INSTITUTE OF ROCK STRUCTURE AND MECHANICS
The Czech Academy of Sciences

DEPARTMENT OF MATERIAL STRUCTURE AND PROPERTIES

LABORATORY OF ENVIRONMENTAL TECHNOLOGIES

THEMATIC RESEARCH FOCUS

- USE OF DIFFERENT ANORGANIC WASTE MATERIALS
- PROCESSING OF BIOMASS, WASTE PLASTICS, SEWAGE SLUDGE AND COAL
- GEOPOLYMER COMPOSITES
- MINERAL PROCESSING OF RAW MATERIALS
- PRACTICAL APPLICATIONS OF GEOPOLYMERS

The process of laying new ceramic tiles: A) the stock of ready-to-lay tiles, B)the laying of the tiles according to the plan, C) a detailed view of the boundary between the original and new tiles, D) the final layout of the repaired floor.

RESEARCH ACTIVITIES

The Laboratory of Environmental Technologies, Department of Material Structure and Properties studies relations between the structure and properties of inorganic and organic materials as well as the methods used for their preparation. It develops energy efficient production processes and environmental technologies. Research fields with application potential are focused on (a) recovery of waste materials, (b) the properties and use of alumino-silicates and preparation of geopolymers, (c) carbonaceous materials, their characteristics and use, and (d) practical applications of geopolymers. The most recent field of study is practical applications of geopolymers in historical field and industry. Pyrolysis of biomass, waste plastics, sewage sludge and coal comprise a traditional field of research.

MAIN SCOPE OF RESEARCH

Chemistry and technology of geopolymers:

preparation of new geopolymer materials; utilization of automotive waste glass; research on the structure and mechanical and conductivity properties of geopolymer composites; geopolymer applications for restoring historical tiles and their use in industry; the impact of temperature and environmental conditions on the stability and properties of geopolymers.

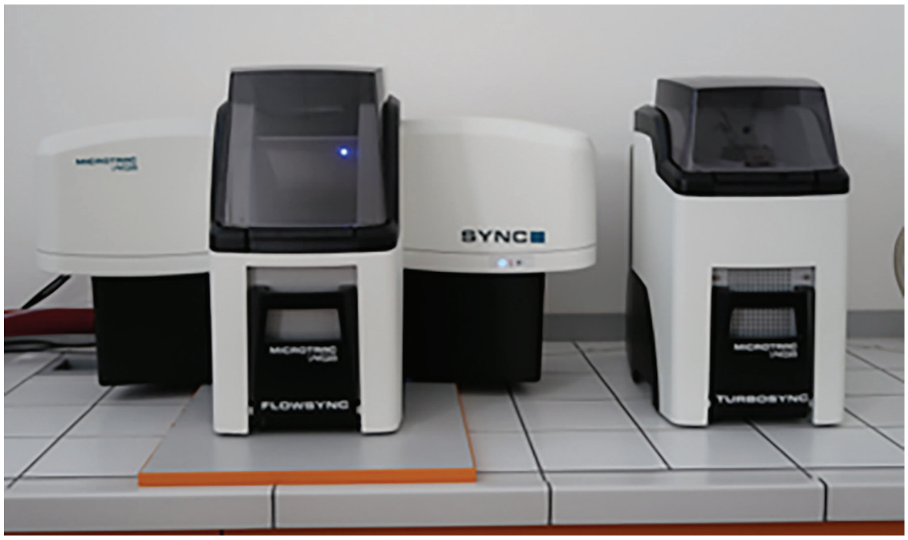
Environmental technologies:

organic waste characterization and treatment; co-gasification of coal with organic waste; processing, characterization and possibilities of safe use of sewage sludge in agriculture, energy; catalytic conversion of biomass into hydrogen-rich gas under well-defined conditions; recovery of waste plastics conversion to oils, gases by low temperature pyrolysis; new porous materials usable as „low-cost“ sorption materials are prepared by pyrolysis of waste materials under specific conditions.

KEY RESEARCH EQUIPMENT

- A SPECTRO Kleve X-ray fluorescence analyzer for elemental analysis of solid and liquid materials.
- Agilent 6890N gas chromatographs with FID and TCD detection.
- A SETARAM Sestys Evolution 18 thermal analyzer with an Omnistar GSD 320 O3 Mass Spectrometer 1–300 amu.
- A Perkin-Elmer thermal analyzer.
- A TERI-MOM thermal analyzer.

  Thermal analyzers work both in inert and in oxidizing atmospheres and are used mainly to characterize polymers, coal, inorganic substances and thermal decomposition reactions of materials.
- A Microtrac S3500 laser particle-size analyzer allowing measurements in liquid / air medium with range of 0.02–2800 µm / 0.02–4000 µm, respectively.
- A Haake Viscometer for determining the viscosity of both Newtonian and non-Newtonian liquids.



A Microtrac S3500 laser particle-size analyzer

- Stationary- and moving-bed furnaces with the continuous monitoring of gas components by IR and Calomat analyzer, the volume of the gas generated, pressure and temperatures.
- A material-firing furnace, a material-strength testing machine, friction mills, a vibration screen grader, a jaw crusher, a vibration mill, a disintegrator, and a programmable drying oven with a maximum temperature of 300 °C.
- Thermal Properties Analyzer ISOMET Model 2114 (Applied Precision, Slovakia) for a determination of thermal conductivity (λ), thermal diffusivity (a) and volume heat capacity (cρ).
- Device Vicatronic (Matest) for determination of setting time by the Vicat penetration test.
- An automatic fusion machine for XRF analysis.

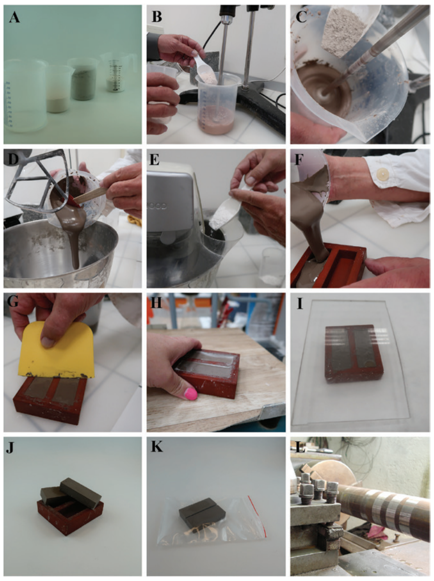
SETARAM Setsys Evolution 18 thermal analyser with an OMNISTAR GSD 3200 Mass Spectrometer

Volumetric Karl Fischer titrator

ACHIEVEMENTS

- **Practical application of geopolymers**

Perná I., Hanzlíček T., Lučaník A., Šupová M. (2023): Geopolymer-based grinding stones utilizable in metal machining. Construction and Building Materials 363, 129869.



An overview of geopolymer grinding stones preparation: A – raw materials; B - addition of clay material in an alkaline solution; C - addition of blast-furnace slag; D –transfer to a planetary mixing device; E - addition of white corundum WhC500; F - casting into molds. G - surface treatment; H – covering against water evaporation; I - demolding; J – curing; K - testing)

Hanzlíček T., Perná I., Michoinová D., Rafl J. (2023): The characterization and renovation of parterre floor tiles in the pilgrimage church of St. John of Nepomuk (Czech Republic). Case Studies in Construction Materials 19, e02297.

Left:Samples of the inquired shade of the beige color compared with the original piece. Right: A view of the inside of the kiln chamber with black tiles.

- **Materials Engineering**

Novotná M., Perná I., Hanzlíček T. (2020): Review of Possible Fillers and Additives for Geopolymer Materials. Waste Forum 2, 78–89.

Perná I., Hanzlíček T., Žaloudková M. (2020): Microscopic study of the concrete/geopolymer coating interface. Ceramics-Silikáty 64 (1), 68-74.

Hanzlíček T., Perná I., Uličná K., Římal V., Štěpánková H. (2020): The Evaluation of Clay Suitability for Geopolymer Technology. Minerals 10, 852.

Perná I., Hanzlíček T., Šupová M., Novotná M. (2020): Phase Transformations in Fly Ash-Based Solids. Minerals 10, 804.

Perná I., Novotná M., Šupová M., Hanzlíček T. (2021): Beach Sand – an Alternative Filler in Metakaolin-Based Geopolymers. Journal of Materials in Civil Engineering 33(4), 04021017-1- 04021017-6.

Perná I., Novotná M., Řimnáčová D., Šupová M. (2021): New metakaolin-based geopolymers with the addition of different types of waste stone powder. Crystals 11(8), 983.

Novotná M., Knotek P., Hanzlíček T., Kutálek P., Perná I., Melánová K., Černošková E., Kopecká K. (2021): TiO2 Modified Geopolymers for the Photocatalytic Dye Decomposition. Crystals 11(12), 1511.

Novotná M., Polonská A., Šídlová M., Perná I. (2021): Geopolymers: The influence of alkaline activator cations on efflorescence. Proceedings of the 8th International Conference on Chemical Technology, Prague, 326-331. ISBN 978-80-88307-08-2.

Perná I., Novotná M., Hanzlíček T., Šupová M., Řimnáčová D.. (2024): Metakaolin-based geopolymer formation and properties: The influence of the maturation period and environment (air, demineralized and sea water). Journal of Industrial and Engineering Chemistry 134, 415–424.

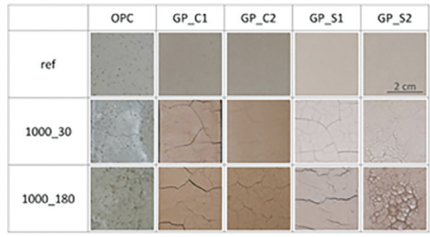
Karoui O., Andrejkovičová S., Pato P., Patinha C., Řimnáčová D., Perná I., Hajjaji W., Rocha F., Mlayah A. (2024): Foamed phosphate by-product based geopolymers and dye adsorption efficiency. Applied Clay Science 257, 107446.

Karoui O., Andrejkovičová S., Pato P., Patinha C., Perná I., Řimnáčová D., Hajjaji W., Ascensão G., Rocha F., Mlayah A. (2024): Alkali-activated geopolymers based on calcined phosphate sludges and metakaolin. Environmental Science and Pollution Research 31, 45138–45161.

Perná I., Havelcová M., Šupová M., Žaloudková M., Bičáková O. (2024): The Synthesis and Characterization of Geopolymers Based on Metakaolin and on Automotive GlassWaste. Appl. Sci. 14, 3439.

Santos A., Andrejkovičová S., Perná I., Hajjaji W., Almeida F., Rocha F. (2024): Mechanical and thermal properties of geopolymers derived from metakaolin with iron mine waste. Applied Clay Science 258, 107452.

Perná I., Zárybnická L., Mácová P., Šupová M., Ševčík R. (2024): Physico-mechanical properties of geopolymers after thermal exposure: Influence of filler, temperature and dwell time. Construction and Building Materials 451, 138893.



Surface quality evaluation of samples before and after thermal exposure.

Straka P. (2020): Anthraxolite – uranium mineral: composition, structural features and genesis. Aspects in Mining & Mineral Science 5, 655–658 Surface quality evaluation of samples before and after thermal exposure.

Pohořelý M., Picek I., Skoblia S., Beňo Z., Bičáková O. (2020): Method and Device for Energy Processing Dried Sewage Sludge. Czech patent No: 308451.

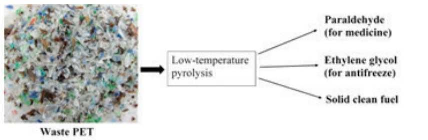
Černý M., Chlup Z., Strachota A., Brus J., Schweigstillová J., Rýglová Š., Bičáková O. (2021): In-situ measurement of mechanical properties and dimensional changes of preceramic thermosets during their pyrolysis conversion to ceramics using thermomechanical analysis. Ceramics International 47, 23285–23294.

Křibek B., Bičáková O., Sýkorová I., Havelcová M., Veselovský F., Knésl I., Mészárosová N. (2021): Experimental pyrolysis of metalliferous coal: A contribution to the understanding of pyrometamorphism of organic matter and sulfides during coal waste heaps fires. International Journal of Coal Geology 245, 103817.

Kříbek B., Rohovec J., Bičáková O., Tuhý M., Sýkorová I., Straka P., Pticen F., Vymazalová A., Poňavič M. (2023): Germanium mineralization in subbituminous coal from the Sokolov Basin, Czech Republic: The origin and volatility of Ge. 17th Biennial SGA meeting. ETH Zurich, Switzerland. Proceedings Volume 2, 381–384.

Straka P., Bičáková O., Šupová M. (2022): Slow pyrolysis of waste polyethylene terephthalate yielding paraldehyde, ethylene

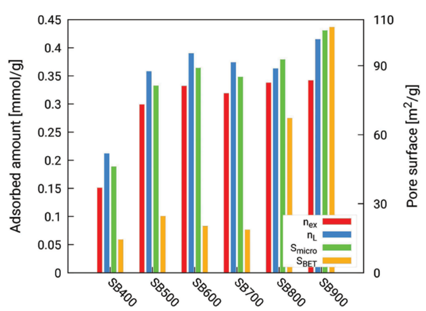
glycol, benzoic acid and clean fuel. Polymer Degradation and Stability 198, 109900.



Low-temperature Pyrolysis of waste PET.

Švábová M., Bičáková O., Vorokhta M. (2023): Biochar as an effective material for acetone sorption and the effect of surface area on the mechanism of sorption. Journal of Environmental Management 348, 119205.

Řimnáčová D., Bičáková O., Moško J., Straka P., Čimová N. (2024): The effect of carbonization temperature on textural properties of sewage sludge-derived biochars as potential adsorbents. Journal of Environmental Management 359, 120947.



The total CO2 adsorption and surface areas in dependence on the carbonization temperature.

Straka P., Bičáková O. (2024): A method of production of industrial oil, technical paraffin and energy gas using a low-temperature cracking of cross-linked polyethylene defined by heating in the presence of a catalyst. Czech patent No: 310024.

- **Energy and Fuels**

Straka P. (2021): A comprehensive study of Power-to-Gas technology: Technical implementations overview, economic assessments, methanation plant as auxiliary operation of lignite-fired power station. Journal of Cleaner Production 311, 127642.

Straka P., Bičáková O., Čimová N. (2021): Low-temperature treatment of waste PET. Paliva 13(1) 1–9.

Bičáková O., Cihlář J., Straka P. (2023): Low temperature pyrolysis of polylactic acid (PLA) and its products. Paliva 15 (2), 56–62.

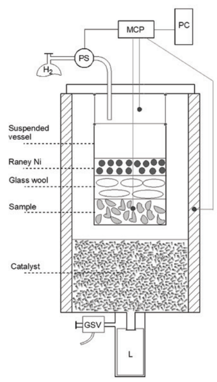
Bičáková O., Straka P. (2023): Method and equipment for processing PLA waste plastic by low-temperature pyrolysis. Functional sample. Internal identification code: USMH/2022/210/117.

The PLA material investigated: 3D printing filament (OP), left; virgin PLA (CP), right

Bičáková O., Straka P. (2024): Stationary equipment for processing waste PLA with low energy consumption. Database know-how IRSM Czech Acad Sci, v.v.i., 15.7.2024.

- **Applied Catalysis**

Straka P., Bičáková O., Hlinčík T. (2021): A Comparison of the Efficiency of Catalysts Based on Ni, Ni-Co and Ni-Mo in Pressure Pyrolysis of Biomass Leading to Hythane. Catalysts 11, 1480.



Pressure reactor. Outer part (500 cm3) is filled with catalyst and fitted with gas-sampling valve (GSV) and a cooled, calibrated glass vessel at the bottom of the reactor (L) for liquid product collection. Inner part (90 cm3) is suspended inside the outer reactor part and contains the sample and Raney nickel layer. PS—pressure sensor, MCP—measuring control panel; hatched areas—electric vertical oven; black dots: thermocouple for measuring the temperature in the center of the sample, control thermocouple and thermocouple measuring the gas temperature

Straka P., Bičáková O., Cihlář J. (2023): Low-temperature treatment of waste crosslinked polyethylene with ruthenium catalyst. Paliva 15 (1), 19–23.

Cihlář J., Navarro L.K.T., Cihlář J., Kasparek V., Michalicka J., Částková K., Lazar I., Kastyl J., Celko L., Vesely M., Dzik P. (2023): Influence of substituted acetic acids on "bridge" synthesis of highly photocatalytic active heterophase TiO2 in hydrogen production. Journal of Sol-Gel Science and Technology 105, 471–488.

Cihlář J., Tkachenko S., Bednaříková V., Cihlář J., Částková K., Trunec M., Celko L. (2024): Study of the Synthesis of Multi-Cationic Sm-Co-O, Sm-Ni-O, Al-Co-O, Al-Ni-O, and Al-Co-Ni-O Aerogels and Their Catalytic Activity in the Dry Reforming of Methane. Gels 10, 328.

Straka P., Bičáková O., Cihlář J. (2024): Slow Low-Temperature Pyrolysis of Waste Cross-Linked Polyethylene with a Ruthenium Catalyst. Preprint. SSRN: http://dx.doi.org/10.2139/ssrn.4577548

MAIN COLLABORATING PARTNERS

- Academy of Arts, Architecture & Design in Prague
- Czech Geological Survey (Prague)
- Czech University of Life Sciences (Prague)
- Geosciences Department, University of Aveiro (Portugal)
- Georessources Laboratory, CERTE, Soliman (Tunisia)
- Institute of Chemical Process Fundamentals of the CAS (Prague)
- Institute of Plasma Physics of the CAS (Prague)
- Institute of Macromolecular Chemistry of the CAS (Prague)
- University of Chemistry and Technology Prague
- University of Pardubice (Pardubice)
- University of West Bohemia (Pilsen)
- The Centre Telč of the Institute of Theoretical and Applied Mechanics of the CAS

V Holešovičkách 94/41,
182 09 Praha 8, Czech Republic
www.irsm.cas.cz

Assoc.Prof. Jaroslav Kloužek, PhD
Head of Department
Phone: +420 266 009 422
E-mail: jaroslav.klouzek@irsm.cas.cz

Ing. Olga Bičáková, Ph.D.
Head of Laboratory of Environmental Technologies
Phone: +420 266 009 251, 321, 403
E-mail: bicakova@irsm.cas.cz