



OULUN YLIOPISTO
UNIVERSITY of OULU

MASS AND HEAT TRANSFER PROCESS LABORATORY

ANNUAL REPORT 2006

Edited by
Mika Huuhtanen, Eva Pongrácz and Liisa Kangasharju

Back cover:
Laboratory staff, photo by Mikko Nelo

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Mass and Heat Transfer Process Laboratory
Annual Report 2006

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Preface

The Mass and Heat Transfer Process Laboratory is one of the founding laboratories of the Department of Process and Environmental Engineering. The first professor in the laboratory was Professor Jorma Sohlo from 1967 to 2000. During his period, the main research areas were heat and mass transfer, and separation processes. Professor Sohlo also introduced bioprocess engineering in the late 1980's to the Department. At the time of his retirement, the Bioprocess Engineering Laboratory was already established, which presently focuses on teaching and conducting research in bioprocess engineering. However, research in the field of food processing and utilization of biomass in product and energy production are active research areas also in the Mass and Heat Transfer Process Laboratory.

Since 2001, Prof. Riitta Keiski has been the professor in mass and heat transfer process engineering. Research and teaching in catalytic processes, reactor analysis and design, green technologies and research methodology have been included into the laboratory's activities. Surface phenomena, environmental and process catalysis, fluid dynamics, heat transfer, fouling of surfaces, food processing, separation processes to recover valuable compounds from waste and biomaterial, Waste Management Theory, Industrial Ecology Theory, waste minimisation and resources use optimisation have become an important part of the laboratory's research profile. Research in our laboratory is now conducted under the following thematic areas: Physical-, chemical- and biochemical phenomena in multiphase and multicomponent systems; Sustainable production and products; Process development and design; Treatment and utilization of industrial by-products and wastes; and Researcher training.

The strategy process of the laboratory was initiated in 2002. The first joint laboratory strategy in education and research was finalized in May 2003 and the second one in 2006. The new strategy was made according to the instructions given by Finnish Founding Agency for Technology and Innovation (Tekes). To describe the strategic expertise of our laboratory, the technology pyramid was built. It shows our spearhead, international level research; cutting edge research, which has national scale intensity; key technologies, where we have traditional, strong knowledge and research experience; as well as related technologies and expertise we rely on and draw from our partners. The strategy process is continuing in sync with the Departments on-going strategy work and the University's new strategy for 2007-2009.

The laboratory is doing research cooperation with VTT, METLA, Helsinki University of Technology, Tampere University of Technology, Lappeenranta University of Technology and Åbo Akademi University. Several industrial partners are participants in the projects listed in this report, funded by Tekes and the Academy of Finland.

The list of projects running in 2006 include ReGenGas (until 2007), KEMLIKA (until 2006) and ODORA (until 2007) funded by Tekes as well as CO2UTIL (until 2010), Novel approach to prevent and avoid WEEE (until 2006), Chemical waste minimization and effluent recycling (until 2008) and Automotive exhaust gas catalysis (until 2007) financed by the Academy of Finland. In addition, the research of our doctoral students was supported by full or half a year research grants of the Maj and Tor Nessling, Alfred Kordelin and Walter Ahlström foundations, and also by smaller personal grants from other foundations.

In 2006, the laboratory has been active in developing the contents of study courses. Since the teaching load of the Laboratory is quite extensive (27 Credits points, or 37.5 ECTS), also researchers are teaching in courses close to their research fields, e.g. in catalysis, separation processes, waste minimisation and resources use optimisation. The staff has improved its teaching skills by taking part in pedagogical studies. As earlier, the laboratory has arranged one annual post-graduate course. In April 2006, the Waste minimisation and resources use

optimisation course was arranged under the aegis of the Graduate School in Environmental Science and Technology.

The Laboratory participated in three Graduate Schools financed by the Ministry of Education: the Graduate School in Chemical Engineering (GSCE), the Graduate School in Environmental Science and Technology (EnSTe) and the Graduate School on Functional Surfaces (GSFS) and had a Ministry of Education position in each of them. The researchers and advisors have also participated in the activities of the Graduate School in Energy Technology, the Multidisciplinary Environmental Graduate Net School at the University of Oulu (EnviroNet) and the JOPOKKI Graduate School of the Department of Process and Environmental Engineering. The Head of the laboratory has also taken an active part in the design and evaluation of the Finnish Graduate School system (Academy of Finland activities).

Nine (9) foreign scientists visited the laboratory in 2006 (one post-graduate student and eight doctors or professors). The visiting periods were from two days to six months. The visitors came from France, China, Russia, Hungary, UK and Australia. Two foreign students from universities in France came to do their practical training period (from 5 to 6 months) in our laboratory. The student exchange has been the most active with the EPF – Engineering School and University of Orleans in France during the past years. Partners in post-graduate and post-doctoral level research and education are found also from the United Kingdom, USA, Hungary, France, Russia, Norway and Sweden.

The laboratory staff has also been actively working abroad as visiting researchers and scientists. Prof. R. Keiski was invited to a CNRS visiting professor post in 2005. She spent two weeks of this period at the University of Bourgogne, Dijon and University of Poitiers, Poitiers, France in July 2006. M.Sc. Veronica Garcia has conducted research at the University of Cantabria in Santander, Spain for 4 months; D.Sc.(Tech.) Satu Ojala visited the University of Poitiers in Poitiers, France and the University of Kaunas, Kaunas, Lithuania for four months and M.Sc. Nora Pap conducted experiments at the University of Szeged, Szeged, Hungary for a month in 2006.

The laboratory has improved its results in research and education. This is seen e.g. in the number and quality of publications and in enhanced national and international collaboration. Two doctoral theses were defended in 2006. The collaboration inside the Department has become increasingly important and the demand for more focused approach in research has been realized via the strategy work. The Laboratory is a member in the newly founded Centre for Advanced Steel Research, CASR. It also made the first plan for the Centre of Excellence in Air Industry Cluster and participated in the design of Water in Processes Center (CWP) and in establishing activities related to Mining industry. Improving the quality of education and the pedagogical skills of teachers are activities that are taken into account in our everyday work. Publications are done not only in research but also in the design and testing of teaching methods and new courses.

The Head of the Laboratory, Prof. Keiski has started as the Provost for Education and the Vice-rector of the University of Oulu on August 1st, 2006. This has brought new responsibilities for the whole research and teaching staff of the Laboratory. Prof. Keiski continued her work at the Academy of Finland until the end of the year 2006. She also acted as the Head of the Industrial Environmental Engineering Unit of the Department.

The Laboratory would like to thank all the partners in Academia and Industry, both in research and education, in Finland and abroad, for the invaluable cooperation, for sharing the researcher's and teacher's identity, and for encouragement.

As the Head of the Laboratory, I would like to express my deepest gratitude to all the members of our group. The atmosphere and attitude in the Laboratory towards higher education, research and industry-academia cooperation, as well as with respect to sharing responsibility, has been supportive and inspiring.



Riitta L. Keiski
Professor,
Head of the Mass and Heat Transfer Process
Laboratory

Personnel

Professors

Keiski, Riitta Liisa Sohlo, Jorma	D.Sc.(Tech.), Docent, Head of the Laboratory Professor emeritus
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Laboratory Manager

Muurinen, Esa	D.Sc.(Tech.)
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Secretary

Kangasharju, Liisa	from 7.8.2006
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Docent

Lassi, Ulla	D.Sc. (Tech.)
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Senior Assistant

Ainassaari, Kaisu	Lic.Sc.(Tech.)	1.1.-31.8. & 1.11.-31.12. 2006
Myllykoski, Liisa	Lic.Sc.(Tech.)	on leave
Tuomaala, Eero	M.Sc.(Eng.)	1.9.-31.10.2006

Assistants

Husu, Tiina	M.Sc.(Eng.)	on leave
Lenkkeri Ritva	Lic.Sc.(Tech.)	
Tuomaala, Eero	M.Sc.(Eng.)	1.1.-31.8. & 1.11.-31.12.2006
Ylönen, Reeta	M.Sc.(Eng.)	1.9.-31.10.2006

Researchers

Ainassaari, Kaisu	Lic.Sc.(Tech.)	1.9.-31.10.2006
García, Verónica	M.Sc.(Chem.)	
Huuhtanen, Mika	M.Sc.(Eng.)	
Kolli, Tanja	D.Sc.(Tech.)	on leave 1.6.-31.12.2006
Kröger, Virpi	M.Sc.(Eng.)	
Laitinen, Tiina	M.Sc. (Eng.)	
Landaburu-Aguirre, Junkal	M.Sc.(Chem.)	
Ojala, Satu	D.Sc.(Tech.)	
Oravisjärvi, Kati	M.Sc.(Env.Sci.)	
Pap, Nora	M.Sc.(Food Eng.)	
Pirilä, Minna	M.Sc.(Chem.)	from 1.9.2006
Pongrácz, Eva	D.Sc.(Tech.)	
Pääkkönen, Tiina M.	M.Sc.(Eng.)	
Raudaskoski, Riitta	M.Sc.(Eng.)	
Riihimäki, Markus	M.Sc.(Eng.)	
Turkki, Auli	M.Sc.(Nutr.)	
Turpeinen, Esa	M.Sc.(Eng.)	
Turunen, Helka	M.Sc.(Eng.)	
Väisänen, Virpi	M.Sc.(Eng.)	
Ylä-Mella, Jenni	M.Sc.(Eng.)	
Ylönen, Reeta	M.Sc.(Eng.)	on leave 17.1-31.8.2006

Technical Support Staff

Penttinen, Jorma	special laboratory master
Koskenkorva, Ismo	laboratory master
Matilainen, Hannu	laboratory master

Research Assistants

Heikkinen, Alli	M.Sc.(Eng.)	1.1.-30.6.2006
Pietikäinen, Mari	M.Sc.(Eng.)	1.1.-30.6.2006
Pitkäaho, Satu	student	



Members of staff after the defence ceremony of Mika Huuhtanen

Foreign Visitors

Visiting Researchers

Ballivet-Tkatchenko, Danielle (<i>France</i>)	Prof.	5.-7.9.2006
Chaoxing, He (<i>China</i>)	Ph.D.	18.-22.10.2006
Kuchеров, Alexei V. (<i>Russia</i>)	Ph.D.	15.5.-5.6.2006
Miklósi, Péter (<i>Hungary</i>)	M.Sc.(Eng.)	6.10.2006-31.3.2007
Picquet, Michel (<i>France</i>)	Ph.D.	5.-7.9.2006
Sinev, Ilya (<i>Russia</i>)	Ph.D.	21.5.-10.6.2006
Vatai, Gyula (<i>Hungary</i>)	Prof.	5.-14.5.2006

Guest Lecturers

Coskeran, Thomas (<i>UK</i>)	Ph.D.	3.-7.4.2006
Dale, Pat (<i>Australia</i>)	Prof.	21.-22.8.2006

Exchange Students

Fauquet, Sylvain (<i>France</i>)		1.4.-25.8.2006
Saliou, Olivier (<i>France</i>)		9.1.-25.6.2006

Education

Courses offered by the Mass and Heat Transfer Process Laboratory in 2006:

Undergraduate Courses

470619A Fluid Mechanics

Credit points: 2

Lecturers: Assistant Eero Tuomaala
Researcher Tiina M. Pääkkönen and Assistant Reeta Ylönen

470620A Heat Transfer

Credit points: 2

Lecturer: Assistant Eero Tuomaala

470621A Mass Transfer

Credit points: 2

Lecturers: Senior Assistant Kaisu Ainassaari
Researcher Esa Turpeinen

470325A Laboratory Exercises of Mass and Heat Transfer

Credit points: 2

Advisors: Senior Assistant Kaisu Ainassaari
Assistants Eero Tuomaala, Ritva Lenkkeri and Reeta Ylönen

470323A Separation Processes

Credit points: 3

Lecturers: Professor Riitta Keiski
Senior Assistant Kaisu Ainassaari

470222A Reactor Analysis and Design II

Credit points: 3

Lecturers: Professor Riitta Keiski
Assistant Ritva Lenkkeri

470302S Multicomponent Separations

Credit points: 3

Lecturers: Laboratory Manager Esa Muurinen
Senior Assistant Kaisu Ainassaari

470303S Fluid Dynamics

Credit points: 2

Lecturers: Laboratory Manager Esa Muurinen
Assistant Eero Tuomaala

470326S Special Work on Mass and Heat Transfer

Credit points: 1

Lecturer: Senior Assistant Kaisu Ainassaari

470226S Catalytic Processes
Credit points: 3
Lecturers: Professor Riitta Keiski
Assistant Ritva Lenkkeri
Researchers of the laboratory

480311S Research Methodology
Credit points: 2
Lecturers: Professor Riitta Keiski
Researchers Mika Huuhtanen and Jenni Ylä-Mella

480360S Environmental Catalysis
Credit points: 3
Lecturers: Professor Riitta Keiski
Assistant Ritva Lenkkeri
Researchers of the laboratory

Post-graduate Courses

Waste minimisation and resources use optimisation

April 3. – 7., 2006

Credits: 3 + (5-7) cr. (theory + exercise)

Funded by:

Finnish Graduate School in
Environmental Science and Technology
University of Oulu, Faculty of
Technology
Thule Institute, Global Change
programme

Course organizer, examiner, exercise supervisor:

Dr. Eva Pongrácz



Dr. Thomas Coskeran supervising waste minimisation
exercise work

Lecturers:

Prof. Riitta Keiski
Prof. Marja Lajunen, University of Oulu, Department of Chemistry
Prof. Harri Haapasalo, University of Oulu, Department of Industrial Management
Dr. Thomas Coskeran, John Moores University, Liverpool, UK
Doc. Jouni Korhonen, University of Tampere
Doc. Pekka Oinas, KemFine Ltd, Finland
Dr. Hannu Nurmesniemi, Stora Enso Oyj
Dr. Eva Pongrácz
Dr. Juha-Pekka Snäkin, Oulu Polytechnic, School of Renewable Resources
Sakari Pulakka, VTT, Building, built environment
Seppo Haimi, SKJ-Yhtiöt Oy

An intensive, one week seminar on the theory, practice of waste minimisation and resources use optimisation. The concepts of waste minimisation and resource use optimisation, as well as related concepts such as Industrial Ecology, eco-efficiency, lean production, green chemistry

and engineering were clarified. Relevant legislative issues were also introduced. State of the art waste minimisation tools, as well as industry case studies were presented. For the practical part, the use of waste mapping tools of the Envirowise Environmental Technology Best Practice Programme were tested in industry and institutes. Envirowise is a government funded organization in the UK that helps companies to become more competitive through improving their environmental performance by reducing waste at source. Environmental Performance Guides provide companies with the tools that allow them to measure and improve their performance. Good Practice Guides describe how practical, cost-saving measures to reduce waste can be put into action.

Contents:

The course content is divided into three themes:

- Introduction of key concepts
- Tools of waste minimisation (waste mapping, lean production, green chemistry, green engineering, design for resource efficiency)
- Waste minimisation in industry (chemical industry, pulp and paper industry, metallurgy industry, agriculture, construction)

Realization: Lectured in English.

Lecture material available at: http://cc.oulu.fi/~polamwww/wasmin_mat_Eva.pdf

Research

The main strategic research objective of the laboratory is to generate new knowledge for the development of sustainable production processes and products. The laboratory's research subjects can be divided under 5 headings:

- 1) Physical-, chemical- and biochemical phenomena in multiphase and multicomponent systems;
- 2) Process development and design;
- 3) Sustainable production processes;
- 4) Treatment and utilization of industrial by-products and wastes; and
- 5) Researcher education.

Mass and heat transfer, fluid dynamics (CFD), surface science studies, process and environmental catalysis, separation science (membranes and adsorption materials) and waste management (chemical- and food industry applications and recycling of electronic waste) have been the main focus areas. The methods used were experimental (laboratory, bench and pilot scale studies), theoretical (Waste Management Theory) and computational (thermodynamics, CFD, kinetic modelling, molecular modelling). The following technology pyramid illustrates the laboratory's strategic expertise areas and key technologies.



The technology pyramid of the Heat and Mass Transfer Process Laboratory

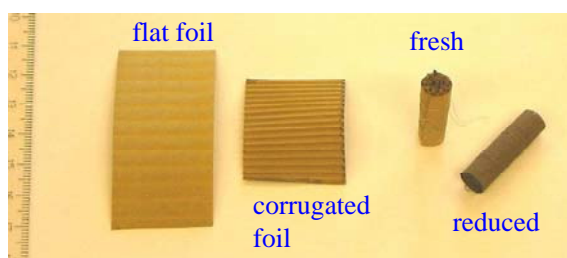
Research projects

During 2006, the Laboratory was involved in the following research projects (in alphabetical order):

Automotive Exhaust Gas Purification

Researcher: M.Sc.(Chem.) Tanja Kolli
Supervisor: Prof. Riitta Keiski
Advisor: D.Sc.(Tech.) Katariina Rahkamaa-Tolonen (Ecocat Oy)
Funding: Academy of Finland, Alfred Kordelin Foundation
Duration: 1.1.2000 – 30.6.2006

The project aimed at improving the understanding of the reactions occurring on the surfaces of precious metal exhaust gas purification catalysts. Several Pd/Al₂O₃-based automotive exhaust purification catalysts were studied to understand CO and hydrocarbon oxidation, as well as NO reduction mechanisms. The results obtained by FT-IR technique, BET, CO chemisorption, dynamic OSC, and XRD measurements were utilised in finding correlation between reactions. The behaviour of OSC and barium oxide (BaO) on Pd/Al₂O₃-based catalysts was also studied.



Exhaust gas catalysts

Catalysts for experimentation were selected and prepared in co-operation with Ecocat Oy. To improve oxygen storage capacity (OSC), the substrates contained, besides Al₂O₃, e.g. rare earth and transition metal oxides. Additionally, recent literature on NO-hydrocarbon-CO-O₂ adsorption and reaction on precious metal catalysts were reviewed.

The research work was published in May 2006 in an Academic Dissertation titled "Pd/Al₂O₃-based automotive exhaust gas catalysts: The effect of BaO and OSC material on NO_x reduction". The thesis contains five articles published in Topics in Catalysis, Catalysis Today and Applied Catalysis A: General.

Catalytic Materials: Characterization and Control of the Surface Poisoning Phenomena

Researcher: M.Sc.(Eng.), M.Sc.(Econ.&Bus.Adm.) Virpi Kröger
Supervisor: Prof. Riitta Keiski
Advisors: D.Sc.(Tech.) Esa Muurinen, Doc., D.Sc.(Tech.) Ulla Lassi
Funding: Graduate School on Functional Surfaces (GSFS), Academy of Finland
Duration: 1.1.2003 – 31.12.2006

Poisoning and contamination of catalytic surfaces is a serious problem in chemical processes and in air pollution control. The aim of the project was to obtain molecular-level knowledge on poisoning of automotive catalysts, containing precious metals, oxides, and zeolites. Development of catalysts that are able to maintain their activity at high temperatures and in the presence of poisons is a very challenging research area. Yet, it is also the most environmentally benign and economic way to cope with the problem. In this project, the basic phenomena behind catalyst poisoning were studied. Attention was paid to the effect of phosphorus (a common oil-derived impurity found in catalysts) on different catalyst components. The research was carried out in co-ordination with the Institute of Materials Science at Tampere University of Technology and the Laboratory of Physics at Helsinki

University of Technology. The industrial advisor in the project was Ecocat Oy. The research work conducted in the Mass and Heat Transfer Process Laboratory focused on combining information produced using different catalyst characterization and surface science techniques. Three manuscripts were submitted for publication in the Topics in Catalysis journal.

Carbon Dioxide and Methanol Refining, Recovery and Utilization in Pulp and Paper Mills

Researcher: M.Sc.(Eng.) Tiina Laitinen
Supervisor: Prof. Riitta Keiski
Funding: Walter Ahlström's foundation
Duration: 1.1.2005 –

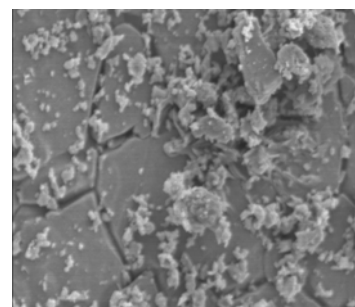
One of the most important environmental challenges is climate change. Carbon dioxide (CO₂) emissions from fossil fuel and peat combustion in Finnish pulp and paper mill were about 5.5 million tonnes in 2002. In pulp mills, the purest CO₂ is formed in the lime sludge reburning kiln, where caustic sludge (CaCO₃) is heated to lime (CaO). Presently, CO₂ is released to the atmosphere, however, CO₂ could be utilized in the pulp and paper manufacture, e.g. in pulp washing and pH controlling. Currently CO₂ is purchased from a gas factory because utilisation of refined carbon dioxide in the pulp and paper process has not yet been investigated.

Methanol is the single largest source of volatile organic compound (VOC) emissions from the Kraft pulp mill. Methanol is formed during the pulping of wood and methanol is collected from the evaporating process. The amount of methanol in the pulping process is about 6–13 kg/t of pulp, depending on the manufacturing process of the pulp. This methanol is contaminated with reduced sulphur compounds (mostly mercaptans); therefore, its conventional treatment option is incineration, resulting in an increase of atmospheric CO₂. In addition, methanol and mercaptans cause odour problems in the immediate environment of the pulp mill. Contaminated methanol, however, could be converted to formaldehyde, which is a valuable by-product. The aim of the research is to find out the advantages and disadvantages of using CO₂, methanol, and formaldehyde in pulp and paper mill; and study the production of formaldehyde from methanol contaminated with reduced sulphur compounds.

Chemical Fouling of Heat Exchangers

Researcher: M.Sc.(Eng.) Markus Riihimäki
Supervisors: Prof. Riitta Keiski, D.Sc.(Tech.) Esa Muurinen
Advisor: D.Sc.(Chem.) Eini Puhakka (VTT Processes)
Funding: Maj and Tor Nessling Foundation
Duration: 1.1.2004 – 31.12.2006

Fouling is a complex phenomenon caused by unwanted inorganic and/or biological material deposition to the surface of industrial equipment. Fouling produces different kinds of deposition layers onto heat-transfer surfaces causing ineffectiveness in heat exchange and an increase in flow resistance that leads to higher operating costs and increased investments. The aim of the research was to obtain new information via chemical engineering and surface science methods on fouling of heat exchangers. The reasons of fouling as a molecular phenomenon was explored and calculation tools for modelling fouling were developed, which can be connected to design equations of heat exchangers.



Fouling on a metal surface
(Magnification: x 5 000)

This consisted of models of particle and surface interaction forces by extended DLVO (Derjaguin-Landau-Verwey-Overbeek) methodology and models of crystallization by thermodynamics of aqueous electrolytes. Also a laboratory scale Fouling Test Apparatus was constructed, which simulates a heat transfer surface that is fouled in controlled conditions. The research will continue in FOULSURFACE ERA-Matera project during 2007-2009.

Chemical Waste Minimisation and Effluent Recycling by Separation Processes

Researchers: M.Sc.(Chem.) Verónica García, M.Sc.(Eng.) Tiina M. Pääkkönen
Supervisors: Prof. Riitta Keiski, D.Sc.(Tech.) Eva Pongrácz
Advisor: Prof. Paul S. Phillips (University of Northampton, UK)
Funding: The Ministry of Environment, The Academy of Finland, Maj and Tor Nessling Foundation, Thule Institute, EnviroNet, Foundation for Advancement of Technical Sciences, Oulu University Scholarship Foundation, Tauno Tønning Foundation, Oskar Öflund Foundation and Finnish Cultural Foundation
Duration: 1.11.2003 – 31.12.2008

Organic solvents are commonly present in chemical effluents and are considered hazardous because of their negative impacts on human health and the environment. Membrane operations such as Pervaporation (PV) can be utilized for waste minimisation through the recovery of these chemicals. The main aim of this work is to isolate the valuable compounds from chemical industry effluents for subsequent re-use as raw material. As a result, the need for virgin material would be decreased and also the hazard of chemical effluents would be lowered. The research is conducted in collaboration with the KemFine company.

Research has focused on studying the effects of process parameters such as temperature and flow rate, and membrane material used on the separation of organic solvents from synthetic binary mixtures. Further, the applicability of computational fluid dynamics for predicting PV process has been investigated. Co-operation has been initiated with the University of Cantabria (Santander, Spain), where the use of PV was studied during April-July 2006.

Environmental Best Practice Technologies in Food Industry for Waste Minimisation and Utilisation

Researcher: M.Sc.(Food Eng.) Nora Pap
Supervisors: Prof. Riitta Keiski, D.Sc.(Tech.) Eva Pongrácz
Advisor: Lic.Sc.(Tech.) Liisa Myllykoski
Funding: Graduate School in Chemical Engineering (GSCE)
Duration: 16.8.2003 – 30.7.2008

Natural and harvested berries are a good source of health-promoting compounds such as vitamins, flavonols and anthocyanins. A large part of these compounds is lost during processing of berries, such as cooking. The purpose of this research work is to develop a membrane-based technology to process berry juices. Ultrafiltration (UF) is used for sterilization and clarification and it is followed by reverse osmosis (RO) for the concentration of the juice. The results showed that UF combined with RO is a viable method for the concentration of blackcurrant juices from a total soluble solid content of 13 °Brix up to 23 °Brix, which is the expected range of the process.

During berry juice pressing, about 80% of the berry fresh weight is acquired as juice, and 20% stays behind as by-product that contains the peels, seeds and pulp. This by-product is rich in valuable compounds, especially anthocyanins. A novel method, microwave-assisted extraction (MAE) is investigated for the extraction of valuable compounds from this by-product. MAE is a

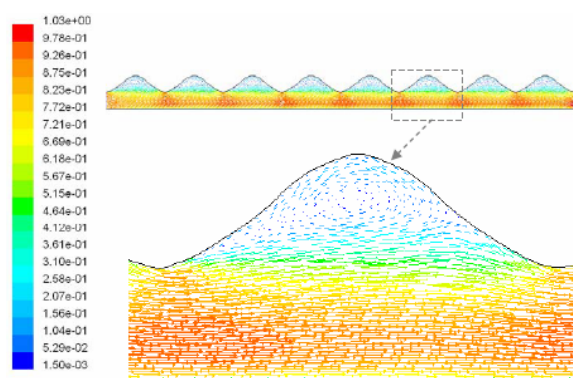
favourable technology compared with the traditional solid-liquid (S/L) extraction, as it gives a possibility to reduce extraction time, increase the concentration of the extracted compounds and use non-hazardous solvents, such as water instead of ethanol or methanol. MAE resulted in doubling of the monomeric anthocyanin pigment concentration, and a 2.85-times higher concentration of flavonols was achieved as compared with solid-liquid extraction, while the time of extraction was reduced from several hours to 20 minutes. MAE tests have been performed at the University of Szeged in Szeged, Hungary in July 2006.

Improving the Energy Efficiency of Processes; Control of Heat Exchanger Fouling

Researcher: M.Sc.(Eng.) Tiina M. Pääkkönen
 Supervisors: Prof. Riitta Keiski, D.Sc.(Tech.) Esa Muurinen
 Funding: Jenny and Antti Wihuri Foundation, Finnish Cultural Fund
 Duration: 1.6.2006 – 31.12.2009

Heat exchanger fouling – deposition of unwanted material to the heat transfer surface – is a significant problem in industry. Due to fouling, energy consumption and operation costs of heat exchangers are growing. By decreasing fouling of heat exchangers, the energy efficiency of processes could be improved.

This study is focused on crystallization fouling of plate heat exchangers. The aim of the study is to clarify both experimentally and computationally by CFD (Computational Fluid Dynamics) the interaction mechanisms of salts, which cause crystallization fouling. From the experimental results and mathematical model, which will be created during the research, fouling of heat exchangers can be predicted and, therefore, detrimental economic and environmental effects can be prevented.



Two-dimensional flow field of a plate heat exchanger calculated by turbulent model

The research is performed in close collaboration with M.Sc. (Eng.) Reeta Ylönen, who is studying particulate fouling, and with M.Sc. (Eng.) Markus Riihimäki.

Novel Approach to Prevent and Avoid WEEE of Nokia Corporations

Researcher: D.Sc.(Tech.) Eva Pongrácz
 Supervisor: Prof. Riitta Keiski
 Funding: Academy of Finland
 Duration: 1.10.2002 – 30.9.2006

During this project, the on-going effort of Waste Management Theory (WMT) development has progressed. The practical role of WMT in electronic waste management was explored. Attention focused on the definition of waste electronic and electric equipment (WEEE), and the effects of relevant waste legislations on producers. Relevant input was delivered in defining non-waste, recovery, and the boundary between recovery and disposal.

Collaboration with Nokia concentrated on the issue of material content of mobile phones, with regards to continuous improvements of their environmental performance, in particular phasing out hazardous materials.

Further to collaboration with an electronics recycler and producer cooperative, the issue of reuse of functional WEEE was explored. The WEEE Directive prescribes that priority should be given to the reuse of WEEE. This would, however, require citizen collaboration, and improvements in the logistics of the WEEE recovery infrastructure. Finally, research has been done in environmental education and motivation for an environmental considerate behaviour.

Odora: Abatement of Odorous and Harmful Emission Gases

Researchers: D.Sc.(Tech.) Satu Ojala, Ms Satu Pitkäaho, Lic.Sc.(Tech.) Kaisu Ainassaari
Supervisor: Prof. Riitta Keiski
Funding: Finnish Funding Agency for Technology and Innovation (Tekes)
Duration: 1.1.2006-31.12.2007



Collecting emission samples

The aims of the project are to develop technologies for simultaneous removal of odours and harmful compounds, to develop and verify measurement methods (analysis and sampling) of these compounds and to create new information on these purification technologies in collaboration with seven industrial partners involved with this project. Application of VOC abatement techniques (e.g. catalytic and thermal oxidation, absorption and hybrid techniques) to novel application areas, such as the abatement of organic emissions containing sulphur and chlorine, sets new challenges. Strict emission limit values and fugitive emission limits and also the fact that VOCs are often present in gas mixtures, makes the development of sampling and analysis a demanding task.

Odora is carried out as a collaboration project between the University of Oulu and Central Ostrobothnia University of Applied Sciences. The Odora project is also very important in researcher education. Ms. Satu Pitkäaho made her Master's thesis in this project in 2006. She and Lic.Sc.(Tech.) Kaisu Ainassaari are doing doctoral research in the project's subject area. D.Sc.(Tech.) Satu Ojala is doing her post-doctoral research period in this project and was a visiting researcher at the University of Poitiers in France from September to December 2006.

Particulate Formation in Combustion Engines: Control of Particulate Formation and their Health Effects

Researchers: M.Sc.(Env.Sci.) Kati Oravisjärvi, M.Sc.(Eng.) Mari Pietikäinen, Mr Olivier Saliou (France)
Supervisor: Prof. Riitta Keiski
Advisors: Prof. Juhani Ruuskanen (Univ. Kuopio), Doc., MD Arja Rautio (Centre for Arctic Medicine), Doc., D.Sc.(Tech.) Mauri Haataja (Oulu Polytechnic)
Funding: Maj and Tor Nessling Foundation, Walter Ahlström Foundation
Duration: 1.1.2005 – 31.12.2009

The aim of the project is to understand the formation of particulates in diesel and gas engines in order to control and reduce particulate emissions. The effect of catalysts on the changes of particulate composition and size is studied, as well as the health effects on humans and deposition of particulates in the respiratory system is analyzed. Physical and chemical properties of particles are important when evaluating their possible adverse health effects. Especially, fine particulates with a diameter smaller than 2.5 μm (PM_{2.5}) are considered to be harmful, and these particulates are generally emitted from the combustion processes of diesel and gas engines.

Tentative test runs of diesel engine have been done in the engine laboratory at Oulu Polytechnic. In addition, concentration and composition analysis of these measured particles have been done. Modelling of deposited dose of formed particles in virtual human lung system and literature search of particulates and their health effects have been done. In addition, modelling how different sizes of diesel particles penetrate in human respiratory system and body has been started. We are trying to find the similarities of models by using in drug research and particles formed in combustion processes in virtual pulmonary system.

The project is multidisciplinary, combining know-how from mechanical engineering, process and catalytic chemistry and environmental and health/medical sciences. The research is done in co-operation with the Department of Mechanical Engineering, the Department of Pharmacology and Toxicology, the Centre for Arctic Medicine, the Mass and Heat Transfer Process Laboratory of Oulu University, the engine laboratory of Oulu Polytechnic, Finnkatalyt Oy, and the Department of Pharmaceutics and Department of Environmental Sciences at University of Kuopio.

Photocatalytic Degradation of Methylene Blue over Titanium Dioxide Catalysts

Researchers: Lic.Sc.(Tech.) Ritva Lenkkeri, M.Sc.(Chem.) Minna Pirilä
Supervisor: Prof. Riitta Keiski
Funding: Kemira Oyj Oulu Research Centre
Duration: Autumn 2006

The aim of the project was to find out if powder photocatalysts could be bound to the surface of a support without the catalysts losing their activity. A general problem with photocatalysts is that they are usually powder materials and, therefore, difficult to separate from the solution. The photocatalytic performance of TiO₂ catalysts, both powders and granules, was studied by photocatalytic degradation of an organic model compound Methylene Blue in a batch photoreactor. The photoactivities of the granular materials were compared to those of powders and also to the physical properties of the materials.

Recovery of Heavy Metals from Chemical Effluents by Membrane Technologies

Researcher: M.Sc.(Chem.) Junkal Landaburu-Aguirre
Supervisors: Prof. Riitta Keiski and D.Sc.(Tech.) Eva Pongrácz
Funding: Maj and Tor Nessling Foundation, The Academy of Finland, Thule Institute
Duration: 1.2.2006 – 31.12.2009

Heavy metals constitute a major portion of the contaminants in chemical effluents and they cannot be degraded or destroyed. Heavy metals are dangerous due to bioaccumulation. In water bodies, they accumulate in sediment and organisms from where they may be transferred into the food chain. Due to their hazard to human health, heavy metals are targeted by international environmental legislation.

Recovery of heavy metals allows their later reuse and thus provides further economic and environmental benefits by contributing to reduced disposal costs and raw material requirements. Membrane processes provide a viable alternative for heavy metal recovery, as they can achieve high permeate fluxes and high rejection coefficients with low energy costs and under mild conditions. In addition, using membrane technology separation can be carried out continuously and membrane processes can easily be combined with other separation processes (hybrid processing). The main objective of the research is to establish the applicability of membrane technologies for the segregation of heavy metals from chemical

industry effluents. For this purpose, micellar-enhanced and polymer-enhanced ultrafiltration technologies are studied and implemented

Recycling of Waste Electrical and Electronic Equipment

Researcher: M.Sc.(Eng.) Jenni Ylä-Mella
Supervisors: Prof. Riitta Keiski, D.Sc.(Tech.) Eva Pongrácz
Funding: Graduate School in Environmental Science and Technology
Duration: 1.1.2003 – 29.2.2008

The implementation of European Council Directives on Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) are the result of a rising concern about the rapid growth in WEEE and the health risks posed by the hazardous content of WEEE. Electrical and electronic equipment contain a considerable number of materials, some of which can have diverse performance at the end-of-life (EOL) phase. Certain hazardous materials may cause problems in landfills but can also be recovered and recycled without posing hazard to human health and the environment. Therefore, a more closed-loop pattern of resources use is needed to reduce the total environmental impacts of WEEE.

The aim of this research is to promote waste prevention and resources use optimisation by the use of environmentally best practice (EBP) technologies for the recovery and recycling of WEEE. Material recovery and recycling do not only reduce the environmental impacts of waste disposal, but they also decrease the amount of virgin materials and energy used in production.

During 2006, legislative compliance and the achievements of the targets set by WEEE Directive in Finland have been surveyed. In particular, the functioning of the collection network and the state of art of WEEE recovery in the Oulu region have been evaluated.

ReGenGas: Hybrid Reforming Process for the Recycling of Greenhouse Gases and for Upgrading in Reduction and Combustion Processes

Researcher: M.Sc.(Eng.) Esa Turpeinen
Supervisors: Prof. Riitta Keiski and D.Sc.(Tech.) Esa Muurinen
Funding: Finnish Funding Agency for Technology and Innovation (Tekes)
Duration: 1.1.2005 – 30.04.2007



Direct reduction unit

The share of the worldwide emissions of CO₂ from energy production and metal manufacturing is estimated to be around 40-50 %. The solutions developed to decrease emissions in both industries have seldom been adaptable outside the target processes. Recycling of emission gases from combustion and reduction processes using reforming would contribute to closing material flows and reducing greenhouse gas emissions. The critical technological challenge in the circulation concept is to develop a hybrid process that connects energy-saving reforming, which has flexible raw materials, with the gasification of biomass. Experiments are conducted on laboratory equipment constructed for this project (see photo). The target is to verify the results that were calculated/simulated in an earlier project on closed gas circulation's reduction and combustion processes and utilisation of CO₂, (CO₂H₂), also funded by Tekes.

The collaboration partners in this project are the Laboratories of Process Metallurgy, and Control Engineering from University of Oulu, Laboratory of Heat Engineering from Åbo Akademi University, Outokumpu Technology Oy, Ehovoc Oy and Neste Oil Oy.

Research and Development of Novel Adsorption Materials for Water Treatment

Researcher: M.Sc.(Chem.) Minna Pirilä
Supervisor: Prof. Riitta Keiski
Advisor: Doc., Ph.D. Toivo Kuokkanen (Univ. Oulu, Department of Chemistry)
Funding: Kemira Oyj Oulu Research Centre
Duration: 1.9.2006 – 31.12.2006 (-2010)

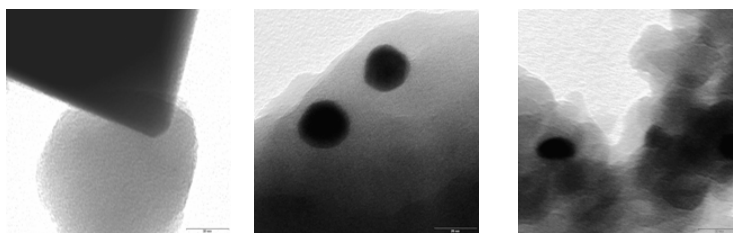
The removal of natural organic matter (NOM) and heavy metal complexes from dilute aqueous solutions by adsorption was studied in this project. Titanium and iron based adsorbents as well as Activated Carbon were used in the NOM removal experiments, in which the test water was obtained from Hintta water purification plant in Oulu. The adsorption of heavy metal complexes was done by titanium based adsorbents and activated carbon was used as a reference material. The project was done in collaboration with Kemira Oyj Oulu Research Centre and the Department of Chemistry of the University of Helsinki.

Zeolite Catalysts for NO_x Reduction by Hydrocarbons from Automotive Exhaust Gases

Researcher: M.Sc.(Eng.) Mika Huuhtanen
Supervisor: Prof. Riitta Keiski
Funding: The Academy of Finland
Duration: 1.1.2006 - 31.12.2007

The aim of this research was to gain knowledge on exhaust gas purification at low temperatures in lean conditions. In addition, the utilisation of Fourier Transform Infrared (FTIR) technique for developing reaction mechanisms and the kinetic model of NO_x mitigation by propene over the platinum loaded zeolite catalysts were considered. The use of zeolite materials for lean exhaust gas NO_x reduction by hydrocarbons can be a possible solution to meet stringent emission limits. The experimental part consists of studies done with Diffuse Reflection Fourier Transform Spectroscopy (formed surface intermediates) and gaseous FTIR (formed reaction products). Adsorption capacities were also studied by Temperature Programmed Desorption method. Based on the experimental results, a plausible reaction mechanisms for NO_x reduction by propene over Pd/Al₂O₃-based and Pt/zeolite catalysts was proposed.

The research work was published in December 2006 in an Academic Dissertation titled “Zeolite catalysts in the reduction of NO_x in lean automotive exhaust gas conditions. Behaviour of catalyst in activity, DRIFT and TPD studies”, which consists of five academic articles published in international journals and a summary article.



TEM images of different zeolite surfaces. Black particles are Pt clusters (Magnification: x 100 000)

Theses

Doctor of Science in Engineering

Kolli, Tanja

Pd/Al₂O₃-based automotive exhaust gas catalysts: The effect of BaO and OSC material on NO_x reductions

(Defended on May 12th, 2006)

Financed by the Academy of Finland and Alfred Kordelin Foundation

The aim of the thesis was to find new information on the effect of BaO and oxygen storage capacity material on NO_x reduction. A total of nine different kinds of Pd/Al₂O₃-based metallic monoliths were studied. Promoters such as oxygen storage capacity material (OSC material in our case Ce_{x-1}Zr_xO₂ mixed oxides) and stabilisers such as barium (BaO) were added into the catalyst alone or together to improve catalyst properties such as catalytic activity, selectivity, and thermal stability.

The key aspects in this thesis can be divided into four parts. First, the behaviour of NO reduction and CO as well as C₂H₄ oxidation over Pd/Al₂O₃-based catalysts in rich, stoichiometric and lean conditions were studied. Secondly, the effect of BaO and the OSC material in NO reduction was considered. Thirdly, the preparation procedure, i.e. the addition order of BaO, OSC material, and Pd on the catalyst was considered. Finally, the effect of ageing on the behaviour of catalysts was investigated.

Several characterization methods (*in situ* DRIFT, catalytic activity measurements, N₂ physisorption, CO chemisorption, dynamic oxygen storage capacity measurements, and X-ray diffraction (XRD)) were utilised to find answers to the behaviour of these catalysts in the studied model reactions. The Rapid Ageing Hot in Laboratory (RAHLAB) method was used to age the catalyst.

First, it was demonstrated that the CO and hydrocarbon oxidation and NO reduction reactions over the Pd/Al₂O₃-based catalyst behave differently. NO reduction and CO and hydrocarbon oxidation reactions were dependent on the reaction conditions and temperatures. Secondly, the effect of OSC and BaO on NO reduction was studied separately. In the case of OSC material, it was observed that the OSC material has an effect on NO reduction as well as on CO and C₂H₄ oxidation. In the case of BaO, it was observed that BaO has a positive effect on NO reduction as well as CO and C₂H₄ oxidation especially in rich conditions. Thirdly, the effects of the addition order of OSC and BaO on the catalyst were studied separately.

It was shown that these have an effect on NO reduction, especially after ageing. First, on the fresh Pd/Al₂O₃ catalyst it was observed that the addition order of OSC on the catalyst has no influence on catalyst performance. The effect of the BaO addition order on the Pd/OSC/Al₂O₃-based catalyst is found to be insignificant, especially, after the ageing process. Furthermore, it was observed that the effect of RAHLAB ageing was that the catalyst lost its catalytic activity, stability, and selectivity.

The thesis is available electronically at: http://herkules.oulu.fi/isbn_9514280563/

Huuhtanen, Mika

Zeolite catalysts in the reduction of NO_x in lean automotive exhaust gas conditions: Behaviour of catalysts in activity, DRIFT and TPD studies

(Defended on December 1st, 2006)

Financed by the Academy of Finland and Maj and Tor Nessling Foundation

The thesis expands the knowledge of the catalytic properties of platinum-loaded zeolite catalysts in the reduction of NO_x by hydrocarbons. The work is divided into three parts. First the recent literature of zeolite catalysts has been introduced, secondly the adsorption capacity, activity, and acidity of the catalysts have been studied by TPD and IR techniques and, thirdly, the derived reaction mechanisms based on the obtained data were presented.

Parent and 1 wt-% Pt-loaded ZSM-5, Beta, Y, and Ferrierite zeolite catalysts were studied in the C₃H₆-assisted reduction of NO. The Pd/Al₂O₃-based catalyst was used as a reference material for the reaction mechanistic studies. Several experimental techniques (in situ DRIFT, activity measurements, CO chemisorption, N₂ physisorption, TPD, and TEM) were used for the characterisation of the catalysts properties. The IR technique was used as the main technique for the determination of activities, surface species, and the acidic properties of the zeolite-based catalysts. The activity studies carried out by the gaseous FTIR technique provided information on the desired reaction products as well as on undesired by-products.

The detection and identification of the surface species as well as the reaction intermediates formed were done by the DRIFT method. The activity experiments indicated the effectiveness of Pt-loaded zeolite catalysts. The reduction of NO was found to decrease in the order: Pt/Beta > Pt/Y > Pt/Ferrierite > Pt/ZSM-5 in the conditions with excess O₂. Platinum was concluded to have an effect on O₂ and NO dissociation. Oxidation reactions of NO to NO₂ and propene to CO₂ were observed to be more intense over the platinum-loaded zeolites than over parent zeolites.

In this work, the reaction mechanisms for the C₃H₆-SCR of NO were derived over the Pt-loaded zeolite as well as the Pd/alumina catalysts based on the data obtained by DRIFT and activity experiments. The kinetics for the NO reduction by CO over Pd/Al₂O₃ was also derived. With the methods employed, the mechanistic steps over the Pt-loaded zeolites and Pd/Al₂O₃-based catalysts could be derived quite precisely and easily for C₃H₆-SCR of NO. Reaction routes were determined to go via different formations of intermediates over the two catalysts, i.e. via organonitrogen and isocyanate routes, respectively. The IR techniques were discovered to be effective tools in applied engineering studies.



Custodian Prof. Riitta Keiski, Mika Huuhtanen and opponent Prof. Lars Pettersson

The thesis is available electronically at: <http://herkules.oulu.fi/isbn9514282868/>

Mikkonen, Helmi

Processing of young shoots of Norway spruce for food applications

Financed by the European Agricultural Guidance and Guarantee Fund and companies



The products of the method: shoot syrup, dried and powdered by-product (shoot sugar)

The annual, young shoots of Norway spruce are traditionally utilised as a raw material for shoot syrup processing. The traditional process is based on cooking and evaporation. Over 50% of valuable shoot material remains as compost able material. The aim of the study was to produce shoot syrup with a cold extracting method. The aim was to improve resources use in processing, particularly the utilization of the shoot material. Spruce shoots processing into shoot syrup with a cold extracting method was studied in laboratory scale and in pilot scale experiments. The following process steps were determined: crushing of shoots, extraction with sugar, preheating, pressing, pasteurization and bottling of syrup and the remaining shoot material (shoot sugar), drying and bagging.

The utilization of shoots and shoot products for food applications was estimated by their nutritional and flavouring factors (phenolic, terpene and alkaloid contents). Furthermore, their heavy metal contents and the microbiological aspects were pointed out. Standard methods for analysis of food products were used.

As a result, a novel cold extracting processing method was suggested. With this method no water adding and reduced amount of heating energy was needed compared to the traditional process, while the needed amount of sugar was doubled, to produce a corresponding amount of shoot syrup. It was suggested that the remaining shoot material (shoot sugar) from the syrup processing could be utilized as herbal seasoning. Young supple shoots were found to be suitable for herbal food applications as such. The dry matter content in young shoots was below 20% (fresh weight, FW). The carbohydrate content was about 14 g/100 g (FW), half of which was dietary fiber. The protein content was 2.8 g/100 g (FW) and the fat content below 1 g/100 g (FW). The sodium content was low, whereas the potassium, iron, magnesium and calcium contents were high. Furthermore, the Norway spruce shoots were rich in ascorbic acid. Flavonoids, i.e. epigallocatechin, kaempferol and quercetin as well as proanthocyanidins and phenolic acids were found within the shoots' phenolic compounds. Monoterpenes, neutral diterpenes and resin acids existed within the shoots' terpenes. Monoterpenes were formed mainly by D-limonene, camphene, bornyl acetate, alpha-pinene, beta-pinene and beta-myrcene. Their total content was about 500 mg/kg (FW). The amount of resin acids was about double compared to monoterpenes. The alkaloid content was below detectable level. All the compounds of shoots enriched mainly into the shoot sugar in the syrup processing. The low heavy metal contents of shoots indicated the purity of the growing place. Normal hygiene practice of food production was needed in shoot processing. The shoot syrup and shoot sugar may be utilized as similar sugar products. The gentle cold extracting syrup processing is a method, where heating steps are minimised for saving the nutrient value and aroma of shoots in its natural form. The raw material can be processed entirely to valuable food products, following resource use optimisation principles.

Aho, Jani

Lämmönsiirtopinnan karheuden yhteys koksaantumiseen (Effect of surface roughness on coking)

Financed by Neste Oil Oy

The objective of this Master's thesis was to determine the effect of surface roughness on coking. Experimental work was done with a laboratory set-up and by polishing the tubes of a process heat exchanger. Also the effect of flow rate, coking time and temperature were investigated with laboratory set-up.

The literature survey includes processing of the heavy hydrocarbon feeds in thermal-cracking, visbreaking and bitumen units, naphthalene acid and sulphur corrosion of steel. Corrosion forms as well as corrosion during maintenance and storage were also reviewed. Further, the mechanisms of coke formation and factors that have effects on coking such as temperature, fluid velocity, surface roughness and oil composition were considered. Chemical and mechanical inhibition of coke formation and removal of coke are described.

At 400°C, the roughest surface coked over five times more than the smoothest surface. At 300°C, the effect of surface roughness was negligible. The effect of temperature was largest on a roughened surface, which had the same surface roughness than in the process. At 400°C, there was twice more coke than at 300°C. Flow rate did not have a significant effect on velocities 0.23 m/s and 0.16 m/s but, with the velocity of 0.09 m/s, there was over 6 times more coke.

Polishing of heat exchanger tubes is a demanding procedure and development of working practices to get satisfactory polishing results is still needed. Unfortunately polished heat exchangers were not taken to maintenance when this thesis was finished. The heat exchangers should be protected against corrosion during maintenance and storage, because corrosion may promote coking.

Heikkinen, Virpi

Laajennetun DLVO-teorian soveltaminen TiO₂:n sulfaattiprosessin likaantuviin lämmönsiirtopintoihin (Extended DLVO theory approach on the fouling of heat transfer surfaces in TiO₂ sulphate process)

Financed by Kemira Pigments Oy

Fouling of heat transfer surfaces has been studied in KEMLIKA research project which belongs to the PINTA-technology program of Tekes (Finnish Funding Agency for Technology and Innovation). One of the case studies in KEMLIKA has been fouling of heat transfer surfaces in sulphate process of TiO₂. The aim of this study was to evaluate adhesion forces between fouling compounds and heat transfer surfaces and between two colloidal particles. In addition, the intention was to find alternatives for currently used surface materials.

Interaction between colloidal particles and heat transfer surfaces and between two colloidal particles was studied using the extended DLVO theory, which takes into account the van der Waals forces, electrostatic double-layer forces, Lewis acid-base interactions and Brownian motion. Interaction forces in the extended DLVO theory are calculated from experimentally determined contact angle and ζ -potential data. In this study, contact angles of heat transfer surface materials were obtained using the Wilhelmy plate method and powdery TiO₂, using the Thin layer wicking method.

In the study, properties of water were used for the process medium. In reality, the process medium is aqueous sulphuric acid. In addition, adhesion forces are defined at 20°C, although in real process conditions temperature is markedly higher.

Adhesion forces between TiO₂ particle and zirconium are an order of magnitude greater than with titanium. Conversely, adhesion forces with graphite were found smaller than for titanium or zirconium. Electrochemical cleaning of titanium surface does not affect markedly the adhesion forces between colloidal particles and heat transfer surfaces, compared with untreated titanium surface. Currently, hydrodynamic forces in heat exchangers are markedly lower compared with adhesion forces, therefore, these forces are not able to keep the heat transfer surfaces clean.

According to calculated adhesion forces between particles and heat transfer surfaces, TiN and SiO_x-plasma CVD-coating seem to be good alternatives for heat transfer surface material. Adhesion forces of these surfaces are substantially smaller than of the surfaces currently used. From the materials used in the process, graphite had the smallest adhesion with particles.

In further studies, the surface energy values of sulphuric acid would be beneficial to determine. In addition, surface energies of particles and surfaces materials would need to be determined at temperatures higher than 20°C, in order to model conditions in heat exchangers. Finally it was concluded that the behaviour of alternative surface materials in the sulphate process of TiO₂ should also be experimentally tested.

Häyrynen, Katri

Käänteismoosi ja nanosuodatus kaivosvesien ravinteiden konsentroinnissa vesien biologista käsittelyä varten (Evaluation of reverse osmosis and nanofiltration to concentrate nutrients in mine water for their subsequent biological treatment)

Financed by Metla

The purpose of this study was to evaluate reverse osmosis (RO) and nanofiltration (NF) as a pretreatment method of mine effluents prior to the removal of nitrogen compounds by a nitrification-denitrification bioreactor.

When released to natural water bodies, nitrogen compounds can cause eutrophication and are detrimental to fish. In bioreactors, these compounds can be converted to nitrogen gas. These nitrogen compounds end up in mine water from undetonated explosives. However, since the annual amount of mine effluents is substantial, there is a need for a pretreatment process to reduce the amount of effluent to be treated in a bioreactor. This pretreatment process should be functional from a technical point of view and also economically feasible.

One alternative to reduce the amount of effluent are membrane separation processes. In a membrane separation process, the membrane acts as a selective barrier, which permits or retains components based on their size, shape, electrical charge, or hydrophilicity. NF and RO are suitable to separate small sized compounds such as nitrate and ammonium from water. The advantage of NF and RO is that they can remove all ions with high efficiency when other methods are normally effective in removing only one form of nitrogen. NF and RO experiments were conducted with three different mine effluents.

The effluents studied originated from Kemi chrome mine, Pahtavaara gold mine and Siilinjärvi phosphate mine. In the first stage of experiments, five different membrane materials were tested to select the most suitable ones for each of the effluent samples. In the second stage, concentration tests were performed with samples from all three mines. Then, large scale RO tests were performed on two types of samples. Finally, the economic and technical feasibility of suggested treatment methods was assessed.

Membrane fouling was a major limiting factor, especially in the large scale RO tests. Therefore, a prefiltration is recommended before the RO unit. According to preliminary economical analysis, the costs for the treatment of mine effluent with RO are reasonable with the prefiltration. This work can lead to pollution prevention and protection of natural water bodies.

Kanala, Heidi

Application of membrane technology for the waste water treatment of a fine chemical plant

Financed by KemFine Oy

The amounts of waste waters produced by industrial activities are huge. Waste water streams of a fine chemical plant contain often residues of compounds that prevent the draining of the waters to the municipal sewer system. Generally, these compounds are organic solvents and inorganic salts. The nature of the waste waters and the quantity of the impurities vary largely, depending on the situation. Although the waste streams are tended to be recycled with help of distillation processes, a complete removal of impurities is impossible. Hence, the waste waters are incinerated. However, distillation and incineration are very expensive. The advantages of the new treatment methods effect on the operational and cost-effective efficiency of the process.

The purpose of this study was to find out the compatibility of the membrane technology for the waste water treatment of a fine chemical plant. Application of membrane technology is discussed as a possibility of the waste water treatment either as such, or combined with other treatment methods. The compatibility of the membrane technology was aspired to find out with help of the filtration experiments by using a five-cell nanofiltration equipment. Ten various waste water streams of KemFine Ltd, Finland, containing among others butyl acetate, dichloromethane, monochlorobenzene, n-butanol and N-methyl pyrrolidone were chosen for the subject of the research. The membranes were chosen from an extensive number of commercially available membranes. The lack of the corresponding research results complicated membrane choice. Therefore, the membranes were chosen on the grounds of the recommendations of membrane manufacturers and experts. One of the studied membranes was a reverse osmosis membrane and the others were nanofiltration membranes. In order to compare the compatibility of the membranes, the volumetric flux data collected during the experiments was changed to the form of a total permeability and furthermore to retentions in percentages. In addition, the mass transfer through the membrane was illustrated as an example for one of the waste waters with the help of the solution-diffusion model equation.

Due to the complexity of the waste waters, it was difficult to interpret the results. Comprehensiveness of the results became complicated because of the used retention calculation equation. The retention capacity of the membranes varied from negative results up to complete retentions. The equation, which is commonly used, was not applicable to evaluate all the experimental results.

Good results were attained with filtrations of three different solutions. Especially, high retention results of inorganic salts were attained. On the contrary, some of the membranes did not tolerate all the solutions. All the solutions that damaged or fouled the membranes originated from the same production process. It is possible that the harmful compounds were included among the group of other compounds. Furthermore, it is possible that a long duration of the experiments in combination with a high pressure assisted the weakening of the membrane structure and separation efficiency.

This study creates a good basis for further studies. Development of membranes requires more basic research to understand the phenomena, and requires collaboration between membrane users and manufacturers. The membranes used in the experiments were very sensitive to damages and fouling when filtering solutions containing organic compounds. The membrane materials should have had to tolerate the solutions when it was not possible to remove harmful compounds before the membrane treatment. In order to study the fouling and damaging factors, filtration experiments with synthetic solutions are recommended.

While comprehensive conclusion could not be made, the study indicates that nanofiltration is applicable to remove small organic compounds at high pressures. Consequently, it was deduced that membrane technology suits well for the treatment of waste waters of a fine chemical plant, provided that the membrane material is chemically resistant and the concentrations of separable compounds are not too high.

Kivijärvi, Marjo

Rasvahappoesterin jatkuvatoiminen valmistaminen (Continuous production of fatty acid esters)

Financed by Arizona Chemical Oy

Fatty acids can be esterified directly or by transesterification. Esterification reactions are reversible and, in order to enhance the conversion of fatty acids, one of the reactants in esterification is fed in excess, or one of the products formed is continuously removed from the reaction mixture. Anhydrides and chlorides or fatty acids are esterifiable, as well, the reaction is essentially irreversible. However, anhydrides and chlorides are rarely utilised in esterification reactions, since they are more expensive than respective acids. Traditionally, strong mineral acids, such as sulphuric or para-toluenesulphonic acids are used to catalyse esterification reactions, but heterogeneous catalysts are studied to replace these corrosive and difficult-to-separate homogeneous catalysts.

In heterogeneous catalysis, the reactants diffuse in the pores and onto the surface of the solid catalyst. The reaction itself takes place on the active sites of the catalyst. According to Langmuir-Hinshelwood mechanism, both of the reactants are adsorbed on the surface and then react together. If the reaction takes place between an adsorbed molecule on the catalytic surface and a molecule in the surrounding fluid, the reaction mechanism in question is Eley-Rideal type. In the case of a homogeneous catalyst, the reaction is rather simple and a power-law type reaction rate equation can be used. A heterogeneously catalysed reaction must be described by complex surface reaction models, which takes into account the effects of adsorption.

In the preliminary experiments, solid zeolite catalysts were studied. These were not active as esterification catalysts, in fact, the reaction rate was similar to that of a non-catalysed reaction. Sulphuric acid was proven to be an efficient esterification catalyst: the reaction proceeded nearly to completion at 100°C during the first 30 minutes. The conversion achieved with solid catalysts at 120°C was approximately 40% after eight hours of reaction.

The mechanism of esterification of tall oil fatty acids and butanol appears to be complex, and the determination of kinetics is impeded by the presence of fatty acid mixture rather than a single fatty acid. The reaction rate is affected by heating as expected, since the esterification reaction is endothermic. Moreover, the reaction rate is strongly affected by the amount of catalyst added: the more catalyst, the faster the esterification reaction. The effect of the reactant ratio, however, is not very significant. With different traditional methods of determination of reaction kinetics different kinds of reaction rate equations are obtained. The formation of products during the reaction should be included in the reaction rate equation.

Oikarinen, Eero**Lämmönvaihtimen suunnittelu** (*Design of heat exchangers*)Financed by Ehovoc Oy

The aim of this Master's thesis was to define Nusselt number and friction factor correlations to the matrix of regenerative heat exchanger. The heat exchanger was used as a pre-heater in a catalytic oxidizer. The further objective of this study was also to develop the design software for the catalytic VOC incineration plant.

In the theory part of this work, the factors affecting the heat exchanger's flow conditions, pressure drop and heat transfer are presented. The theory part further focuses on the effect of matrix's geometry and fluid flow conditions on heat transfer and pressure drop. Finally, the work principles of the sizing and design program of a heat exchanger are studied.

The practical part of the work includes experimental measurements of the heat exchanger performance and development of pressure and heat transfer correlations for the simulation software. Based on the defined Nusselt number correlation, it was found that the thermal effectiveness of the regenerator differs by 3% units from experimental effectiveness. By the defined friction factor correlation, the calculated pressure drop deviates 2% from the experimentally determined value. Correlation was determined using flow rates from 4600 to 6100 Nm³/h and the temperature range was 29–370°C.

Pitkäaho, Satu**Catalytic incineration of chlorinated volatile organic compounds**Financed by Ecocat Oy

The aim of this Master's thesis was to obtain information on the catalytic oxidation of chlorinated volatile organic compounds (CVOCs) by reviewing the latest literature on the subject and by studying catalytic CVOc oxidation over metallic monoliths in the laboratory scale. In the literature review section, different abatement methods for CVOc emissions are presented. Catalytic materials, fundamentals of catalytic oxidation and catalyst deactivation are also reviewed.

In Finland, the three most commonly used and mostly imported CVOcs are methylene chloride (dichloromethane, DCM), trichloroethylene (TCE) and perchloroethylene (PCE). Of these compounds, DCM and PCE were used in laboratory experiments. Other two model compounds used were VOCs, dimethylformamide (DMF, N,N-dimethylformamide) and oxitol (EGEE, ethylene glycol monoethyl ether). The activities of 16 different Pt, Pd, and Pt/Pd catalysts supported on four different washcoats were studied in the laboratory scale light-off tests. The concentration of an individual model compound was 500 ppm, thus the total concentration of a two component mixture was 1000 ppm. The gas hourly space velocity (GHSV) was ~28 000 h⁻¹ and CVOc screening tests were carried out in moist (1.5vol-% water) conditions. The effect of other additives such as ethanol, and ethylene was also tested.

Overall, Pt catalysts showed better activity than Pd- or Pt/Pd catalysts in DCM oxidation. Over the most active catalysts, the DCM light-off was achieved at a significantly lower temperature ($T_{50} \approx 290^\circ\text{C}$) than the PCE light-off ($T_{50} \approx 480^\circ\text{C}$). In DCM oxidation catalysts reached 100% conversions at temperatures between 330°C and 500°C. The most active catalyst was platinum catalyst modified with addI-addition. In general, total oxidation of PCE remained unattainable and the highest achieved conversions ranged from 92% to 98% depending on the catalyst. Increasing the noble metal (Pt) loading from 0.23 wt.% to 0.42wt.% did not affect the DCM or PCE conversion nor the HCl yield.

Mixture tests were performed in dry and moist conditions. DMF affected the DCM conversion positively, e.g. the T_{50} of DCM decreased by $\sim 140^{\circ}\text{C}$. Both ethanol and EGEE decreased slightly the conversion of DCM. None of the compounds tested did not show any impact on the PCE conversion. Tests were also performed in order to study the effects of operation conditions on the catalyst's performance. Decreasing the feed concentration from 500 ppm to 250 ppm enhanced the PCE conversion slightly and increased the HCl yield slightly as well. This may indicate that increase in hydrogen source, e.g. water, possibly will improve selectivity towards HCl.

The effect of reducing the GHSV to half caused only a small change to the DCM light-off curve so that T_{100} was decreased from 480°C to 440°C . At the end, the effect of used catalysts and of the absence of water was tested. In this case, 'used catalyst' means a catalyst which was used for approximately 10 hours with 10 pre-treatments performed between every light-off test. The usage of catalyst did not alter the catalyst performance. Removing the water feed from the inlet affected the conversion of DCM only slightly, however, it had a major effect on the yield of HCl. This deterioration towards formation of HCl is associated with the decrease of hydrogen atoms present in the reaction mixture. During these experiments, phosgene sensitive Dräger-tubes were used to analyze the outlet gas flow from time to time to see if there would be even traces of this potential and extremely toxic by-product in the gas flow. No phosgene formation was observed during the experiments.

Based on these laboratory experiments and literature review, it can be concluded that there are solutions available among noble metal catalysts for CVOCs to be fully oxidized to the desired products: CO_2 , H_2O , and HCl. However, further tests will need to be done to discover good catalysts and optimum operational conditions and, therefore, reaching high conversions and also high selectivities.

Ritvonen, Tapio

Rakeenkasvuinhibiittoreiden saostus kobolttioksidin (*Precipitation of grain growth inhibitors into cobalt oxide*)

Financed by OMG Kokkola Chemicals Oy

In this Master's thesis, precipitation of grain growth inhibitors, vanadium and chrome was studied in hydrothermal oxidation of cobalt hydroxide slurries. The effect of process conditions was studied in order to prepare cobalt oxide powder from cobalt sulphate solute and cobalt hydroxide slurry. Cobalt oxide powders doped with grain growth inhibitors may be used in hard metal production as cemented carbide binder.

The literature survey focused on the use of grain growth inhibitors to prepare cemented carbide, and on the changes that occur during sintering and structure of ion-doped cobalt mixed oxide. Theory of X-ray diffraction method was referred and used in determining the crystal structure and ion replacements of produced oxide powders. The experimental part consisted of oxidation experiments from cobalt sulphate solute and cobalt hydroxide slurry in the autoclave. The process parameters affecting residual concentrations of initial solution were verified by the experiments. Spectrum analysis of X-ray diffraction showed changes in crystal structure and electron microscopy showed the effects of grain growth inhibitors on shape, size and degree of agglomeration of produced powders.

Based on the experiments, it was concluded that grain growth inhibitors can precipitate with cobalt oxide, and part of cobalt ions are replaced with inhibitors ions in spinel structure. The pH value near 9 in initial and final solution gives high yield of both cobalt oxide powder and precipitated inhibitors. Reaction conditions in which residual concentrations of initial solution were under 0.5% and average particle size about 50 nm were found.

Preparing cobalt mixed oxide powders succeeded better from cobalt hydroxide than from cobalt sulphate raw material. The main task of forthcoming research is to find how grain growth inhibitors prevent grain growth in cemented carbide by experiments of sintering. Additionally, nickel's performance to prevent grain growth should be studied.

Tilus, Jussi

Sulfaattitasapainon hallinta peittaushappojen regeneroinnissa (*Sulphate balance controlling in pickling acid recovery process*)

Financed by Outokumpu Oyj

The aim of this Master's thesis was to find better ways to control the sulphate balance of Outokumpu pickling acid recovery process (OPAR-process). The main focus was on crystallization and submerged combustion units.

In the theory part of this thesis, the working principles of the recovery process have been described. Much attention was paid to submerged combustion and salt crystallization. Also the basics of metal sulphates complex chemistry were studied.

In the experimental part of this thesis, the full scale experiments (with regeneration I – HPI plant, regeneration plants 2 and 3, and submerged combustion units) aimed to find optimal processing temperature, increase processing speed and improve crystallization capacity. The experiments and calculations indicated that this could be realized by preheating the submerged combustion unit's feed. Submerged combustion units increased the volumetric processing capacity and increased also the crystallizer's temperature. This gives positive effects on the crystallization process. The regeneration I – HPI experiment showed that, if the pickling acid bath's total metal concentration is raised, the total amount of mixed acid decreases. This would allow increasing the plant's production capacity while maintaining the recovery plant's current acid recovery capacity.

Ylimaunu, Maria

Painekuumentuslaitoksen merkitys sulfaattiselluloosatehtaan kemikaalikierrossa ja laitoksen toiminnan optimointi (*The influence of liquor heat treatment plant on circulation of chemicals in kraft pulp mill and optimizing the process*)

Financed by Metsäbotnia Oy

The aim of this Master's thesis was to find out the influence of a liquor heat treatment plant (LHT) on the circulation of chemicals in a kraft pulp mill, and optimizing the process of the LHT plant in terms of better usability. One of the main objectives was to examine the influence of the LHT plant on sulphur-sodium balance in a kraft pulp mill. The influence of temperature of the LHT reactor on the quantity of concentrated non-condensable gases (CNCG) and vapourization of sulphur was also examined by measuring concentrated non-condensable gases. In addition, the influence of CNCG on the lime kiln's process was studied. Another important objective was improving the usability of LHT by resolving the fouling of heat exchangers and, secondary, condensates and by determining optimal process conditions of LHT. The effect of LHT on the enrichment of turpentine in the stripper column's circulation of foul condensate and enrichment of potassium and chloride in fly ash of the recovery boiler were also examined. In addition, profitability calculations of LHT were done. In the theory part of the thesis, the sulphur-sodium balance in the kraft pulp mill was studied. Non-condensable gases in the kraft pulp mill and especially CNCG were also handled. In addition, fouling of the evaporation unit and possible options of controlling them were examined.

In LHT, a remarkable amount of sulphur is vaporized and recovered from combustion gases of lime kiln as sodium bisulphate solution in gas scrubbers. Sulphidity level in the mill has decreased clearly since implementing the LHT plant. The LHT plant influences remarkably on

the sulphur-sodium balance as an increased production of sodium bisulphate solution decreased the need for purging fly ash, as well as consumption of the make-up NaOH in recausticizing plant and in oxygen delignification.

Based on the measurements of CNCG, the concentration of sulphur in gases was 4.5–5.5 kg S/ADt in birch pulping, while the temperatures of the LHT's reactor was between 172–184°C. The amount of LHT's gases of all CNCG was about 2–3 kg S/ADt depending on temperature of the reactor. Temperature of the LHT's reactor influenced remarkably also on the TOC-concentration of gases. Increased amount of gases due to the influence of LHT was found not to be harmful in the lime kiln's process. Moreover, even positive impact of LHT's CNCG on combustion of lime kiln was noticed.

The depositions of LHT's heat exchangers were found to be mainly calcium carbonate precipitations. Small amounts of sodium carbonate, magnesium, silicate and fibres were also found in the depositions. Sudden blocks of heat exchangers due to changes in process conditions were found to be easily-dissolved burkeite precipitations. The optimum temperatures in the LHT's reactor were determined to be 174°C in birch pulping and 178°C in pine pulping. The position of the bypass valve should be set under 35% and the position of valve replaced after the LHT's reactor must be 60% at minimum. The reason for fouling of secondary condensates while LHT's bypass valve is off or almost off could not be explained.

Turpentine was found to be enriched in the stripper column's circulation of the foul condensate. However, based on test-drives, the so-called line of Lintunen could not be utilized in solving this particular problem. Potassium and chloride were not enriched in fly ash after implementation of the LHT plant. The annual cost savings by the implementation of the LHT plant is estimated to be 163 500€, based on the present situation and possible annual savings in the future were counted to be 430 000€, at the least.

Based on the examinations related to the thesis, the implementation of formic acid wash system to control the fouling of LHT's heat exchangers is to be considered. Also based on the thesis, the need for investing a monitoring device for the flow monitoring of black liquor was noticed. The bottom part of the LHT's reactor could be replaced with a new one. This would raise the pressure level of the reactor. In this way, also a greater flow of black liquor through the LHT plant would be achieved.

Official Visits of Personnel

Research exchange visits

University of Cantabria, Santander, Spain

M.Sc. (Chem.) Verónica García, visiting researcher, 1.4.2006-31.7.2006

University of Szeged, Szeged, Hungary

M.Sc.(Eng.) Nora Pap visiting researcher, 4.-31.7.2006

University of Poitiers, Poitiers, France

D.Sc.(Tech.) Satu Ojala, visiting researcher, 10.9.2006-31.12.2006

University of Kaunas, Kaunas, Lithuania

D.Sc.(Tech.) Satu Ojala, visiting researcher, 3.-11.12.2006



Verónica in Santander

Conferences and Seminars

Delivering invited speeches

Waste management and sustainable use of resources VALTSU (Valtakunnallinen jätesuunnitelma) seminar

February 6, SYKE, Helsinki (E. Pongrácz)

Rotary Club seminar; Sustainable production and products

March 3, Oulu (R. Keiski)

Cleaner production seminar

April 21, Murmansk, Russia (E. Pongrácz)

The state and quality of research in Finland: Natural sciences and engineering

April 25, Helsinki (R. Keiski)

Industrial Ecology and Green Chemistry seminars

May 2 – 4, University of Bourgogne, Laboratory of Organometallic and Electrochemical Synthesis, Dijon, France (E. Pongrácz)

Cleaner production seminar

May 16, Petrozavodsk, Russia (E. Pongrácz)

Water management in North seminar

May 23, University of Oulu, Oulu (R. Keiski)

Green and sustainable chemistry and chemical engineering

July 4, University of Poitiers, Poitiers, France (R. Keiski)

M.Sc. thesis End Seminar on Fouling of Surfaces

August 29, Porvoo (R. Keiski)

Workshop on Women in Science, Engineering and Technology (SET): Strategies for a global workforce

September 28 – 29, Ottawa, Canada (R. Keiski)

Environmental catalysis seminar

October 4 – 6, Tallin Technical University, Tallin, Estonia (R. Keiski)

Anniversary of the Karelian Pedagogical State University

November 6 – 7, Petrozavodsk, Russia (R. Keiski)

Researcher education: Evaluation procedures at the Academy of Finland

December 4, University of Oulu, Oulu (R. Keiski)

Presenting or participating**Spring seminar of international co-ordinators**

January 26, University of Oulu, Oulu (E. Pongrácz)

Presentation of SITRA

January 27, VTT Oulu (E. Pongrácz)

National UNESCO Commission meeting

February 2, Ministry of Education, Helsinki (R. Keiski)

Academy of Values seminar (the Finnish Church and the Archbishop)

February 9 – 10, Järvenpää (R. Keiski)

Teakes days

March 8, Helsinki (R. Keiski)

Closing seminar of the FINE – technology programme

March 12 – 14, Tampere (K. Oravisjärvi, M. Pietikäinen)

**Near field optical, infrared and Raman imaging: from molecules to nanoparticles –
Optisen jaoston koulutusseminaari**

March 23 – 24, Jyväskylä (M. Huuhtanen)

Nordic UNESCO Meeting

March 28 – 29, Stockholm, Sweden (R. Keiski)

National UNESCO Commission Meeting

April 10, Ministry of Education, Helsinki (R. Keiski)

National Data GRID Meeting

April 12, CSC Scientific Computing, Espoo (R. Keiski)

Cleaner production seminar

April 21, Murmansk, Russia (E. Pongrácz)

Ecoforum breakfast meeting

May 2, Oulu (E. Pongrácz)

The Science Forum

May 3, Finlandia Hall, Helsinki (R. Keiski)

Academy of Values seminar (the Finnish Church and the Archbishop)

May 3 – 5, Järvenpää (R. Keiski)

Sustainable chemistry (SusChem) seminar

May 7, Bank Restaurant, Helsinki (E. Pongrácz)

Steel refining days

May 11 – 12, Kokkola City Hall, Kokkola (R. Keiski)

XVII International Conference on Chemical Reactors

May 15 – 19, Athens, Greece (R. Raudaskoski)

Cleaner production seminar

May 16, Petrozavodsk, Russia (E. Pongrácz)

NOS-N meeting, Nordic Research Councils on Natural Sciences and Engineering

May 18 – 19, Reykjavik, Iceland (R. Keiski)

3rd Central European Congress on Food (CEFood)

May 22 – 24, Sofia, Bulgaria (N. Pap)

12th Nordic Symposium on Catalysis

May 28 – 30, Trondheim, Norway (S. Ojala, R. Raudaskoski and V. Kröger)

CBU, Environmental Engineering meeting

June 1 – 2, Arkhangelsk State Technical University, Arkhangelsk, Russia (R. Keiski)

FinnSight 2015 Seminar

June 13, Kiasma, Helsinki (R. Keiski)

Visit of Kenyan Delegation to the University of Oulu

June 14 – 15, University of Oulu, Oulu (R. Keiski)

Seminar on student advisement

August 15, University of Oulu, Oulu (R. Keiski)

Oulu-Luleå Seminar on Work Sciences

August 17, University of Oulu, Oulu (R. Keiski)

17th International Congress of Chemical and Process Engineering CHISA 2006

August 27 – 31, Prague, Czech Republic (S. Pitkääho)

Pedaforum 2006, Vice-rectors' meeting

August 24, University of Helsinki, Helsinki (R. Keiski)

Oppimisympäristöjä kehittämässä

September 28 – 29, University of Oulu, Oulu (J. Ylä-Mella)

CAPoC7

August 30 – September 1, Bryssel, Belgium (V. Kröger)

4th EFCATS School on Catalysis

September 20 – 24, St Petersburg, Russia (R. Raudaskoski, V. Kröger and S. Pitkäaho)

The challenges for knowledge based economics

September 21 – 22, Marina Congress Centre, Helsinki (R. Keiski)

Network Young Membrains 8 (NYM8)

September 21 – 23, Rende, Italy (V. García and J. Landaburu-Aguirre)

Euromembranes 2006

September 24 – 28, Giardina Naxos, Sicily, Italy (V. García and J. Landaburu-Aguirre)

20th Valtakunnalliset Jätehuoltopäivät

October 4 – 5, Tampere (J. Ylä-Mella)

Science Festival

October 24, Helsinki (R. Keiski)

CBU Master's programme meeting

November 6 – 7, Petrozavodsk, Russia (R. Keiski)

AIChE Annual Meeting 2006

November 12– 17, San Francisco CA, USA (T. Pääkkönen and M. Riihimäki)



Markus and Tiina in San Francisco

Bio Well Being seminar

November 17, Oulu (R. Keiski)

NOS-N meeting, Nordic Research Councils on Natural Sciences and Engineering

November 21 – 22, Lund, Sweden (R. Keiski)

The 5th International Kastelli Symposium

November 22 – 25, Oulu (K. Oravisjärvi)

Kasvatustieteen päivät 2006

November 23 – 24, University of Oulu, Oulu (M. Huuhtanen)

CIMO seminar

December 13, University of Oulu, Oulu (R. Keiski)

Journées de la Section Regionale Centre-Ouest, Societe Francaise de Chimie

December 14 – 15, Poitiers, France (S. Ojala)

Memberships and other professional activities

Riitta L. Keiski

Vice-Rector of the University of Oulu in Education, teaching and student matters, since August 2006.

Head of the Department of Process and Environmental Engineering, January-July 2006.

Vice-Head of the Department of Process and Environmental Engineering, since August 2006.

Head of the Laboratory of Mass and Heat Transfer Process Engineering

CNRS Visiting Professor:

- University of Poitiers in Poitiers, France and University of Bourgogne in Dijon, France, from July 3, 2006 to July 13, 2006; Area of Research: Separation processes, chemical utilization of carbon dioxide, hybrid materials, environmental catalysis.

The Academy of Finland

- Member of the Board of the Academy of Finland
- Chair of the Research Council for Natural Sciences and Engineering
- Chair of the Sub-committee of Development Studies
- Member and chair in preparatory and steering groups of research programmes at the Academy of Finland (Research Programmes KETJU, Sustainable production and products (chair))
- Member of the Working group for the evaluation and selection of the Finnish Centre of Excellence research groups
- Member of the Working group for the evaluation of the Finnish Graduate School groups
- Observer of the follow-up groups of one Nordic and one National Centre of Excellence programme
- Member of FCIBER steering group
- Chair of the Working group of the State and quality of Finnish research in Natural sciences and Engineering
- Member of the Programme groups of KETJU, Sustainable production and products, ESGEMO, WOOD WISDOM, LIIKE2 (vice-chair)
- Member of the Steering group of the Forum for Ageing Research

Ministry of Education

- Member of the Finnish National Commission for UNESCO
- Member of the Development Group of the Graduate School System in Finland
- Member of the Working Group of the National GRID strategy
- Member of the Board of Study Programme on Russian and Eastern-European Research
- Member of the National Review Group of the UNESCO Science Programmes

Ministry of Trade and Industry:

- Vice-chair of the Board of MIKES, Centre for Metrology and Accreditation

Nordic Activities

- Member of the Joint Committee of the Nordic Natural Science Research Councils (NOS-N)

University of Oulu

- Specialist member of the Board of the University of Oulu, since August 2006
- Vice-chair of the Board of Infotech Oulu
- Vice-member of the Board of the Thule Institute
- Member of the Board of the Micro- and Nanotechnology Centre
- Chair of the Advisory Committee of the Female Studies
- Chair of the Equality Working group of the University of Oulu
- Chair of the Working Group of Northern Environmental Research Alliance, NorNet
- Member of the Working Group for Environmental Research and Education at the University of Oulu, Industrial Ecology and Green Chemistry
- Specialist member of the Leading Group of the Northern Environmental Research Alliance, NorNet
- Member of the Working Group for the Northern Cross Boarder University collaboration; Head of the team for Environmental Engineering Master's programme
- Member of the Follow-up group of post-graduate studies at the Department of Chemistry
- Member of the Board of the Center of Advanced Steel Research
- Vice-member of the Council of the Faculty of Technology
- Member of the Council of the Department of Process and Environmental Engineering
- Chair of the Post-graduate study development group (JOPOKKI) at the Department of Process and Environmental Engineering
- Chair of the Industrial Environmental Engineering unit's support group (TYTTI)
- Member of the Working groups for the LAATU II and III (quality of research) in the Department of Process and Environmental Engineering

Other activities

- Member of the evaluation group in Maj and Tor Nessling Foundation
- Member of the Board of the Foundation for Environmental Technology
- Member of the organizing group (financing group) of EUROPACAT 2007 (European Catalysis Conference)
- Member of the Editorial Board of Catalysis Today
- Academy of Values, seminars offered by the Finnish Church and the Archbishop

Mika Huuhtanen

- Member of the Post-graduate study development group (JOPOKKI), University of Oulu, Department of Process and Environmental Engineering

Satu Ojala

- Secretary of the Board of the Finnish Catalysis Society

Eva Pongrácz

- Vice chair of the Post-graduate study development group (JOPOKKI), University of Oulu, Department of Process and Environmental Engineering
- University of Oulu, EnviroNET doctoral school, Industrial Ecology and Green Chemistry committee member
- Member of the follow-up group of post-graduate studies at the University of Oulu, Department of Chemistry
- Member of the working group for industrial environmental engineering education at the Department of Process and Environmental Engineering, University of Oulu

- Member of the working group for research and education self-evaluation and strategy development at the Mass and Heat Transfer Process Laboratory, University of Oulu
- Participation in strategy planning working group at the Department of Process and Environmental Engineering, University of Oulu
- Member of the Water in chemical industry processes (CWP) thematic research and education peer- network at Oulu University
- Editorial Board Member, *Progress in Industrial Ecology, An International Journal*
- Editorial Advisory Panel member, *Waste and Resource Management*, journal of the Institution of Civil Engineers
- Expert task for the Northern Cross-border University joint Finnish-Russian master's degree development project of Thule Institute, University of Oulu
- Steering committee member and expert task for the Cleaner Production Continuing education of Northwest Russian university teachers, project of NorTech, University of Oulu

Publications

INTERNATIONAL

Articles in Scientific Journals

- Ballivet-Tkatchenko D, Chambrey S, Keiski RL, Ligabue R, Plasseraud L, Richard P & Turunen H* Direct synthesis of dimethyl carbonate with supercritical carbon dioxide: Characterization of a key organotin oxide intermediate. - *Catalysis Today*, vol. 115, no 1-4, p. 80-87.
- García V, Landaburu-Aguirre J, Pongrácz E, Phillips P & Keiski R* Recycling of organic solvents by pervaporation and micellar-enhanced ultrafiltration. - *Desalination. The international journal on the science and technology of desalting and water purification*, 2006, vol. 200, no 1-3, p. 383-384.
- Kolli T, Lassi U, Rahkamaa-Tolonen K, Kinnunen T-J & Keiski RL* Effect of barium on the catalytic behaviour of fresh and aged Pd-Ba-OSC/Al₂O₃ catalysts. - *Applied Catalysis A: General*, 2006, vol. 298, p. 65-72.
- Kordás K., Tóth G, Levoska J, Huuhtanen M, Keiski R, Härkönen M, George TF & Vähäkangas J* Room temperature chemical deposition of palladium nanoparticles in anodic aluminium oxide templates. - *Nanotechnology*, 2006, vol. 17, p. 1459-1463.
- Kröger V, Lassi U, Kynkäänniemi K, Suopanki A & Keiski RL* Methodology development for laboratory-scale exhaust gas catalyst studies on phosphorus poisoning. - *Chemical Engineering Journal*, 2006, vol. 120, no 1-2, p. 113-118.
- Landaburu-Aguirre J, García V, Pongrácz E & Keiski R* Applicability of membrane technologies for the removal of heavy metals. - *Desalination. The international journal on the science and technology of desalting and water purification*, 2006, vol. 200, no 1-3, p. 272-273.
- Ojala S, Lassi U & Keiski RL* Testing VOC emission measurement techniques in wood-coating industrial processes and developing a cost-effective measurement technology. - *Chemosphere*, 2006, vol. 62, no 1, p. 113-120.
- Ojala S, Lassi U, Härkönen M, Maunula T, Silvonen R & Keiski RL* Durability of VOC catalysts in solvent emission oxidation. - *Chemical Engineering Journal*, 2006, vol. 120, no 1-2, s. 11-16.
- Pongrácz E* Industrial ecology and waste management: from theories to applications. - *Progress in Industrial Ecology - An International Journal*, 2006, vol. 3, no 1-2, p. 59-74.

Articles in Compilations or Proceedings

- Carpen L, Kinnunen P, Hakkarainen T, Sarpola A, Riihimäki M, Rämö J & Pohjanne P* Prediction of corrosion risk of stainless steel in concentrated solutions. - *Corrosion nacepo 2006, 61st annual conference & exposition. NACE. Corrosion nacepo vol. 61, no 61. Houston, USA. NACE 2006. s. 1-12. Institute of Chemical Engineers 2006.*
- Kolli T, Chichova D, Rahkamaa-Tolonen K, Väyrynen J & Keiski RL* XPS study of Pd-Ba-OSC/Al₂O₃-based catalysts and the effect of ageing. - *Seventh International Congress on Catalysis and Automotive Pollution Control, CAPoC7. Preprints, Volume 3, Poster sessions. August 30 - September 1, 2006, Brussels, Belgium. Eds. N. Kruse et al. Bruxelles. Université Libre de Bruxelles 2006. p. 17-23.*
- Kröger V, Kanerva T, Lassi U, Rahkamaa-Tolonen K, Lepistö T & Keiski RL* Phosphorus poisoning of ZSM-5 and Pt/ZSM-5 zeolite catalyst components. - *Seventh International Congress on Catalysis and Automotive Pollution Control, CAPoC7. Preprints, Volume 3, Poster sessions. August 30 - September 1, 2006, Brussels, Belgium. Eds. N. Kruse et al. Bruxelles. Université Libre de Bruxelles 2006. p. 41-47.*
- Kröger V, Hietikko M, Angove D, French D, Lassi U, Suopanki A, Laitinen R & Keiski RL* Effect of phosphorus poisoning on catalytic activity of diesel exhaust gas catalyst components

containing oxide and Pt. - Seventh International Congress on Catalysis and Automotive Pollution Control, CAPoC7. Preprints, Volume I, Oral sessions. August 30 - September 1, 2006, Brussels, Belgium. Eds. N. Kruse et al. Bruxelles. Université Libre de Bruxelles 2006. p. 255-261.

Kvist S, Pongrácz E & Keiski RL Effect of environmental systems on waste awareness in Finnish metal engineering SMEs. - The Twelfth Annual International Sustainable Development Research Conference 2006. 6-8 April 2006, Hong Kong Convention & Exhibition Centre. Conference Proceedings. CD-ROM. Hong Kong. The University of Hong Kong 2006.

Pääkkönen TM, Riihimäki M, Ylönen R, Muurinen E & Keiski RL Evaluation of the boundary conditions in CFD modeling of heat transfer in the 3D chevron type plate heat exchanger. - 2006 AIChE Meeting, November 12-17, 2006, San Francisco, CA, USA. Conference Proceedings. CD-ROM. New York, NY, USA. American Institute of Chemical Engineers 2006.

Raudaskoski R, Turpeinen E & Keiski RL Evaluation of CO and CO₂ based methanol syntheses using Aspen Plus simulation software. - XVII International Conference on Chemical Reactors CHEMREACTOR-17. Post-Symposium, Catalytic Processing of Renewable Sources: Fuel, Energy, Chemicals. May 15-19, 2006 in Athens and Crete, Greece. CD-ROM. Novosibirsk. Boreskov Institute of Catalysis 2006. p. 520-523.

Riihimäki M, Pääkkönen TM, Ylönen R, Muurinen E & Keiski RL Controlling of particle interactions with process pipes in calcite mineral processing to prevent depositions. - 2006 AIChE Meeting, November 12-17, 2006, San Francisco, CA, USA. Conference Proceedings. CD-ROM. New York, NY, USA. American Institute of Chemical Engineers 2006.

Lehtinen U, Poikela K & Pongrácz E Drivers and constraints of SMEs in Finnish Environmental Industry - a study of an environmental cluster in Oulu region. - 14th Nordic Conference on Small Business Research. May 11-13, 2006, Stockholm, Sweden. <http://www.ncsb2006.se/pdf/Drivers%20and%20constraints.pdf>

Printed Abstracts

García V Recovery of bilberry aroma compound by pervaporation. - NYM 8, Network Young MemBrains 8th meeting. September 21-23, 2006, Rende, Italy. Extended Abstracts. 2006. p. 189-190.

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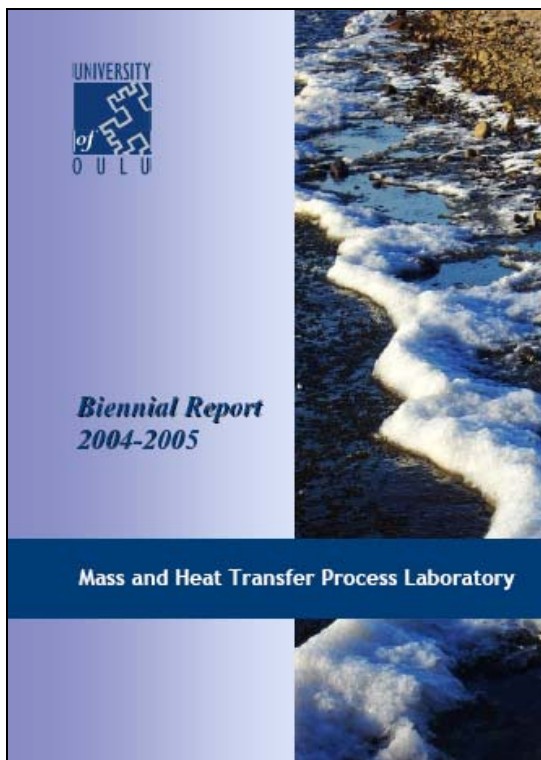
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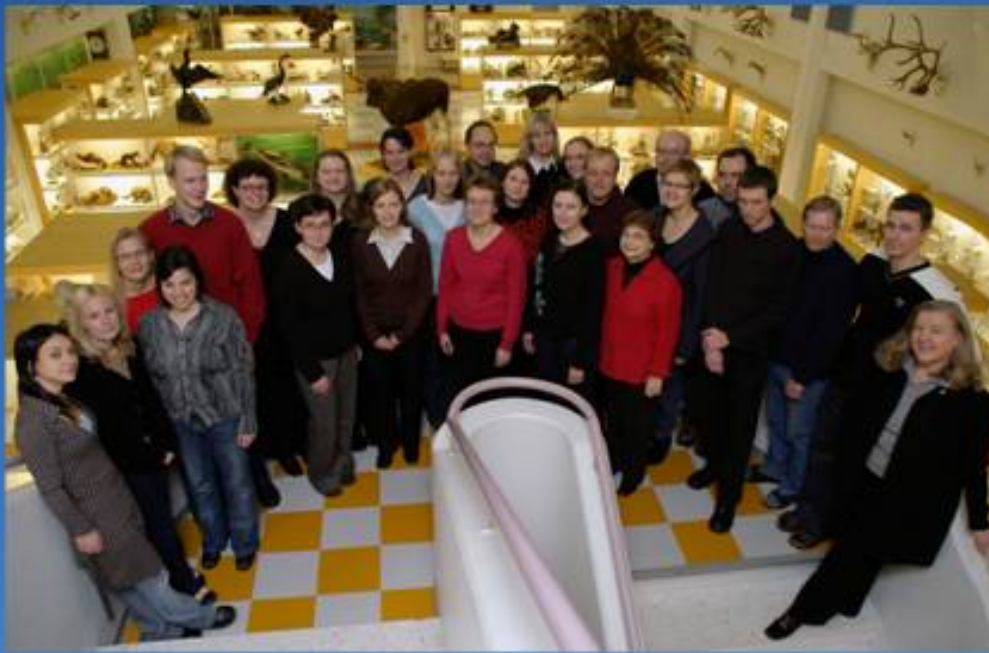
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