layer Deposition (ALD) to deposit ZnO nano thin films at varying deposition temperatures (100°C and 200°C) in order to produce high functioning DSSC that can be an alternative to the traditional silicon solar cells.

Figure 1 illustrates how the Energy Dispersive X-ray Spectroscopy (EDS) images produced a discernible trend in b) and c) when the deposition temperature changed. Even with equal cycles of deposition, the layer of FTO-ZnO at 200°C is more uniform and well-defined.

The observed variations in film morphology may be explained by fluctuations in the deposition temperature during the ALD process. As the temperature rises, the trend throughout the photos shows a definite increase in structural definition. This is due to the fact that temperature influences gas-phase chemical processes, which are necessary for the atomic layer deposition process's layer-by-layer growth. In general, films with higher deposition temperatures are smoother and more crystalline, and their growth rate is accelerated. This is because the precursor molecules' reactivity and mobility on the substrate surface are enhanced by their higher kinetic energy. According to these findings, temperature has a significant impact on the effectiveness and quality of ZnO thin film deposition using ALD.

Higher deposition temperatures in ALD improve the quality of ZnO films; 200°C produces more consistent, structured films with a higher zinc oxide content, which makes it perfect for photovoltaic and optoelectronic applications.

This Research Project is scientific research affiliated to the Doctoral degree work of Elizabeth Addae from the Silesian University of Technology and is supervised by Wojciech Sitek and Marek Szindler.

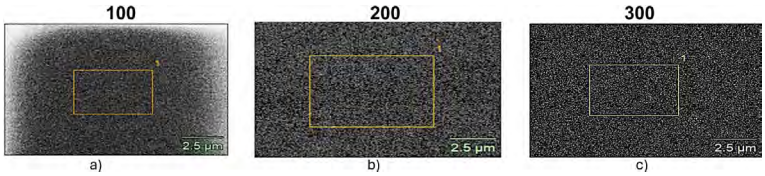

Figure 1. EDS image: a) pure FTO DSSC; b) FTO-ZnO DSSC at 100°C; c) FTO-ZnO DSSC at 200°C

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Antimicrobial evaluation of quaternary ammonium dimethacrylate monomers for dental applications

Dental resin composites formulated with dimethacrylate monomers have become integral to restorative practice, offering strong mechanical performance and desirable esthetics. However, their inherent vulnerability to bacterial adhesion and biofilm development continues to undermine long-term clinical outcomes through recurrent caries. Conventional antimicrobial strategies – relying on the incorporation of agents such as nanoparticles or antibiotics – lead to short-term action, leachable components, and the promotion of microbial resistance. In contrast, quaternary ammonium dimethacrylate monomers (QADMs) represent a next-generation solution by chemically integrating antibacterial functionality directly into the polymer network. This covalent incorporation not only confers sustained antimicrobial activity but also preserves the composite's mechanical and physicochemical stability, positioning QADMs as a compelling platform for durable, bioactive dental restorations.

Literature research aimed to review the antimicrobial activity of quaternary ammonium dimethacrylate monomers (QADMs) in restorative dental materials. A decade-spanned search from 2016 targeted all study types related to quaternary ammonium dimethacrylates, reflecting the emerging but still limited body of literature. The hypothesis was that quaternary ammonium dimethacrylate monomers as additives to materials for dental applications are a promising solution for the prevention of secondary caries.

The identified monomers comprise diverse structural variants, characterized by differences in alkyl chain length, methacrylate functionalization, and spacer architecture – each parameter critically shaping their antimicrobial activity, hydrophobic behavior, copolymerization potential, and network stability within dental resin systems.

Studies confirmed QADMs' efficacy against key oral pathogens including *Streptococcus mutans*, *Lactobacillus casei*, *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*, however antimicrobial efficacy was validated through different methods. QADMs consistently reduced bacterial viability, biofilm development, and expression of biofilm-related genes (*gtfB*, *gtfC*, *gtfD*). Evidence also showed durable antibacterial activity after prolonged water ageing and effective suppression of metabolic markers such as lactic acid production. TEM and SEM imaging confirmed membrane damage and cytoplasmic leakage, supporting a mechanism involving electrostatic disruption and hydrophobic chain penetration. Compared to monomethacrylates, QADMs offered greater surface activity and reduced leaching due to covalent bonding into polymer networks.

Despite concerns over mechanical performance and water affinity in some formulations, QADMs present a promising strategy for long-term microbial control in dental composites. Further structural optimization and co-polymer integration may enhance both clinical efficacy and material properties.

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Improving additive manufacturing of Duplex stainless steel through artificial intelligence

Duplex stainless steels (DSS), comprising a near-equal distribution of ferrite (α-phase) and austenite (γ-phase), are increasingly favored in high performance environments such as marine, chemical processing, and energy sectors due to their superior combination of mechanical strength, fracture toughness, and corrosion resistance. The functional integrity of DSS critically depends on achieving a balanced γ/α phase ratio, typically in the range of 40–60%. However, additive manufacturing (AM) techniques such as Laser Powder Bed Fusion (LPBF), while offering unprecedented design freedom and geometric complexity, often disrupt this balance. The rapid cooling and steep thermal gradients inherent to LPBF promote ferrite stabilization and suppress austenite formation, resulting in ferrite-dominated microstructures that compromise the material's corrosion and mechanical performance.

This study aims to develop a predictive, microstructure-informed process optimization framework for LPBF of DSS by integrating compositional tuning with machine learning (ML). The central hypothesis posits that systematic variation of nickel content, coupled with LPBF parameter control, can be leveraged through artificial neural networks (ANN) to predict and guide γ/α phase formation under non-equilibrium solidification conditions. Traditional equilibrium-based thermodynamic models have shown limited predictive capacity in LPBF regimes due to transient thermal histories and rapid solidification kinetics; thus, a data-driven model offers a viable alternative. Preliminary results indicate that increasing nickel content to 4–6 wt% enhances γ-phase stabilization in LPBF-fabricated SDSS 2507. EBSD analyses confirm improved phase balance and favorable grain boundary character distribution, with a measurable increase in Σ3 twin boundaries. Early ML models trained on experimental datasets demonstrate promising accuracy in correlating LPBF input variables with phase fraction outcomes, indicating strong potential for predictive process design. The outcomes of this research will contribute to advancing the processability of DSS via AM by enabling in-situ control of microstructure, reducing the need for post-processing, and lowering development costs. Ultimately, this work supports the broader goal of deploying high-performance DSS components in corrosive and mechanically demanding service environments through intelligent, data-driven manufacturing strategies.

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Thermoplastic material based on chitosan and innovative plasticizers

The evaluation of the state of the art shows that acetic acid or hydrochloric acid are often used in processing chitosan materials. Similarly to formic acid, they are not always a desirable processing and application component, especially in products for medical, hygiene or packaging purposes. Although lactic acid is a more friendly agent, it is still reasonable to reduce its relative share in the target material.

Using a bioadditive system, a recipe for producing plasticized chitosan material by thermomechanical method was developed with the use of screw devices designed for processing thermoplastics. Chitosan was mixed with the components of the auxiliary system and the resulting mixture was plasticized, then its physical-mechanical, thermal and structural properties were studied. For the product in the form of a line, selected performance properties were presented, including physical and mechanical parameters, SEM analysis and thermal analysis.

In contrast to the most commonly used methods, the developed formula limits the use of acid solutions and excludes, the use of the most aggressive ones, such as acetic acid, formic acid and hydrochloric acid. Moreover, the content of chitosan in the material itself is relatively high (over 50% w/w). The key component of the plasticizing system is an esterification product from the group including: esterification products of lactic acid and a polyol such as glycerin.

The obtained material can be used especially in the production of dressing/medical and packaging products.

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Analysis of the influence of annealing temperature on the optical parameters of a SiO_2:MoS_2 multilayer antireflection system for near-infrared applications

The aim of this study was to investigate the influence of annealing temperature on the anti-reflective properties of a multilayer SiO_2:MoS_2 system designed for near-infrared applications. The study included an analysis of the optical parameters of the fabricated coatings and a comparison of the experimentally obtained results with those from modeling.

The set of test samples consisted of four anti-reflective systems fabricated using the magnetron sputtering method. The prepared four-layer structures consisted of alternating layers of SiO_2 and MoS_2 with a total thickness of 180 nm, deposited on a silicon glass substrate with a thickness of 3 mm. The thicknesses of the individual layers were selected to achieve anti-reflective properties over the widest possible range within the near-infrared region. The target anti-reflection spectral range was chosen to be 1,100–1,500 nm, due to the broad applicability of laser radiation in this wavelength range. The prepared thin-film systems were subjected to annealing at selected temperatures to evaluate the impact of thermal processing on their optical parameters. The thermal treatment was conducted at three different temperatures, namely 300°C, 600°C, and 900°C, with an annealing time of one hour. An unannealed multilayer system served as the reference sample.

The fabricated coatings underwent optical characterization, including spectrophotometric and ellipsometric measurements. Spectrophotometric analysis provided reflection and transmission spectra in the range of 200–2500 nm. Ellipsometric studies allowed for the determination of refractive and extinction coefficients, the thickness of individual layers, as well as an assessment of the coating quality and surface roughness.

Thin-film technologies play a crucial role in the production of microprocessors, displays, sensors, and other electronic devices [1]. Optical filters are widely used in systems that require the minimization of electromagnetic radiation losses. Potential applications for the studied optical filters include the photovoltaic industry and optoelectronics. Currently developing photovoltaic technologies, such as gallium antimonide-based cells or multilayer photovoltaic structures, enable the efficient utilization of electromagnetic radiation, including near-infrared wavelengths [2, 3]. In fiber optic technologies, electromagnetic radiation is used at specific wavelengths, with data transmission typically occurring within the 1,260–1,675 nm range [4]. Additionally, optical distance measurement systems (LiDAR) employ lasers emitting radiation at a wavelength of 1550 nm [5]. The operational wavelength ranges

of these technologies overlap with the investigated electromagnetic spectrum. Therefore, the presented research may contribute to the further development of these technologies and serve as a foundation for the creation of devices with improved performance and enhanced functionality.

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316L steel – Inconel 625 gradient material additively manufactured by LPBF process – fabrication, characterization of microstructure and hardness

Laser Powder Bed Fusion (LPBF) is one of the additive manufacturing (AM) processes widely used to fabricate metallic parts with complex shapes, typically from a single material powder. The layer-by-layer deposition in AM allows the production of multi-material parts with a designed gradient of chemical composition by mixing powders of dissimilar alloys in different proportions.

The Inconel 625 nickel superalloy is characterized by high strength and corrosion resistance in a wide temperature range from cryogenic to high up to 982°C. Creating gradient material by gradually adding the corrosion-resistant superalloy Inconel 625 to 316L steel in layers allows to obtain the properties of Inconel 625 in the zone exposed to the high temperature and corrosive environment, while reducing the production costs of the final product.

The purpose of this study was to design and fabricate a 316L steel – Inconel 625 gradient material using the LPBF process and to investigate its microstructure, chemical composition, and hardness. Gradient material was manufactured using spherical 316L steel and Inconel 625 powders. A six-zone gradient material was designed with a content of 0 – 20 – 40 – 60 – 80 – 100 wt.% of Inconel 625. After the LPBF process, the material was annealed at 900 and 1,000°C for 1 h. The microstructure and chemical composition were examined using a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDS). The hardness profile of the gradient material was also determined.

The manufactured gradient material was characterized by low porosity, not exceeding 0.4%. With the increase in the Inconel 625 content, the concentration of Ni, Cr, Mo and Nb in the individual gradient zones increased. This was accompanied by an increase in the number of carbides and Laves phase precipitates containing Nb, Mo, and Cr, located mainly at the grain, cell, and melt pool boundaries. The hardness profile directly reflected the gradient change in the chemical composition and microstructure and gradually increased from 230 HV for 316L steel to 300 HV for Inconel 625. Annealing at 900°C did not cause significant changes in microstructure at every gradient zone and had a stress-relieving nature. After annealing at 1,000°C, recovery occurred in all zones, and the zone containing 100% Inconel 625 was partially recrystallized.

The result of the study is the development of LPBF process conditions, which enabled the manufacturing of 316L steel – Inconel 625 gradient material with low porosity, as well as a demonstration of the potential possibility of manufacturing products with complex geometry. The innovative method of LPBF fabrication of a newly designed gradient material was used to produce a prototype of an exhaust valve for a combustion engine with improved functionality.

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Biomaterials for regenerative medicine – selection of synthesis conditions

Biomaterials play a key role in regenerative medicine, supporting tissue reconstruction and regeneration. Their properties depend on the synthesis conditions, such as raw material composition, temperature, reaction time or manufacturing method. The appropriate selection of these parameters allows for the control of the structure, porosity, bioactivity and biodegradation of materials, which affects their integration with tissues. This paper discusses the importance of biomaterial synthesis conditions and their impact on functionality in medical applications, emphasizing the need to optimize processes in order to obtain the desired biological and mechanical properties.

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Implementing a circular economy model in the waste electric and electronic equipment management sector in Poland

The production of electrical and electronic equipment in Poland is one of the fastest-growing sectors of the economy. One reason is the constant technical and technological progress that favors the replacement of old electronic equipment with new ones. This results in the generation of enormous amounts of waste, which is not always processed properly. One of the priority environmental protection issues is therefore the proper management of the significant amounts of e-waste generated each year in accordance with the principle of a circular economy. Analyzing changes in consumer attitudes towards waste electrical and electronic equipment management processes in the context of both a circular economy and sustainable development strategies.

This article analyzes European legislation and the provisions of evolving Polish law. Based on available statistical data, the changes in the electrical equipment production market are demonstrated. The main part of the work consists of an analysis of the individual stages of waste refrigeration equipment logistics (collection, processing, transport, and recovery), along with a cost analysis. The impact of e-waste components on the natural environment and humans is also identified.

Waste electrical and electronic equipment (WEEE) is a group of waste that requires special handling in terms of collection, transport, and, above all, proper processing. WEEE contains a number of harmful compounds and substances that significantly contribute to ozone depletion, pollute soil and water, and significantly impact the human body. On the other hand, through proper recovery and recycling processes, significant amounts of secondary raw materials can be used, which is a key principle of a circular economy.

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The use of sewage sludge as substrates for bioenergy production in a water company in the context of a circular economy

A growing problem, particularly in large urban areas, is the proper management of sewage sludge. Sewage sludge is generated in sewage treatment plants as a specific waste product of sewage treatment processes. It poses a significant technical and ecological problem due to its high hydration and mass, as well as its potential sanitary hazard. An additional issue requiring detailed research is the contamination of sewage sludge with xenobiotics, pharmaceuticals and their derivatives, and other micropollutants. Microplastics constitute a separate group of sewage sludge contaminants. Therefore, some sewage sludge is unsuitable for agricultural use.

The aim of this study was to analyze the process of obtaining and using biogas from sewage sludge from the Płaszów Sewage Treatment Plant in Krakow in the context of the Circular Economy.

The study included an analysis of the amount of biogas produced from sewage sludge and the electricity generated from its combustion over the study period. Electricity constitutes a significant operating cost for every enterprise. Therefore, its production from sewage sludge is an example of applying circular economy principles to the business model of a wastewater treatment plant.

The study showed that generating biogas from sewage sludge reduces the operating costs of the wastewater treatment plant, including electricity, by up to 30%. Increasing the plant's energy self-sufficiency reduces its demand for energy from conventional sources, such as coal, leading to a reduction in pollutant emissions.

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Non-ferrous alloys for medical applications

Biodegradable metallic materials have gained increasing attention in recent years as potential candidates for temporary medical implants, especially in orthopedics and cardiovascular applications. Non-ferrous alloys are an important group of materials in biomedical engineering, particularly for temporary and permanent implants. Resorbable magnesium or zinc alloys are of particular interest as they are biodegradable and eliminate the need for secondary surgery. However, a key challenge in the development of these materials lies in controlling their degradation rate to ensure both mechanical integrity and biocompatibility during the healing process. Magnesium alloys, particularly WE43, are known for their favorable properties such as lightweight nature and good biocompatibility, yet their rapid degradation in physiological environments limits their broader clinical application.

The aim of this study is to develop and characterise a novel biomaterial based on the WE43 magnesium alloy with a modified surface designed to prolong the degradation time. The hypothesis is that the application of a layer coating of hydroxyapatite or whitlockite, using the sol-gel method, will significantly enhance corrosion resistance while maintaining or improving the biological performance of the material. The samples with coatings were subjected to comprehensive testing, including chemical composition analysis, mechanical property evaluation, non-destructive testing, corrosion resistance assays, and biological assessments.

The study should confirm that the sol-gel coating of hydroxyapatite or whitlockite on the WE43 magnesium alloy effectively extends the degradation time of the material, making it a promising candidate for temporary implant applications. The combination of physicochemical stability and biological activity presents a significant step forward in biomaterial engineering.

Research is being conducted as part of an Implementation Doctorate project entitled: “Development of technology for the production of a magnesium-based biomaterial for medical applications”. Their aim is to develop a bioresorbable biomaterial.

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The role of a dry polder in the circular economy and climate change adaptation

The aim of this study was to assess whether the extraction of natural aggregates within the dry polder basin on the Oder River upstream of Racibórz supports climate change adaptation efforts and aligns with the principles of the circular economy–particularly local resource utilization and efficient material use. The analysis considered the future role of the excavation site as a flood retention reservoir.

The study was based on an analysis of data from the Mineral Resource Balance, geological reports, and planning documents from 2007–2023, complemented by field reconnaissance. The assessment also took into account the operation of the reservoir during the September 2024 flood event. Aggregate extraction within the Racibórz Dolny polder basin is consistent with circular economy principles. On-site material sourcing supports basin shaping, reduces transportation needs and emissions, and allows overburden to be reused for engineering and reclamation purposes. The deposits are of high quality and easily accessible. Mining activities contributed to a 13% increase in the reservoir's flood retention capacity between 2007 and 2023.

Despite losses incurred by mining companies during the 2024 flood, the reservoir enables rational environmental resource management while preserving the river's hydrological regime–benefiting aquatic habitats. The project demonstrates effective integration of mineral extraction with flood protection.

Although the deposits were classified as low-conflict (i.e., not containing protected natural features), the proximity of a Natura 2000 area imposed environmental constraints and delayed large-scale operations. The Oder valley serves as a key ecological corridor with valuable habitats and protected species, requiring tailored management, including water regime maintenance and preservation of old-growth trees. Dry polders such as Racibórz Dolny play a significant role in climate change adaptation by temporarily storing excess water and reducing peak flood flows. The reservoir effectively mitigated the 2024 flood wave, providing increased safety for the populations of Racibórz, Opole, and Wrocław.

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Energy modelling of multi-material 3D printed walls

The integration of 3D printing into construction allows for the design of walls with complex geometries that combine both structural integrity and advanced thermal insulation. This research investigates the energy modelling of 3D printed walls composed of three interconnected materials, each serving a dual function as both structural support and thermal insulation. By using a combination of load-bearing and insulating materials within a single 3D printed structure, the study explores how optimised material distribution and geometric configurations can enhance energy efficiency while maintaining necessary strength.

The simulations focus on hybrid wall designs where materials with varying thermal conductivities are layered and interwoven within the geometry. These materials include: a high-strength scaffold for structural support, an intermediate layer with moderate insulation and load-bearing properties and a lightweight, high-performance insulating inside filling.

The results demonstrate the strategic interplay between structural and insulating materials within complex 3D printed geometries: patterned structures, lattice frameworks and void-filled designs, can significantly reduce heat loss while maintaining structural performance. The study also evaluates the balance between thermal efficiency, material costs, and manufacturing feasibility. This research highlights the potential of such hybrid material systems to advance sustainable building practices by enabling energy-efficient wall solutions, that can transform the designs of energy-optimised 3D printed walls.

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Recycled aggregates in construction. Analysis of global trends and Polish challenges

Recycling construction aggregates is a crucial component of sustainable development in the construction industry, both globally and nationally. Across the European Union, construction and demolition waste represents the largest waste stream, with a mandatory recycling target of 70%. Countries such as Germany and the Netherlands demonstrate best practices in this area. In Germany, strict regulations require minimizing waste generation and maximizing the use of recycled materials. As a result, recycled aggregates are widely used in road construction, asphalt mixtures, and even structural concrete. Similarly, the Netherlands has developed an advanced system of sorting and processing construction waste, enabling the broad application of recycled concrete aggregates (RCA) in roadworks, concrete mixes, and prefabricated building elements. The country serves as a model for implementing circular economy principles.

In the United States, more flexible regulations have fostered technological innovation, allowing for the rapid implementation of new recycling methods. Recycled aggregates are commonly used in road construction, asphalt layers, and low-strength concrete applications, with solutions tailored to local conditions. In Asia, Japan and China are investing in advanced recycling technologies, using RCA in high-performance concrete and prefabricated components. Japan, in particular, leads in processing efficiency and technology, while China applies recycled materials in major infrastructure projects such as roads, bridges, and buildings.

In Poland, despite adopting EU standards (e.g., PN-EN 13108-8:2006), regulatory development remains limited, hindering market growth. Recycled aggregates are primarily used in road construction, especially in sub-base layers. Their use in concrete faces technological and practical limitations. The recycling rate remains below the EU average due to low environmental awareness, inadequate infrastructure, and high processing costs. The findings presented in this paper are based on an analysis of scientific literature, available statistical data, and technical reports related to construction and demolition waste recycling.

To unlock the full environmental and economic potential of aggregate recycling, Poland must enhance its recycling infrastructure, provide financial incentives, and increase public and industry awareness.

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Ecological innovations supporting sustainable development: the case of Polish tire industry

Valuable eco-innovations are emerging through increasingly close cooperation between the scientific community, the industry, energy sector, and public institutions supporting research, development, and the commercialization of new technologies that meet specific market needs. Today, the implementation of eco-innovations is a key factor across many sectors and constitutes a significant market entry barrier. Smaller entities, particularly recyclers, often face difficulties in generating innovative solutions, primarily due to limited knowledge and technological capabilities. Although innovations are being developed, statistical data show that their implementation within the Polish tire sector remains relatively limited. Several factors contribute to this situation, including the low level of ecological awareness among Polish entrepreneurs, their predominant focus on maximizing profits, and a general failure to recognize the long-term benefits of eco-innovations. In Poland, eco-innovations are typically implemented by large enterprises (such as tire manufacturers), often as part of their corporate social responsibility strategies. It can be assumed that enterprises across the sector will increasingly adopt ecological innovations once they perceive clear benefits, whether through operational cost reductions or enhanced corporate image. The success of eco-innovations in the tire industry depends not only on advancements in technical knowledge but also on pro-innovation education, which should constitute a fundamental element of every organization's development strategy.

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