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Main fields of research

- Advanced processes for Waste-to-Energy (WtE)
- Advanced processes for gasification, gas cleaning and hydrogen production
- Urban mining
- Persistent organic pollutants and heavy metals emissions and behavior
- Environmental organic chemistry and microwave photochemistry

Applied research

- Development of a pilot plant for monitoring of Hg emissions reduction
- Design optimization of multi-stage biomass gasifier generating gas with low tar content
- Fluidized bed combustion of coal, biomass and sewage sludge
- 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

Research projects

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)

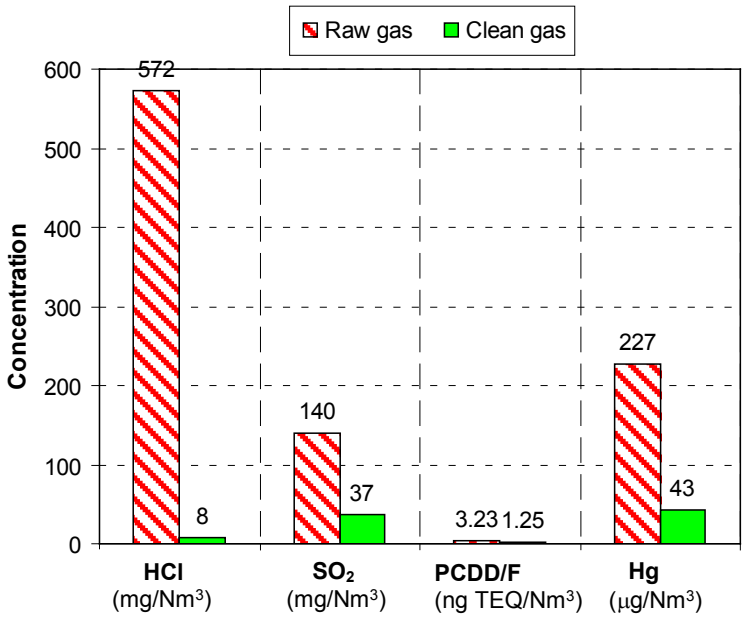
Waste-to-Energy (WtE) Competence Centre activities are aimed at increasing the competitiveness of the Czech Republic in the field of WtE. The activities are specified in such a way to be able to cover WtE from a primary idea to final products based on recent results of strategic planning, selection and 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 the leader of a work package focused on innovation and re-design of components of WtE with respect to overall energy optimization and increase of efficiency.

Our research tasks can be summarized as follows: [Refs. 4, 8-11]

- Development of new efficient dry cleaning methods for simultaneous removal of acid gases, particulate matter, NO_x, PCDD/F, and heavy metals including Hg.
- MSWI solid residues (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 thermal treatment with phosphorous recovery.

New efficient dry cleaning methods for simultaneous removal of flue gas pollutants (HCl, dust, NO_x, PCDD/F, Hg, etc.) from waste-to-energy process are studied and developed within the project. A unique apparatus for bag filters testing and optimization of dry cleaning process operating conditions was built and the effect of operational conditions on removal efficiency of each pollutant was studied. Research efforts are also focused on the development of mineral sorbents with and without chemical impregnation for dry sorption of mercury and $HgCl_2$ vapors in the temperature range 130-280 °C.



Removal of HCl, SO_2, Hg and PCDD/F by $Ca(OH)_2$-based sorbent with large specific surface, type Sorbacal® (Sindram and Walter, 2006) at temperatures 160-170 °C

Bottom ash from waste-to-energy plants contains valuable components, especially ferrous and non-ferrous metals, which can be recovered as secondary materials. The development of technology for recovering of metals from bottom ash is next task of the project. The first part of our work was the analysis of bottom ash from Czech waste-to-energy plants. We found that bottom ash contained 1.3-2.4 wt. % of non-ferrous metals, up to 10 wt. % of ferrous scrap, and 10-24 wt. % of glass. The exact distribution of valuable materials with respect to particle size was also determined. This knowledge is essential for development of an efficient recovery method.

Valuable components in MSWI bottom ash

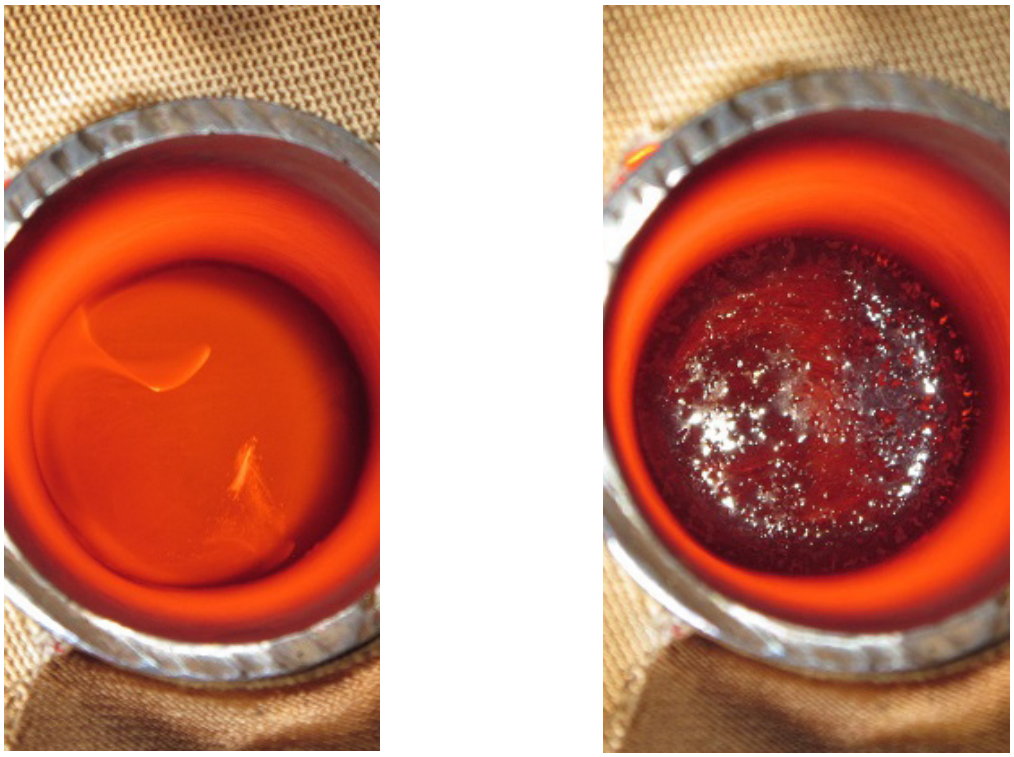
Sewage sludge incineration with subsequent phosphorus recovery from ash is the last research task of the project. We focus on finding of the optimal incineration conditions and application of primary measures in fluidized bed for minimization of gaseous pollutants. The effect of sewage sludge composition and incineration conditions on sewage sludge ash composition is also studied because ash has similar content of phosphorus like apatite (5-25 % P_2O_5) and serves as the most important secondary source of phosphorus. The development of suitable methods for phosphorus recovery from the ash is the project sub-task. Thermochemical treatment and various hydrometallurgical methods are studied and evaluated with respect to main aim of the task, which is separation of phosphorus and heavy metals and increase of phosphorus bioavailability.

Sewage sludge pellets after thermochemical treatment

Processing of radioactively contaminated ion exchangers by oxidation in molten salts

(M. Šyc, M. Pohořelý, syc@icpf.cas.cz; joint project with Research Centre Rez and CHEMCOMEX Praha, a.s.; supported by TACR, project No. TA04021660)

The project focuses on development of efficient method for thermal destruction of radioactively contaminated ion exchangers in molten salts. Various mixtures of molten salts are tested (e.g. selected carbonates or borates concentrates produced in cleaning station of the primary circuit of VVER type nuclear power plants. Main target of the project is to propose optimal conditions of process considering technological, operational, and economic factors and to verify them on the semi-pilot plant.



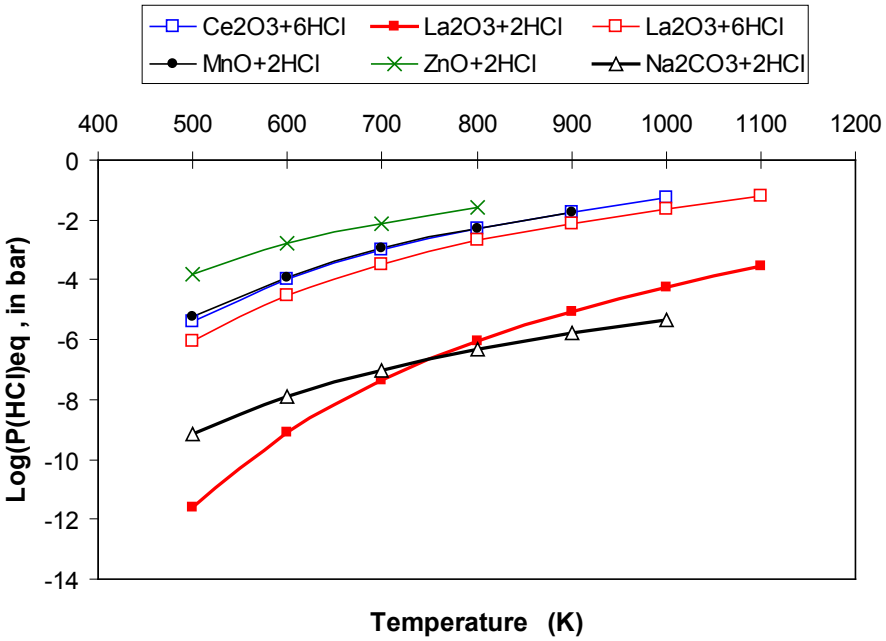
Oxidation of ion exchanger in molten mixture of sodium, lithium and potassium carbonates, on the left - volatiles incineration above the molten salts, on the right - ash layer on the top of molten salt

Cleaning of syngas 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 ^{o}C. A soda-based sorbents 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, CeO_x and $La_2O_3/La_2O_2CO_3$ serve for removal of H_2S, COS, destruction/removal of thiophene and for study of interferences (CO_2, H_2O(g) and HCl). 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 are developed and solved. Possibilities of regeneration of the sulfur compounds sorbents are assessed. [Ref. 1]



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

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).

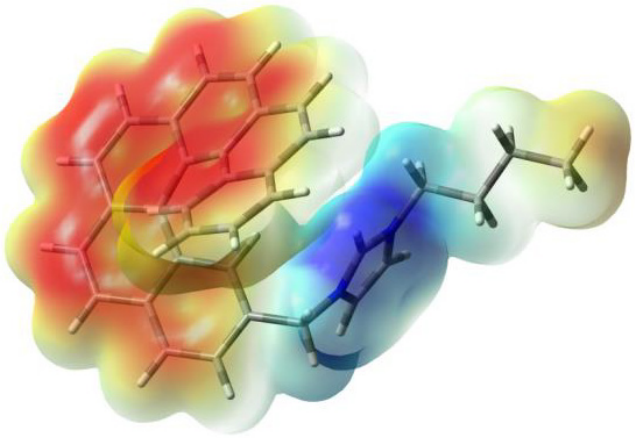
The effects of operating conditions and selective catalytic reduction on Hg concentration in flue gas will be investigated on a developed pilot plant. The result of the project solution will serve as basis for technical documentation for the existing energy sources modifications, or preliminary documentation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

Aplication in Organic Molecular Electronics

(V. Církva, cirkva@icpf.cas.cz; joint project with Palacky University, University of Pardubice, UCT Prague, Institute of Physics of the CAS, Czech University of Life Sciences Prague, Institute of Organic Chemistry and Biochemistry of the CAS, Charles University Prague, supported by MIT, project No. FR-TI3/628; TACR, project No. TA04010082 and TA01010646)

During the past 30 years, the study of organic electronics based on π-electron network molecules has made rapid progress and practical organic devices are currently being produced. Polycyclic aromatic hydrocarbons with their extended two-dimensional (2D) π-conjugated frameworks are of particular interest for this purpose as they can provide charge-transporting pathways when arranged into appropriated superstructures in the solid state.

The study was focused on the substitution of the imidazolium cation with [6]helicene to improve surface immobilization and to enhance its solubility in polar solvents. The deposited layers were used for the development of organic molecular semiconductor devices and the construction of fully reversible humidity sensor. [Refs. 2, 3, 6, 7]



Electron density isosurface mapped with electrostatic potential surface of 1-butyl-3-(2-methyl[6]helicenyl)-imidazolium bromide in the range from 0.06 (red) to 0.20 (blue)

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 a compact technology for high efficiency dry refining flue gas technology for small and mobile incinerators was developed. This refining technology 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 no sustainable water management options are available.

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 28% and for modern engines to an efficiency of 32%. On the basis of the above equipment four thermal power stations are operated in the Czech Republic, one facility in Slovakia and one facility is under construction in Czech Republic.

Combined heat and power generation plant in Kozumín – under construction

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

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

Project is developing 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)

The 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 lead 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 will be a technical-economical study which will 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, a part of the output will 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.

In-situ thermal desorption with use of microwaves

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.

High effective machine FT3 for pothole road repairs (http://www.iwme.cz/produkt/)

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.

Microwave reactor for drying of surfactants

Recovery of lanthanides from spent NIB magnets

(V. Gruber, gruber@icpf.cas.cz; supported by TA CR, research project Gama, project No TG01010097)

The research was focused on a chemical recovery of neodymium and other lanthanides from spent neodymium-iron-boron permanent magnets. To improve magnetic properties, NIB magnets were often doped with other elements (Pr, Dy, Co) and their composition varies. For a complete recovery of all valuable components, the two-steps isolation process was designed. First, neodymium and praseodymium have been separated from ferrous metals by fractional crystallization of complex sulfate salts. Then solvent extraction of dysprosium by bis-(2-ethylhexyl)phosphoric acid was employed. Pure neodymium, didymium and dysprosium oxides were finally obtained by precipitation of oxalates and their thermic decomposition.

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 gasification of biomass, urban mining
CIEMAT Madrid, Spain: gas cleaning, processes for carbon capture and storage (CCS)
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

M. Jeremiáš, Cranfield University, United Kingdom

Publications

Original papers

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Review papers

[11] Šolcová O., Šyc M.: Využití odpadů pro cenné produkty a energii. ÚCHP využívá odpady pro cenné produkty a energii. (Czech) Waste Utilization for Valuable Products and Energy. *Vesmír* 94(10), 571 (2015).

Chapters in books

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Patents

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