Department of Environmental Engineering

Michal Šyc

Department Focus

The department focuses on systematic research of:

- minimization of the environmental impact of thermal treatment of solid fuels,
- processing or recycling of wastes and waste materials.

We combine **fundamental and applied research** in the attempt to understand the essence of phenomena and then apply this to the current requirements of our partners in the industry.

Main research topics – Waste-to-energy/Waste-to-product

Motivation

- WtE a key technology for treatment of non-reusable wastes,
- thermal treatment as first step in urban mining → thermo-recycling,
- secondary raw materials – bottom ash/fly ash.

We focus on:

- methods for metals recovery,
- recovery of salts,
- mineral matrix utilization in construction industry,
- enhancing environmental parameters/removal of hazardous properties.

Main research topics – Flue gas treatment

Motivation

- minimization of environmental impact,
- tightening emission limits/emerging pollutants → new methods for flue gas cleaning and process optimization.

We focus on:

- dry methods for acid gases – evaluation of reaction kinetics for HCl and SO_2,
- mercury capture and behaviour in flue gases,
- greenhouse gas mitigation.

Main research topics – Thermochemical fuel conversion

Motivation

- thermochemical alternative fuel conversion as a part of urban mining/circular economy.

We focus on:

- Process optimization, operational parameters influence on:
  - plastic waste pyrolysis as chemical recycling,
  - biomass and bio-waste pyrolysis to biochar.

Main research topics – Waste processing/recycling

Motivation

- Shift from linear production economy to circular economy.

We focus on:

- various municipal and industrial wastes, metal-bearing wastes and mine tailings,
- recovery of metals and rare earth elements from various types of electronic waste,
- sewage sludge treatment with phosphorus recovery,
- use of wastes from building construction, mainly so-called wearing courses of road/asphalt,
- recycling of plastic and composite wastes with a focus on material recycling of hard plastics and foil composite materials.

Bottom ash utilization

We focus on **systematic research of bottom ash utilization** and develop an entire system for IBA treatment in the Czech Republic in cooperation with Waste-to-Energy plants and stakeholders.

From **recovery potential analysis** to the **legal framework and real-scale plant**.

	WtE Prague	WtE Liberec	WtE Brno
Glass	14-23	9-12	15
Ceramics and porcelain	2.0-5.0	2.0-3.0	3.6
Unburned org. matter	0.2-0.6	0.5-1.0	0.2
Magnetic fraction	11-16	14-17	10
Ferrous scrap	8.5-10.5	6.0-7.0	11
Non-ferrous metals	1.6-2.2	1.3-1.5	2.8
Residual fraction	20-26	25-29	21
Particles < 2 mm	30-35	33-36	36.8

Material analysis of IBA

2015-2016

Negotiation with construction companies

2018

Pilot plant operation and testing

2018-2019

New legislation is valid

07/2021

Construction of demonstration road with IBA

2022-2023

Full implementation of modern IBA treatment

2024-2025

2017

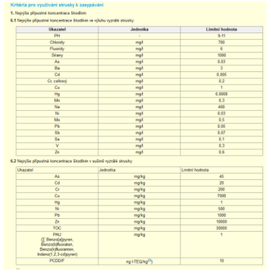
NFe recovery pilot plant construction started

2018

CAS+DWS started negotiation with Ministry of Environment

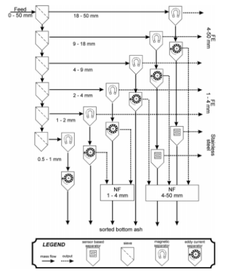
2020

Proposal of technical and environment al criteria for IBA utilization



10/2021

Feasibility study for IBA treatment plant



2022-2023

Real scale plant construction

Systematic approach to research – Recovery of heavy non-ferrous metals (HNFe) from bottom ash fine fraction

- Characterization of fine fraction via advanced methods (TESCAN TIMA)

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- State-of-the-art analysis

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- Project proposal - beyond state-of-the-art for minerals and HNFe metals recovery from IBA fines

H2020 ERA-MIN2 - Novel methods for enhanced recovery of metals and minerals from fine incineration ash

Term 10/2020-09/2023, overall budget 2.4 mil. EUR

Consortium 2 industrial partners Pražské služby (CZ), Indaver (B), 4 academia partners ICPF (CZ), LEPMI (FR), INSA (FR), VITO (B)

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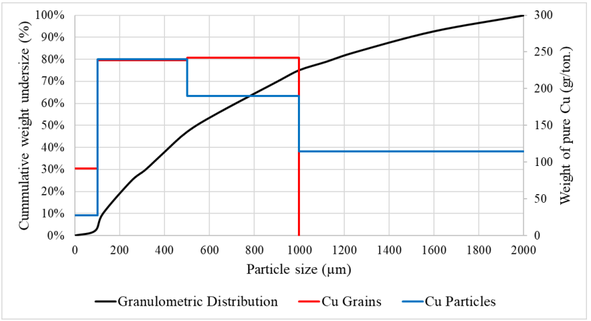
Research results – Cu up-concentration by wet shaking table to the product with 300 g Cu/kg



(%)	<0.5 mm	0.5-2 mm
Native copper	75.4	41.3
Bronze and brass	12.5	39.8
Oxides, chlorides and other phases	7.5	11.6
Glass and silicate phases	4.1	3.8
Other Cu bearing alloys	0.04	2.8
Phosphates, sulphates and carbonates	0.5	0.7
Copper content (mg/kg)	6 270	4 640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Review

Metal recovery from incineration bottom ash: State-of-the-art and recent developments

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Fly ash treatment and utilization

We focus on **systematic research of fly ash/APCr utilization with respect to circular economy**

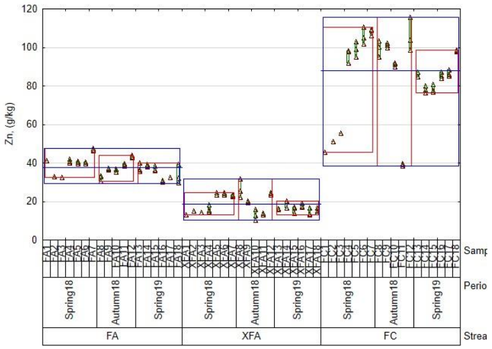
- Flue gas cleaning system analysis and determination of its effect on fly ash/APCr composition and properties

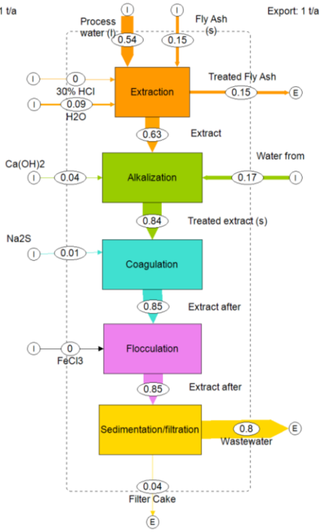
- Analysis of recovery potential and treatment methods

- R&D project proposal formulation
- Formulation of technological concept and lab-scale and semi-pilot scale verification

- Technological development and impact analysis within WtE plant environment

- Techno-economical evaluation and LCA





Fly ash treatment and utilization – 2 case studies

Prague WtE plant

- APCr from calcium based wet scrubbing system with spray dryer

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- Removal of hazardous properties
- Recovery of gypsum, salts and metals

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- Lab-scale verification and impact analysis

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- Pre-feasibility study and techno-economical assessment

Termizo WtE plant

- Fly ash from three step wet scrubbing system with caustic soda

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- FLUWA technology optimization and modification – Hg removal, acid extraction optimization, gypsum, Zn and salts recovery, mineral matrix utilization

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- Zero waste production
- Semi-pilot scale verification in WtE plant environment

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- Pre-feasibility study and techno-economical assessment

Systematic research - Mercury removal

- Analysis of mercury speciation and behavior in flue gas → crucial for effective capture

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- Development of new methods for mercury capture
- Proposal of mineral-based sorbents for mercury capture under high temperature
- Patented electrochemical method for mercury capture in wet scrubbing system

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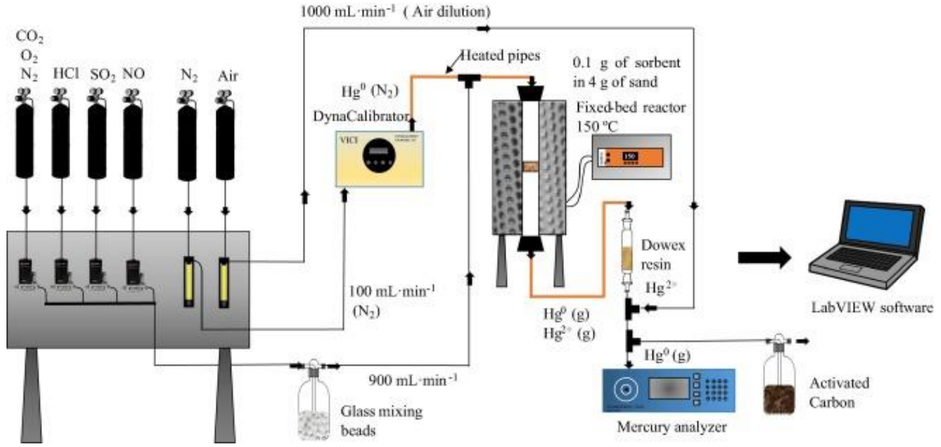
- Mercury removal upscaling and verification
- Technical consultation for plant operators
- Analysis of methods for Hg removal, analysis of Hg behavior in flue gas cleaning system



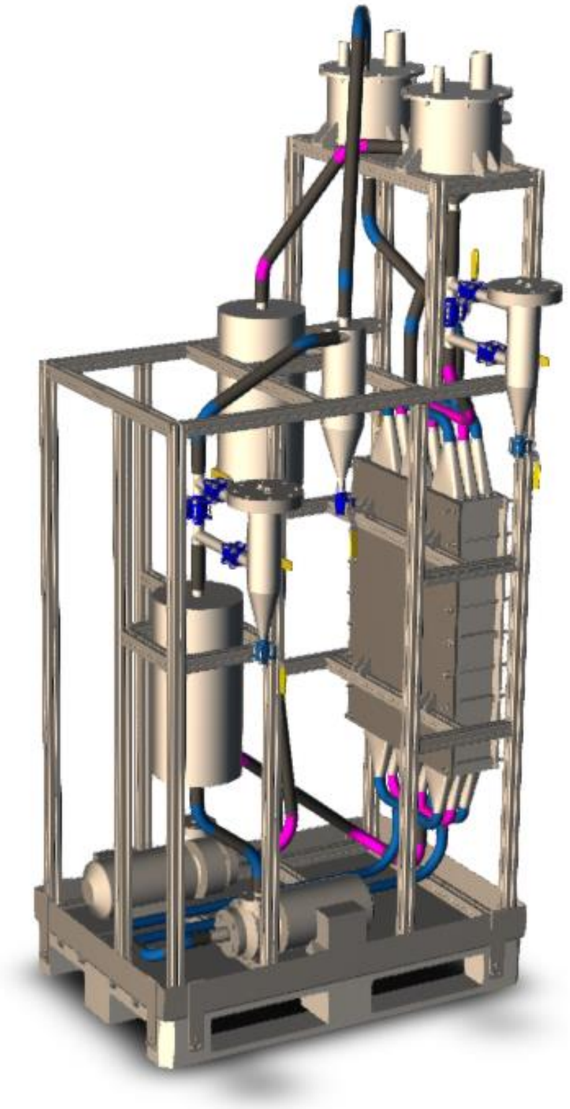
Selected results

Svoboda et al. Possibilities of Mercury Removal in the Dry Flue Gas Cleaning Lines of Solid Waste Incineration Units. J. Envi Manag, 2016, 166, 499-511, IF=4.01, 21 citation
Rumayor et al., Mitigation of gaseous mercury emissions from waste-to-energy facilities: Homogeneous and heterogeneous Hg-oxidation pathways in presence of fly ashes, J. Envi Manag, 2018, 206, 276-283, IF=4.865, 19 citation
Rumayor et al., Mercury Removal from MSW Incineration Flue Gas by Mineral-based Sorbents. Waste Management, 2018, 265-270, IF=5.431, 7 citation
Veselý et al., Process for isolating mercury from a solution and apparatus for carrying out the process. 2019, Patent No. 308148, protection CZ, D, AT, PL

Mercury removal – pilot plant construction/patent verification

New patented method, protected in CZ, DE, AT

- electrochemical removal of Hg in wet scrubbing system with simultaneous oxidation of Hg^0 for coal firing power plants,
- method is using salinity of suspension for Hg capture → lower production of wastes and low operation costs,
- pilot plant is under construction in Chvaletice power plant,
- results will be used for feasibility study.



Membrane-based Carbon Capture

- Technology development and experimental verification of membrane based GHG separation

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- Detailed knowledge of limits and benefits of technology

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- Mathematical modelling of multistage process

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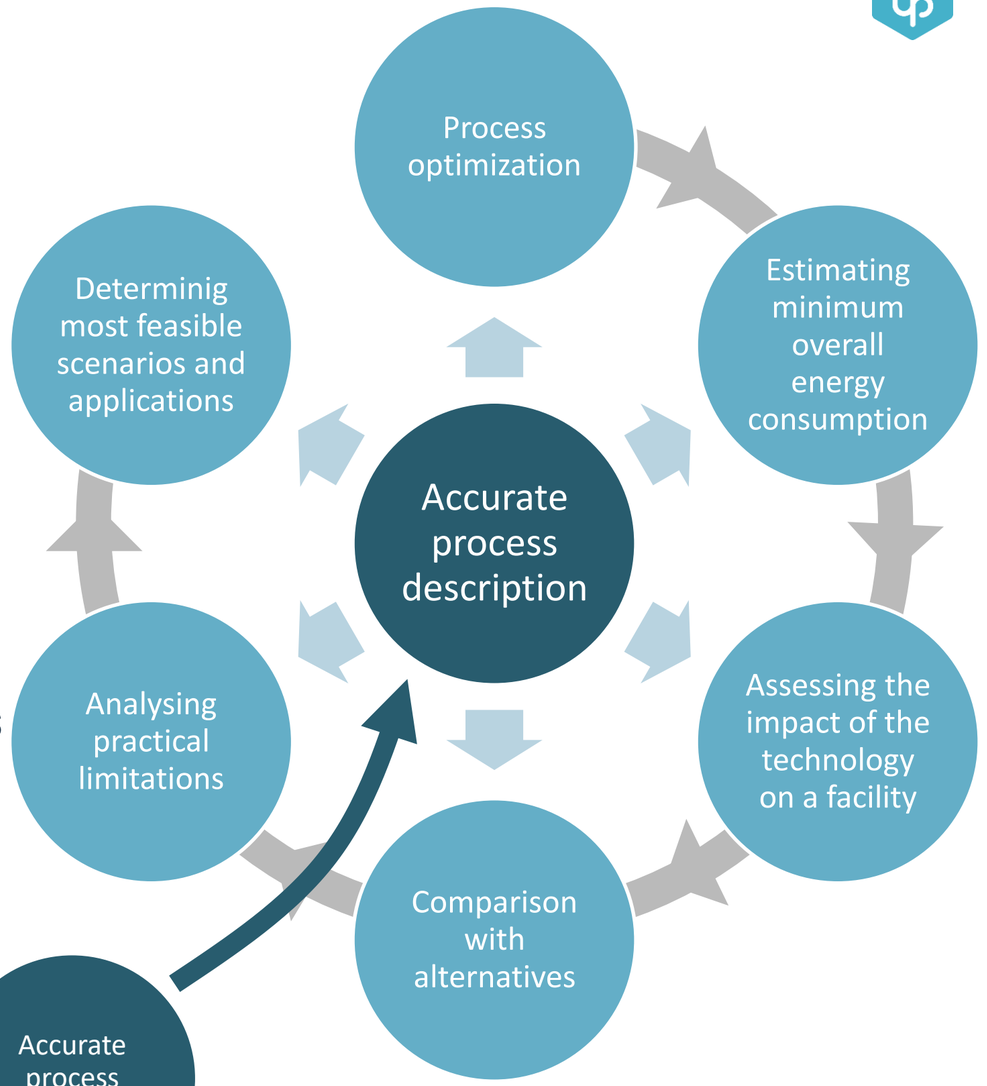
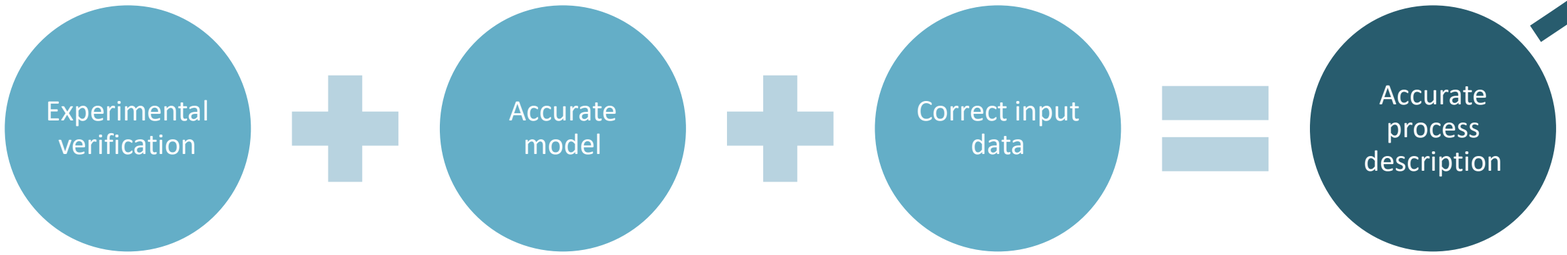
- Case studies for real scale plant, environmental, economic and energetic impact assessment and analysis

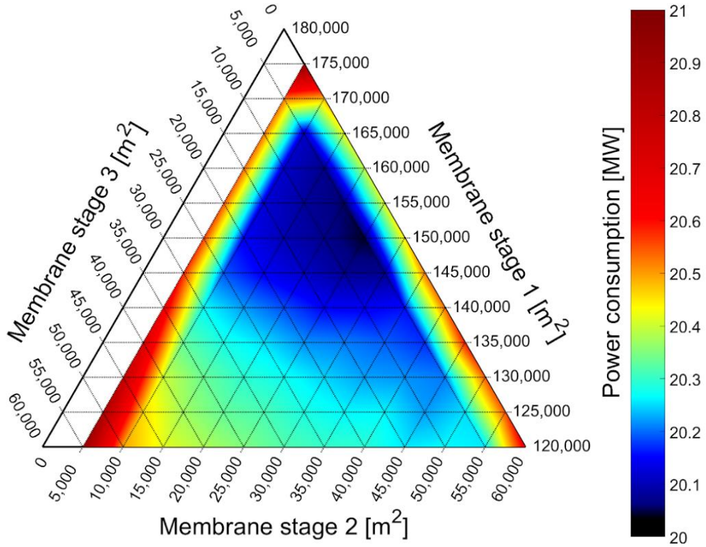




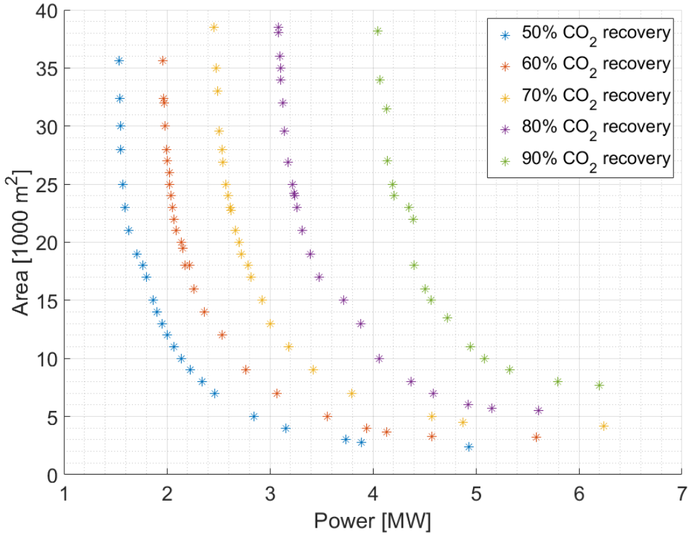
Membrane-based Carbon Capture

Case studies for WtE plant:

- analysis of technology integration for real-scale plant based on detailed technology knowledge and parameters sensitivity,
- mathematical modelling and calculations of:
  - multi-stage processes and GHG separation efficiency
  - energy consumption and requirements
  - overall impact assessment (area, flue gas cleaning system, etc.)



Stage area optimization - WtE plant with the capacity of about 300 kt of MSW/year



Impact of total membrane area and CO_2 recovery - WtE plant with the capacity of 100 kt of MSW/year

Research background for Czech Ministry of Enviroment

Project Centre of Environmental Research Waste management, circular economy and environmental security:

- Partnership of 8 research organization,
- Project serves as background for Ministry of Environment for transition to Circular economy,
- Combination of data treatment, MFA, technology analysis and development, legal framework analysis, current state and practise, etc.
- We focus solely or in cooperation with partners on:
  - textile wastes,
  - municipal sewage sludge,
  - WEEE,
  - plastics treatment,
  - mineral wastes and metal bearing wastes,
  - monitoring of waste circularity in Czech Republic, etc.

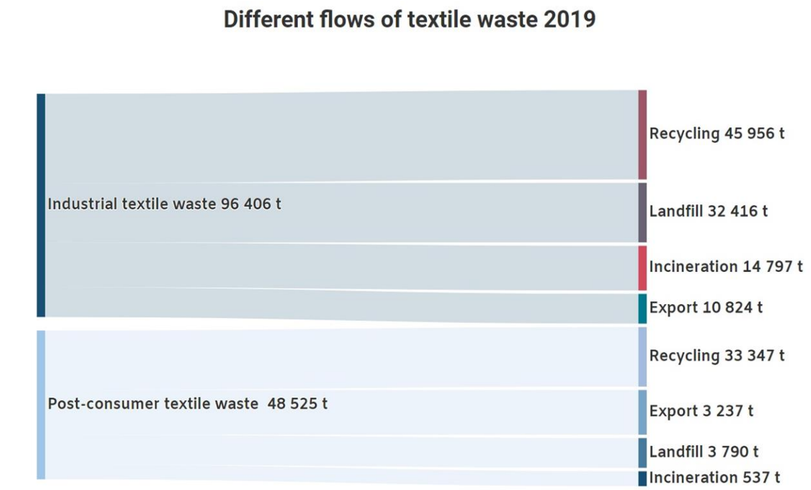
CEVOOH

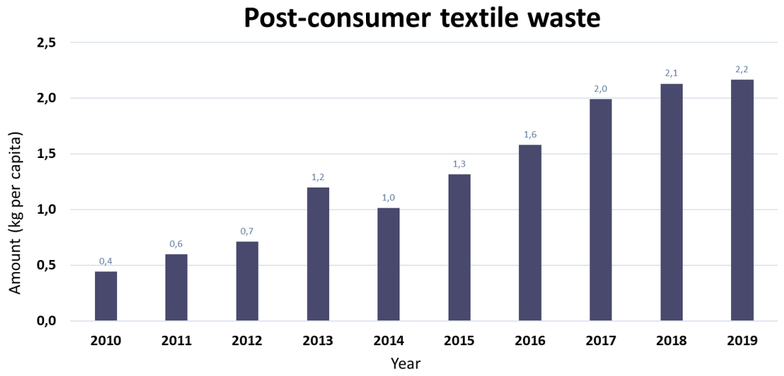
Analysis of textile waste streams in the Czech Republic

- Current state analysis for textile waste streams
- Analysis of material streams and flow (MFA)
- To analyze possible toxic impacts of the textile industry and textile waste
- Cooperation with the Association of Textile-Clothing–Leather Industry in the Czech Republic.
- Participating in EURATEX project - the European Apparel and Textile Confederation.

- Proposal of effective collection system for textile waste and textile waste treatment and recycling

- Cooperation with industrial partners for the development of re-use/recycling methods





Sewage sludge treatment

- Experimental research of sewage sludge incineration, co-incineration, thermochemical treatment and pyrolysis (lab-scale/semi-pilot/real scale level)

- Knowledge of sludge treatment and phosphorus recovery methods

- Data treatment and MFA for current ways of utilization

- Analysis of sewage sludge utilization impact (nutrition values, contamination incl. emerging pollutants like PFAS, treatment methods effect, etc.)

- Proposal of legal framework with respect to WWTP size and character

	EVO	Odstranění	MVO	Ostatní –	Předání	Celkem
nad 500 000 EO	111	–	79 500	–	5 134	**84 745**
Podíl v %	*0,13%*	–	*93,8%*	–	*6,06%*	–
100 000 – 499 999 EO	–	–	84 510	1 400	164 413	**250 323**
Podíl v %	–	–	*33,8%*	*0,56%*	*65,7%*	–
40 000 – 99 999 EO	–	–	69 554	23 301	161 022	**253 877**
Podíl v %	–	–	*27,4%*	*9,18%*	*63,4%*	–
10 000 – 39 999 EO	–	99,1	141 865	7 883	241 520	**391 368**
Podíl v %	–	*0,03%*	*36,2%*	*2,01%*	*61,7%*	–
Celková	**111**	**99,1**	**375 429**	**32 584**	**572 089**	**980 312**
Celkový podíl v %	**0,01%**	**0,01%**	**38,3%**	**3,3%**	**58,4%**	–

EVO energetické využití odpadů
MVO materiálové využití odpadů

	KAL 1	KAL 2	KAL 3	KAL 4	KAL 5	KAL 6	KAL 7	KAL 8	KAL 9	KAL 10	KAL 11	KAL 12 (kořenová čistírna)
	< 2 000 EO	< 2 000 EO	2 – 10 000 EO	2 – 10 000 EO	10 – 40 000 EO	10 – 40 000 EO	40 – 100 000 EO	40 – 100 000 EO	100 – 500 000 EO	100 – 500 000 EO	> 500 000 EO	< 2 000 EO
∑ 37 PFASs (ng.g^{-1} DM)	34,8	39,7	83,3	67,9	46,2	80,4	43,6	75,3	55,2	337,8	88,0	31,9

Contractual research and subcontracts

- Analysis of gas formation and kinetics during various fly ash extraction for safety measure and process risk assessment – **HALOSEP project simulation,** Stena Recycling,
- Waste characterization and leaching – batch tests, tank test, pH stat, etc. – subcontract for DWS, Stena Recycling, AFATEK, etc.,
- Waste classification – hazardous vs. non-hazardous waste,
- Zn wastes leaching and conditions – subcontract for engineering company for pre-feasibility study,
- Feasibility study - bottom ash treatment plant for NFe metals recovery, various approach evaluation, economic model, effect of capacity etc. – contract for Prague WtE plant,
- POPs formation and behaviour in combustion, emissions and environmental impact – contract for WtE plant investor,
- Etc.