Environmental Process Engineering Laboratory

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Fields of research

- Environmental organic chemistry and microwave photochemistry
- Advanced processes for Waste-to-Energy (WtE)
- Cleaning of syngas from fluidized-bed gasification of coal-biomass blends
- Advanced processes for gasification, gas cleaning and hydrogen production
- Persistent organic pollutants and heavy metals emissions and behaviour
- Urban mining - metals recovery from waste ashes

Applied research

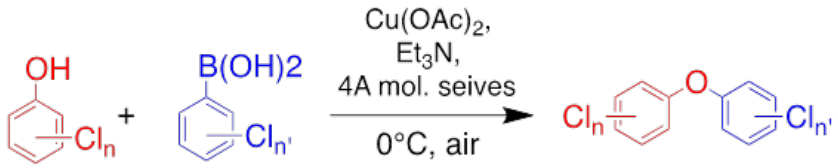
- Brownfields - Source of renewable energy
- Development of a pilot plant for monitoring of Hg emissions reduction
- Design optimization of multi-stage biomass gasifier generating gas with low tar content
- Co-combustion of coal and rubber granulate in a fluidized bed
- New gas refining technology for small and mobile thermal waste degradation units
- Wet precipitators PM for medium-power boilers burning renewable biomass
- Production of paper products with special properties from waste security paper
- In-situ thermal desorption with applications of microwaves
- Development and verification of thermal desorption technology using microwaves
- Advanced method using microwaves for repair of damaged roads
- Progressive method and new equipment using microwaves for drying of surfactants
- Revolutionary method using microwaves for the chemical depolymerization of waste polyethylene terephthalate (PET)

Research projects

Applications on the field of environmental organic chemistry and microwave photochemistry

(V. Církva, cirkva@icpf.cas.cz; supported by ICPF; TACR, project No. TA01010646)

An efficient synthesis of polychlorinated diphenyl ethers (PCDEs) using the $Cu(OAc)_2$-catalyzed Chan-Lam coupling reaction has been described. A library of all possible mono- and dichlorinated diphenyl ether congeners was prepared and characterized using MS, ^1H, and ^{13}C NMR spectroscopy, and Kovats retention indices. Our approach, using the optimized reaction conditions (i.e., reaction temperature, oxidizing atmosphere and base), significantly improves and simplifies the process compared to previously reported syntheses [Ref. 1].



Copper mediated synthesis of mono- and dichlorinated diaryl ethers

The coupled activation of photochemical reactions by using of two different types of radiation, microwave and UV/Vis, is covered by the new discipline called microwave photochemistry. Such a connection might have a synergic effect on reaction efficiencies or, at least, enhance them by summing up the individual effects. The objective of this discipline is frequently, but not necessarily, connected to the electrodeless discharge lamp (EDL) as a novel light source which generates efficiently UV/Vis radiation when placed into a microwave field. We have applied this concept on photochemical synthesis of helicenes and phenacenes [Ref. 6].

Experimental set-up for microwave photochemical experiments with EDLs

Waste-to-Energy Competence Center

(M. Šyc, syc@icpf.cas.cz; joint project with Brno University of Technology, EVECO Brno s.r.o., ZVVZ-Enven Engineering a.s., PBS INDUSTRY a.s., ČEZ a.s., supported by TACR, project No. TE02000236)

Waste-to-Energy (WtE) Competence Centre activities are aimed at increasing competitiveness of the Czech Republic in the field of WtE. Activities are specified in such a way to be able to cover WtE from a primary idea to final products based on recent results of strategic planning, selection and design of up-to-date technologies and equipment. One of the main aims of the consortium is the development of small scale waste-to-energy plant (with capacity below 40 kt/year).

ICPF is leader of work package focused on innovation and re-design of components of WtE with respect to overall energy optimization and increase of efficiency.

Our research interests/tasks can be summarized as follows:

- Optimization of dry cleaning methods with simultaneous flue gas deNO_x and dioxin removal on catalytic bag filters, handling of spent sorbents, etc.;
- MSWI solid residuals (bottom ash and fly ashes) utilization and development of methods for recovery of non-ferrous metals, precious metals, REE etc. and application of selected fraction in construction industry;
- Sewage sludge combustion and co-combustion with other waste fuels;
- Phosphorus recovery from sewage sludge ash.

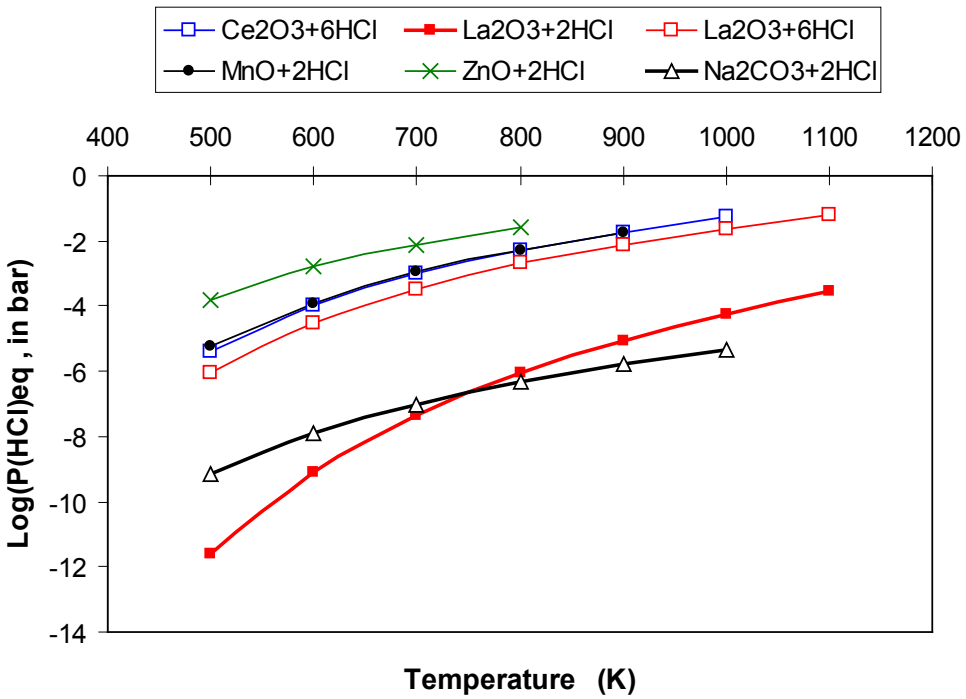
Valuable components in MSWI bottom ash

Cleaning of syngas from from fluidized-bed gasification of coal-biomass blends for advanced power generation

(K. Svoboda, svoboda@icpf.cas.cz; bilateral research project (NSC Taiwan) with INER - Taiwan; supported by GACR, project No. 14-09692J, reg. number of the foreign project: 102WBS0300011)

The research is aimed at study and solution of problems (thermodynamic constraints, reactivity, capacity and deactivation of the sorbents, textural changes, interferences of HCl) in

removal of sulfur compounds from fuel gas by solid sorbents at temperatures 400-600 °C. A soda-based sorbent are used for pre-cleaning of syngas and for study of important effects of accompanying gases (mainly, H_2S, naphthalene) and temperature on the sorption process of HCl. Sorbents based on ZnO and CeO_x serve for removal of H_2S, COS, destruction/removal of thiophene and for study of the intereferences (CO_2, H_2O(g), HCl, naphthalene). For characterization of sorbents, TG, XRD, SEM/EDS, textural and other tools are employed. The sorption reactions are studied by means of a differential, fixed-bed reactor and by an integral fluidized-bed reactor. Theoretical models with simplified reaction kinetics and particle structure for description and analyses of sorption process in fixed and fluidized bed will be developed and solved. [Refs. 5, 7, 9, 18]

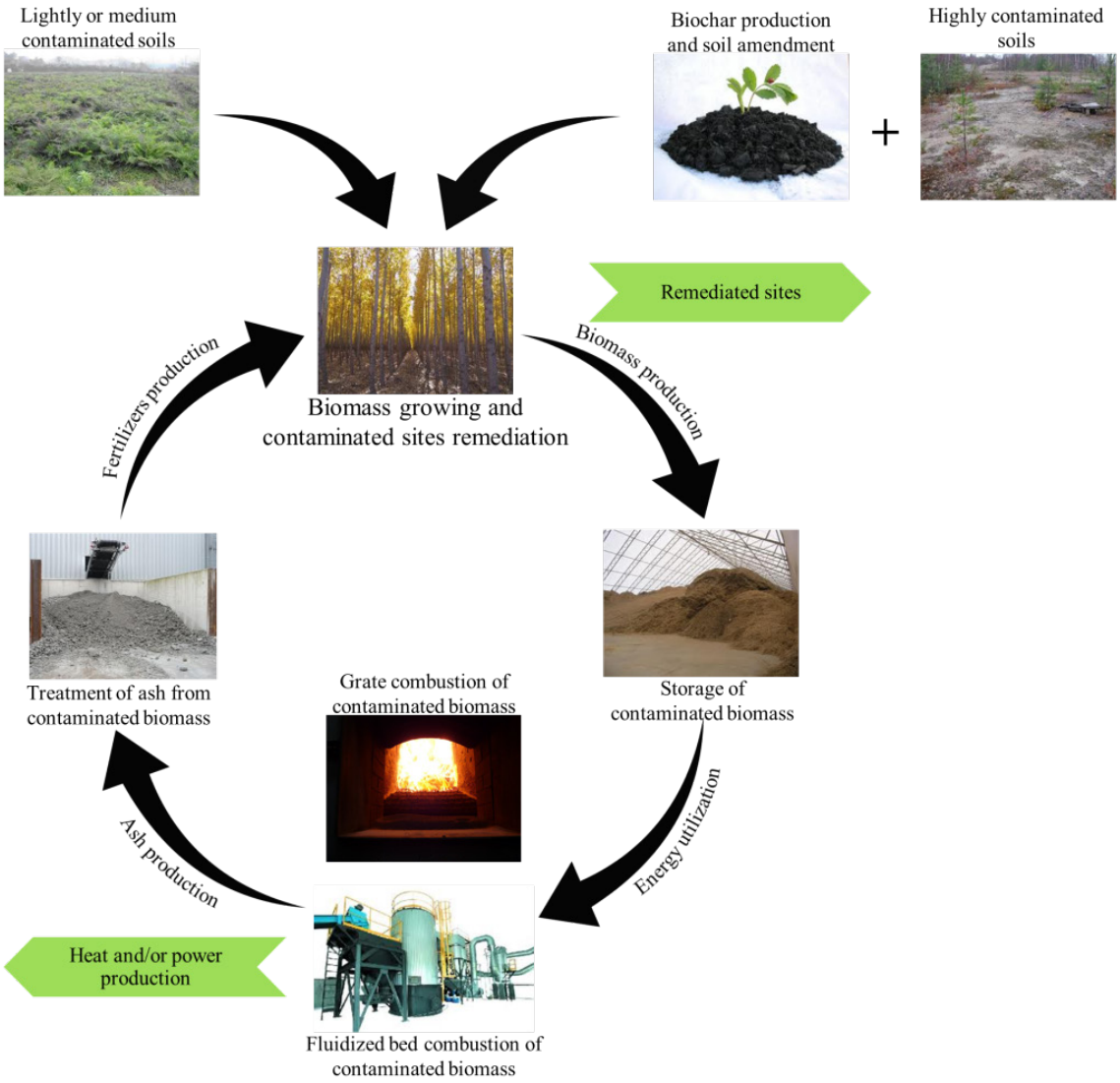


Dependence of equilibrium HCl pressures on temperature for ZnO, MnO, La_2O_3 and Ce_2O_3 solid sorbents (assumed P_{H2O} = 0.1 bar, P_{CO2} = 0.2 bar) - comparison with equilibrium HCl pressure in the reaction of HCl with soda

Brownfields - source of renewable energy

(M. Šyc, syc@icpf.cas.cz; joint project with EVECO Brno s.r.o. and CULS; supported by TACR, project No. 01020366)

The phytoextraction ability of some fast-growing plant species leads to the idea of connecting biomass production with soil remediation on contaminated industrial zones and regions. This biomass will contain significant amount of heavy metals and its energetic utilization has to be considered carefully to minimize negative environmental impacts. Therefore, the behavior of selected heavy metals was observed during thermal treatment of contaminated biomass. Moreover, a detailed analysis of trace and nutrient elements distribution and chemical speciation in ashes was performed. The potential of the application of these ashes and methods of treatment for heavy metals removal was evaluated. This knowledge is essential for further utilization of all products of gasification and for the fulfillment of emission limits during combustion. The concept of contaminated biomass growing and utilization was proposed. [Refs. 11, 21, 22]



The concept of contaminated biomass growing and utilization

Development of a pilot plant for monitoring of Hg emissions reduction from large and medium capacity energy sources

(V. Veselý, vesely@icpf.cas.cz; joint project with ÚJV Řež a.s., ENVIRMINE-ENERGO, a.s. and Technical University Ostrava; supported by TACR, project No. TA04020723)

The objective of the project is identification of the issue concerning meeting of presumed Hg emission limits in single energy sources burning fossil fuels in the Czech Republic and a draft of technical and economical solution to meet predicted Hg emission limits at fossil fuel burning. Measurement in the existing energy sources will be performed to determine concentration of Hg in flue gas in forms of Hg^0 (gaseous atomic mercury), Hg^{2+} (oxidized mercury) and Hg^P (gaseous Hg bonded with solid particles, such as fly ash and combustible carbon in the fly ash).

The effects of operating conditions and selective catalytic reduction on Hg concentration in flue gas will be investigated on a developed pilot plant. The result of the project solution will serve as basis for technical documentation for the existing energy sources modifications, or preliminary documentation of new plants determined for Hg emission elimination.

Design optimization of multi-stage biomass gasifier generating gas with very low tar content

(M. Pohořelý, pohorely@icpf.cas.cz; joint project with TARPO spol. s r.o. and University of Chemistry and Technology, Prague; supported by TACR, project No. TA04020583)

The aim of this project is full utilization of the main advantages of a multi-stage gasification concept using the original know-how of the unique multistage gasifier Tarpo. The goals of the project are to increase the efficiency of cold gas efficiency (from the raw fuel) to a value of min. 89%, which can increase the efficiency of power generation in the combustion engine to a value of 32% and for modern engines to an efficiency of 36%. On the basis of the above equipment three thermal power stations are operated in the Czech Republic and additional three are under construction (2 in Czech Republic, 1 in Slovakia). [Refs. 8, 9]

Combined heat and power generation plant in Kozumín – under construction

Co-combustion of coal and rubber granulate in a fluidized bed

(M. Pohořelý, pohorely@icpf.cas.cz; joint project with PATREM PIPE TECHNOLOGIES, s.r.o. and Alpiq Generation (CZ), s.r.o.)

It has been demonstrated how to effectively co-combust commonly used brown and black coal with rubber granules in fuel blends containing up to 15 wt. % of rubber granules. Combustion investigations have been carried out in our experimental fluidized-bed reactor as well as in a commercial heating plant in Zlín with the circulating fluidized-bed boiler K31 (Alpiq Generation s.r.o.).

Fluidized bed reactor at ICPF

New gas refining technology for small and mobile thermal waste degradation units

(V. Veselý, vesely@icpf.cas.cz; joint project with SMS CZ, s.r.o. and ALG Europe, s.r.o.; supported by TACR, project No. TA03020880)

Within project scope was developed a compact technology for high efficiency dry refining flue gas technology for small and mobile incinerators. This refining technology is consisted of three separate stages of cleaning, which are arranged in a logical sequence and serves to maximize the refining effect. The primary stage of treatment is based on the use of crushed limestone as the raw high-temperature catalyst, the secondary stage is purifying flue gas from acidic and heavy metals components in the flue gas by sprayed milled waste from the primary stage of treatment and tertiary treatment are stationary filter, which consists of a new type of sorbent-based product Chezacarb, which is produced as a waste product of hydrogen production from partial oxidation in Unipetrol RPA. These cleaning elements under specified conditions of temperature and residence time are able to remove tar residues from the flue gases, VOCs, acid gases and especially PCDD/F and PCB and mercury vapor without wet scrubber at any stage of cleaning. This allows you to use this system in the areas where is no sustainable water management options.

Research and development of wet precipitators PM for medium-power boilers burning renewable biomass

(J. Hanika, V. Veselý, hanika@icpf.cas.cz, vesely@icpf.cas.cz; joint project with TENZA, a.s., Brno and VSB-TU Ostrava; supported by TACR, project No. TA02020369)

Project is developed the new technology for separating solid particles from flowing mass of air, especially for middle-burning source of renewable biomass resources and the technology present in the form of a utility model and a prototype of representative size. The

size of the prototype was chosen to allow transfer of results of experimental research and development in commercial use after project completion.

Wet separator for flying ash

Production of new kinds of paper products with special properties from waste security paper

(J. Sobek, sobek@icpf.cas.cz; joint project with SPM - Security Paper Mill, a.s.; supported by TACR, project No. TA04010051)

Project is aimed at creating new product portfolio derived from paper with new antimicrobial and thermal insulation properties. The technology will utilize waste security paper. Due to falsification concerns discarded material is used for energetic purposes only so far (i.e. is burnt). The sub-objective is the development of unique antibacterial fillers and insulating fillers exploiting PET waste materials. The technology will led to reduction of natural resources usage and is environmentally friendly owing to exploitation of recycled component materials (security paper and PET). Newly developed products with added value are designated for immediate commercialization and market entry. High quality security paper with new properties produced by Neograph a.s. will further increase competitiveness of the principal beneficiary.

In-situ thermal desorption with applications of microwaves

(J. Sobek, sobek@icpf.cas.cz; joint project with Dekonta a.s.; supported by TACR, project No. TA04020981)

The aim of the project is to develop and verify a method of an in-situ thermal desorption with use of microwaves. One of the results would be a technical-economical study which would be based on results obtained from pilot tests of new microwave technology and also from comparison of other methods of in-situ thermal desorption as electrical heating, steam enhanced extraction or gas heating. Of course, part of the output would be the patent and

utility models of new technology and constructed technical parts as waveguides. To present the results of the project is also one of the project's aims. If other companies and specialists who deal with environment protection know about the new technology and it's benefits, the expected gains will be reached. [Ref. 19]

Development and verification of thermal desorption technology using microwave radiation

(M. Hájek, J. Sobek, hajek@icpf.cas.cz, sobek@icpf.cas.cz; joint project with UCT and Dekonta, a.s; supported by TACR, project No. TA01020383)

The main goal of the project was the development and verification of thermal treatment method utilizing microwave radiation for heating up contaminated material in a primary treatment unit. An originally designed pilot-scale treatment unit was assembled. Operation efficiency of the unit was verified by treatment of wide range of contaminated soil and solid waste samples. By development of this innovative technology, the applicant is able to strengthen his market position and improve his competitiveness on the field of remediation services and hazardous waste treatment activities.

In this study, were compared efficiencies of persistent organic pollutants (POPs) removal from solid materials (soil and building waste) using conventional and microwave heating. These experiments were performed in laboratory apparatus and pilot scale devices. It was confirmed that more polar pollutants (for example chlorinated pesticides) can be effectively removed at a temperature below their boiling point. Probably, this effect was evoked through co-transport some contaminants with water vapour. Microwave heating was a very applicable alternative heating method that brings about faster heating of the material and saving of energy. The examined groups of pollutants (pesticides and PCBs,) were removed with high efficiency at temperatures around 250 °C. [Refs. 14, 15, 16, 19]

Pilot equipment for microwave thermal desorption (Dekonta a.s.)

Advanced method using microwaves for repair of damaged roads

(M. Hájek, J. Sobek, hajek@icpf.cas.cz, sobek@icpf.cas.cz; supported by FUTTEC a.s.)

New and modern method of microwave heating was applied for repairing roads with asphalt material. The aim is year-round repair of the local surface cracks, joints or pot holes which have arisen during winter season.

The quality tests of repaired place showed that after 3 years good quality of repaired place by microwave heating was obtained. Present research is now focused on reparation of roads with low absorption for microwaves. [Ref. 12]

Progressive method and new equipment using microwaves for drying of surfactants

(M. Hájek, J. Sobek, hajek@icpf.cas.cz, sobek@icpf.cas.cz; supported by CHEMPHARM Engineering, s.r.o.)

The method and equipment making use of microwaves was applied on drying of surfactants from water solutions. It was found that use of microwave heating provides better quality of dried surfactants compared to conventional method. Drying was performed under mild condition and was found that process was significantly energy saving. The aim was to prepare such different surfactants (anion-active, cation-active, non-ionic, and/or amphoteric) in powder form having a high quality. [Refs. 13, 20]

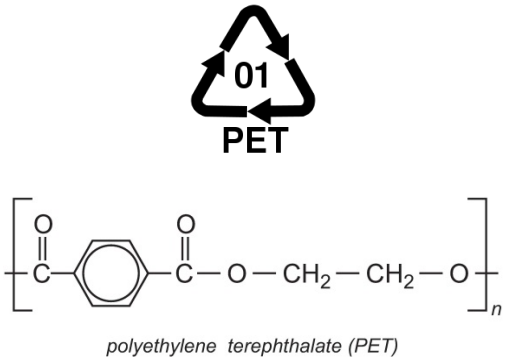
Microwave reactor

Revolutionary method using microwaves for the chemical depolymerization of waste polyethylene terephthalate (PET)

(M. Hájek, J. Sobek, hajek@icpf.cas.cz, sobek@icpf.cas.cz; supported by NOEN, s.r.o.)

New technology has been developed in order to solve problems of growing production and accumulation of waste PET bottles. This recycling technology is based on use of microwave energy for PET depolymerization and it is characterized by low energy consumption and by high purity of products (terephthalic acid, monoethylene glycol) so called "Polymer Grade" quality. It was tested on pilot plant with capacity 1-10 kg/h PET bottles with MW reactor of 0.12-1.0 m^3.

One advantage of this method over others is that it does not require sorting before processing. This new technology is protected by patent documents both in the Czech Republic (CZ299908) and in 5 countries (EP2176327), in Germany, Italy, France, UK and in China. Recently the technology was sold to the Polish company NRT Polska Sp. Z.o.o. Successful technology was verified on microwave reactor with working capacity of 280-1000 L. In 2013 was started in Poland the construction of factory with capacity of 10 000 ton of PET per year. [Refs. 2, 3, 4, 17, 23]



Recycling technology based on use of microwave energy for PET depolymerization

International co-operations

Central Mechanical Engineering Research Institute, Durgapur, India: Waste gasification
Institute for Energy and Transport, Joint Research Centre of EC, Petten, the Netherlands: Atmospheric and pressurized fluidized bed combustion/gasification technologies; Waste incineration/gasification
University of KwaZulu-Natal, Durban, Republic of South Africa: Gaseous and particulate emissions
The Vienna University of Technology, Austria: Fluidized bed biomass gasification
Imperial College, London, United Kingdom: Pressurized FB gasification, combination with SOFC
The Combustion Research Institute, National Research Council, Napoli, Italy: In-bed catalytical processes for fluidized bed gasification and tar reduction
Institute of Nuclear Energy Research, Atomic Energy Council, Taiwan: Development of fluidized bed gasification with efficient gas cleaning, chemical looping production of hydrogen
Laboratório Nacional de Energia e Geologia, Portugal: Syngas cleaning, removal of tar, sulfur and nitrogen compounds

Visitors

M. Čárský, University of Kwazulu-Natal, Durban, Republic of South Africa
Y.-P. Chyou, Institute of Nuclear Energy Research (INER), Taiwan

Teaching

V. Církva: UCT, Faculty of Chemical Technology, postgraduate course "Microwave Chemistry"
V. Církva: UCT, Faculty of Chemical Technology, postgraduate course "Photochemistry"
M. Pohořelý: UCT, Faculty of Environmental Technology, postgraduate course "Energetic Using of Biomass" and courses "Alternative Energy Sources I", "Chemical Calculations", "Laboratory of Fuel Analysis", and "Laboratory of Fuels"
M. Punčochář: Czech University of Life Sciences Prague, course "Renewable and Alternative Sources of Energy"
K. Svoboda: UJEP, Faculty of Environment, courses "Decontamination and Bio-remediation Technologies" and "Energetics (Power generation) and Protection of the Environment"

Publications

Original papers

[1] Čermák J.K., Církva V.: Copper-mediated Synthesis of Mono- and Dichlorinated Diaryl Ethers. *Tetrahedron Letters* 55(30), 4185–4188 (2014).

[2] Hájek M.: Mikrovlnná recyklace PET lahví. Microwave Recycling of Waste PET Bottles. *Akademický bulletin* 6, 12-13 (2014).

[3] Hájek M.: Mikrovlnná recyklace odpadních PET lahví. Microwave Recycling of Waste PET Bottles. *Odpady* 24(6), 25-26 (2014).

[4] Hájek M.: Mikrovlnná recyklace odpadních PET lahví. Microwave Recycling of Waste PET Bottles. *Chemagazín* 24(4), 8-9 (2014).

[5] Hartman M., Svoboda K., Pohořelý M., Šyc M., Skoblia S., Chen Po-Ch.: Reaction of Hydrogen Chloride Gas with Sodium Carbonate and Its Deep Removal in a Fixed-Bed Reactor. *Ind. Eng. Chem. Res.* 53(49), 19145-19158 (2014).

[6] Hrbáč J., Storch J., Halouzka V., Církva V., Matějka P., Vacek J.: Immobilization of Helicene onto Carbon Substrates through Electropolymerization of [7]Helicenyl-thiophene. *RSC Adv.* 4(86), 46102-46105 (2014).

[7] Jeremiáš M., Pohořelý M., Bode P., Skoblia S., Beňo Z., Svoboda K.: Ammonia Yield from Gasification of Biomass and Coal in Fluidized Bed Reactor. *Fuel* 117(Part B), 917-925 (2014).

[8] Pohořelý M.: Sdružení chce zvýšit důvěryhodnost oboru. The Association Wants to Increase the Credibility of the Field. *Odpady* 24(3), 16 (2014).

[9] Pohořelý M., Jeremiáš M., Svoboda K., Kameníková P., Skoblia S., Beňo Z.: CO_2 as Moderator for Biomass Gasification. *Fuel* 117(Part A), 198-205 (2014).

[10] Šimčík M., Punčochář M., Růžička M.: Added Mass of a Spherical Cap Body. *Chem. Eng. Sci.* 118, 1-8 (2014).

[11] Trakal L., Bingöl D., Pohořelý M., Hruška M., Komárek M.: Geochemical and Spectroscopic Investigations of Cd and Pb Sorption Mechanisms on Contrasting Biochars: Engineering Implications. *Bioresour. Technol.* 171, 442–451 (2014).

Patents

[12] Hájek M., Sobek J.: Způsob opravy poškozených míst vozovek a komunikací. Method of Reparation of Demaged Roads. *Pat. No. 304810*/PV 2013 - 705. Applied: 13.09.17, Patented: 14.09.24.

[13] Hájek M., Sobek J., Přáda D., Ba A.: Způsob sušení tenzidů. Method of Drying of Surfactants. *Pat. No. 304481*/PV 2013-439. Applied: 13.06.11, Patented: 14.04.09.

[14] Hendrych J., Novotná R., Špaček P., Kroužek J., Randula D., Sobek J.: Zařízení pro stabilizaci a solidifikaci kapalných odpadů. Device for Stabilization and Solidification of Liquid Waste. *Pat. No. 26652*/UV 2013-28266. Applied: 13.07.29, Patented: 14.03.24.

[15] Hendrych J., Novotná R., Špaček P., Kroužek J., Randula D., Sobek J., Kubal M.: Pojivová směs pro stabilizaci a solidifikaci kapalného odpadu a vzniklý stabilizát a solidifikát. Binder Mixture for Stabilization and Solidification of Liquid Waste and the Stabilization Product and Solidification Product. *Pat. No. 26651*/UV 2013-28265. Applied: 13.07.29, Patented: 14.03.24.

[16] Hendrych J., Novotná R., Špaček P., Kroužek J., Randula D., Sobek J.: Separátor přebytečné kapalné fáze z pasty stabilizátu a solidifikátu kapalného odpadu. Separator of Excess Liquid from the Paste Stabilizate and Liquid Waste Solidificate. *Pat. No. 27367*/UV 2014-29655. Applied: 14.06.10, Patented: 14.09.29.

[17] Kruliš Z., Horák Z., Beneš H., Hájek M.: Method of Recycling Waste Polyurethane Foams. *Pat. No. EP2183311*. Applied: 10.05.12, Patented: 14.12.03.

[18] Pohořelý M., Svoboda K., Šyc M., Durda T., Punčochář M., Hartman M.: Zařízení pro fluidní spalování pevných paliv či suspenzí. Facilities for Fluidized Bed Combustion of Solid Fuels or Suspensions. *Pat. No. 26697*/PUV-28341. Applied: 13.08.20, Patented: 14.03.31.

[19] Sobek J., Hájek M., Mašín P., Hendrych J., Kroužek J., Kubal M., Kukačka J.: Zařízení pro dekontaminaci tuhých materiálů. Equipment for Decontamination of Solids. *Pat. No. 26360*/UV 2013-28260. Applied: 12.07.29, Patented: 14.01.20.

[20] Sobek J., Hájek M., Práda D., Ba A., Bartůněk P.: Zařízení pro sušení tenzidů. Equipment for Drying of Surfactants. *Pat. No. 26524*/UV 2013-27960. Applied: 13.05.22, Patented: 14.02.27.

[21] Šyc M., Pohořelý M., Punčochář M., Tlustoš P., Habart J., Ucekaj V.: Zařízení pro přípravu hnojiva z popela získaného spalováním kontaminované biomasy. Apparatus for Preparation of Fertilizing Material from Ash from Combustion of Contaminated Biomass. *Pat. No. 27624*/PUV 2014-29810. Applied: 14.07.23, Patented: 14.12.18.

[22] Tlustoš P., Habart J., Břendová K., Jelínek F., Pohořelý M., Punčochář M., Šyc M.: Zařízení pro přípravu pyrolýzního koksu. Equipment for the Preparation of Pyrolysis Coke. *Pat. No. 26846*/PUV 2014-29083. Applied: 14.01.14, Patented: 14.04.24.

[23] Veselý V., Drahoš J., Šírek M.: Process for Recovering Terephthalic Acid. *Pat. No. EP2061744*/PCT/CZ2007/000086. Applied: 07.09.06, Patented: 14.04.30.

[24] Sobek J., Hájek M., Veselý V., Punčochář M., Církva V.: Způsob zpracování řas a sinic. The Processing of Algae for Obtaining Oil Resulting. *Pat. No. 304392*/PV 2013-323. Applied: 13.04.30, Patented: 14.02.26.

[25] Punčochář M., Sobek J., Veselý V.: Způsob hydrolýzy inulinového roztoku a zařízení k provádění způsobu. Inulin Solution Hydrolysis Process and Apparatus for Carrying Out the Method. *Pat. No. 304803*/PV 2013-799. Applied: 13.10.18, Patented: 14.09.18.