



ATHENS INSTITUTE

Abstract Book

14th Annual International Forum on Water
13-18 July 2026, Athens, Greece

Edited by
Isaac T. Rampedi, Teodoro Georgiadis
& Olga Gkounta

2026

Abstracts
14th Annual International Forum
on Water

13-18 July 2026, Athens, Greece

Edited by
Isaac T. Rampedi, Teodoro Georgiadis
& Olga Gkounta

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Preface

This book includes the abstracts of all the papers presented at the 14th Annual International Forum on Water (13-18 July 2026), organized by the Athens Institute.

A full program can be found before the relevant abstracts. In accordance with Athens Institute's Publication Policy, the papers presented during this conference will be considered for inclusion in one of the Athens Institute's many publications only after a blind peer review process.

The purpose of this abstract book is to provide members of the Athens Institute and other academics around the world with a resource through which they can discover colleagues and additional research relevant to their own work. This purpose is in congruence with the overall mission of the association. Athens Institute was established in 1995 as an independent academic organization with the mission to become a forum where academics and researchers from all over the world can meet to exchange ideas on their work and consider the future developments of their fields of study.

To facilitate the communication, a references section includes all the abstract books published as part of this forum (Table 1). I invite the readers to access these abstract books –these are available for free– and compare how the themes of the forum have evolved over the years. According to the Athens Institute's mission, the presenters in these conferences are coming from many different countries, presenting various topics.

Table 1. *Publication of Books of Abstracts of Proceedings, 2014-2026*

Year	Papers	Countries	References
2026	31	18	Rampedi et al. (2026)
2025	30	17	Al-Ansari and Papanikou (2025)
2024	46	25	Al-Ansari and Gkounta (2024)
2023	35	23	Al-Ansari and Gkounta (2023)
2022	34	23	Uddin and Gkounta (2022)
2021	11	10	Papanikos (2021)
2020	8	6	Papanikos (2020)
2019	29	18	Papanikos (2019)
2018	27	17	Papanikos (2018)
2017	41	23	Papanikos (2017)
2016	39	23	Papanikos (2016)
2015	87	43	Papanikos (2015)
2014	45	26	Papanikos (2014)

It is our hope that through Athens Institute's conferences and publications, Athens will become a place where academics and researchers from all over the world can regularly meet to discuss the developments of their disciplines and present their work. Since 1995, Athens Institute has organized more than 400 international conferences and has published over 200 books. Academically, the institute is organized into 7 divisions and 37 units. Each unit organizes at least one annual conference and undertakes various small and large research projects.

For each of these events, the involvement of multiple parties is crucial. I would like to thank all the participants, the members of the organizing and academic committees, and most importantly the administration staff of the Athens Institute for putting this forum and its subsequent publications together.

Gregory T. Papanikos
President

Editors' Note

These abstracts provide a vital means to the dissemination of scholarly inquiry in the field of Water. The breadth and depth of research approaches and topics represented in this book underscores the diversity of the forum.

Athens Institute's mission is to bring together academics from all corners of the world in order to engage with each other, brainstorm, exchange ideas, be inspired by one another, and once they are back in their institutions and countries to implement what they have acquired. The *14th Annual International Forum on Water*, accomplished this goal by bringing together academics and scholars from 18 different countries (Albania, Bosnia and Herzegovina, Canada, China, Costa Rica, Croatia, Estonia, Hungary, Italy, Poland, Portugal, Romania, Slovenia, South Africa, South Korea, Spain, Türkiye, USA), which brought in the forum the perspectives of many different country approaches and realities in the field.

Publishing this book can help that spirit of engaged scholarship continue into the future. With our joint efforts, the next editions of this forum will be even better. We hope that this abstract book as a whole will be both of interest and of value to the reading audience.

Isaac T. Rampedi, Teodoro Georgiadis & Olga Gkounta
Editors

14th Annual International Forum on Water, 13-18 July 2026, Athens, Greece

Organizing & Scientific Committee

All Athens Institute's conferences are organized by the Academic Council. This conference has been organized with the assistance of the following academic members of Athens Institute.

Dr. Gregory T. Papanikos, President, Athens Institute & Professor (Adjunct), University of Tennessee, Knoxville, USA.

Dr. Isaac T. Rampedi, Deputy Director, Sciences Division, Athens Institute & Associate Professor, University of Johannesburg, South Africa.

Dr. Teodoro Georgiadis, Deputy Head, Environment Unit, Athens Institute & Senior Research Associate, Institute of Biometeorology-CNR, Italy.

Dr. Timothy M. Young, Head, Agriculture Unit, Athens Institute, Emeritus Professor, The University of Tennessee, USA & CEO and President, T.M. Young Institute, LLC.

Dr. Ampalavanar Nanthakumar, Director, Sciences Division, Athens Institute & Professor, State University of New York (Oswego), USA.

FINAL CONFERENCE PROGRAM
14th Annual International Forum on Water, 13-18 July 2026, Athens, Greece

PROGRAM

Monday 13 July 2026

08:30-09:15

Registration

09:15-10:00 Opening Speech and Welcoming Remarks

Speakers: Gregory T. Papanikos, President, Athens Institute & Professor (Adjunct), University of Tennessee, Knoxville, USA.

10:45-11:30 Session 1 – Microsymposium on “Waste Management and Recycling”

Moderator: Teodoro Georgiadis, Deputy Head, Environment Unit, Athens Institute & Senior Research Associate, Institute of Biometeorology-CNR, Italy.

1. **Pinar Gultekin**, Professor, Düzce University, Türkiye.
Nermin Başaran, Assistant Professor, Düzce University, Türkiye.
Melek Yılmaz Kaya, Research Assistant, Düzce University, Türkiye.
Kıymet Uzun Yüksel, Research Assistant, Düzce University, Türkiye.
Title: Wastewater Recovery and Reuse at Düzce University Campus: An Integrated Model Proposal Using the Water4Reuse Approach.
2. **Ebru Cokay**, Professor, Dokuz Eylül University, Türkiye.
Deniz Dölgen, Professor, Dokuz Eylül University, Türkiye.
Serkan Eker, Professor, Dokuz Eylül University, Türkiye.
Yonca Dikici, Student, Dokuz Eylül University, Türkiye.
Tamer Atabarut, Professor, Boğaziçi University, Türkiye.
M. Necdet Alpaslan, Professor, MNA Engineering and Consultancy, Türkiye.
Title: Evaluation of Electrocoagulation for the Pre-Treatment of Wastewater from Table Olive Production.
3. **Savannalee Ahmed-Hodgkinson**, Lecturer, University of Johannesburg, South Africa.
Thea Schoeman, Head, Department of Geography, Environmental Management and Energy Studies, University of Johannesburg, South Africa.
Title: E-waste: The Good, the Bad and the Ugly in South Africa.
4. **Tamer Atabarut**, Faculty Member, Bogazici University, Türkiye.
Deniz Dölgen, Professor, Dokuz Eylul University, Türkiye.
M. Necdet Alpaslan, Professor, MNA Engineering and Consultancy, Türkiye.
Title: Sustainable Waste Management: Promoting the Circular Economy through Industrial Symbiosis.

11:30-13:00 Session 2

Moderator: Andreea Maria Iordache, Head of Metal Isotopes Laboratory, National Research and Development Institute for Cryogenics and Isotopic Technologies (ICSI), Romania.

1. **Jose Manuel Castillo Lopez**, Full Professor, University of Granada, Spain.
Title: Competition for Water Use in the European Mediterranean: Agriculture, Urban Uses, and Tourism. The Case of the Tropical Coast of Granada.
2. **Atheesha Singh**, Associate Professor, University of Johannesburg, South Africa.
Tobias George Barnard, Associate Professor and Director, Water and Health Research Centre, University of Johannesburg, South Africa.
Title: Hidden Microbial Contamination in Urban Water Systems from Source to Use in the Gauteng Research Triangle, South Africa.
3. **Idair Espinosa**, Condition Assessment Engineer, Xylem Water Solutions, Spain.
Title: No Dig, No Disruption: Free-Swimming Tools for Metallic Pipeline Integrity Assessment.

13:00-14:30 Session 3

Moderator: Marta Torres, Researcher, NOVA University Lisbon, Portugal.

1. **Kongyou Wu**, Professor, China University of Petroleum (Huadong), China.
Mei Hong, Associate Professor, China University of Petroleum (Huadong), China.
Title: Research on the Controlling Effects of Strike-Slip Faults on Carboniferous Volcanic Hydrocarbon Accumulation in the Chepaizi Uplift.
2. **Archana Sharma**, Associate Professor, Morgan State University, USA.
Title: Indian Garden: Ecological Thinking and Landscape Epistemology.
3. **Martin Knez**, Head, UNESCO Chair on Karst Education, Karst Research Institute – ZRC SAZU, Slovenia.
Tadej Slabe, Karstologist, Karst Research Institute – ZRC SAZU, Slovenia.
Title: Karstification of Cultural Heritage, Focused Especially on Old Greek Monuments.
4. **Jae Gon Kim**, Principal Scientist, Korea Institute of Geoscience and Mineral Resources, South Korea.
Title: Management of Acid Rock Drainage in a Highway Construction Site.
5. **Klajdi Qoshi**, Assistant Researcher, Institute of GeoSciences, Polytechnic University of Tirana, Albania.
Edmond Dushi, Associate Professor, Institute of GeoSciences, Polytechnic University of Tirana, Albania.
Title: An Updated, Homogeneous, and Declustered Earthquake Catalog for Albania and the Surrounding Region.

14:30-15:30 Lunch

15:30-17:00 Session 4

Moderator: Isaac T. Rampedi, Deputy Director, Sciences Division, Athens Institute & Associate Professor, University of Johannesburg, South Africa

1. **Teodoro Georgiadis**, Senior Scientist, Institute of BioEconomy, CNR, Italy.
Letizia Cremonini, Researcher, Institute of BioEconomy, CNR, Italy.
Title: How to Organize Green Nature-Based Solutions in Cities for Elderly People and Those with Chronic Conditions.
2. **Justyna Gołębiowska**, Assistant professor, Lublin University of Technology, Poland.
Title: Comparative Life Cycle Assessment of Photovoltaic-Thermal Collectors and Hybrid PV-Solar Thermal Systems for Residential Applications.
3. **Marta Torres**, Researcher, NOVA University Lisbon, Portugal.
Title: The Dialogue between Environmental Education and Social Sciences.
4. **Nesreen Weshah**, Instructor, Southern Alberta Institute of Technology (SAIT), Canada.
ShahinazHanem Abdellatif, Associate Professor, University Canada West, Canada.
Fazal Aseef Shaikh, Master's Student, University Canada West, Canada.
Navjot Kaur, Master's Student, University Canada West, Canada.
Title: A Multi-layer Conceptual Framework for Circular Economy Integration in Cold-Climate Construction Policy in Canada.

18:00-20:00 Session 5 – Visit Aristotle's Lyceum

This is not a guided tour, and participation in this visit is **not included in any conference registration fee. It requires pre-booking.** It includes visits to Aristotle's Lyceum, the Panathenaic Stadium (Kallimarmaro), the National Garden, the statues of Sophocles, Aeschylus, and Euripides, and Syntagma Square, where the tour concludes in front of the Hellenic Parliament. [Click here](#) for more details.

20:30-22:30 Athenian Early Evening Symposium (Sequence of Events: Ongoing Academic Discussions, Dinner, Wine and Water, Music, Dance)

Tuesday 14 July 2026

09:00-10:30 Session 6

Moderator: Raluca Laura Dornean Paunescu, Associate Professor, Universitatea Europeană Drăgan din Lugoj, Romania.

1. **Magdalena Rybaczevska-Blazejowska**, Professor, Kielce University of Technology, Poland.
Title: Corporate Environmental Transparency: An Analysis of mWIG40 ESG Disclosure Practices.
2. **Tanya Wagenaar**, Senior Lecturer, Nelson Mandela University, South Africa.
Title: Best Available Climate Science: A Guiding Principle or a Legal Obligation?
3. **Daniel Humpel**, Lecturer, University of Fort Hare, South Africa.
Title: Existing in the Periphery: Moral Patienthood as a Basis for Personhood for Non-human Animals.

10:30-12:00 Session 7

Moderator: Onder Kilic, Professor, Istanbul University, Türkiye.

1. **Xin Song**, Professor, Institute of Soil Science, Chinese Academy of Sciences, China.
Title: MWCNT/LDH-Based Composite Adsorbents for Efficient Removal of PFAS from Water: Batch and Column Studies.
2. **Nanping Wang**, Professor, China University of Geosciences, Beijing, China.
Nan Gan, Engineer, Beijing Research Institute of Chemical Engineering and Metallurgy, China.
Title: Study on the Long-Term Variation Pattern of Soil Radon Concentration and Main Control Factors in the In-Situ Leaching Uranium Ore Area of Yili Basin, Xinjiang.
3. **Soyoung Jeon**, PhD Student, Pukyong National University, South Korea.
Title: Layered Double Hydroxide (LDH) Improved by Sulfur and Supercritical CO₂ Treatment for Cesium Removal in Aqueous System.
4. **Isaac T. Rampedi**, Associate Professor, University of Johannesburg, South Africa.
Title: A Comparative Study of Household Pharmaceutical Waste Storage and Disposal in Katlehong Township and Lambton Suburb in the Ekurhuleni Metropolitan Municipality of South Africa.

12:00-13:30 Session 8

Moderator: Savannalee Ahmed-Hodgkinson, Lecturer, University of Johannesburg, South Africa.

1. **Onder Kilic**, Professor, Istanbul University, Türkiye.
Murat Belivermiş, Professor, Istanbul University, Türkiye.
Vahap Eldem, Professor, Istanbul University, Türkiye.
Melis Özdemir, MSc Student, Istanbul University, Türkiye.
Berna Şahin, PhD Student, Istanbul University, Türkiye.
Selcan Demiralp, PhD Student, Istanbul University, Türkiye.
Narin Sezer, Researcher, Istanbul Arel University, Türkiye.
Selahattin Barış Çay, PhD Student, Istanbul University, Türkiye.
Mehmet Ali Balci, PhD Student, Istanbul University, Türkiye.
Suna Bektaş, PhD Student, Istanbul University, Türkiye.
Title: The Combined Effects of Ocean Acidification and Benzo(a)anthracene on the Mediterranean Mussel Mytilus Galloprovincialis.
2. **Fengmei Yao**, Professor, University of Chinese Academy of Sciences, China.
Title: Widespread Vegetation Greening under Multiscale Drought Mitigation across Northern China during 2001-2022.
3. **Maria Maglianesi**, Research Scientist, Instituto Tecnológico de Costa Rica, Universidad Estatal a Distancia, Costa Rica.
Luis Felipe Sancho Jiménez, Instituto Tecnológico de Costa Rica, Universidad Estatal a Distancia, Costa Rica.

Joaquín Durán Mora, Instituto Tecnológico de Costa Rica, Universidad Estatal a Distancia, Costa Rica. <i>Title: How Agricultural Lands Contribute to Bird Diversity in Northern Costa Rica.</i> 4. Elle Rajandu, Lecturer, Tallinn University, Estonia. Maria Kulp, Senior Researcher, Tallinn University of Technology, Estonia. Marko Kaasik, Associate Professor, University of Tartu, Estonia. Aaro Videvik, MSc Graduate, Tallinn University, Estonia. Kadi Karmen Kaldma, PhD Candidate, Tallinn University, Estonia. Martin Küttim, Researcher, Tallinn University, Estonia. <i>Title: Monitoring Environmental Quality in Urban Gardens Using Moss Analyses of Heavy Metals and Pigments.</i>	13:30-15:00 Session 9 Moderator: Atheesha Singh, Associate Professor, University of Johannesburg, South Africa. 1. Martina Sopta Coric, Full Professor, University of Zagreb, Croatia. Mihaela Mikic, Associate Professor, University of Zagreb, Croatia. <i>Title: A Digital Transformation Model for Enhancing the Operational Efficiency of Energy Infrastructure under Climate and Crisis Challenges.</i> 2. Jiahua Zhang, Professor, Qingdao University, China. <i>Title: Abnormal Spring Climate and Greener Amplify Impacts of Summer Drought on Ecosystem Carbon-Water Fluxes.</i> 3. Johanna Ficsor, Assistant Professor, Ludovika University of Public Service, Hungary. <i>Title: Technical Solutions for Small-Scale Nature-Based Water Retention.</i> 4. Maja Jankovic, Expert Associate, Institute for Development and International Relations, Croatia. Sanja Tišma, Director, Institute for Development and International Relations, Croatia. Milenko Krajišnik, Dean and Professor, University of Banja Luka, Bosnia and Herzegovina. <i>Title: Bioeconomy as a Driver of Sustainable Development: Opportunities and Challenges in the 21st Century.</i>
15:00-15:45 Lunch	
15:45-19:30 Session 10 Old and New-An Educational Urban Walk The urban walk ticket is not included as part of your registration fee. It includes transportation costs and the cost to enter the Parthenon and the other monuments on the Acropolis Hill. The urban walk tour includes the broader area of Athens. Among other sites, it includes: Zappion, Syntagma Square, Temple of Olympian Zeus, Ancient Roman Agora and on Acropolis Hill: the Propylaea, the Temple of Athena Nike, the Erechtheion, and the Parthenon. The program of the tour may be adjusted, if there is a need beyond our control. This is a private event organized by the Athens Institute exclusively for the conference participants.	
20:30-22:30 Closing Remarks by Gregory T. Papanikos: “<u>Wine, Words, and Wisdom: An Ancient Athenian Dinner Symposium</u>” followed by an Ancient Athenian Dinner	

Wednesday 15 July 2026
An Educational Visit to Selected Islands
or Nafplio & Mycenae Visit

Thursday 16 July 2026
Visiting the Oracle of Delphi

Friday 17 July 2026
Visiting the Ancient Corinth and Cape Sounion

Saturday 18 July 2026
09:00-10:00 – The Academic Discussion continues in the downtown open agora (close to the
Aristotelian Lyceum)

Savannalee Ahmed-Hodgkinson

Lecturer, University of Johannesburg, South Africa

&

Thea Schoeman

Head, Department of Geography, Environmental Management and
Energy Studies, University of Johannesburg, South Africa

E-waste: The Good, the Bad and the Ugly in South Africa

The rapid accumulation of e-waste is a growing concern, especially in the context of climate change and necessitates strategies for sustainable management. This study brings together the results of three areas of research and provides information from the informal sector to the e-waste recycling behaviour of residents. The first area investigated the operations of waste pickers regarding e-waste and 229 waste reclaimers completed a questionnaire. The results showed 74.2% of e-waste collected was from bins outside of households, that the most common e-waste collected was cables (45.9%) and the majority (76.4%) sold their e-waste to scrap metal dealers.

An often-overlooked strategy is to repair e-waste instead of dismantling and recycling it. The University of Johannesburg developed a short learning programme in the repair of e-waste based on the needs expressed in the first part of this study. The second part of the study evaluated a training hosted for Gauteng reclaimers to equip them with the correct knowledge, skills and tools to handle e-waste sustainably. The training hosted 20 reclaimers operating in Gauteng and the Kirkpatrick Model was used to evaluate the training, focusing on the reaction and learning components of the reclaimers. The reclaimers completed a questionnaire after their training and the self-evaluation results indicated that the reclaimers had improved their knowledge and skills in repairing e-waste.

The third part of the study determined the ownership status, the characterisation and disposal methods of appliances in households. A total of 346 respondents completed the online survey and the most common large appliance owned was a fridge (99.4%), small appliance was a kettle (96.8%), while 88.2% owned a television and 98.6% owned a mobile phone. The respondents were asked what appliances are no longer needed or used and VCR players (50.9%), GPS devices (44.2%) and mobile phones (31.4%) were the top three. Equipment no longer working was mobile phones (28.7%), e-smoking devices (27.9%) and laptops (19.4%). In terms of large appliances, the most preferred method

of disposal was to sell it to a second-hand shop, while for all the other appliances and devices the preferred method was to 'give it to someone'.

Tamer Atabarut

Faculty Member, Boğaziçi University, Türkiye

Deniz Dölgen

Professor, Dokuz Eylül University, Türkiye

&

M. Necdet Alpaslan

Professor, MNA Engineering and Consultancy, Türkiye

Sustainable Waste Management: Promoting the Circular Economy through Industrial Symbiosis

The transition to a circular economy has become increasingly important in addressing environmental degradation, resource depletion, and climate change. By promoting resource efficiency, waste minimization, reuse, and recycling, circular economy practices contribute significantly to cutting greenhouse gas emissions (GHG) and supporting sustainable industrial development. In this context, the European Green Deal highlights climate neutrality, sustainable production, energy efficiency, and responsible resource management as key priorities for the future. Similarly, Türkiye has accelerated its sustainability efforts through national policies such as the Turkish Circular Economy Action Plan and related green transformation strategies, which encourage efficient resource use, waste recovery, cleaner production, and industrial sustainability practices. These policies support industries in adapting to international environmental standards while strengthening their competitiveness in global markets. Among the approaches that contribute to these objectives, Industrial Symbiosis (IS) has emerged as one of the most effective tools for improving industrial sustainability and accelerating the transition toward a circular economy.

Industrial Symbiosis can be defined as the exchange or shared use of raw materials, energy, infrastructure, human resources, and by-products among industrial facilities, preferably located in close geographical proximity. Through collaborative resource utilization, IS enhances resource efficiency, reduces production costs, minimizes waste generation, and decreases greenhouse gas emissions. These benefits not only improve environmental performance but also strengthen industrial competitiveness and profitability, making IS an important mechanism for achieving circular economy and green growth objectives. In addition, IS contributes to sustainable waste management by transforming industrial waste into valuable secondary resources that can be reused by other industries, thereby reducing dependency on virgin raw materials and landfill disposal.

The concept of IS first emerged in the 1960s in Kalundborg, where strong cooperation between local authorities and industrial enterprises transformed a single exchange initiative into one of the world's best-known industrial symbiosis networks. Today, the Kalundborg network includes six industries and three public institutions connected through approximately 25 material and energy exchange flows. The success of this model has attracted global attention and demonstrated that cooperation among industries can simultaneously generate economic, environmental, and social benefits.

Over time, important developments in IS have been observed in countries such as the United States, China, Japan, Canada, and South Korea, as well as in several European countries including Denmark, the United Kingdom, Norway, the Netherlands, Sweden, Switzerland, Germany, and Italy. In Türkiye, although various national and international policies encourage environmentally friendly industrial practices, comprehensive IS applications remain limited. Nevertheless, some initiatives have been implemented, including the IS Projects in the İskenderun Gulf, Black Sea Basin, the Thrace region, the Bursa-Eskişehir-Bilecik zone, Ankara, Antalya, Gaziantep, Kayseri, Tire, Bagyurdu and İzmir besides development of an IS Roadmap for Türkiye Project.

This paper presents the concept and development of ISs by examining both international and national applications. In addition, focusing on projects implemented in İzmir and its surrounding regions, the study evaluates the IS potential of the region and provides recommendations regarding waste management, resource efficiency, and sustainable industrial cooperation, which remain among the major challenges faced by industrial facilities today.

Jose Manuel Castillo Lopez
Full Professor, University of Granada, Spain

Competition for Water Use in the European Mediterranean: Agriculture, Urban Uses, and Tourism – The Case of the Tropical Coast of Granada

This article analyzes the current and recent reality of competition for water in the European Mediterranean between agriculture and urban and tourism uses, addressing the theoretical foundations, the physical reality, the institutional role, and the main existing conflicts.

Particular attention will be paid to the case of the Tropical Coast of the Province of Granada in Spain, where, in addition to the general characteristics of the European Mediterranean, there is the particular circumstance that the urban water supply service is provided through a concession granted to a private company belonging to a multinational group.

Among the classic theoretical contributions, we will include, among others, that developed by Garrett Hardin (1968) in *The Tragedy of the Commons*, which argues that common goods tend to be overexploited when multiple actors compete for them without effective regulatory mechanisms. The analysis will also be informed by the principles and experiences of the so-called “New Water Culture,” which has its institutional origins in the European framework and already has relevant experiences in Mediterranean countries.

The climatic characteristics of the Mediterranean include scarce and irregular rainfall, frequent droughts in spring and summer, high evapotranspiration, and the concentration of rainfall in autumn and winter.

The situation becomes even more extreme due to climate change. According to data from the World Meteorological Organization (WMO, 2023), temperatures in the Mediterranean are increasing 20% faster than the global average. This situation reduces river flows and accelerates desertification.

In the European Mediterranean, agriculture demands large volumes of water to sustain intensive and export-oriented crops, while cities and tourism require a continuous and high-quality water supply, especially during the summer, which coincides precisely with the period of lowest water availability.

In the Tropical Coast area of the Province of Granada, the aforementioned physical characteristics are reproduced. In addition, the situation in this region is complicated by the institutional framework

involving responsibilities for water management for agricultural use and urban supply.

Finally, the paper will analyze the particular circumstance that the urban water supply is granted to a private company belonging to a multinational group, which gives rise to conflicts between the interests of local citizens and environmental concerns on the one hand, and the economic and strategic interests of the corporate group on the other.

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Evaluation of Electrocoagulation for the Pre-Treatment of Wastewater from Table Olive Production

Electrocoagulation (EC) is a versatile treatment method applied across various fields, including drinking water purification, leachate treatment, and the management of domestic and industrial wastewater (e.g., textile, paint, slaughterhouse, dairy, and paper industry effluents). Numerous studies have demonstrated its efficacy in removing complex pollutants such as organic substances, suspended solids, oil-grease, color, phenol, and heavy metals.

The treatability of table olive processing wastewater using the EC method is investigated in this study. The presence of high salinity, alkalinity, dark colour, and high concentrations of organic matter and phenolic compounds in table olive effluents poses significant challenges for conventional treatment plants. In particular, the presence of phenolic compounds and high salt content results in the inhibition of biological treatment and makes the integration of alternative methods necessary. The EC method offers distinct advantages, such as eliminating the need for chemical additives and generating less sludge. Wastewater samples were collected from an olive processing facility in the Aegean region to evaluate their treatability via EC based on this approach. The experimental framework was designed using Box-Behnken response surface methodology. The setup utilized a 5-liter batch reactor equipped with three aluminium anodes and three aluminium cathodes, arranged in a monopolar parallel connection with an inter-electrode distance of 2.5 cm. The effects of the initial pH (3–11), the current/voltage (0–5 V), and the reaction time (5–60 min) based on the removal of chemical oxygen demand (COD) and colour were investigated.

Based on the experimental results, the optimum operating conditions were determined to be a pH of 11, a voltage of 5 V, and a reaction time of 35 minutes. Under these conditions, the removal efficiencies were achieved as 80% for color ($R^2 = 0.9949$), and 34% for COD ($R^2 = 0.9244$). Although literature on treating table olive wastewater using the EC method remains limited, these findings align well with existing data. The requirement of a highly alkaline medium (pH 11) for optimum treatment was attributed to the enhanced precipitation of phenolic compounds at elevated pH levels, which directly contributed to the high color removal efficiency (80%). Conversely, the relatively low COD removal (6%) indicates that while the complex, dark-colored organic structures were successfully broken down and decolorized, the residual organic fragments remained in the solution. This technical outcome validates the necessity of a combined treatment approach, proving that EC is highly effective at destroying toxicity and complex color chains, thereby preparing the matrix for subsequent biological degradation. Besides, post-treatment, the reduction in phenolic components suggests that the wastewater becomes significantly more amenable to subsequent biological treatment. The results highlight electrocoagulation as a sustainable and effective pre-treatment strategy that enhances the biodegradability of agro-industrial effluents, paving the way for more efficient subsequent biological treatment. Therefore, using the EC method as a pre-treatment step before biological systems has been highly recommended to achieve the desired effluent quality.

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No Dig, No Disruption: Free-Swimming Tools for Metallic Pipeline Integrity Assessment

Large diameter pipelines carry vast amounts of water. Failure in these pipelines can cause great material loss, water loss, and dangerous consequences for public safety and the environment. Effective management of pressurized metallic pipelines begins with reliable condition data. This study integrates acoustic and ultrasonic sensing with **free-swimming tools** – without service disruption – to deliver that comprehensive condition assessment.

Acoustic data identifies leaks and detects gas pockets; **ultrasonic data** identifies and quantifies wall thickness loss, lining holidays, and debris accumulation, among other condition indicators. These complementary datasets provide a complete picture of the pipeline condition, enabling utilities to not only pinpoint active failures but also proactively target pipes at greatest risk of deterioration.

Corrosion data from ultrasonic inspection feeds directly into **structural assessment**, enabling evaluation of pipe distress severity. This assessment quantifies the impact of material loss on structural integrity, allowing the development of targeted **maintenance strategies** and pinpointing critical pipes that may require repair or replacement before failure occurs. This approach is also well-suited for challenging environments such as wastewater force mains, where leaks pose public health risks and gas pockets can accelerate corrosion processes.

Field deployments demonstrate that this dual-sensing strategy enhances the prioritization of rehabilitation, repair, or replacement decisions. These insights directly support a transition toward predictive maintenance and **smarter asset management** practices, reducing the likelihood of catastrophic failure, minimizing service disruptions, and extending the service life of critical water infrastructure.

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Technical Solutions for Small-Scale Nature-Based Water Retention

Climate change is a global phenomenon that we are unable to stop, but we can prepare for its expected effects and adapt to the situation as it develops. Extreme weather events do not recognize administrative boundaries; sudden heavy rainfall can cause serious damage in one municipality, while the neighboring municipality suffers from water shortages. It is therefore worth seeking an integrated solution at the small catchment level, which lies primarily in balancing periods of water abundance and water scarcity as far as possible. At the small catchment level, the most important tools for this are natural water retention solutions.

These are solutions whose primary goal is to increase the water storage capacity of soils and wetlands. They are generally small in scale and retain surface water, such as water from rivers, streams, or runoff after precipitation, and then slowly and controlled release it back into the environment, thereby rehabilitating the small-scale water cycle while retaining water.

These solutions are not new in themselves, as they have been widely used in the past, sometimes under different names. Examples include sustainable rainwater management systems, field protection forest strips, wetland restoration, and storm water retention basins. What is new is the recognition that these solutions, when applied widely, well-planned, and at multiple points, can achieve a much more complex, landscape-level or even national impact, and can thus replace or supplement costly gray infrastructure.

The aim of the presentation is to provide a comprehensive overview of such technical solutions by presenting Hungarian examples.

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How to Organize Green Nature-Based Solutions in Cities for Elderly People and Those with Chronic Conditions

It has been highlighted (Cremonini et al., Athens Journal of Health and Medical Sciences, Volume 12, Issue 3, September 2025) that there may be an element not considered in European policies on heatwave protection: the specific vulnerability of the elderly, particularly those with chronic conditions, when organizing urban spaces with green areas for the physiological recovery of citizens. The city's design must consider its citizens' specific demographics if it is to be truly effective and achieve the equity described in Goal 11 of the UN 20-30 Agenda for Sustainable Cities and Communities. The achievement of true equity for citizens cannot, therefore, be separated from an assessment of the specific vulnerabilities that give rise to direct climate risks. This study presents the physiological responses of elderly subjects (healthy, with diabetes, and with early cognitive decline) to varying ambient air temperatures. This assessment enables defining the maximum distance that exposed subjects can walk before experiencing significant physiological effects. An example of an urban route structured according to these criteria is provided, serving as a guide for urban planning and social and health care facilities.

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Comparative Life Cycle Assessment of Photovoltaic-Thermal Collectors and Hybrid PV-Solar Thermal Systems for Residential Applications

The implementation of renewable energy systems to support the green transition and decarbonization of the residential energy sector requires a comprehensive evaluation of these technologies, considering their operational performance as well as their overall environmental impacts across different life-cycle stages. Although the application of renewable energy technologies in residential buildings is considered as one of the key directions for sustainable development, the selection of the most appropriate technological solution for specific climate conditions remains a challenging issue.

This study presents a comparative assessment of two solar energy system configurations for a single-family house located in Lublin, Poland. The first system involves the application of photovoltaic-thermal (PVT) collectors to cover the building's electricity demand and support domestic hot water preparation. The second system, designed to achieve the same goals, consists of two separate installations: a conventional photovoltaic (PV) system and a solar thermal (ST) collector system.

The aim of the study is to compare the operation of both systems from energetic and environmental perspectives. The energy performance of both configurations is simulated using Polysun software, providing detailed information on energy yields. The environmental assessment and comparison of the systems are based on the Life Cycle Assessment (LCA) methodology and are carried out using SimaPro software and selected impact assessment methods.

The application of different assessment perspectives to such systems may support decision-making regarding the selection of renewable energy technologies suitable for specific locations and climate conditions.

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Wastewater Recovery and Reuse at Düzce University Campus: An Integrated Model Proposal Using the Water4Reuse Approach

Increasing water stress and the effects of climate change are making sustainable water management practices mandatory on university campuses. This study aims to evaluate the potential for water reuse at Düzce University Campus within the framework of the criteria under the “Water” heading in the UI GreenMetric ranking (water conservation programs, recycled water use, water-efficient infrastructure, and wastewater management). The study addresses the recovery of domestic wastewater from the campus through advanced treatment technologies for use in landscape irrigation and technical water applications. The Water4Reuse approach was adopted in the evaluation process; environmental impacts, health risks, and resource efficiency were analyzed from a holistic perspective, in addition to technical feasibility. The findings show that reclaimed water use improves water management performance by reducing drinking water consumption across the campus and contributes positively to the sustainability score under the GreenMetric “Water” criteria. The study presents a feasible model for university campuses to consider wastewater as a “new resource.”

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Existing in the Periphery: Moral Patienthood as a Basis for Personhood for Non-human Animals

Legal personhood is a construct that affords humans and artificial entities legal recognition (categorically classified as natural and juristic persons, respectively), which enables them to bear rights and duties. The same treatment has been sought for non-human animals (traditionally classified as legal objects, things or *res*), a development that has recently gained significant traction. Jurisdictions such as India and Argentina have proven that conferring legal personhood is not only *prima facie* theoretically possible but also practically achievable. This demonstrates the malleability of legal personhood, yet it remains conceptually problematic when scrutinised through moral, metaphysical, and linguistic lenses. These challenges can be attributed to the anthropocentric orientation of current legal paradigms, which continually shapes intense resistance to expanding legal personhood to include non-human animals.

As such, this paper proposes moral patienthood as a conceptual tool for adapting the current configuration of legal personhood to an extent that safeguards the welfare interests of non-human animals. This remains a contentious area in academic discourse, as several known and emerging theories of legal personhood often fragment the construct without formulating a stable foundation for its conferment to non-human animals. On the contrary, moral patienthood, a status that is already utilised in law for recognising the interests of infants and persons with cognitive impairments, is dependent on the minimum threshold of sentience. Sentience confers moral status, which recognises a being having intrinsic moral value and the capacity to be harmed. Sequentially, moral status requires that a being's interests must be accorded moral consideration, regardless of their lack of agency or capacity to bear duties, ultimately leading to moral patienthood. Conclusively, moral patients are conferred legal personhood, thereby demonstrating that agency is not a precondition for their recognition.

Moral patienthood can serve as a vital tool and principled lens for reconceptualising the current classification of non-human animals as things in South African law, a status that has remained unchanged and is, in essence, a legal habit inherited from Roman law. This paper examines the construct of legal personhood and the role of moral patienthood as a precursor for conferring a limited form of legal

personhood to non-human animals as a means of meaningfully safeguarding their welfare interests.

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Bioeconomy as a Driver of Sustainable Development: Opportunities and Challenges in the 21st Century

The bioeconomy represents a promising approach to sustainable development by increasingly utilizing biological resources and biotechnological innovations as alternatives to fossil-based systems. This paper examines its potential contribution to advancing the United Nations Sustainable Development Goals (SDGs), particularly in addressing climate change, improving resource efficiency, and supporting inclusive growth. Unlike traditional linear economies, the bioeconomy encourages circular and regenerative models, employing processes such as photosynthesis, microbial conversion, and waste valorization to foster more sustainable value chains.

The European Union's Bioeconomy Strategy reflects this paradigm shift, aiming to reduce the reliance of economic growth on finite resources through innovations like lignin-based textiles and agricultural residue biorefineries. These initiatives are designed to support multiple SDGs, including SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), by promoting circular principles and reducing environmental impacts.

Nevertheless, the development of the bioeconomy faces systemic challenges, including technological limitations, fragmented policy landscapes, and ethical considerations regarding land use planning, despite its potential to contribute positively to ecosystem preservation and biodiversity. Through a mixed-methods approach—combining policy analysis and EU case studies—this paper underscores the importance of integrated governance, cross-sectoral cooperation, and carefully designed public-private partnerships in supporting the responsible expansion of bioeconomic activities.

The findings suggest that although the bioeconomy may contribute to long-term reductions in carbon emissions, its success depends on adaptive policy frameworks that align innovation with environmental stewardship and social equity. Ultimately, unlocking the full potential of

the bioeconomy requires inclusive strategies that equitably distribute benefits while critically managing trade-offs inherent in sustainable development transitions.

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**Layered Double Hydroxide (LDH) Improved by Sulfur and
Supercritical CO₂ Treatment for Cesium Removal in
Aqueous System**

The excessive release of carbon dioxide (CO₂) from fossil fuel combustion has accelerated global warming, emphasizing the need for sustainable and low carbon energy sources. The usage of nuclear power has been widely considered to reduce CO₂ emissions while ensuring a stable energy supply. However, nuclear power generation produces spent nuclear fuels, and without proper care, various radionuclides may be released into the environment during long term storage time, posing risks to ecosystems and human health. Unexpected nuclear accidents may also cause large scale radionuclide releases, highlighting the necessity of developing reliable preventive measures and efficient remediation materials. Cesium-137 (Cs) is particularly concerning as a typical radionuclide because of its relatively long half-life (30 year) and high solubility in water. Although numerous adsorbents for Cs⁺ have been developed, many suffer from high production costs and low adsorption efficiency in high ionic strength solutions like seawater. This study aims to develop the layered double hydroxide (LDH)-based adsorbent, improved by using supercritical CO₂ (scCO₂) and sulfur treatment, contributing to the CO₂ reduction and to the Cs⁺ removal.

The LDH consists of brucite-like layers containing divalent and trivalent metal cations, alternately stacked with interlayer anions for charge compensation. It also has the large surface area and high ion

exchange capacity. To improve its Cs^+ adsorption efficiency, the original LDH was modified by incorporating sulfur (S), since S^{2-} has a strong affinity for Cs^+ according to the hard-soft acid-base (HSAB) theory. The inherent characteristics of scCO_2 , such as low viscosity, high diffusivity, excellent solvation capacity, non-toxicity, and low cost, make it an effective medium for facilitate S incorporation and structural modification of LDH. In this study, the original Mg-Fe LDH was synthesized via a conventional coprecipitation method from the previous study. The LDH and Na_2S powders were mixed at various ratios with a small amount of ethanol and sealed in an O_2 free reactor vessel. The reactor was then exposed to scCO_2 at 10 MPa and 60 °C for 4 h and subsequently rapidly depressurized to atmospheric pressure within 30 seconds to produce the S incorporated LDH (named as "S-LDH").

Result of the XRF analysis supported the successful incorporation of S into the original LDH structure, and result of the XPS analysis further verified the stable states of S species within S-LDH. The XRD analysis result also showed a slight decrease in interlayer spacing, confirming the effective incorporation of S into the interlayer space. Batch adsorption experiments of LDH and S-LDH for Cs^+ were conducted under various conditions (initial concentration, reaction time, pH, and different ion strength) to evaluate the enhanced Cs^+ adsorption efficiency of S-LDH. At an initial Cs^+ concentration of 0.5 mg/L, S-LDH achieved a removal efficiency greater than 90%, which is approximately 13 times higher than that of the unmodified LDH. Results from this study demonstrate that the scCO_2 treatment also enables the efficient S incorporation in S-LDH, yielding an environmentally friendly adsorbent with greatly improved Cs^+ adsorption efficiency and strong potential for practical radionuclide remediation in aqueous system.

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**The Combined Effects of Ocean Acidification and
Benzo(a)anthracene on the Mediterranean Mussel *Mytilus
Galloprovincialis***

Marine ecosystems are negatively affected by abiotic stressors and contaminants. Ocean acidification (OA) is one of the most critical environmental changes resulting from the high amount of CO₂ emissions into the atmosphere. It has a particularly significant impact on shellfish inhabiting coastal zones. On the other hand, polycyclic aromatic hydrocarbons (PAHs) are widespread environmental contaminants that enter marine ecosystems primarily through the combustion of fossil fuels, pyrolytic processes, oil spills, ship traffic, and similar anthropogenic activities. Benzo(a)anthracene (BaA), one of the PAHs, is a high-molecular-weight compound with four fused benzene rings. BaA is classified as a priority pollutant and is known to have possible carcinogenic effects on humans. The Mediterranean mussel *Mytilus galloprovincialis* is an important model species and plays a crucial role in both human nutrition and marine ecology. Therefore, it is essential to assess the extent to which it is affected by environmental stressors.

In the present study, we investigated the combined effects of OA (pH 7.7) and BaA (9 $\mu\text{g L}^{-1}$) on the Mediterranean mussel *M. galloprovincialis*. The experimental design included treatments with OA, BaA, and OA + BaA, alongside a control group. After a 10-day acclimatisation period, the organisms were exposed to these stressors for 30 days. Subsequently, physiological and transcriptomic analyses were conducted. The results demonstrated significant effects on total haemocytes, haemocyte viability, respiration rate, and neutral red uptake, although no effects were observed on condition index and filtration rate. Transcriptomic analysis indicated that combined exposure to ocean acidification and benzo(a)anthracene induces a synergistic transcriptional reprogramming in *M. galloprovincialis* gills that surpasses responses to individual stressors. While acidification mainly drives innate immune activation through CARD and C1q domains alongside extracellular matrix remodelling, organic pollution distinctly affects intracellular vesicular organisation and morphogenetic developmental processes. Notably, the dual-stressor environment exceeds cellular adaptive capacity, leading to the unique suppression of key mitochondrial functions and xenobiotic detoxification pathways that remain active during single-stressor exposure. This stressed state is marked by the emergence of novel neuro-immune phenotypes, including the activation of axon regeneration mechanisms and specialised B-1 B cell differentiation, features absent in isolation. Finally, validation through RT-qPCR confirms these distinct patterns, identifying cellulase and CARD domain-containing protein as high-fidelity molecular biomarkers for monitoring these interactive environmental pressures. Overall, the findings suggest that the individual and combined effects of both stressors generally negatively influence the mussels. Further research with more graded concentrations is essential to better elucidate the interactions of these stressors.

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Management of Acid Rock Drainage in a Highway Construction Site

Acid rock drainage (ARD) is the outflow of metal containing acidic water from sulfide bearing rocks. When the sulfide bearing rocks are exposed to air and water by mining and construction works, the sulfides are oxidized by oxygen in air and water producing ARD. The ARD causes the contamination and acidification of soil and water and the reduction of slope stability in some construction sites in south Korea. We tried to develop a proper management strategy of the ARD in a highway construction site in south Kora. We tested the ARD producing potential of the basement rock of the studied site with the acid base accounting (ABA) test and reviewed the damage reduction strategies based the ABA test result. The basement rocks of the studied site consist of a sandstone and an intermediate to acidic volcanic rock. Sulfides occur as a disseminated type in the sandstone and volcanic rock which were altered by the hydrothermal solution of granite intrusion. The volcanic rock and sandstone contained more than 0.1% of sulfide and were classified as the ARD producing rock. The ABA test results indicate that the drainage from those rocks may acidify and contaminate the surrounding water and soil during and after the highway construction. Therefore, the drainage should be properly treated before it is discharged. The reduction of slope stability due to the fast weathering of rocks by the ARD was also expected. A phosphate coating technology was adopted for the reduction of ARD generation as a preemptive measure before reinforcement works for enhancing slope stability such as shotcrete and anchor. A vegetation cover method with an acid neutralizing material was adopted for the ecological restoration of the slope. Those rocks should not be used as concrete aggregate, but can be utilized as a bank filling material amended with acid neutralizing materials such as limestone and steel slag.

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Karstification of Cultural Heritage, Focused Especially on Old Greek Monuments

Twenty years of field documentation of transformation traces on cultural heritage, namely buildings, rock-cut monuments, and sculptures constructed from carbonate rocks, clearly demonstrate varied yet characteristic karstification resulting from diverse environmental influences. In several instances, karstification is highly intense, necessitating urgent consideration of protection and conservation measures, as well as potential restoration. To date, protective measures have been implemented only at the remains of the Hagar Qim temple in Malta and, to a lesser extent, at the Roman arena in Nîmes, while restoration efforts are also ongoing at the Acropolis in Athens.

At the same time, the study of these monuments could provide an exceptional record of karstification rates across different carbonate lithologies and environmental conditions, as many of these heritage objects are precisely dated.

Material has been collected from a wide range of global sites, including the Great Pyramid of Giza; the Hagar Qim temple in Malta; carbonate dolmens in Sardinia (Figures 1, 2) and southern France; Persepolis and Taq-e Bostan in Iran; the Acropolis and temples in Athens; the stone lions of Delos; the quarries of Favignana; the Pantalica necropolis in Sicily; Roman amphitheatres in Nîmes and Arles; the Pont du Gard aqueduct; the theatre in Alexandria; the medieval fortress of Les Baux-de-Provence; the Papal Palace in Avignon; Baroque heritage sites in Sicily (Modica, Ragusa); the historic centre of Cairo; and various buildings in Slovenia. Field findings from investigations of Stonehenge are also intriguing; although constructed of silicate rocks, the megaliths display distinct traces of rainfall- and runoff-induced weathering along their surfaces.

We have also succeeded in producing our first, already well-received study, explaining the karstification of the Great Pyramid of Giza (Knez et al., 2025; Figures 3, 4).

Figures 1, 2. *Dolmen on Sardinia.* **Figures 3, 4.** *Great Pyramid of Giza with Typical Shape of Rock Block*



For all other documented examples of carbonate rock-based cultural heritage, comprehensive data on rock relief have been systematically collected. The relevant archive currently contains approximately 5,000 photographs depicting specific rock features and rock relief.

Furthermore, field investigations into the geological characteristics of the rocks have been conducted, including sampling for detailed geological analysis.

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How Agricultural Lands Contribute to Bird Diversity in Northern Costa Rica

Agricultural expansion is a major driver of biodiversity loss in tropical regions. However, human-dominated lands also hold potential for biodiversity conservation when managed as multifunctional mosaics that preserve patches of native vegetation. Understanding the specific ways in which natural and semi-natural habitats within agricultural farms support wildlife is essential for designing effective conservation strategies. While the impacts of agriculture on biodiversity and strategies for mitigating them have been widely studied, the potential of small-scale farms to sustain diverse bird assemblages has received considerably less attention. We assessed how three different habitats contribute to avian diversity in a tropical agricultural farm in northern Costa Rica by analysing species richness and overall abundance across space and time. Over one year, we sampled bird assemblages in live fences, pastures and a riparian forest, at La Balsa farm. Using point counts surveyed every month during the year, we recorded 165 bird species from 44 families and 19 orders, including 20 migratory and six species of global conservation concern, and four regionally endemic species. Species richness and overall abundance were lower in the riparian forest compared to live fences and pastures and bird assemblage composition differed markedly among habitats, with community in riparian forest exhibiting a distinct assemblage structure. These results indicate that though the riparian forest host fewer species and individuals, it harbors a characteristic bird assemblage, highlighting its irreplaceable ecological role in providing habitat to forest-dependent species. Temporal variation in species richness, peaking in October and declining in July, suggests a seasonal component associated with migratory dynamics and resource availability. Together, our findings reveal that a structurally diverse agricultural mosaic can sustain

remarkably high bird diversity when complemented by habitats including native vegetation, and that these bird assemblages shift over time likely because of habitat-related changes. Long-term monitoring will be essential to understand how these assemblages respond to ongoing environmental change and to guide the development of farming systems that support both production and biodiversity conservation.

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An Updated, Homogeneous, and Declustered Earthquake Catalog for Albania and the Surrounding Region

This paper presents a homogenized earthquake catalog for Albania and the surrounding region covering the period 1900 - 2024. The study area is defined by a geographical polygon bounded by latitudes 38.0°-44.5° N and longitudes 17.0°- 23.5° E. The catalogue was developed by integrating data from multiple authoritative sources, including the Albanian National Earthquake Data Center (IGEO), the European-Mediterranean Earthquake Catalogue (EMEC) up to 2021, and the reviewed data from the International Seismological Centre (ISC) for the period 2022–2024. A rigorous data integration and quality-control procedure was applied to identify and remove duplicate events using spatial and temporal matching criteria. Catalogue homogeneity was ensured by converting all reported magnitudes to M_w using established empirical relations and a newly derived M_L - M_w regression for Albania. The resulting catalog contains 10946 seismic events with magnitudes ranging from 3.5 to 7.2 M_w . To identify independent seismic events, three declustering methods were applied: Gardner and Knopoff (1974), Grünthal (as reported in Stiphout et al., 2012), and Uhrhammer (1986). Catalogue completeness was evaluated using the Stepp (1972) method, allowing the determination of completeness magnitudes and their temporal evolution. The resulting catalog represents an updated and homogeneous seismic database for Albania and provides a consistent basis for seismicity studies, seismotectonic analyses, seismic source characterization, and future probabilistic seismic hazard assessments.

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Monitoring Environmental Quality in Urban Gardens Using Moss Analyses of Heavy Metals and Pigments

Urban gardening has become popular in recent years, raising concerns about the safety of growing vegetables in several locations. However, direct measurements of pollution are often time-consuming and expensive. This study, therefore, explored alternative ways to obtain primary information about environmental pollution.

In thirty study areas of Tallinn (22 of them located near community or educational gardens), levels of Zn, Cu, Ni, Cd, Pb, Hg, and chlorophyll a, chlorophyll b, and carotenoids in the moss *Syntrichia ruralis* were measured in autumn 2019. Long-term concentrations of PM₁₀ and NO_x were estimated using stationary and traffic-related emission inventories together with air pollution dispersion modelling. For eight sites, moss pigment content was also measured in spring 2018. Soil heavy-metal data were available for eleven studied gardens. Differences between groups were evaluated using one-way ANOVA, with Bartlett's test applied to assess homogeneity of variances. When variances were unequal, Welch's ANOVA was used. Spearman's rank correlation was used for correlation analysis. To examine relationships among variables, Canonical Correspondence Analysis (CCA) and General Linear Models (GLM) were performed.

The study found no relationship between PM₁₀ and most metal concentrations in the moss, with the exception of Cu, which showed a significant positive correlation. In some areas, heavy metal pollution was detected that likely did not originate from traffic. The concentrations of Cu, Cd, Ni, and Pb in *S. ruralis* were strongly intercorrelated. Higher

concentrations of Hg, Cd, and Cu in soil were associated with higher Hg levels in the moss.

Analyses including GLM, ordination, and correlation revealed weak or inconsistent relationships between moss pigments and heavy metal concentrations. Ordination results showed that light availability was the main factor explaining variation in pigment content of *S. ruralis*. Pigment levels differed significantly (Welch's ANOVA, $p < 0.05$) across substrates, being highest on trees and lowest on soil and asphalt. Pigment concentrations were, on average, about twice as high in spring 2018 as in autumn 2019, with differences statistically significant (Welch's ANOVA, $p < 0.05$).

The study revealed that among the six heavy metals measured in the moss *S. ruralis*, Cu proved to be the most suitable indicator of environmental pollution. Pigment content in moss, however, is not a reliable practical bioindicator for detecting pollution in Tallinn's urban gardens due to strong dependence on environmental conditions, particularly light, as well as seasonality and substrate type. To explore further ways to use the moss *S. ruralis* for detecting environmental pollution, future studies could investigate the dependence of its morphological features (e.g. stem length, number of adventitious branches) on environmental pollution and other environmental factors.

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A Comparative Study of Household Pharmaceutical Waste Storage and Disposal in Katlehong Township and Lambton Suburb in the Ekurhuleni Metropolitan Municipality of South Africa

Household pharmaceutical waste (HPW) is becoming an increasingly significant environmental and public health challenge, particularly in urban centers such as Johannesburg in South Africa. With growing populations, improved access to healthcare, and the increasing burden of disease, the consumption of pharmaceuticals continues to rise. Consequently, the volume of unused or expired medications within households, referred to as household pharmaceutical waste (HPW), is growing. However, improper disposal methods, such as flushing medications down toilets or discarding them with general household waste, pose serious environmental and health risks. This study assessed and compared the awareness, disposal behavior, and management practices of household pharmaceutical waste in two contrasting communities: Katlehong Township and Lambton Suburb, both situated within the Ekurhuleni Metropolitan Municipality in South Africa. A stratified random sample of 303 participants (Katlehong = 221; Lambton = 82) completed a semi-structured questionnaire gathering data on demographics, awareness of environmental impacts, current storage and disposal practices, and sources of information on pharmaceutical waste. The sample was nearly evenly distributed by gender (n = 151 male; n = 150 female) with most participants aged 20–39 years (59.1%). The descriptive statistical results further revealed that only 39.4% (n = 87) of respondents in Katlehong and 42.7% (n = 35) in Lambton knew what pharmaceutical waste is, indicating low knowledge in both areas. However, 77% (n = 233) of the respondents showed willingness to adopt proper disposal practices if supported by pharmacies and health professionals. In conclusion, HPW in both Katlehong and Lambton was commonly stored and disposed of unsafely, and levels of public knowledge were generally low. Nevertheless, respondents showed a strong willingness to adopt formal take-back or pharmacy-based programmes. These findings underscore the pressing need for public education campaigns, efficient HPW collection systems, and transparent regulatory frameworks to promote safe and sustainable HPW management, thereby contributing to the United Nations'

Sustainable Development Goals on health, clean water, responsible consumption, and climate action.

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Corporate Environmental Transparency: An Analysis of mWIG40 ESG Disclosure Practices

Corporate sustainability reporting is currently undergoing a profound transformation, shifting from voluntary non-financial disclosures towards a formalised reporting framework. In the European Union, this transition is driven by the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), which aim to ensure the comparability of Environmental, Social and Governance (ESG) disclosure. The article examines the quality of environmental disclosure practices among companies listed on the mWIG40 index.

The study employed a desk research methodology, using content analysis of financial and non-financial reports of mWIG40 companies, Poland. The analysis focused on the scope and quality of disclosures, the methodological approaches adopted, and the level of alignment with the ESRS requirements regarding climate change, pollution, water and marine resources, biodiversity and ecosystems, and resource use and the circular economy.

The findings reveal significant disparities in environmental accountability among the mWIG40 companies. Companies operating in high-emission industries, such as energy and manufacturing, demonstrate a significantly higher degree of advancement in sustainability reporting, including measurable environmental key performance indicators (KPIs), compared to those in the service, banking and information technology sectors. The analysis demonstrated that disclosures concerning Greenhouse Gas (GHG) emissions management were the most extensively developed, whereas biodiversity-related disclosures remained significantly underdeveloped. Furthermore, despite ongoing progress in ESG reporting practices, Polish mid-cap companies still encounter significant challenges in achieving full alignment with EU ESG standards. The findings indicate the need for greater standardisation of data collection processes and reporting methodologies to improve the consistency, comparability, and reliability of sustainable disclosures.

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Indian Garden: Ecological Thinking and Landscape Epistemology

The “palimpsestic” re-writing of Indian culture and heritage, mostly through the lens of other cultures. This historical occlusion has left a major gap in global landscape architecture literature, which heavily favors Eurocentric and far East Asian typologies. The global discourse in landscape architecture lacks a clear textual foundation and a systematic vocabulary for the “Indian Garden,” as well as for its inherent ecological and metaphysical intelligence. This research re-centers the Indian garden as a high-functioning socio-ecological system, using Sanskrit planning treatises and the Vastupurusha Mandala to articulate an indigenous framework for climate resilience and geomorphological contextualism.

The study reconstructs the ontological, cosmological, and theoretical frame of the Indian garden by returning to historic textual references and planning principles. It shows how the Vastupurusha Mandala mediates between formless cosmic forces (Nirakara) and tangible site realities (Sakara), manifesting the “spirit of the place” (genius loci) through spatial order. In this framework, the garden is not decorative but a calibrated expression of cosmic-terrestrial correspondence.

Beyond cosmology, the research demonstrates that Indian garden design responded to geomorphological, environmental, social, economic, and geo-political conditions. Rather than ornamental greening, traditional practice used landscape as a strategic tool for water management, microclimate regulation, soil stabilization, and resource organization. These high-functioning socio-ecological systems offer contemporary design frameworks with indigenous strategies for climate resilience and context-sensitive planning that are largely absent in modern discourse.

The overarching aim is to place the art, science, and design of the traditional Indian garden within mainstream garden theories alongside Chinese, Japanese, and European traditions. By treating historic site layouts as dynamic, adaptive systems rather than static relics, the research seeks to recover a systematic Indian garden vocabulary grounded in ecological thinking and cosmological coherence. This recovery not only fills a critical gap in global landscape architecture literature but also provides a robust

indigenous epistemology for future ecological and cultural landscape
design.

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Hidden Microbial Contamination in Urban Water Systems from Source to Use in the Gauteng Research Triangle, South Africa

Water, sanitation and hygiene (WaSH) systems influence microbial exposure in low-income urban settings where infrastructure, water access, and storage practices vary. In rapidly urbanising regions, these disparities are amplified by ageing infrastructure, intermittent supply, and reliance on household water storage. This study examines how such conditions shape microbial contamination patterns across an urbanisation gradient in South Africa, that links environmental, infrastructural, and behavioural data. The study was conducted across contrasting settlement typologies in Gauteng Province of South Africa, including high-density formal housing (Hillbrow), peri-urban transitional areas (Atteridgeville), and informal settlements (Melusi). These environments differ markedly in infrastructure reliability, water access, and storage practices, providing a basis for comparative analysis of microbial risk. Sampling was performed at multiple points within each system to assess changes in water quality from source to use. Water samples were collected from inlets, storage tanks, taps, and showerheads across different building levels. Biofilm samples were obtained from faucets, showerheads, toilets, and high-touch surfaces. Walkthrough assessments documented infrastructure condition, plumbing maintenance, sanitation access, and water-use practices. Physicochemical parameters, including temperature, pH, turbidity, conductivity, and total dissolved solids, were measured on site. Microbiological analysis showed that source water was generally compliant with drinking-water standards, with no detectable *Escherichia coli* or total coliforms. In contrast, stored household water showed contamination, with detectable *E. coli* and coliforms, indicating post-collection contamination. This pattern was most pronounced in Atteridgeville and Melusi, where water storage is routine due to intermittent or limited supply. Experimental observations confirmed that contamination occurs during handling and storage. Pathogen profiling identified clinically relevant organisms across all sites. ESKAPE

pathogens, including *Klebsiella pneumoniae*, *Enterobacter* spp., and *Enterococcus faecium*, were detected in water, surfaces, and household materials. These organisms were most frequently identified in Hillbrow and Melusi, reflecting higher density, shared facilities, and limited hygiene control.

Legionella pneumophila was detected using culture-based Legiolert™ assays. Positive detections were observed across all three locations, particularly in stored water and heated systems. Detection occurred across temperature ranges of 17–39 °C, with higher occurrence between 30–39 °C. These findings indicate that temperature, stagnation, and biofilm formation support persistence of *Legionella* within plumbing and storage systems. Infrastructure assessments showed clear links between system condition and contamination. In Hillbrow, ageing plumbing, complex distribution systems, and poor maintenance created conditions for stagnation and biofilm formation. In Atteridgeville, intermittent supply resulted in routine storage and variable water quality. In Melusi, lack of piped water and reliance on communal sources led to repeated contamination during collection and use.

The results show that water quality declines between source and point of use across all sites. Microbial risk is driven by infrastructure condition, water storage, and household practices rather than access alone. Monitoring approaches that focus only on source water do not capture this risk. Improving water safety requires infrastructure maintenance, safe storage practices, and routine microbial monitoring. These findings support integrated WaSH interventions tailored to local conditions in rapidly urbanising settings.

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MWCNT/LDH-Based Composite Adsorbents for Efficient Removal of PFAS from Water: Batch and Column Studies

In this study, a novel multiwalled carbon nanotube/layered double hydroxide (MWCNT/LDH) composite was synthesized via a co-precipitation method and systematically evaluated for the removal of per- and polyfluoroalkyl substances (PFAS) from aqueous environments. Batch adsorption experiments revealed rapid uptake kinetics, with equilibrium achieved within 2 h, and a maximum PFOS removal efficiency of 99.7% at an initial concentration of 500 $\mu\text{g/L}$, corresponding to a maximum adsorption capacity of 2990 mg/g. The adsorption behavior followed a pseudo-second-order kinetic model ($R^2 = 0.97$), indicating that chemisorption dominated the removal process. The composite exhibited a point of zero charge (pH_{pzc}) of 9.2, and PFOS removal was enhanced under acidic to neutral conditions ($\text{pH} < \text{pH}_{\text{pzc}}$). The presence of coexisting anions (NO_3^- and SO_4^{2-}) showed negligible influence on adsorption performance, whereas CO_3^{2-} caused an initial inhibition followed by partial recovery. Mechanistic analysis suggested that ion exchange, electrostatic interactions, and hydrogen bonding were the primary contributors to PFAS adsorption. To improve practical applicability, a granular activated carbon-MWCNT/LDH (GAC-MWCNT/LDH) composite was further tested in fixed-bed column experiments using mixed PFAS solutions. Breakthrough curve analyses showed that PFOA exceeded the US EPA guideline at 4 h, PFHxS at 8 h, and PFNA and PFOS at 24 h, demonstrating the feasibility of this material for drinking water treatment. Material optimization indicated that a GAC particle size of 40–60 mesh and a GAC content of 4.3% resulted in optimal adsorption performance, achieving removal efficiencies of 88.20% for PFOA, 81.72% for PFNA, 98.56% for PFHxS, and 97.41% for PFOS. Overall, the results demonstrate that GAC-MWCNT/LDH composites are promising adsorbents for efficient PFAS removal in water treatment applications.

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A Digital Transformation Model for Enhancing the Operational Efficiency of Energy Infrastructure under Climate and Crisis Challenges

Energy infrastructure is increasingly exposed to systemic risks driven by climate change, geopolitical instability, and rapid socio-economic transformation. These pressures highlight the need for more efficient, resilient, and sustainable management approaches within energy corporations. At the same time, European energy companies face a strategic opportunity to strengthen digital sovereignty and global competitiveness through the adoption of advanced digital solutions aligned with green transition objectives.

The goal of this paper is to present a comprehensive digital transformation model designed to enhance operational efficiency and support the modernization of energy infrastructure. The model aims to improve resilience, enable the integration of renewable energy sources, and ensure the sustainability of existing resources and supply chains. By aligning digital transformation with strategic corporate objectives, the proposed approach contributes to both ecological sustainability and long-term system stability.

The model is structured into four implementation phases. The first phase focuses on the digitalization of communication infrastructure through the establishment of a centralized Resource Inventory System (RIS), integrated with Network Management Systems (NMS) and Enterprise Resource Planning (ERP) platforms. This enables a unified, accurate, and real-time overview of all network resources. The second phase addresses the digitalization of material and technical asset management, aiming to increase efficiency, accuracy, and transparency through centralized digital records. The third phase involves the digitalization of planning, construction, and maintenance processes in energy production. It introduces an integrated system for the automation and orchestration of key operational processes, resulting in improved efficiency, enhanced control, and reduced decision-making time and operational costs. The fourth phase focuses on energy distribution, where the highest levels of energy and financial losses typically occur.

Through the digitalization of distribution processes, the model seeks to optimize network performance and improve overall system sustainability.

The paper argues that the implementation of such a model enables the development of sustainable industrial practices, supporting the expansion of renewable energy sources and the modernization of power grids. Ultimately, the proposed approach contributes to building a more resilient and environmentally sustainable energy system capable of responding effectively to future crisis conditions.

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The Dialogue between Environmental Education and Social Sciences

The study was part of a postdoctoral research carried out within the scope of the Ocean Literacy Observatory (OLO), project in the field of environmental education, which developed the valorisation of informal knowledge among students from a fishing community in the Costa de Caparica school group, in Portugal. These students reveal a strong commitment to Local Ecological Knowledge and Traditional Ecological Knowledge. In this sense, and in order to outline activities and interventions in the field of environmental education, in co-construction with students and the local community, a historical analysis of the human behaviour of these communities at the local level and the impact they have had on the natural environment and ecosystems they share, has proven to be fundamental to the development of the field of Environmental History research. In this sense, the relevance of the Social Sciences in the design of environmental policies has been reinforced, whether in an educational, political, social or economic context. Social and natural lines of research intersect, adding value for future projects, studies, and the design of economic and social policies, as revealed in this study. The interdisciplinary theoretical framework seeks to deepen the emerging movement around Environmental Education that today's challenges demand, while the methodological contribution, based on Critical Ethnography, aims to contribute to a greater reflection on the behavioural attitudes of young people in the fishing community, based on their ancestral knowledge.

The importance of social sciences for understanding and valuing environmental education is related to the actions that humans engage in within the environment and their impact on societies and the environment. Working in environmental education means interacting with humans who will act within the habitat in which they live or in other habitats. We must give a voice to local actors who have been interacting with their environment for generations. Going further, there is an urgent need for an educational plan in which Environmental Humanities or Environmental Human Sciences are integrated and developed. Valuing the ancestry of local knowledge, which is silent in everyday life, involves a complex and systemic reflection on each individual and the collective. This research considers the integration of social sciences in the design of sustainability policies, as well as the informal knowledge of students,

which provides the basis for the production of meaningful and usable knowledge. The importance of co-construction in each of the products was understood, as local/traditional knowledge complements scientific knowledge, increasing its power.

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Best Available Climate Science: A Guiding Principle or a Legal Obligation?

Climate change is the biggest threat that modern humanity has ever faced, resulting in a climate emergency that requires immediate and decisive action. While States, for the most part, seem to have accepted what the scientific community has reached consensus on, there seems to be some uncertainty as to what their legal responsibilities are to mitigate and adapt to climate change and how best to achieve this. Science has played a crucial role in climate change litigation to date as a means of supporting the courts' deliberations on the scope of a State's human rights obligations in the face of climate change. This signifies the "rights turn", understood to be the shift towards using human rights to hold States responsible for climate inaction. More recently, the focus of climate change litigation appears to be shifting to issues such as risk assessment and attribution in terms of which science is used to establish a causal link between climate harm and climate inaction. The use of science in this way, referred to as the "science turn", is paving the way for evidence-based policy formation. However, questions arise regarding the legal standard applicable and the enforceability thereof. The Paris Agreement provides that member States, *inter alia*, acknowledge that climate action should be guided by the best available science (BAS). While not precisely defined, BAS is an accepted principle of international environmental law and represents the most reliable, valid, current and relevant body of organised knowledge made available through conventional and non-conventional sources and is generated and applied using best practice standards. As stated by the International Tribunal for Law of the Sea and the International Court of Justice, the works of the Intergovernmental Panel on Climate Change reflects the BAS relevant to climate change; and, as per the Inter-American Court on Human Rights, should be utilised by States when designing and implementing climate action. Whether States can be held liable for a failure to take climate action is not in dispute. Whether States can be held liable for a failure to rely on the BAS when taking such action is less clear. However, the International Covenant on Economic, Social and Cultural Rights provides for the right to science as a legally binding human right, albeit underdeveloped and thought to be more aspirational than mandatory. Within the context of climate change this right can be operationalised in two main ways: firstly, through the adoption of mitigation and adaptation strategies

guided by the BAS; and secondly, through active efforts to combat climate disinformation that undermines evidence-based policy formation. Essentially, it can be said that reliance on the BAS is crucial for the realisation of the right to science since it provides the evidence needed to hold States liable for human rights violations resulting from climate inaction. Accordingly, this paper will argue that failure to rely on the BAS when taking climate action constitutes an infringement of the right to science, potentially elevating the BAS yardstick from guiding principle to a legally binding obligation.

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Study on the Long-Term Variation Pattern of Soil Radon Concentration and Main Control Factors in the In-Situ Leaching Uranium Ore Area of Yili Basin, Xinjiang

The in-situ leaching mining of sandstone uranium deposits involves injecting a solvent underground, extracting the mineral solution to the surface, and then extracting uranium. To study the changes in surface soil radon concentration during uranium mining, two ZnS scintillation radon detectors were installed at a depth of 0.8m and 1.5m in a uranium mine in the Yili Basin of Xinjiang, China. A long-term observation of one year was conducted with a sampling period of 1 hour from October 2023 to October 2024. The long-term monitoring results show that the radon concentration in the soil at different depths underground varies, and the radon concentration increases with the increase in depth, which conforms to the diffusion law of radon in soil. The average radon concentrations in the soil at 0.8m and 1.5m in the uranium mining area were 22.5 ± 3.4 kBq/m³ and 28.5 ± 2.9 kBq/m³, respectively. These values are 1.8 and 1.4 times the radon concentration in the soil of the control background area 2 kilometers away from the uranium mine test site. The radon concentrations in the soil of the uranium mining area and the background area show seasonal variation characteristics and change in the same phase. The radon concentration is higher in winter than in summer. The increase in radon concentration in winter is mainly controlled by soil temperature changes and surface snow cover. The results of this study indicate that no local enrichment of radioactive uranium and radium was found on the surface of this in-situ leaching mining area.

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Integration of Circular Economy Principles into Canadian Energy Policy and Cold-Climate Construction Practices

Canada faces numerous challenges with recycling, managing the lifecycle of materials, and addressing the additional complexities arising from climate-related effects due to freeze-thaw temperatures in cold climates. Greenhouse gas (GHG) emissions and waste generation worldwide are significantly influenced by the construction sector. And construction, renovation, and demolition (CRD) waste accounts for a substantial portion of national waste streams.

This research aims to integrate Circular Economy (CE) principles into Canada's construction and energy policy context, with a specific emphasis on cold-climate conditions. The purpose of this study is to determine how CE strategies can enhance material efficiency, reduce waste, and improve sustainability outcomes in regions affected by extreme climate conditions. By applying CE practices such as lifecycle optimization and material reuse, the aim is to improve energy efficiency and sustainability outcomes.

A qualitative research design, including structured policy analysis and a systematic literature review, was used to assess CE frameworks and evaluate construction and energy policies across Canadian provinces. This study demonstrates the necessity of implementing CE practices within Canada's policy framework to mitigate the climate impacts of cold weather. Findings indicate major challenges, including inconsistent provincial CE policies, limited incentives, and gaps in lifecycle assessment requirements, especially for materials affected by freeze-thaw deterioration.

To create a solid framework for CE implementation, this study combines structured policy analysis with a literature-review-driven methodology. Additionally, this research draws on existing CE frameworks identified by Environment and Climate Change Canada (2024) and Natural Resources Canada (2022) to evaluate and identify best practices, barriers, and implementation challenges for sustainability and energy efficiency. The study also contributes a comparable analytical

framework for evaluating CE policies across provinces and identifying the unique challenges of CE adoption in cold-climate contexts.

This project will produce three formal deliverables to structure the research outcomes: Deliverable 1: Comparative Policy and Framework Analysis (Inception + Findings Report), Deliverable 2: a Circular Economy Adoption Matrix and Comparative Policy Framework for cold-climate construction across Canadian provinces (the core research contribution), and Deliverable 3: the Final Circular Construction Report.

This study contributes practical insights and supports the development of sustainability policy and management across Canada. It offers actionable recommendations to enhance CE integration, strengthen provincial alignment, and support the transition to low-carbon construction. The study also aims to maintain stable energy costs, reduce consumption, and accelerate the shift to renewable energy sources by focusing on supply-chain resilience, energy policy, affordability, and emerging technologies.

The research emphasizes CE-based strategies to reduce waste, lower emissions, and support resilient construction. This study will inform CE policy development by providing a framework for integrating CE principles into Canada's construction and energy sectors. This framework can guide government and industry stakeholders in aligning construction regulations with sustainability and energy-transition goals.

The findings are expected to support future CE adoption and policy improvements across Canada. Future research may focus on piloting CE-based construction practices in selected Canadian provinces, developing lifecycle assessment models for cold-climate buildings, and conducting stakeholder surveys to evaluate policy and industry readiness for integrating CE principles into provincial building codes.

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Research on the Controlling Effects of Strike-Slip Faults on Carboniferous Volcanic Hydrocarbon Accumulation in the Chepaizi Uplift

Research on the controlling effects of strike-slip faults on hydrocarbon accumulation has recently emerged as a cutting-edge and focal area of study. However, existing work predominantly concentrates on clastic and carbonate rock terrains, with comparatively less attention paid to volcanic reservoirs. This study integrates field outcrop reconnaissance, laboratory core observation, seismic data interpretation, and well logging data processing to analyze the developmental characteristics, combinatorial patterns, and structural architectures of strike-slip faults within the Carboniferous volcanic rocks of the eastern Chepaizi Uplift. Subsequently, it constructs a hydrocarbon accumulation model for the volcanic region controlled by these strike-slip faults. The research indicates that the Carboniferous volcanic rocks are primarily dissected by thrust faults and strike-slip faults. Among these, the strike-slip faults trend in four principal directions: nearly SN-oriented, NWW-oriented, NE-oriented, and nearly EW-oriented. Their planar combinatorial patterns can be classified into two types: grid-pattern and oblique-intersection pattern. The grid-pattern configuration is conducive to hydrocarbon accumulation, whereas the oblique-intersection pattern facilitates hydrocarbon migration. Based on outcrop and core observations, well log analysis, and sample testing, the internal architecture of the strike-slip fault zones is identified and subdivided into a slip-brecciated zone and an induced fracture zone. The slip-brecciated zone exhibits poorer physical properties but possesses strong sealing capacity. In contrast, the induced fracture zone demonstrates enhanced physical properties and provides effective conduits for hydrocarbon migration. Through the detailed dissection of typical reservoir units, the Carboniferous volcanic hydrocarbon accumulations are categorized into three types: weathering crust-type reservoirs, fracture-type interior reservoirs, and anticlinal-type interior reservoirs. Furthermore, the study delineates prospective exploration fairways.

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Widespread Vegetation Greening under Multiscale Drought Mitigation across Northern China during 2001-2022

Vegetation greening and drought alleviation are concurrent ecological signals under recent climate variability. This study examines ecosystem vegetation responses to multiscale drought mitigation across northern China (2001-2022) using satellite-based Normalized Difference Vegetation Index (NDVI), Standardized Precipitation Index (SPI), and Standardized Precipitation Evapotranspiration Index (SPEI) at 1-12-month scale. Theil-Sen and Mann-Kendall tests captured long-term trends, while Random Forest (RF), XGBoost, and LightGBM models, coupled with SHAP interpretation, revealed drought-vegetation linkages. Widespread greening dominated 82.9% of the region, with NDVI increasing by $0.021 \text{ decade}^{-1}$. High-NDVI zones (>0.7) expanded mainly in the eastern and central areas, while localized browning remained in Xinjiang (XJ). At the same time, multiscale drought indices showed notable wetting, with SPI rising by $0.115\text{--}0.388 \text{ decade}^{-1}$ and SPEI $0.057\text{--}0.232 \text{ decade}^{-1}$, particularly at longer accumulation periods. Correlation analysis revealed that shrubs and grasslands were closely linked to drought alleviation (up to 72% positive for SPI12), while forests showed higher moisture sensitivity and partial decline under excessive wetness. RF-SHAP analysis identified short- to long-term drought indices as dominant predictors of vegetation variability, highlighting nonlinear and region-specific responses. These results show that persistent wetting has supported vegetation recovery and improved ecosystem resilience across northern China, emphasizing the importance of adaptive ecosystem management under ongoing climate and moisture shifts.

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Abnormal Spring Climate and Greener Amplify Impacts of Summer Drought on Ecosystem Carbon-Water Fluxes

Understanding how spring climatic changes and vegetation dynamics modulate ecosystem responses to summer drought is critical for advancing early warning systems and improving impact assessments. Favorable spring climates enhance ecosystem productivity, but accelerated soil moisture depletion by greener spring exacerbates summer drought. However, the relative role in modulating ecosystem responses to summer drought remain unclear. We investigated extreme summer drought events to disentangle contributions of spring climate anomalies and greening to summer carbon and water flux responses. Our findings reveal that abnormal spring climates exert comparable or marginally greater influence on ecosystem responses to summer drought than concurrent summer climate. Warm-induced greener spring amplify summer drought impact due to rapid soil water depletion, but partly offsets 3–20% of summer carbon losses through seasonal compensation effect. These results highlight the dual role of spring climate and vegetation as both buffer and amplifier of summer drought impacts, with critical implications for vegetation-climate feedback.

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