Environmental Process Engineering Laboratory

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Fields of research

- Microwaves in photochemistry and photocatalysis
- 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
- Fluidized bed gasification of solid, liquid and slurry feedstock
- Medium and high temperature gas cleaning (particularly removal of HCl and H_2S from producer gas) for advanced applications
- Advanced processes for waste-to-energy

Applied research

- Moving bed gasification of wood and waste wood
- Brownfields - Source of renewable energy
- Development and verification of thermal desorption technology using microwaves
- Method for the chemical depolymerization of waste polyethylene terephthalate (PET)
- Complex recycling of compact fluorescent lamps (CFLs) and removal of toxic mercury
- Process for preparing hydrogen by partial oxidation of high-boiling hydrocarbon mixtures and biomass
- Wet precipitators PM for medium-power boilers burning renewable fuels
- Fluidized bed combustion and gasification
- Sewage sludge combustion and co-combustion
- Optimization of waste-to-energy plant and air pollution control devices

Research projects

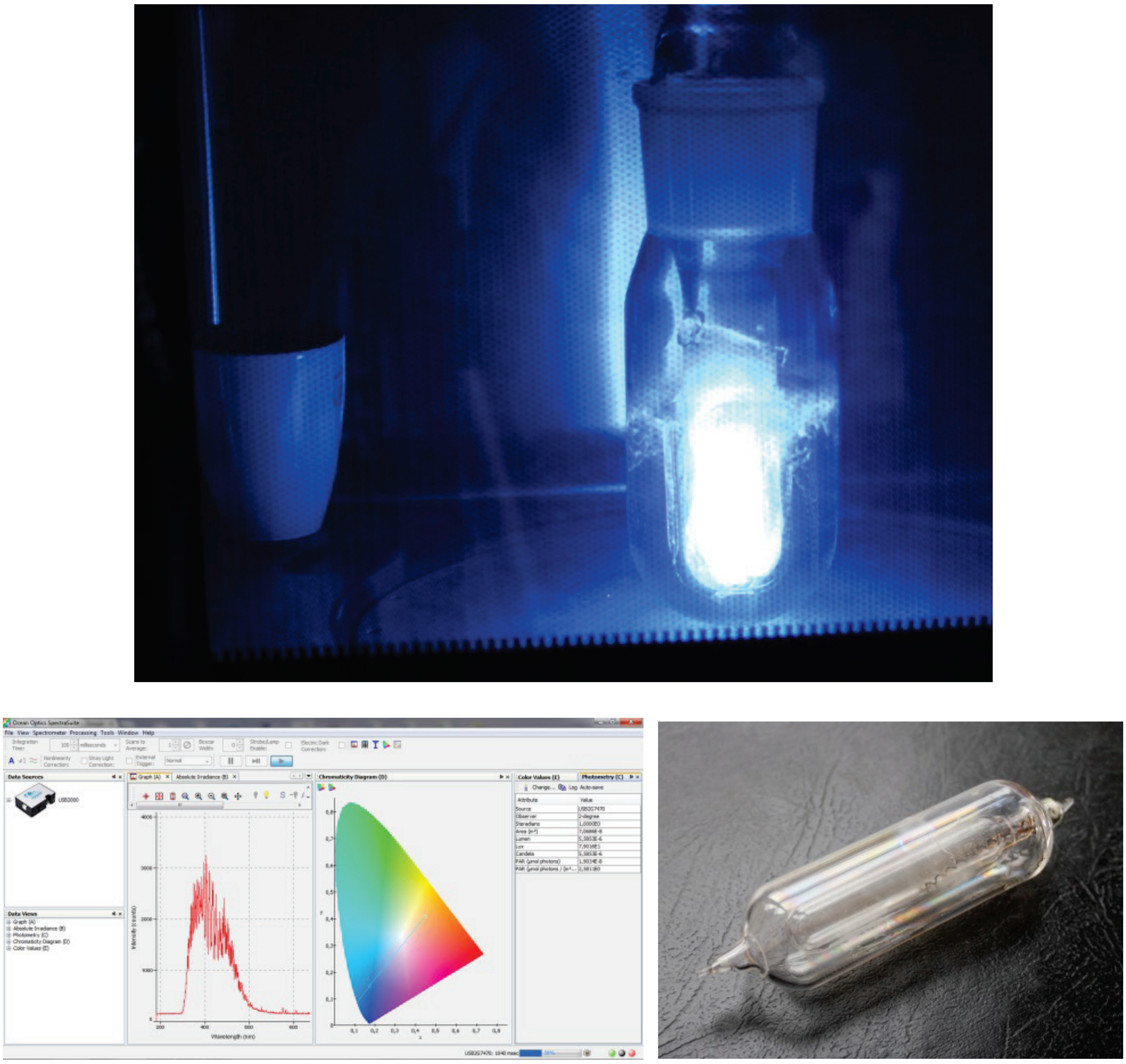
Microwave applications on the field of environmental chemistry, photochemistry and photocatalysis

(V. Církva, cirkva@icpf.cas.cz; supported by ICPF; TACR, project No. TA01010646; and MIT, project No. FR-TI3/628)

The coupled activation of photochemical and photocatalytic reactions by using of two different types of radiation, microwave and UV/Vis, is covered by the new discipline called microwave photochemistry and photocatalysis. 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 the concept of microwaves in the field of organic photochemical [9, 12] and photocatalytic synthesis [6], or environmental chemistry [1, 20].

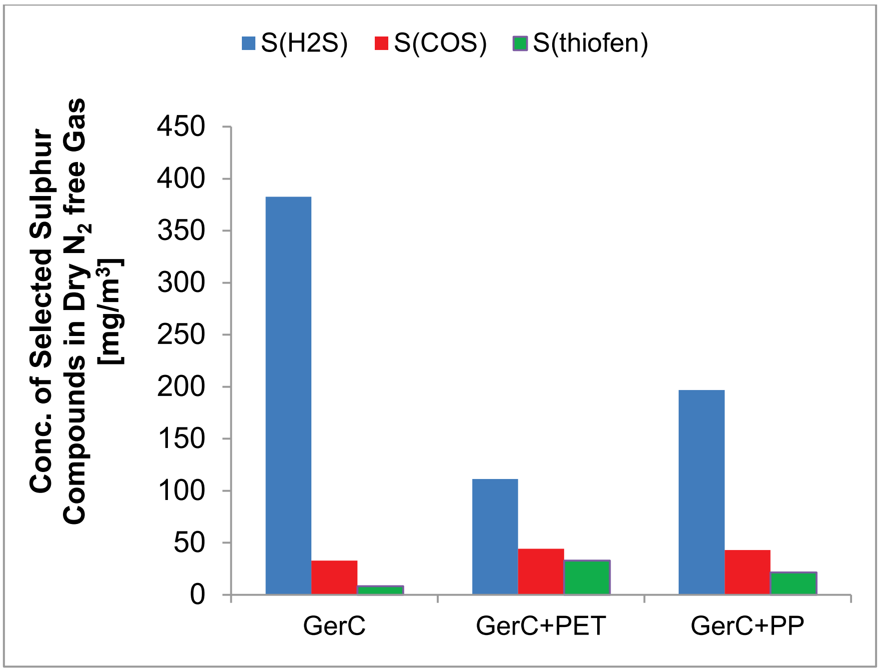


Experimental set-up for microwave photochemical experiments with EDLs

Advanced concepts and process schemes for CO_2 free fluidized and entrained bed co-gasification of coals

(K. Svoboda, svoboda@icpf.cas.cz; joint research project with CNR - Italy, LNEG - Portugal, CIEMAT - Spain, TUV - Austria, ICL - UK, ELCOGAS - Spain, UNISA - Italy; supported by RFCS, project No. RFCR-CT-2010-00009, and MEYS, project No. 7C11009)

The project aims at integrating gasification schemes for the co-gasification of coal, biomass and waste with processes for CO_2 separation and capture. Fluidized bed and entrained flow gasification processes are considered thanks to their flexibility and effectiveness for carrying out thermal conversion of different feedstock, for matching different requirements of producer gas end-users and for effective CO_2 separation. Fuel feeding in a form of solid particles, mixtures of solid particles and various slurries (suspensions of solid fuel particles) and different fluidized bed particulate materials (sand, dolomite, olivine) are compared in terms of their effects in fluidized bed gasification. Effects of both, primary measures (involved in overall conditions of a given gasification process) and secondary (downstream) measures on syngas properties (particularly composition, purity and heating value) and possible applications are studied as well as effects of partial substitution of steam by CO_2 in gasification medium on gasification characteristics and producer gas properties. At the end of the project solution period (June 12-14, 2013) the international workshop on *"New processes for fuel conversion gas cleaning and CO_2 separation in FB and EF gasification of coal, biomass and waste"* was organized in Prague. Invited lectures of foreign experts have been presented. [Refs. 2, 4, 5, 11, 15, 16]

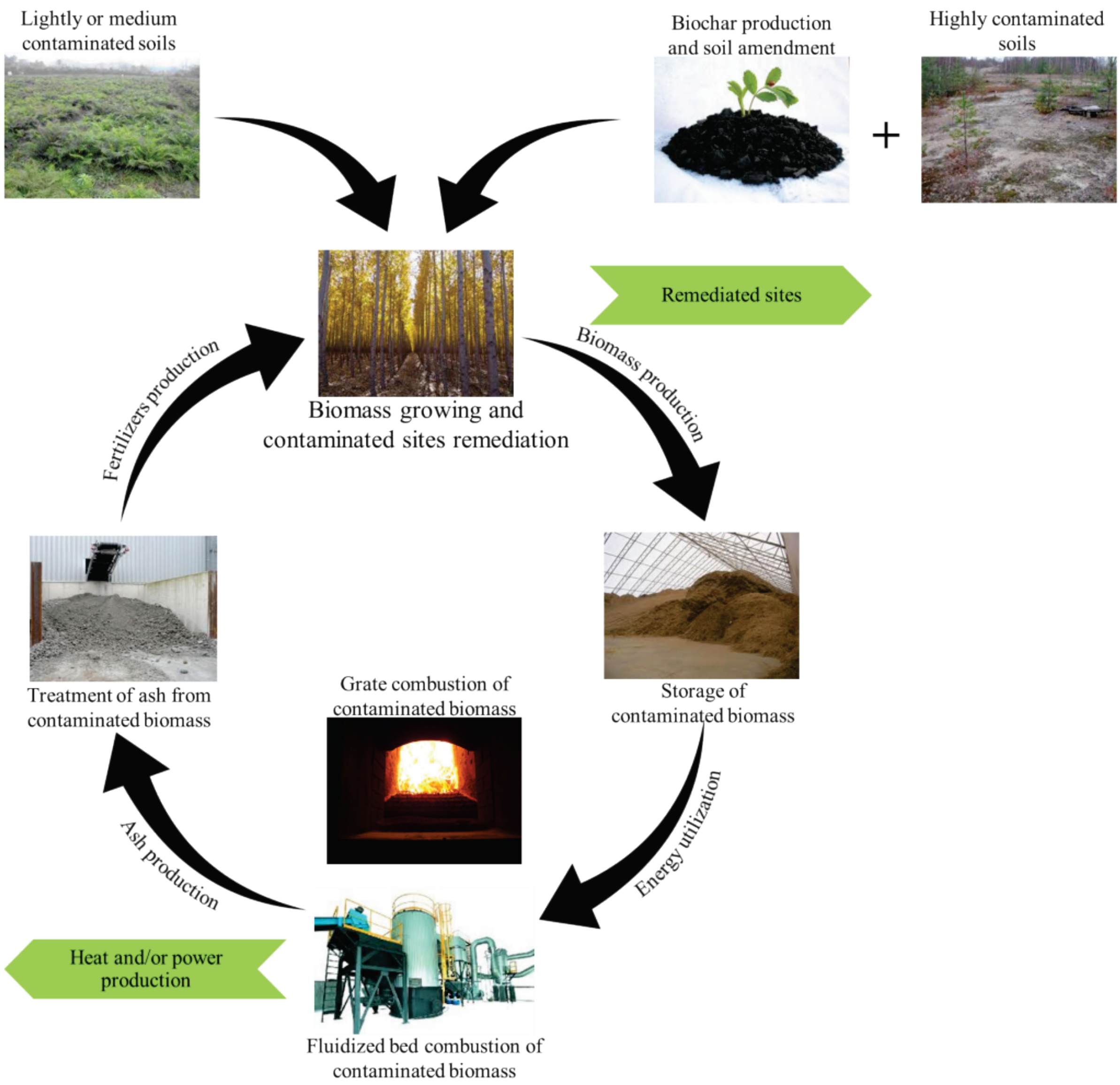


Comparison of concentrations of selected sulfur compounds (H_2S, COS and thiophene) in dry, N_2-free producer gas for fluidized bed (FB) gasification of German coal with gas concentrations of the sulfur compounds in FB co-gasification with PET (24 wt. %) and PP (20 wt. %). T = 850 °C, air/steam, ER = 0.21, H_2O/C mol. ratio ≈ 1, FB-material: sand/dolomite ≈ 1/1

Front page of the Proceedings from the International workshop of the Fecundus project

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, 15, 16]



The concept of contaminated biomass growing and utilization

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 ICT 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. 7, 21]

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. 13]

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.)

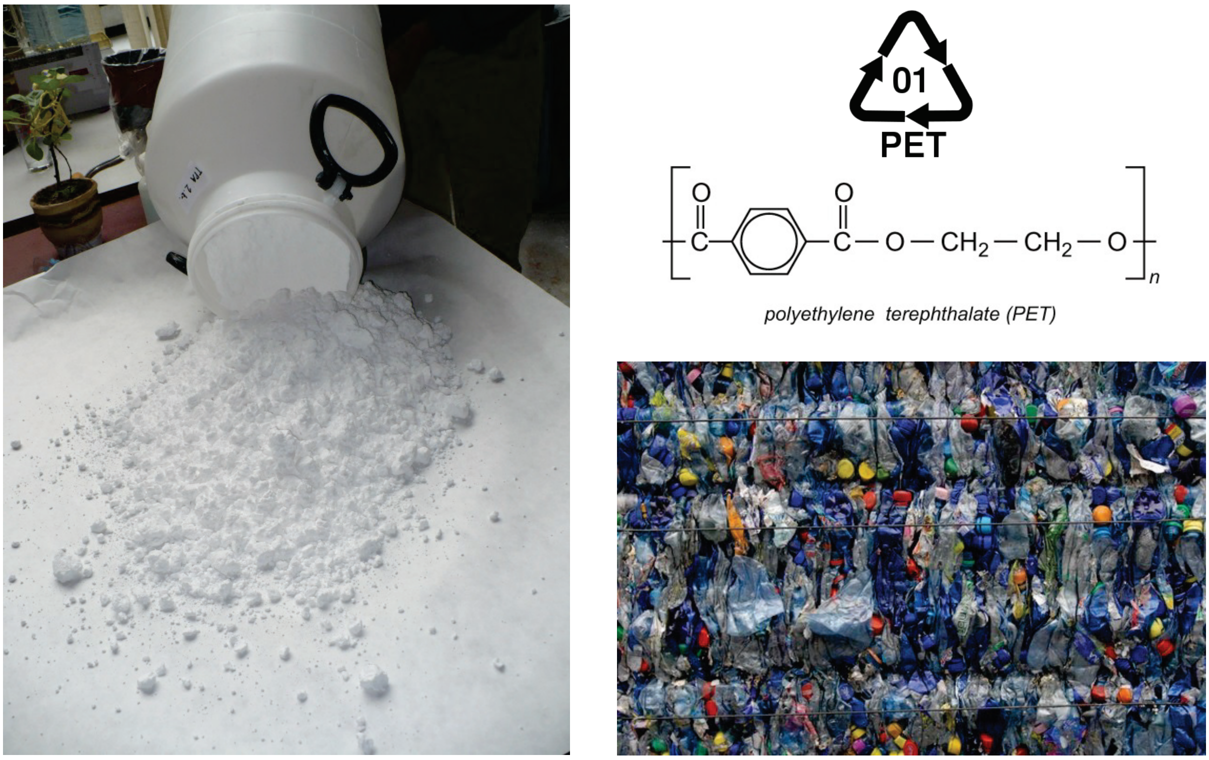
The method and equipment making use of microwaves was applied on drying of surfactants from water solutions. It was found that use of microwave heating provides better quality of dried surfactants compared to conventional method. Drying was performed under mild condition and was found that process was 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. 14, 19]

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.)

The recycling of waste PET is currently one of the most important tasks in the polymers recycling industry. In ICPF, the unique technology for processing of waste PET material on appropriate monomers (i.e. terephthalic acid and ethylene glycol) was developed. This new method for the chemical depolymerization of PET by application of microwaves was applied. One advantage of this method over others is that it does not require sorting before processing.

The mentioned method is patented in Czech Republic (patent No. CZ299908) and also in foreign countries (patent No. EP2176327, WO2009010435, and CN101688015). 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. The realization of microwave technology is supported by the European Union.



Purified terephthalic acid, chemical formula of PET, and waste PET bottles

Complex recycling of compact fluorescent lamps (CFLs) and removal of toxic mercury contained in input material

(V. Gruber, A. Heyberger, gruber@icpf.cas.cz, heyberger@icpf.cas.cz; joint project with Recyklace Ekovuk, a.s., supported by TACR, project No. TA02021290)

Project was solving the new complex recycling method of compact fluorescent lamps (CFLs) with mercury content: from controlled destruction over the part sorting on glass, metal and luminophore, separation of mercury from luminophore and mercury conversion to chemical stable form suitable for deposition or repeated utilization, up to isolation of precious components (yttrium and europium) and their repeated utilization at fabrication of lighting devices. Pilot plant unit was constructed in cooperation with Kwa-Zulu Natal University, Durban, Republic of South Africa, and is just being prepared to start the operation. [Ref. 18]

Apparatus for recovery of rare metals

Process for preparing hydrogen by partial oxidation of high-boiling hydrocarbon mixtures and biomass and apparatus for making the same

(V. Veselý, J. Hanika, vesely@icpf.cas.cz, hanika@icpf.cas.cz; joint project with VÚAnCh, a.s., Ústí n. Labem and ICT; supported by MIT, project No. MPO 2A-2TP1/024)

The present invention relates to a process for preparing hydrogen by partial oxidation of high-boiling hydrocarbon mixtures and biomass wherein the invented preparation process is characterized in that biomass with moisture level of 10 % at the most is treated to a particle size in the range of 0.1 to 0.5 mm. Subsequently, so treated biomass is then mixed in a high-boiling hydrocarbon mixture. The biomass and the high-boiling hydrocarbon mixture ratio ranges within 4:100 to 12:100. Finally, an oxygen-steam mixture is added. The reaction mixture reacts within a reactor at a temperature ranging from 1100 to 1250°C, at a pressure in the range of 3 to 4 MPa and with a dwell of 7 to 20 s to obtain hydrogen and synthesis gases. In the invention, there is further described an apparatus for making the above-indicated preparation process. [Refs. 3, 8]

Quench of the POX reactor

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. [Ref. 8]

Wet separator for flying ash

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.

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

Visits Abroad

P. Kameníková: Hawaii Natural Energy Institute, University of Hawaii, USA (6 months)

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: ICT, Faculty of Chemical Technology, postgraduate course "Microwave Chemistry"
V. Církva: ICT, Faculty of Chemical Technology, postgraduate course "Photochemistry"
M. Pohořelý: ICT, 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., Kolář K., Církva V.: Rapid and Efficient Synthesis of N-alkylbenzamides Under Microwave Irradiation. *Lett. Org. Chem.* 10(2), 126-130 (2013).

[2] Elsasser T., Pohořelý M., Jecha D., Punčochář M., Stehlík P.: Thermische Klärschlammbehandlung in der Tschechischen Republik und experimentelle Bestimmung der Emissionen aus der Verbrennung. *Chemie Ingenieur Technik* 85(12), 1-7 (2013).

[3] Hanika J., Lederer J., Veselý V.: Produkce dioxinů při spalování směsných plastů. (Czech) Dioxins Formation during Incineration of Complex Plastics Mixtures. *Odpadové fórum* 203(4), 15 (2013).

[4] Hartman M., Svoboda K., Pohořelý M., Šyc M.: Thermal Decomposition of Sodium Hydrogen Carbonate and Textural Features of Its Calcines. *Ind. Eng. Chem. Res.* 52(31), 10619-10626 (2013).

[5] Hartman M., Svoboda K., Pohořelý M., Šyc M., Jeremiáš M.: Attrition of Dolomitic Lime in a Fluidized-Bed at High Temperature. *Chem. Pap.* 67(2), 164-172 (2013).

[6] Kmentová H., Církva V.: Microwave Photocatalysis IV: Effects of Additional Operational Parameters on the Microwave Photocatalytic Degradation of Mono-Chloroacetic Acid Using Titania-Coated Mercury Electrodeless Discharge Lamps. *J. Chem. Technol. Biotechnol.* 88(6), 1109-1113 (2013).

[7] Mašín P., Hendrych J., Kroužek J., Kubal M., Kochánková L., Sobek J.: Removal of Persistent Organic Pollutants from a Solid Matrix by Thermal Desorption Technology Using Conventional and Microwave Heating. *Fresenius Environ. Bull.* 22(7A), 2017-2021 (2013).

[8] Veselý V., Hanika J., Tukač V., Lederer J., Kovač D.: Catalytic Partial Oxidation of Biomass/Oil Mixture. *Journal of Energy and Power Engineering* 7(10), 1940-1945 (2013).

[9] Žádný J., Velíšek P., Jakubec M., Sýkora J., Církva V., Storch J.: Exploration of 9-bromo[7]Helicene Reactivity. *Tetrahedron* 69(30), 6213-6218 (2013).

Review papers

[10] Punčochář M.: Institute of Chemical Process Fundamentals of the ASCR: Expectation. *Kemija u industriji* 62(5-6), 214-215 (2013).

Patents

[11] Pohořelý M., Kameníková P., Svoboda K., Skoblia S., Jeremiáš M., Šyc M., Punčochář M., Hartman M.: Zařízení pro fluidní zplyňování tuhých paliv. (Czech) The Facility for the Fluidized-Bed Gasification of Solid Fuels. *Pat. No. 304060*/PV 2012-516. Applied: 12.07.27, Patented: 13.07.31.

[12] Storch J., Církva V., Bernard M., Vokál J.: Způsob výroby [6]helicenů fotocyklizací. (Czech) Method and Apparatus for Production of [6]Helicenes. *Pat. No. 303997*/PV 2012 - 245. Applied: 12.04.11, Patented: 13.06.26.

[13] Hájek M., Sobek J.: Způsob opravy poškozených míst vozovek a komunikací. (Czech) Method of Reparation of Demaged Roads. *PV 2013-705*. Applied: 13.09.17.

[14] Hájek M., Sobek J., Přáda D., Ba A.: Způsob sušení tenzidů. (Czech) Method for Drying of Surfactants. *PV 2013-439*. Applied: 13.06.11.

[15] Pohořelý M., Svoboda K., Šyc M., Durda T., Punčochář M., Hartman M.: Zařízení pro fluidní spalování pevných paliv či suspenzí. (Czech) Facilities for Fluidized Bed Combustion of Solid Fuels or Suspensions. *PV 2013-638*. Applied: 13.08.20.

[16] Pohořelý M., Svoboda K., Šyc M., Durda T., Punčochář M., Hartman M.: Zařízení pro fluidní spalování pevných paliv či suspenzí. (Czech) Facilities for Fluidized Bed Combustion of Solid Fuels or Suspensions. *PUV-28341*. Applied: 13.08.20. Patented: 14.03.31.

[17] Punčochář M., Sobek J., Veselý V.: Způsob hydrolýzy inulinového roztoku a zařízení k provádění způsobu. (Czech). Method and Device for Hydrolysis of Inulin Solution. *PV 2013-799*. Applied: 13.10.18.

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[19] Sobek J., Hájek M., Práda D., Ba A., Bartůněk P.: Zařízení pro sušení tenzidů. (Czech) Equipment for Drying of Surfactants. *Pat. No. 26524*/ PUV 2013-27960. Applied: 13.05.22. Patented: 14.03.12.

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[21] Sobek J., Hájek M., Mašín P., Hendrych J., Kroužek J., Kubal M., Kukačka J.: Zařízení pro dekontaminaci tuhých odpadů. (Czech) Apparatus for decontamination of solid materials. Pat. No. 26360/ PUV 2013-28260. Applied: 13.07.29. Patented: 14.01.20.