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LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO LUT
LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY LUT
School of Engineering Sciences
Department of Separation Science

50 YEARS OF SEPARATION SCIENCE IN LUT

EROTUSTEKNIIKAN OSASTO 50 VUOTTA

Editor/Toimittaja: Jutta Nuortila-Jokinen

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50 years of Separation Science in LUT
Erotustekniikan osasto 50 vuotta

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Foreword

This year the Department of Separation Science is celebrating its 50th anniversary. The discipline is one of the oldest and most traditional ones in the history of LUT University. The current name Separation Science reflects the department's research focus, which has progressively shifted over its 50-year history toward various separation technologies and processes. Previously, the department was known as the Department of Chemical Technology.

The initial activities of the department focused on teaching, as there were insufficient laboratory facilities. Consequently, early students completed their specialization studies in different departments. In the early 1980s, the department acquired its own laboratory facilities, which facilitated research activities and allowed students to specialize in chemical technology topics. Over the following approximately 20 years, recruitment and research efforts increasingly concentrated on separation technologies. In 1994, *the Centre for Separation Technology* was established with strong industrial support, marking a significant development in the department's focus and capabilities.

Over the years, the department has developed into a leading center for chemical technology education and research in South-Eastern Finland. It currently operates in the cities of *Lappeenranta, Lahti, Mikkeli, and Kouvola*. Historically, the department has also been active in *Savonlinna, and Kotka*.

In 2025, the department's research approach can be conceptualized as a two-dimensional framework. One dimension encompasses chemical technology, represented by 13 research groups and teams, each specializing in unit separation technologies or process and plant design. The other dimension emphasizes societal impact areas, which are *food engineering, water treatment, minerals and metals, power-to-X technologies, and biorefining*. The research groups leverage their expertise across multiple sectors, like for example membrane technology has impact in all of these focus areas.

In the 2025-2026 academic year, the Department of Separation Science offers a bachelor's degree program taught in Finnish, known as *Kemiantekniikka* or *Chemical Engineering*. This program attracts approximately 40 students annually. The department's four master's programs align with societal research impact areas: *Food Processing Technology* in Kouvola, *Water Technology* in Mikkeli, *Chemical Engineering for Energy Transition* in Lappeenranta, and *Biorefineries* in Lahti. Over recent years, these programs have attracted 10-20 students annually, in addition to our own bachelor graduates. Except for *Food Processing Technology*, all programs hold EUR-ACE® and ASIIN accreditation. Starting in autumn 2026, an English-taught bachelor's program in *Chemical and Process Engineering* will be launched.

Beyond the previously mentioned initiatives, the department offers two Erasmus Mundus joint programs: *International Master of Science in Engineering, Entrepreneurship and Resources (MSc. ENTER) and Sustainable Biomass and Engineering (SBEE)*. Additionally, it participates in the EIT Raw Materials-funded triple degree program, *Master's Programme in Entrepreneurship, Innovation and Technology Integration in Mining (MEITIM)*. These programs collectively attract numerous students and confer multiple Master's degrees each year.

The department has made significant investments and continues to prioritize the development of research and educational infrastructure through both internal funding from LUT and external sources. These cutting-edge facilities and experimental infrastructures are among the department's most valuable assets, recognized globally. The department boasts over 3000 m^2 of laboratory space across four cities, equipped with more than 350 pieces of equipment.

Throughout the years, industrial collaboration has played a vital role in enhancing the scientific impact of the department. Many partnerships have endured for decades, and new opportunities continue to emerge.

In the future, *the Department of Separation Science* aims to become a globally recognized leader in education and research within chemical technology, with a particular focus on separation processes. The department is committed to applying these processes to address critical global societal challenges, especially the sustainable use of planetary resources. Throughout 2024, department members collaborated to develop a comprehensive long-term development plan to support this vision.

This anniversary publication comprehensively addresses all relevant aspects through concise articles authored by our current and former professors, along with contributions and insights from key collaborators.

We, the department management team want to extend our sincere gratitude to all past and present students, employees, and our industrial and academic partners for contributing to this 50-year journey. Your support has been instrumental along the way and in establishing a foundation for a promising future. These successful years, marked by significant advancements towards becoming a world-class center of excellence in separation science, would not have been achievable without your dedication and collaboration. Let's make the future even brighter. Together!

Sami Virolainen
Head of the Department of Separation Science

Editor's Foreword

Marking the 50th anniversary of the Department of Separation Science is both a joyful and humbling moment. This commemorative volume brings together voices from across generations — colleagues, researchers, and friends—who have shaped and been shaped by our Department's journey over the past five decades.

Editing this collection has been a deeply meaningful experience. As I read through the contributions, I was reminded not only of the Department's academic achievements, but also of the people, stories, and shared moments that have made this community so special. The articles reflect a rich tapestry of scholarship, collaboration, and curiosity—values that continue to define who we are.

The document is structured into five comprehensive sections, each providing insights into the history, current activities, and future prospects of the Department. The first section reflects the Department's historical milestones, emphasizing its foundational achievements and evolution over time. The second section focuses on ongoing research and teaching initiatives, offering also a glimpse into future developments and strategic directions.

The third part provides an overview of undergraduate and graduate education programs, highlighting the diverse career paths available to students. It features profiles of four individuals at different stages of their careers: a Bachelor student, a recent Master of Science graduate, a seasoned professional in her prime, and a recently retired Chief Specialist. These profiles illustrate the educational opportunities and career trajectories facilitated by the Department of Separation Science.

The fourth section details the Department's engagement across various platforms and networks, including testimonials from partners over the years, demonstrating collaborative efforts and community involvement. The fifth part presents graphical data illustrating the Department's growth and development, alongside a historical list of personnel, emphasizing stability and expansion.

Collectively, these sections create a dialogue that connects the Department's past achievements, current endeavors, and future ambitions, providing a comprehensive overview of its ongoing journey and strategic vision.

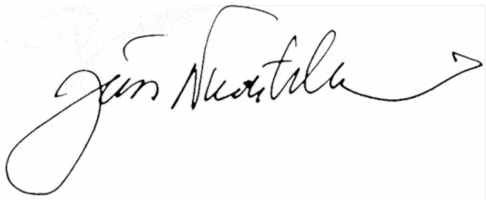
I wish to express my sincere gratitude to all those who contributed their time, insights, and generosity to this project. My heartfelt appreciation goes to the dedicated editorial team—Sami Virolainen, Katja Lahikainen, Ritva Tuunila, and Kati Korhonen—for their support and expertise. I am also deeply thankful to my colleagues who have helped me along the way. Especially warm thanks go to my colleague and friend Eero Kaipainen for e.g. digging out old photos and other material to me and for helping me in numerous other ways so many times during the project that I lost count. I owe you a big time!

Throughout this project, I have greatly valued the engaging email correspondence and conversations with Professors (Em.) Erkki Paatero and Matti Lindström. Their guidance and collective expertise offered insightful perspectives that enriched my understanding of the Department's development. Beyond the academic discussions, I also deeply enjoyed the personal stories shared and the discussions that extended from the industrial plant reform policy to the composition of the dark matter. This is exactly what makes this work so exciting and delightful.

The editorial team also wants to thank LUT Administration for putting in the extra effort to provide us with the data to complete the relevant statistics.

This book is a celebration—not only of what we have accomplished, but of the spirit that carries us forward. I hope it brings pride to those who have been part of our story, and inspiration to those who will continue it.

With warmest regards,



Jutta Nuortila-Jokinen
Editor

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DEPARTMENT OF CHEMICAL TECHNOLOGY 1975-2019

In 1974, Dr. Seppo Wilska, then research manager at Kemira Oy and a highly esteemed scientist, was invited to develop chemical engineering education at Lappeenranta University of Technology (LTKK). He designed the first curriculum based on the idea that a Master of Science in Chemical Engineering should have a solid foundation in chemistry combined with engineering knowledge and skills to succeed in the chemical and process industries. The Department of Chemical Technology was officially founded in 1975 and Wilska was appointed as its first professor (Technical chemistry) and the inaugural Head of Department. The new program was initiated in 1975, marked by the establishment of a modest laboratory dedicated to fundamental chemical experiments.

Figure 1. Professor Seppo Wilska

Instruction during this period was primarily led by Wilska, with Helinä Pihlaja serving as an assistant, contributing to the foundational phase of the program's development.

In 1976, Pentti Minkkinen began as an associate professor of inorganic and analytical chemistry, marking the start of the department's second academic year. Over time, the staff expanded to include professors and other teaching staff such as Seppo Palosaari (chemical engineering), Matti Lindström (physical chemistry), Salme Koskimies (nee Ojanperä) (organic chemistry), and Riitta Mennola (analytical chemistry), all contributing to the education of new students in chemical technology.

Throughout the 1980s and 1990s, the department grew steadily, guided by Wilska's vision to strengthen both the engineering and chemistry aspects of chemical technology. The department's focus was originally organized into two main sections: Applied Chemistry and Process Technology. From 1994 onwards Paper Technology formed a third section.

Applied Chemistry encompassed technical chemistry, inorganic and analytical chemistry, organic chemistry, physical chemistry, and technical polymer chemistry. Process Technology included chemical engineering, process engineering, product and process development (formerly plant design), and later, process systems engineering. The section of Paper Technology consisted of Laboratories of Paper Technology and Membrane Technology and Technical Polymer Chemistry, as well as the special satellite activities in Savonlinna and Kotka.

In 1980, the department moved physically into the newly completed second building phase, known as the “KETE”-wing, which was essential for expanding its research and measurement capabilities. Laboratories were gradually filled with both self-constructed and commercial research equipment, ranging from laboratory to pilot scale. To gain a comprehensive understanding of separation processes, specialized measurement methods and equipment are essential. For example, techniques such as streaming potential and quartz crystal microbalance (QCM) were developed to analyze membrane charge and surface adsorption, respectively.

In addition to the teaching staff, competent technical personnel have been vital for the efficient operation of the department laboratories. Markku Levomäki was appointed as laboratory engineer, and Pekka Järvi served as laboratory technician for applied chemistry laboratories from the very beginning. In 1983, Paavo Nurminen joined the department as a laboratory engineer and Markku Maijanen became a laboratory technician for process technology. In 1990, Eero Kaipainen was appointed as laboratory engineer for paper technology and technical polymer chemistry. These individuals are maybe best-known to both advanced students and researchers, as they are there when practical advice is needed, for example, on equipment malfunctions or supplies need to be ordered.

Due to the active apparatus development and building taking place in the Department mechanical and electric workshops were established. Markku Korhola headed the mechanical workshop and Ari Ryhänen the electrical one.

The analytical laboratory and analytical services on Lappeenranta Campus were organizationally centralized in 2011 and Dr Liisa Puro has been a key person in their development since then. In addition, laboratories have been lucky to have many skillfull laborants and laboratory technicians during the years to help the researchers in their work: Jaana Ruokonen, Helvi Turkia, Anne Hyrkkänen, Anne Kokko and Päivi Hovila just to mention a few.

Applied Chemistry

Professor Wilska devoted considerable effort to establishing and expanding the department. His research primarily focused on pigments and paints. After his retirement Erkki Paatero was appointed Professor of Technical Chemistry in 1992, transferring his hydrometallurgical extraction research from Åbo Akademi to LUT. The research concentrated on extraction chemistry, factors influencing selectivity, reagent composition changes under process conditions, and impurity effects. The laboratory also studied adsorption and ion exchange, applied in surface treatment applications and hydrometallurgical solution purification.

The Laboratory of Inorganic and Analytical Chemistry was under the leadership of Professor Pentti Minkkinen since 1976, and this laboratory has been the first place where students are introduced to laboratory work. In 1978, Minkkinen expanded the curriculum to include sampling theory and its applications, later integrating chemometrics into process analytical chemistry. Following Professor Minkkinen’s retirement in 2007, Professor Heli Siren took over the leadership. Since 1992, Satu-Pia Reinikainen has led the Chemometric Group and was appointed Professor of Digitalization in Chemical and Process Engineering in 2017.

The Laboratory of Physical Chemistry, initially led by acting Associate Professor Pentti Passiniemi, who later became notable for research into lithium-polymer batteries, specialized in applications of electrochemistry as well as in sorption, diffusion and reaction kinetics under Professor Matti Lindström. Associate Professor Jaakko Partanen was focusing on chemical thermodynamics.

Dr Salme Koskimies led the Laboratory of Organic Chemistry until 1981 when she moved to Neste Oy. She was followed by Tapio Miettinen, a lecturer in organic chemistry from 1981 to 2005. He was particularly interested in the chemistry of betulin derived from birch bark.

The curriculum introduced technical polymer chemistry in 1986. Since 1988 Marianne Nyström was leading the Laboratory of Technical Polymer Chemistry. From early on the research was focused on membrane characterization, particle-membrane interactions and anti-fouling techniques across various industrial sectors, including dairy, metallurgy, pulp and paper just to mention a few. In 1998, the laboratory was renamed the Laboratory of Membrane Technology and Technical Polymer Chemistry (MemPo for friends), coinciding with Marianne Nyström's appointment as Professor of Membrane Technology. Research on membrane applications in the pulp and paper industry was conducted under the leadership of Research Professor Jutta Nuortila-Jokinen, supported by an endowed professorship and Academy of Finland.

Process Technology

The Laboratory of Chemical Engineering, led by Professor Seppo Palosaari, concentrated to big extent on industrial crystallization. After his retirement in 1999, Professor Juha Kallas and Dr. Marjatta Louhi-Kultanen continued research in crystallization modeling, simulation, and scale-up, with Kallas also contributing expertise in water and air purification and advanced oxidation processes. The laboratory was renamed Separation Processes to better reflect its core competencies.

Process engineering education and research, initiated by Professor Lars Nyström in 1982, covered mechanical separation and classification methods, including filtration, grinding, hydrocyclones, and screens. Nyström's work emphasized sludge characterization and industrial filtration optimization, fostering collaboration with local industry, notably Larox Oy, which led to e.g. the establishment of an endowed professorship in solid-liquid separation in 1997, held by Marja Oja. Additionally, the Particle Laboratory was established with advanced technology to characterize various solid specimens, making it unique in Finland.

Plant design, later known as Product and Process Development, began as an individual laboratory in 1994, but obtained permanent professor when Professor Ilkka Turunen was appointed in 1999. The group specialized in computer-aided design and integration of separation processes into overall process design, aiming to optimize and intensify separation techniques. Subsequently, process system engineering evolved into an independent laboratory in 2005 led by Professor Andrzej Kraslawski.

Paper Technology

Given the prominence of pulp and paper industries in southeastern Finland, the Department has historically integrated paper industry-related issues into its teaching and research. Dedicated courses in paper technology were introduced in 1990, initially led by Jouko Lehto and later by acting Professor Matti Stén. In 1994 Hannu Manner succeeded Professor Stén as professor of Paper technology. Paper technology gained popularity among students and regional companies, fostering collaboration and employment opportunities.

The regional focus expanded with projects like Cleantech 2000 led by Research Professor Jutta Nuortila-Jokinen and financed by the European Regional Development Fund, City of Savonlinna and local companies, emphasizing water reduction, energy-efficient effluent treatment, and chemical mixing in paper manufacturing. This success led to the FiberTech 2010 project in 2002, focusing on fiber physics and regional development, and the establishment of the Fiber Technology Center of Excellence in Kotka in 2002, aimed at doctoral research and business development in fiber technology. Dr. Jari Käyhkö led the FiberTech 2010 project in Savonlinna, where a significant pilot-scale laboratory was established for testing industrial processes. Professor Kaj Henricson supervised operations in Kotka, focusing on doctoral-level research and education in Fiber Technology, as well as initiating business projects, particularly in machinery development. These efforts facilitated closer collaboration between LUT and Andritz, culminating in the creation of a joint research center at the LUT Lahti campus in autumn 2022.

Regional Development

In addition to satellite activities related to paper technology in Savonlinna and Kotka, Mikkeli became a prominent center for the Department's expertise in green chemistry and water technology. This development has been supported by the City of Mikkeli and local companies. Professor Mika Sillanpää led the Green Chemistry Laboratory in Mikkeli from 2014 to 2019. Since 2020, Professor Amit Bhatnagar has been overseeing activities in Mikkeli.

Centre for Separation Technology

Although the pulp and paper industry was a significant focus within the department, another crucial area that linked various laboratories was separation science.

By the 1990s, the department possessed a diverse array of expertise in separation technology. Seppo Palosaari specialized in crystallization and filtration, Lars Nyström was an authority in solid-liquid separation, Marianne Nyström focused on membrane technology, and Erkki Paatero contributed expertise in liquid-liquid extraction. In 1997, the need for a dedicated approach to separation technology was recognized, leading to the establishment of the Centre for Separation Technology (CST). This centre was created to facilitate research and foster collaboration between industry and academia in the field of separation technologies at the department.

CST's mission has always been to transfer university research to industry and foster collaboration, involving companies like Larox, UPM, StoraEnso, Andritz just to mention a few. Timo Vartiainen of Larox served as CST's first chairman for 23 years, exemplifying long-term industry-academic cooperation. CST has also benefited from long-standing professorships funded by industry, notably in solid-liquid separation technology and paper technology related topics.

Figure 2. CST around 1998. Front row from left to right: Professors Hannu Manner, Lars Nyström, Marja Oja, Marianne Nyström, Jutta Nuortila-Jokinen, Erkki Paatero and Juha Kallas.

To summarize...

The early decades of development, characterized by vision and determination, positioned the Department to refine its strategy and emphasize separation technology, a core element in numerous processes and the circular economy. The innovative spirit and bold risk-taking of the initial generation of professors in the Department, along with dedicated research and teaching efforts, were instrumental in achieving the Department's ambitious long-term goals to become acknowledged authority in separation technology.

The following documents in this Chapter present a series of recollections from the formative years of the Department of Chemical Technology, authored by individuals who experienced those early days firsthand. These reflections offer valuable insights into the Department's development, challenges faced, and milestones achieved during its initial phase. The narratives encompass personal anecdotes, historical context, and the evolution of academic and research activities within the Department. Such accounts are instrumental in understanding the foundational principles, institutional growth, and the contributions of pioneering staff and students. The recollections provide a useful historical overview, showing how the Department has developed over time. They emphasize the importance of keeping a record of the institution's history for future reference.

References

Unknown author (1960) Professor Seppo Wilska. [Image]. Suomen Kuvalehti 50/1960. Public Domain. Available at: https://commons.wikimedia.org/w/index.php?curid=96882603 (Accessed: 20 August 2025).

MATTI LINDSTRÖM

Professori (Em.) Fysikaalinen kemia

Miten Lappeenrantaan saatiin Teknillinen korkeakoulu ja sinne Kemiantekniikan osasto?

Suomessa oli tehty korkeakoulupolitiikkaa jo 1800-luvulla yliopistolakien ja -asetusten muodossa, mutta suunnitelmallisempaa politiikkaa ryhdyttiin tekemään 1950- ja erityisesti 1960-luvulla, kun korkeakoulutus alettiin nähdä tärkeänä osana valtion kehittämistä ja kilpailukykyä. Myös ikäluokkien kasvu toi painetta koulutuksen kehittämiseen.

Korkeakoululaitos oli vielä 1960-luvulla keskittynyt muutamiin suurimpiin kaupunkeihin, ja sitä sitoi yhteen Helsingin yliopiston hegemonia. Aina 1970-luvulle saakka korkeakoulupolitiikassa elettiin vaihetta, jossa varsinaista valtiollista kontrollia nykyisessä muodossa ei ollut. Keskeinen korkeakoulupoliittisen vallan käyttäjä oli Helsingin yliopisto. Sen kannanotot edustivat yliopistolaitoksen yhteistä kantaa, eikä niistä ollut soveliasta poiketa. Helsingin yliopisto valvoi käytännössä virkakelpoisuuksia koskevien asetusten nojalla myös muiden yliopistojen tutkintovaatimuksia.

Presidentti Kekkonen nimitti vuonna 1965 työryhmän, ns. ”Ketosen komitean”, laatimaan ehdotuksen toimenpiteistä, jotka toteuttamalla Suomen tieteellinen tutkimus sekä yliopistoissa ja korkeakouluissa annettava opetus voitaisiin pitää kansainvälisen kehityksen tasalla. Helsingin yliopiston silloinen teoreettisen filosofian professori Oiva Ketonen asetettiin presidentin työryhmän puheenjohtajaksi. Työryhmä esitti lain säätämistä esittämiensä toimenpiteiden toteuttamiseksi. Niinpä Ketonen sai tehtäväkseen laatia myös ehdotuksen kehittämislaista ja edisti lain läpimenoa niin tiedeneuvoston jaostossa kuin kulissien takana. Korkeakoululaitoksen kehittämislaki hyväksyttiin maaliskuussa 1966.

> **”Eipä tiennyt Pappa-Ketonen, että samaan aikaan kun hän komiteoineen valmisteli korkeakoululaitoksen kehittämislakia, hänen poikansa Matti Ketonen läiski iltaisin korttia Papan työhuoneella mm. perustettavan Lappeenrannan teknillisen korkeakoulun tulevan fysikaalisen kemian professorin Matti Lindströmin kanssa. Pokerivoitoillaan Matti K. osti vanhan mustan mersun, jolla nuoret miehet sitten ajelivat mm. Otaniemeen opiskelemaan.**

60-luvun loppupuoliskolla alkoi liikkua huhuja Oiva Ketosen korkeakoulupoliittisen komitean toiminnoista, jotka olisivat muuttamassa radikaalisti Suomen korkeakouluverkostoa. Tuohon aikaan Maalaisliitto (nyk. Keskustapuolue), presidentti Kekkosen oma puolue, pyrki vahvasti muuttumaan agraaripuolueesta sivistyspuolueeksi, joten oli selvää, että Suomen korkeakouluverkostoa tultaisiin laajentamaan sijoittamalla uusia korkeakouluja maakuntiin ja vahvistamalla vanhojen yliopistokaupunkien ulkopuolelle jäävien maakuntakorkeakoulujen asemaa.

Erityisesti, ajatellen Kaakkois- ja Itä-Suomea, oli aluksi ajatuksena sijoittaa vain yksi uusi korkeakoulu Itä-Suomeen. Tällöin kyseeseen tulisivat kaupungit, joilla olisi riittävä väestö-rakenne. Ainakin Joensuu, Jyväskylä, Kotka, Lappeenranta ja Savonlinna olivat mukana itäsuomalaisen yliopiston sijoituspaikkakeskusteluissa.

Pitkällisten vääntöjen jälkeen Itä-Suomen korkeakoulu päätettiin jakaa kolmelle eri paikkakunnalle. Keskustapuolueen (Kepu) sisäpiireistä onkin kerrottu, että kun maakuntien kepulaiset johtomiehet pitivät riitaista kokousta uuden korkeakoulun sijoituspaikasta silloisen opetusministeri Johannes Virolaisen kotitalolla, eikä sopua alkanut iltamyöhälläkään syntyä, tokaisi rouva Kaarina Virolainen neuvottelijoille kahvia tarjotessaan: "Jakakaa yliopisto kolmelle eri paikkakunnalle!" Ja niin Lappeenranta sai kovasti kaivatun teknillisen korkeakoulunsa.

LTKK:n kemiantekniikan osasto syntyy

Kun oli poliittisesti päästy yhteisymmärrykseen Itä-Suomen korkeakoululaitoksen perustamisesta ja paikkakunnista, joilla opetusta ja tutkimusta tultaisiin harjoittamaan, alkoi Lappeenrannan teknillisen korkeakoulun (LTKK) osalta kiivas väittely siitä, mitä tekniikan aloja LTKK:lla tulisi opettaa. Aika nopeasti päästiin yksimielisyyteen siitä, että ainakin konetekniikan, energiatekniikan ja uuden, hyvin suosituksi muodostuneen alan, tuotantotalouden (TuTa), opetusohjelmat aloitettaisiin mahdollisimman nopeasti.

Uudessa korkeakoulussa vallitsi heti alusta alkaen hyvä pöhinä, ja opiskelijoita saatiin runsaasti aloittamaan opinnot niin kone- kuin energiatekniikan osastoilla. Yhtenä syynä oli varmaan se, että esim. energiatekniikan opetusohjelma (EnTe) oli jo heti alusta pitäen varsin moderni verrattuna TKK:n sähkötekniikan osaston opintoihin. Siksi se kiinnosti monia, erityisesti kun sisäänpääsypisteet ko. opintoihin eivät nousseet kovin korkeiksi. LTKK:n energiatekniikan osaston opetusohjelmassa oli otettu huomioon myös sellaiset modernit opetusalueet kuin ydinvoimatekniikka ja energiatalous, mitkä varsin hyvin houkuttelivat hakemaan opintopaikkaa LTKK:lta.

TuTa:n opinnot erosivat tuona aikana varsin paljon TKK:n tuotantotalouden opinnoista. LTKK:n TuTa-opinnoissa painotettiin enemmän taloutta, kun taas TKK:n TuTa-opinnot sisälsivät tuohon aikaan paljon teoreettisia, matemaattispainotteisia opintoja. Ei siis ollut ihme, että Lappeenrantaan saatiin helposti tälle uudelle, suositulle tekniikan ja talouden alalle pyrkimään kiinnostuneita opiskelijoita.

Sangen erikoinen sivujuonne oli se, että Viipurin perinteitä vaalivat johtavat lappeenrantalaiset poliittiset piirit alkoivat ajaa varsin äänekkäästi LTKK:n tuotantotalouden osaston asteittaista muuttamista Lappeenrannan vanhojen Viipurin perinteiden mukaisesti kauppakorkeakouluksi. Tämä johtikin nopeasti tilanteeseen, jossa peistä väännettiin siitä, tulisiko Lappeenrantaan kauppatieteen vai kemiantekniikan osasto.

Lappeenrannan ja sen ympäristön elinkeinoelämä asettui kuitenkin vahvasti tukemaan kemiantekniikan osastoa. Myös hyvää vauhtia Suomen suurimmaksi yritykseksi kehittymässä olevan Neste Oy:n toimitusjohtaja Uolevi Raade vaikutti voimakkaasti LTKK:n rakenteen kehittymiseen tukemalla kemiantekniikan osaston perustamista. Niinpä pitkällisen poliittisen väännön jälkeen saatiin lopulta aikaan päätös kemiantekniikan osaston perustamisesta LTK-K:uun ja kemiantekniikan perusopinnot päästiin aloittamaan v. 1975.

KeTe 1980-luvulla

1970-luvun puolella LTKK:n kemiantekniikan osaston resurssit olivat varsin vaatimattomat, sillä tuolloin sillä ei ollut omia tiloja eikä kovin paljon henkilöresurssejakaan. Käynnissä olivat kuitenkin jo uudisrakennuksen suunnittelu- ja rakennustyöt. Valmistuvassa uudisrakennuksessa tulisivat sijaitsemaan KeTe-osaston uudet tilat, joiden suunnitteluun teknillisen kemian professori ja osaston johtaja Seppo Wilska oli osallistunut aktiivisesti.

Seppo Wilskan ohella osaston professoriksi oli nimitetty prof. Seppo Palosaari, jonka opetus- ja tutkimusalaksi oli tullut "kemian laitetekniikka". Seppo Palosaaren tieteellisteknillinen mielenkiinto kohdistui pitkälti tietokoneiden käyttöön ja ohjelmointiin ratkaistaessa kemiallisteknisten laitteiden suunnitteluongelmia.

Professori Palosaari olikin avustanut varsin paljon professori Wilskaa tämän suunnitellessa toisaalta osaston opetusohjelmaa ja toisaalta rakenteilla olevan uuden KeTe-osaston eri laboratorioiden laitteiden ja niiden toimintojen valintoja ja hankintoja. Mitään suurisuuntaistahan ei ollut voitu aikaisemmin toteuttaa jo siitäkin syystä, että osaston käytössä oli ollut vain yksi laboratoriotila LTKK:n yleisten tieteiden laitoksen väliaikaiseen käyttöön luovuttamissa tiloissa, jotka sijaitsivat LTKK:n ensimmäisessä rakennusvaiheessa ja soveltuivat ainoastaan "peruskemioiden" opetukseen.

Kemiantekniikan osaston (KeTe) perusopetuksesta vastasivat vuoden 1980 alussa apul. prof. Pentti Minkkinen, jonka opetusaloja olivat epäorgaaninen kemia ja analyyttinen kemia, fysikaalisen kemian apul.prof. Matti Lindström sekä FT Salme Koskimies, jonka opetusalana oli orgaaninen kemia. Assistentteina toimivat FM Helinä Pihlaja, FM Maija-Riitta Lyytinen ja DI Riitta Mennola.

Heidän lisäkseen osastolla oli tuolloin osastosihteeri Taina Haapasalo, laboratorioinsinööri DI Markku Levomäki ja laboratoriomestari Pekka Järvi sekä muutamia tuntiopettajia.

Apul.prof. Minkkisen tutkimusintressit kohdistuivat pitkälti analyyttisessä kemiassa saata-

Kuva 1. LTKK vietti 10-vuotisjuhliaan ja toisen rakennusvaiheen ("KETE-siipi") vihkiäisiä maanantaina 3.3.1980. Juhlapuheet pidettiin uuden siiven laitehallisssa, jossa ei vielä tuolloin ollut yhtäkään tutkimuslaitteistoa

vien mittaustulosten tulkinnassa tarvittaviin tilastollisiin menetelmiin. Fysikaalisen kemian apul.prof. Matti Lindström jatkoi sähkökemiaan liittyvää tutkimustaan ja kiinnostui mm. sähkökemiallisista vuorovaikutuksista suodatuskalvojen ja suodatettavien aineiden välillä.

Mainittakoon vielä, että FT Salme Koskimies, joka oli kekseliäs tutkija ja ahkera patentoija, teki sittemmin pitkän uran Neste Oy:ssä ja VTT:ssa johtavissa kehitystehtävissä. Matin edeltäjä vt. apul.prof. Pentti Passiniemestä tuli Neste Oy:n palveluksessa luultavasti ensimmäinen henkilö Suomessa, joka paneutui syvällisesti litium-polymeeri-akkujen tutkimukseen. Kovia tekijöitä siis.

Tekniikka vai talous?

Maaliskuussa 1980 vietettiin LTKK:n kemiantekniikan (KETE) osaston rakennuksen vihkiäisiä. Paikalla juhlatilassa, kemian laitetekniikan laitehallissa, oli varattu istumapaikat kutsuvieraille. Juhlatila oli varsin karu, koska KeTe:n laitehalli ammotti tyhjyyttään, kun lukuun ottamatta juhlayleisölle varattuja tuolirivejä ja tasavallan presidentti Urho Kekkoselle varattua puhujapönttöä laitehallissa ei ollut yhtään mitään.

Itse laitehallissa ei ollut edes kahvitarjoilua, vaan se oli järjestetty LTKK:n 1. rakennusvaiheen opiskelijoiden ruokailutilaan. Siellä virisi-

☐ Tasavallan presidentti Urho Kekkonen kunnioitti läsnäolollaan Lappeenrannan teknillisen korkeakoulun 10-vuotisjuhlaa ja samalla II-rakennusvaiheen vihkiäistilaisuutta maanantaina. Presidentin lisäksi kutsuvierasjoukossa oli runsaasti arvovaltaisia vaikuttajia sekä Lappeenrannasta että kauempaa.

LTKK juhli, UKK mukana

E-S. 4.3.80

☐ Lappeenrannan teknillinen korkeakoulu vietti toimintansa 10-vuotisjuhlia ja II-rakennusvaiheen vihkiäisiä Lappeenrannassa maanantaina. Tasavallan presidentti Urho Kekkonen kunnioitti tilaisuutta läsnäolollaan. Tasavallan Presidentti paljasti pääjuhlassa 10-vuotisjuhlalaatan ja samalla vihki II-rakennusvaiheen käyttöön.

Kuva 2. Etelä-Saimaa raportoi Kemiantekniikan osaston uusien tilojen vihkimisestä 4.3.1980.

kin juhlayleisön keskuudessa vireä keskustelu siitä, voitaisiinko jollakin keinoin kuitenkin saada LTKK muutetuksi Lappeenrannan kauppakorkeakouluksi (LKKK), joka olisi sopinut paljon paremmin niille lappeenrantalaisille, jotka olivat pitkään haaveilleet siitä, että Lappeenrannasta jonakin kauniina päivänä tulisi uusi Viipuri. Myös Neuvostoliiton romahtaminen pani monet miettimään hyvien kaupallisten yhteyksien luomisen tärkeyttä, vaikkapa pietarilaisten tahojen kanssa, jossa kauppakorkeakoululla voisi olla merkittävä rooli. Vastakkainasettelu Lappeenrannan teknillinen korkeakoulu versus kauppakorkeakoulu jatkui hyvin pitkään. Viimein haave kauppakorkeakoulusta toteutui, kun TuTa-osaston kauppatieteiden laitoksesta syntyi LUT-kauppakorkeakoulu (LUT Business School) syksyllä 1991.

Erotustekniikka nostaa päätään

Kun Suomen teollisuudesta alkoi kantautua tietoja halukkuudesta lähteä kehittelemään yhteisprojekteja LTKK:n kemiantekniikan osaston kanssa, haistettiin KETE:llä mahdollisuuksia aloittaa mielenkiintoisia ja ajankohtaisia tutkimusprojekteja niiden kanssa. Erotustekniikat tunnistettiin jo silloin keskeiseksi teemaksi, johon uudet laboratoriot voisivat sitoutua ja hakea projektirahoitusta sitä mahdollisesti myöntäviltä tahoilta.

Jo 80-luvun alussa saatiinkin pyörimään Nesslingin säätiön apurahan ja Kaukas Oy:n yhteistoiminnan ansiosta jätevesien käsittelyä ja sellun valkaisussa syntyvien klooriyhdisteiden määrää ja poistoa käsittelevä varsin laaja, mutta silti pienimuotoinen tutkimus. Aika pian projektin aloituksen jälkeen ko. ongelma kuitenkin poistui, kun Kaukas Oy:n tehtaat muuttivat radikaalisti sellun valkaisuprosessejaan sekä tehtaan jätevesien käsittelyä.

Nämä pienet "yritysmäiset" ja tunnustelevat projektit eivät kuitenkaan johtaneet mihinkään tiettyyn suhteellisen laaja-alaiseen ja tärkeään teemaan liittyvän tutkimusprojektin aloittamiseen. Professorikunnalla oli kyllä tiedossa, että professori Palosaarella oli mielessä valmiiksi mietittynä useita mielenkiintoisilta vaikuttavia tutkimusaiheita. Niitä olisi mahdollista tutkia lähes teollisessa mittakaavassa olevilla uskottavilla laitteilla paremmin kuin pienillä laboratoriolaitteilla. KETE-osastolla olisi riittävästi tilaa lähes tyhjillään seisovassa laitehallissa, kunhan ensin tarvittavat laitteet saataisiin rakennettua. Tiedostettiin, että laitteiden rakentaminen olisi ehkä mahdollista, jos KETE-osastolle saataisiin palkattua tarvittava ja riittävän osaava henkilökunta niitä kehittämään ja rakentamaan.

Professori Palosaari oli hyvin varhaisessa vaiheessa jo TKK:n kemianosastolla toimiessaan todennut, että Neste Oy:n jalostamoiden kehittäminen tulisi vaatimaan satsauksia ainakin petrokemiallisissa prosesseissa tarvittavien yksikköoperaatioiden kehittämiseen. Tämän aihepiirin tutkimusta ja laitesuunnittelua tiedettiin tehtävän Neste Oy:n ja yhtiötä lähellä olevan insinööritoimisto Rinteknon toimesta. Tavallaan saman tyyppisten aiheiden parissa työskenteli myös Lappeenrannassa PI-consulting-niminen insinööritoimisto, joka kuitenkin oli enemmänkin puunjalostukseen liittyvien aiheiden parissa toimiva yritys. Tokihan puunjalostusteollisuuskin oli kiinnostunut erotustekniikoista, mutta hieman eri lailla kuin kemianteollisuus.

Kun oli selvää, että kysyntää todennäköisesti löytyisi, Seppo Palosaaren halua hankkia LTKK:lle erotustekniikoita tutkivia laitteistoja ei kukaan LTKK:n KETE-osaston henkilökunnassa vastustanut ja useimmilla professoreilla olikin jo mielessä erotustekniikoihin liittyviä tutkimusaiheita, mutta rahoitus puuttui.

Kemian laitehallissa alkoi tapahtua

Vuonna 1983 Itä-Suomen korkeakoulujen kehittämistä ansiokkaasti ajanut Keskustapuolue hävisi eduskuntavaalit, ja valtaan nousi sosialidemokraattien ja muutaman pienemmän puolueen muodostama koalitiohallitus, jossa vallankäytöstä nauttimaan pääsi Veikko Vennamon perustama Suomen Maaseudun Puolue (SMP). Uuden hallituksen sosiaalidemokraateilla oli halua parantaa työttömäksi jääneiden ihmisten elintasoa ottamalla käyttöön valtion kassasta maksettavat työttömyyskorvaukset. Myös SMP tuki päähallituspuoluetta ainakin osittain tässä asiassa, ja asian vauhdittamiseksi uusi hallitus perusti työllisyysministerin viran, johon nimitettiin Etelä-Karjalan vaalipiiristä eduskuntaan valittu SMP:n Urpo Leppänen. Liekö kyseessä sitten ollut kotiseuturakkaus vai toive uudelleenvalinnasta eduskuntaan, mutta Leppänen myönsi työllistämisrahoitusta vastavalmistuneiden teknikoiden palkkaamiseksi LTKK:n kemiantekniikan osastolle.

KETE-osasto saikin näistä teknikoista erinomaista työvoimaa osaston laitehallin rakentamiseen ja sinne sijoitettavien professori Palosaaren piirustusten mukaan rakennettavien laitteiden toteutukselle. Alkuun joku professori saattoi kuitenkin joutua kahnaukseen nuoren, vasta teknillisestä koulusta valmistuneen teknikon kanssa, jonka oli kantapään kautta opeteltava, että koulussa opetetut tiedot mahdollisimman halvan materiaalin, useimmiten meltoraudan, käytön taloudellisuudesta eivät pitäneetkään paikkaansa KETE-osastolla, jossa "musta rauta" saattoi muuttua punaisenkirjavaksi muutamassa päivässä. Kiitettävällä tavalla uudet teknikot kuitenkin oppivat, että käyttökelpoisia materiaaleja laitevalmistuksessa voivat olla lämpöä ja kemikaaleja kestävät eksoottisiksikin koetut muovit ja metallit, kuten teflon, nailon ja titaani, happoteräs ja jalometallit.

Kaiken kaikkiaan Urpo Leppäsen hallituskauden alun jälkeen alkoi KETE-osaston laitehalliin syntyä massiivisen kokoisia tislaimia, kiteyttimiä ja melko pian myös kalvoteknisiä laitteita.

Pikantti yksityiskohta lähiseudun teollisuuden uudelle kemiaan erikoistuneelle osastolle tarjotusta avusta oli mahdollisuus ottaa talteen Imatralle rakennetun, mutta toimintansa keskeyttäneen Finnvalco-nimisen televisioiden ja tietokonenäyttöjä valmistavan kuvaputkitehtaan konkurssipesän käyttölaboratorion laitteita ja tarvikkeita. Käyttölaboratoriosta löytyi muiden muassa massaspektrometri, joka kiinnosti meitä kovastikin. Ilmeni kuitenkin pian, että ko. laitteen sydän, suurikokoinen kestomagneetti, makasi huonokuntoisena ja asentamattomana laitteen kaapin pohjalla. Poistuimme paikalta tyhjin käsin.

Näin jälkeen päin mietittynä...

Lappeenrannan teknillinen korkeakoulu ja sen kemiantekniikan osasto oli nuori ja ketterä, ja se pystyi kehittämään toimintaansa ilman edellisten (professori)sukupolvien painolastia. Maalaiskorkeakoulun osastosta on 50 vuodessa kehittynyt kansainvälisesti tunnustettu erotustekniikan osaaja. Tämä ei olisi onnistunut ilman onnistuneita rekrytointeja, kaukonäköistä visiota sekä lisäksi järjestelmällistä ja innostunutta tutkimus- ja opetustoimintaa – eikä tietenkään ilman ensimmäisen sukupolven luovaa hulluutta ja mitään pelkäämätöntä riskinottoa!

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PENTTI MINKKINEN

Professori (Em) Epäorgaaninen ja analyyttinen kemia

Miten erotustekniikasta tuli Kemiantekniikan osaston keskeinen tutkimusala?

Seppo Wilska kutsuttiin 1974 suunnittelemaan kemian tekniikan opetuksen aloittamista Lappeenrannan teknillisessä korkeakoulussa ja nimitettiin osaston ensimmäiseksi professoriksi erikoisalana teknillinen kemia. Osaston opetussuunnitelma ja tarvittavat tehtävänimikkeet perustuivat hänen suunnitelmiinsa. Erityisesti hän korosti sitä, että kemisti-insinööri tarvitsee varsinaisten insinööritaitojen lisäksi hyvät tiedot kemiasta ja sen perusilmiöistä. Perusopetus alkoi 1975 Wilskan ja yhden assistentin (Helinä Pihlaja) voimin. Ensimmäisen rakennusvaiheen tiloihin oli rakennettu oppilaslaboratorio, jossa voitiin tehdä peruskemian laboratoriotyöt. Itse aloitin 1.9.1976 epäorgaanisen ja analyyttisen kemian apulaisprofessorina, pysyvän nimityksen sain 1.3.1978 ja samalla nimityksen osaston varajohtajaksi. Koska syventävissä opinnoissa tarvittavia tutkimuslaboratorioita ja -laitteita ei vielä silloin ollut käytettävissä, kaksi ensin aloittanutta kurssia suoritti eräänlaisen hybriditutkinnon (tuota hienoa termiä ei silloin osattu vielä käyttää). Tämän yhdistelmätutkinnon suorittaneet opiskelijat suorittivat syventävät opinnot ja diplomityön muilla osastoilla, suurin osa tuotantotalouden osastolla. Kemiantekniikan opetuksen aloitus tällä tavalla oli fiksu ratkaisu. Jos aloitusta olisi myöhennetty, olisi ollut mahdollista, että kemiantekniikan opetusta ei olisi aloitettu tai se olisi ainakin viivästynyt.

Tutkimustoiminta käynnistyi vasta 80-luvun alussa, kun osasto sai omat tilat käyttöönsä toisen rakennusvaiheen valmistuttua. Aloitus olikin komea, sillä rakennuksen vihki käyttöön itse tasavallan presidentti Urho Kaleva Kekkonen. Tärkeimmät professuuritkin oli jo saatu täytetyksi ja hyvät suhteet teollisuuteen alkoivat rakentua. Silloin pohdittiin, voitaisiinko käynnistää jokin yhteinen tutkimushanke. Siihen aikaan sellun valkaisuun käytettiin yleisesti klooria, joka sivutuotteena synnyttää ympäristölle haitallisia kemiallisesti kestäviä kloorattuja orgaanisia yhdisteitä, joita ei silloisilla jäteveden puhdistustekniikoilla voitu poistaa jätevesistä. Kiinnostavaksi tutkimuskohteeksi tuli "Metsäteollisuuden valkaisujätevesien käsittely". Wilska ehdotti hankkeen vetäjäksi Seppo Palosaarta. Lupaavana tekniikkana pidettiin kalvotekniikoita, jotka olivat juuri kehitysvaiheessa. Tekniikka tarjosi sopivasti sekä tieteellisiä että käytännön haasteita. Matti Lindström pääsi soveltamaan fysikaalisen kemian osaamistaan, Seppo Palosaari kemian laitetekniikan. Markku Laatikainen oli tässä vaiheessa vahvasti mukana Palosaaren tutkijana. Minä sain tähän projektiin vuodeksi työntekijäksi Teknillisessä korkeakoulussa DI-tutkinnon suorittaneen Marja Korpion. Hänen kanssaan tutkimme mielenkiintoista mahdollisuutta, missä puhdistettava aine muodostaa itse suodatuskalvon sopivan tukimateriaalin päälle. Tämä on mielenkiintoinen, mutta vaikeasti hallittava tekniikka isossa mittakaavassa. Hankkeen tuloksia käytiin esittelemässä Ruotsissa (Minkkinen ja Korpio, 1982) ja LTKK:n julkaisusarjassa (Korpio ja Minkkinen,1983)

Tämän alun jälkeen oma tutkimusalueeni suuntautui muualle, mutta erotustekniikka jäi LUT:n repertuaariin pysyvästi. Marianne Nyström kiinnostui kalvotekniikasta väitöskirjatutkimuksensa aiheena ja onnistui kasvattamaan innostuneen tutkijaryhmän ympärilleen. 90-luvulle tultaessa osastolla oli jo varsin monipuolinen osaaminen erotustekniikasta. Palosaari oli tutkinut kiteytystä ja suodatusta, Lars Nyström oli prosessitekniikan osaaja, Erkki Paatero toi palettiin neste-nesteuuton. Siihen mennessä, kun tuli minun vuoroni toimia osaston johtajana (1.1.1995–31.7.1998), aika oli kypsä siihen, että tämä monipuolinen osaaminen haluttiin koota yhteen perustamalla erillinen Erotustekniikan keskus. Kemian tekniikan osaston johtajana kannatin ajatusta.

Paikallinen teollisuus suhtautui ajatukseen innostuneesti, erityisesti Larox, joka neuvotteluissamme tarjosi keskukselle viiden vuoden professuuria erotustekniikkaan. Se tarjous oli helppo hyväksyä ja valituksi tuli Marja Oja. Samaan aikaan kävin neuvottelua myös Savonlinnan kanssa. Savonlinna toivoi, että sinne perustettaisiin LTKK:n sivuosasto.

Toiminta Savonlinnassa aloitettiin 3-vuotisella Cleantech2000-hankkeella (1997–2000), jota rahoittivat Euroopan aluekehitysrahasto (EAKR), Euroopan sosiaalirahasto (ESR) sekä Savonlinnan kaupunki yhdessä paikallisten yritysten, kuten Ahlstrom Machinery Oy:n, Aquaflow Oy:n ja useiden Savonlinnan seudulla toimivien pk-yritysten, kanssa. Jutta Nuortila-Jokinen toimi hankkeessa tutkimusprofessorina. Cleantech2000-projekti loi pohjan Savonlinnaan perustetulle LTKK:n kuitutekniikan laboratoriolle.

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MARJATTA LOUHI-KULTANEN

Professori, Aalto yliopisto

Kemian laitetekniikan laboratorio 1980–2017

Professori Seppo Palosaaren kemian laitetekniikan tutkimusryhmä 1980- ja 1990-luvulla LTKK:ssa

Prof. Palosaaren päätutkimusaiheina olivat mm. teollinen kiteytys, kalvoerotusprosessien mallinnus, adsorptio, CFD-mallinnus sekä monimuuttujamallinnus kehitettyyn SMIN-optimointiohjelmistoon pohjautuen. Yksi tutkimushankkeista oli Teknologian kehittämiskeskuksen (TEKES), Lääketehdas-Medica Oy:n, Orion-Yhtymä Oy Fermionin, Huhtamäki Oy Lääketehdas Leiraksen, Farmos-Yhtymä Oy Medipolarin sekä Oy Star Ab:n rahoittama Orgaanisten kemikaalien puhdistaminen sulakiteytyksellä -tutkimushanke. Hanke edisti verkostoitumista, ja sen kautta oli mahdollista tehdä hienokemikaalien puhdistuvuustutkimusta kiteytyksellä. Kauppa- ja teollisuusministeriön energiaosasto, Cultor Oy Suomen Sokeri sekä Imatran Voima Oy rahoittivat Vesiliuosten väkevöinti kiteyttämällä -hankkeen. Mustalipeän sekä sokeriteollisuudesta betaiinia sisältävän vesiliuoksen jäädytysväkevöintiä tutkittiin jatkuvatoimisilla jäädytyskokeilla hyödyntäen kemiantekniikan osaston laitehalliin rakennettua pilot-mittakaavan jäälämpöpumppulaitteistoa. Jäälämpöpumpun toimintaolosuhteet perustuvat vesiliuoksen trippelipisteeseen: samanaikaisesti liuos sekä kiehuu n. 6 mbarin paineessa että osittain jäätyy alle nolla-asteen lämpötiloissa. Tiivistyvä höyry tuo systeemiin energiaa, jota voidaan edelleen hyödyntää väkevöintiprosessin myöhemmissä vaiheissa.

Tutkimusta tehtiin pitkälti kemiantekniikan osaston korjauspajan suunnittelemilla ja rakentamilla koelaitteistoilla. Yrityspartnereina kiteytystutkimushankkeissa olivat mm. Kemira Oy, Cultor Oy sekä Orion-Yhtymä Oy Fermion.

Tutkimusyhteistyö oli erittäin vireää japanilaistutkimusryhmien kanssa. Esimerkiksi prof. Ken Toyokura Wasedan yliopistosta, prof. Kohei Ogawa Tokyo Institute of Technologysta, prof. Noriaki Kubota Iwaten yliopistosta sekä Dr. Yoshihito Shirai Kioton yliopistosta vierailivat LTKK:ssa.

Professori Juha Kallaksen (2000-2008) ja Professori Marjatta Louhi-Kultasen (2009–2017) tutkimusryhmät 2000- ja 2010-luvulla

Prof. Kallas käynnisti jätevesien käsittelytutkimukset eri hapetustekniikoihin perustuen sekä kalsiumkarbonaatin uusiokäyttötutkimukset jätevirroista. Väitöskirjatutkimuksissa tutkittiin lääkeaineita ja ligniiniä sisältävien jätevesien käsittelyä ja energiatehokkuutta kaasufaasissa tapahtuvaan pulssitettuun koronasähköpurkaukseen pohjautuen.

Kiteytystutkimusta jatkettiin Suomen Akatemian ja Tekesin rahoittamissa hankkeissa. Lääkeaineiden liuoskiteytys- ja suodatustutkimukseen paneuduttiin Tekesin rahoittamissa Lääke 2000 -ohjelman hankkeissa. Näissä lääkeainetutkimushankkeissa oli mukana Helsingin yliopiston farmasian teknologian tutkimusryhmä, jonka kanssa tehtiin tutkimusyhteistyötä myös lääkeaineprosessien jatkuvasta seurannasta spektroskopiaa ja prosessimikroskopiaa hyödyntäen yhdessä prosessien monitorointimenetelmiä kehittäneiden suomalaisyritysten kanssa. Suomen Akatemian rahoittamassa hankkeessa tutkittiin luonnollista jäädytystä kylmän ilmaston talviolosuhteita hyödyntäen muun muassa kenttäkokein jätevesialtailla kunnallisilla jätevedenpuhdistamoilla ja kaivannaisteollisuudessa. Hankkeessa tutkittiin myös tuuliolosuhteiden ja lämpötilan vaikutusta kemiantekniikan osaston konepajan rakentamalla talvisimulaattorilla. Jäänäytteiden mekaanisia ominaisuuksia tutkittiin yhdessä LUT:n konetekniikan ja Aallon meritekniikan tutkimusryhmien kanssa.

Lähteet

1) Professori Marjatta Louhi-Kultanen työskenteli mm Kemian laitekniikan (sittemmin Erotustekniikan) laboratoriossa Erotustekniikan ja Termisten erotusprosessien professorina vuosina 2009-2017.

ERKKI PAATERO

Professori (Em) Teknillinen kemia

Teknillisen kemian laboratorio 1990-luvulla

Tässä kappaleessa kerron omasta näkövinkkelistäni, miksi ja miten Teknillisen kemian laboratorio suuntautui erotustekniikan alueelle 1990-luvulla. Näin se suunnilleen meni. Oli sattuman seuraus, että aloitin kemiantekniikan professorina ja laboratorion esimiehenä Lappeenrannassa. Aikoinaan omassa diplomityössäni Åbo Akademissa sain opastusta Honeywell 316 -tietokoneen käytössä Lars Nyströmiltä, joka myöhemmin siirtyi professoriksi Lappeenrantaan, ja hän oli siten ennakkotapaus. Väitöstutkimuksen tein Åbo Akademissa metallinuutosta.

Osallistuin 80-luvun lopulla luennoitsijana eräälle INSKO:n kurssille. Samoin siellä oli myös LTKK:n prof. Seppo Palosaari, ja järjestäjät olivat sattumoisin sijoittaneet meidät samaan hotellihuoneeseen. Tunsimme toisemme ennestään aiemmilta INSKO:n kursseilta. Tiesin, että hän oli tehnyt mm. neste-nesteuuttoon ja uuttokennoihin liittyvää tutkimustyötä. Keskustelimme hotellihuoneessa erotustekniikoihin liittyvistä aiheista, ja kesken kaiken hän yht'äkkiä tokaisi: "Seppo Wilskan professuuri tulee kohta hakuun Lappeenrannassa. Sinähän voisit sopia siihen. Tosiaan, hae sitä." (lyhyitä täsmällisiä lauseita, jotka jäivät mieleen). Kun aika koitti, lähetin, kuten silloin oli tapana, tasavallan presidentti Mauno Koivistolle osoitetun hakemukseni. Aloitin LTKK:ssa sitten vuoden 1992 alussa, jolloin Teknillisen kemian päätutkimusaloiksi tulivat kemialliset erotusmenetelmät, etenkin neste-nesteuutto ja ioninvaihtomateriaaleihin liittyvät teknologiat.

Kemiallisten erotusmenetelmien sovelluksia Suomessa

Taustaksi on hyvä kertoa, mikä metallien uuton ja ioninvaihtohartseja käyttävän kromatografisen erotuksen tilanne oli Suomessa ennen vuotta 1992.

Olin Åbo Akademissa prof. Leif Hummelstedtin jatko-opiskelijana 70- ja 80-luvuilla. Hän sai joskus 1970-luvulla soiton Outokumpu Oy:stä dipl.ins. Tapio Tuomiselta, joka ehdotti yhteistyötä metallinuuton tutkimuksessa. Niinpä Åbo Akademiin muodostui pieni tutkijaryhmä, ja siellä tehtiin useita peräkkäisiä diplomityöprojekteja. Valmistuneet työllistyivät hyvin Outokumpu Oy:n Porin tutkimuskeskukseen sekä Kokkolan tehtaille, jossa neste-nesteuuttoa alettiin soveltaa mm. koboltin, nikkelin, molybdeenin ja reniumin erottamiseen. Ohessa on kuva vuodelta 1980 molybdeenin talteenottoprosessista, joka koostui yhteensä kahdeksasta mixer-settler-uuttokennosta, jotka pilkottavat kuvan taustalla. Tuote oli Tornion jaloterästehtaalle toimitettu kalsiummolybdaatti. Reniumin uutto sijaitsi myös samassa tilassa, mutta siitä ei haluttu tiedottaa, sillä prosessi oli aikoinaan yksi maailman merkittävimpiä reniumin tuottajia.

Outokumpu Oy:n keskeinen uuttoprosessien

Kuva 1 Molybdeenin uuttoprosessi (Outokumpu Oy, 1980)

osaaja, niin tässä kuin muissakin projekteissa, oli tekn.lis. Bror Nyman. Hän oli jatkossa tärkeä LTKK:n yhteistyökumppani.

Tänään on mielenkiintoista todeta, että Suomessa myös Typpi Oy (nyk. Kemira Oyj) on kehittänyt aktiivisesti neste-nesteuuttoa ja uuttamalla erottanut harvinaisia maametalleja sivutuotteena Kuolasta tuodusta apatiitista Oulussa vuosina 1965–1972 (Judin & Sund, 1981). Prosessin kehittämisessä oli avainasemassa TKK:n prof. Olavi Erämetsä.

Myös tämän kirjoittajalla oli mahdollisuus nähdä prosessi, tosin vasta kun se oli jo ollut vuosia poissa käytöstä kannattamattomana. Harvinaisten maametallien nimitys on hieman harhaanjohtava, sillä nykytietämyksen mukaan ne eivät ole maaperässä kovin harvinaisia. Niiden erottaminen puhtaina on sen sijaan erittäin monivaiheinen ja kallis prosessi. Suomessakin tunnetaan useampi hyödynnettävissä oleva esiintymä.

Oulussa yksi uuton asiantuntijoista oli Åbo Akademista valmistunut dipl.ins. Jerker Örjans, joka Oulusta siirtyi Sambiaan maailman silloin suurimmalle kuparinuuttolaitokselle. Olin siellä yhden kesän 1978, ja minulle oli selvää, että uutto olisi tulevaisuuden teknologiaa. Se osoittautui soveltuvan hyvin metallien selektiiviseen talteenottoon ja väkevöintiin suhteellisen laimeista liuoksista. Sambian prosessista Örjans julkaisi erinomaisen kuvauksen ISEC77-konferensissa (Örjans *et al.*, 1979).

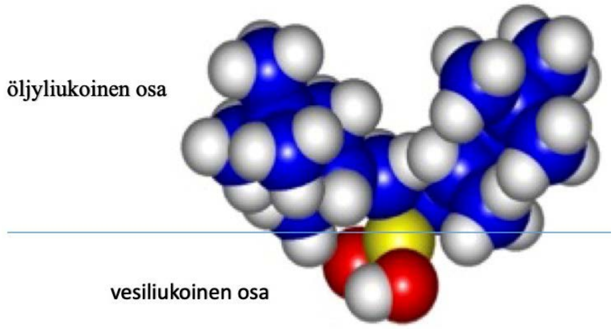
Tässä yhteydessä on välttämätöntä mainita, että myös UPM-Kymmene Oyj:n Kaukaan kemiantehtaalla Lappeenrannassa oli vuodesta 1977 alkaen ollut toiminnassa mixer-settler-neste-nesteuuttoon perustuva sekasuovan puhdistusprosessi. Vuonna 1980 siellä alettiin myös kolonnissa uuttamalla ottaa talteen sitosterolia. Tämän kirjoittajallakin oli aikoinaan ilo olla mukana pilotoimassa ao. kolonniuuttoa ÅA:n laitehallissa.

Monet uuttoreagenssit toimivat nestemäisinä ioninvaihtimina, joten meidän oli Teknillisen kemian laboratoriossa luonnollista ottaa mukaan tutkimusaiheina myös ioninvaihtohartsit, joita käytetään laajasti kemianteollisuudessa. Varsinkin kun niiden teollisia sovelluksiakin oli melko lähellä yliopistoa. Maailman ensimmäinen ksylitolitehdas aloitti nimittäin silloisen Suomen Sokeri Oy:n omistuksessa tuotannon Kotkassa vuonna 1975. Se perustui kromatografiseen erotukseen käyttäen itse kehitettyjä ja valmistettuja erotushartseja. Myöhemmin hartsiliiketoiminta myytiin sen toimivalle johdolle ja syntyi Finex Oy, jonka toimitusjohtajaksi tuli dipl.ins. Heikki Mononen. Molemmat firmat olivat alkuaikoina hyvin tärkeitä teknillisen kemian yhteistyökumppaneita. Sittemmin kumpikin on vaihtanut useamman kerran omistajaa.

Neste-nesteuutto, ioninvaihto ja kromatografinen erotus – ripaus teoriaa

Metallien neste-nesteuutto (jatkossa uutto) on kemiallinen erotusmenetelmä, joka perustuu siihen, että malmi, rikaste tai metallia sisältävä jäte liuotetaan sopivaan happoon (yleensä rikkihappoon). Tästä vesiliuoksesta metalli-ionit tai metalliyhdisteet uutetaan hiilivetyliuottimeen (öljyyn) käyttäen hyväksi orgaanisia uuttoreagensseja. Oheisessa kuvassa on esimerkkinä koboltin uuttoon soveltuva yhdiste bis(2,4,4-trimetyylipentyyli)fosfiinihappo. Siinä, kuten kaikissa teollisesti merkittävissä uuttoreagensseissa, on happiatomeita toiminnallisessa ryhmässä. Ne pystyvät muodostamaan veden kanssa vetysidoksia ja hakeutuvat siksi veden ja öljyn rajapinnalle ja sitovat siellä ioninvaihtona Co^{2+}-ionin. Reagenssissa on kaksi haaroittunutta hiilivetyketjua, jotka viihtyvät liuotinfaasissa, ja niin myös metallikompleksista tulee liukoinen liuotinfaasiin. Molekyyli on siis amfifiili, ja rakenne muistuttaa siinä mielessä pesuaineina käytettäviä tensidejä.

Kirjoittaja oli 80-luvulla oman väitöstutkimuksensa yhteydessä tutkijana Tukholman Ytkemiska Institutet -tutkimuslaitoksessa. Se auttoi ymmärtämään myös metallin uuttoprosessien



Kuva 2. Uuttoreagenssin molekyylirakenne. (Valkoinen = vety, punainen = happi keltainen = fosfori, sininen = hiili)

yhteydessä pinta- ja kolloidikemiaan liittyviä ilmiöitä, kuten käänteismisellien muodostuminen liuotinfaasissa, nestekidefaasien muodostuminen, geeliytyminen ja faasien selkeytyminen. Tämä teema jatkui myös LTKK:ssa ja antoi tutkimusryhmällemme kansainvälisesti muista poikkeavan "nichen", esimerkkinä E. Jääskeläisen väitöskirja (Jääskeläinen, 2000).

Suomessa 90-luvun alussa ainoastaan Outokumpu Oy oli kunnolla kiinnostunut neste-nesteuutosta, mistä johtuen Teknillisen kemian laboratorion kannalta oli välttämätöntä laajentaa erikoistumisalaa ioninvaihtomateriaaleihin ja niiden teknisiin sovelluksiin.

Tätä tavoitetta avitti sellainen sattuma, että omassa väitöstilaisuudessani oli yleisössä ÅA:n Polymeerikemian laboratoriosta FT Jan Näsman. Hänen ryhmänsä tutki tuolloin säteilytyksen avulla oksastettuja polyolefiinikuituja. Hän oli kiinnittänyt esityksessäni huomiota uuttoreagenssien rakenteisiin ja tuli tilaisuuden jälkeen keskustelemaan, millaisia toiminnallisia ryhmiä uuttoreagensseissa käytetään. Hän jäi miettimään, miten ne saisi kuidun pinnalle. Tuloksena oli kaupallisen Versatic 10 -uuttoreagenssin toiminnallisen ryhmän inspiroimana polyakryylihapolla oksastettu polyeteenikuitu. Kuidun geometrisella muodolla olisi se ilmeinen etu, että ryhmät olisivat hyvin ohuen kuidun pinnalla eikä materiaalin sisällä, kuten pallomaisissa ioninvaihtohartseissa.

Tutkimme Lappeenrannassa ÅA:n valmistamien kuitujen käyttöä niin metallien kuin aminohappojen talteenotossa (Kärki, Paatero & Sundell, 1996). Kuitujen potentiaalisimmaksi sovellukseksi osoittautui kuitenkin niiden käyttö katalyyttien kantajana (Helminen *et al.*, 1997).

Åbo Akademin tutkimusryhmä perusti myöhemmin Smoptek-nimisen yrityksen kuituioninvahtimien kaupallista valmistamista varten. Laboratoriomme ioninvaihtotutkimus alkoi näillä kuiduilla, mutta sitten pääpaino siirtyi kromatografisiin erotushartseihin ja niiden sovelluksiin. Tästä aiheesta enemmän toisaalla tässä kirjassa.

Opetuksesta

Vaikka laboratoriotutkimus vuonna 1992 uudistui, opetuksessa ei muutos ollut niin suuri. Assistenttien Markku Laatikaisen ja Leena Kantasen sekä lab.ins. Markku Levomäen ansiosta esim. laboratoriotyöt sujuivat vanhan hyväksi todetun mallin mukaan. Myös näin jälkikäteen katsoen erityisesti teknillisen kemian syventäviin opintoihin (SOJ) kuulunut pitkä, usein pareittain tehtävä projektiluonteinen laboratoriotyö oli onnistunut opetusmuoto. Se tuki myös laboratorion muuta tutkimusta ja saattoi olla osa sitä. Tällaisissa projekteissa oli mahdollisuus myös ottaa riskejä ja testata jotain uutta ideaa. Esimerkiksi diplomityössä se on vaikeampaa jo opiskelijan opintojen sujuvuuden kannalta. SOJ-töiden tulokset esiteltiin posterilla laboratorion käytävällä. Moni niistä oli niin hieno, että olisi kelvannut hyvin kansainväliseen konferenssiin.

GSCE:n ja CST:n synty

Osallistuminen kemiantekniikan valtakunnalliseen tutkijakouluun (*Graduate School in Chemical Engineering*, GSCE) vuosina 1995–2015 oli Kemiantekniikan osastolle äärimmäisen tärkeää. Miten se kohdallamme sai alkunsa, on kertomisen arvoista.

Kesäkuun 1994 alussa avasin Suomen Akatemiasta tulleen kirjeen, jonka merkitys ei aivan heti tullut ilmi. Kirjeessä yliopistoilta pyydettiin esityksiä uusista tutkijakoulutusohjelmista. Rahoitus oli tullut mahdolliseksi, kun valtion vuoden 1994 lisämenoarvioon sisältyi korkeakouluille osoitettu 48 milj. markan (8,1 milj. €) määräraha. Se oli päätetty suunnata jatko-opiskelijoiden palkkaamiseen ja se oli käytettävä vuoden 1995 loppuun mennessä. Näin ollen hakuprosessilla oli kiire ja esitykset oli toimitettava elokuun puoliväliin mennessä. Todella iso summa oli jaossa ja vielä loma-aikana. Tieto siitä tuli yliopistoille ilman ennakkovaroitusta eli "puskista", kuten Yrjö Haila kuvasi tapahtumia mainiossa artikkelissaan (Haila, 2016). Virassa olevilla professoreillahan ei ollut kesälomaa (vaan ainoastaan virkaan kuuluvia velvoitteita).

Tämä vaikutti olevan selvä "nopeat syö hitaat" -tapaus! Aloin heti työstää hakemusta, jonka otsikko oli *Graduate School for Separation Technology*. Soitin myös Åbo Akademin kollegalleni prof. Tapio Salmelle, joka ei silloin ollut huomannut SA:n kirjettä ja sen merkitystä. Kaavailimme, että ÅA:n Kemisk tekniska fakultet ja LTKK:n kemiantekniikan osasto jättäisivät myös yhteisen hakemuksen. Myös TKK oli jättämässä hakemuksen, ja lopulta SA käsitteli molemmat hakemukset yhdessä. Syyskuun lopulla SA teki myönteisen päätöksen, ja sen pohjalta käynnistettiin valtakunnallinen *Graduate School in Chemical Engineering* (GSCE) -tutkijakoulu. Erotustekniikan tutkijakouluhakemus ei luonnollisesti sitten enää sopinut tähän kuvaan.

GSCE:n johtokunnan ensimmäinen kokous alkoi lokakuussa hyvillä mielin, kun kuulimme, että meille oli myönnetty rahoitus 28 tohtoriopiskelijalle neljäksi vuodeksi. Sitten tuli ehkä vaikein ja tärkein päätös, kun piti sopia rahoituksenjaosta korkeakoulujen kesken. Tunnelma kiristyi kuultuamme, että paikat tulisi SA:n päätöksen mukaan jakaa kiintiöittäin ja LTKK:n osuus olisi ollut kaksi opiskelijaa. Tilanne ratkesi Mikko Hupan ehdottaessa, että paikat jaettaisiin opiskelijoiden ansioiden mukaan kunkin hakemuksen pohjalta. Se osoittautui erinomaiseksi ratkaisuksi. Menettely oli oikeudenmukainen myös hakijoiden kannalta, ja kouluun saatiin parhaat opiskelijat. Olisi ollut myös outoa, jos hakijoita ei olisi riittänyt kiintiöiden mukaan, kuten oli ilmeistä. Opiskelijoiden valinta tapahtui sitten hyvässä hengessä, ja vältyttiin professuurien välillä syntyviltä ristiriidoilta, mikä joissain tutkijakouluissa tuli eteen.

Väitöstutkimuksen ongelmana on tyypillisesti liian lyhytaikainen rahoitus ja usein vielä eri projekteissa, jolloin niistä on vaikea saada kokoon väitöskirjaa. Monivuotinen GSCE-rahoitus helpotti ratkaisevasti tohtoriopiskelijoiden asemaa. Tutkijakoulujärjestelmä oli meidän kannaltamme todella menestykäs, kuten oheinen inforuutu osoittaa. Todettakoon, että useampi nykyinen osaston professori on tehnyt väitöstyönsä GSCE:n puitteissa.

Myös Erotustekniikan keskuksen (*Centre for Separation Technologies*, CST) synty on siis perua samasta SA-tutkijakouluhausta, sillä sen pohjalta tehtiin LTKK:n sisäinen hanke-esitys, joka johti CST:n perustamiseen.

Hyvä idea mutta...

Spede Pasanen aikoinaan keksi ns. peräpurjeen. Eräässä tv-ohjelmassa toimittaja yllätti Speden näyttämällä piirroskuvaa, jossa jo foinikialaisilla oli veneessään peräpurje. Siihen Spede vastasi silmääkään räpäyttämättä: "hyvän keksinnön voi tehdä useampaan kertaan". No Speden peräpurje valitettavasti ei sitten ollutkaan menestys.

Ajat ja olosuhteet muuttuvat, mutta perusasiat varsinkin kemiassa pysyvät. Tällä periaatteella "sakkakurssin" opit ja vanhat analyyttisen kemian kirjat ovat hyviä tietolähteitä uusia teollisia sovelluksia kehitettäessä. Hyvä esimerkki on metallien kromatografiseen erotukseen liittyvä Samuelsonin 1950-luvun klassikkokirja (Samuelson, 1952).

Yleensä kirjoitetaan siitä, mikä on onnistunut, ja se päätyy tieteellisiin julkaisuihin ja patentteihin. Väittäisin, että kaikki metallit ovat erotettavissa laboratoriossa hydrometallurgisin menetelmin. Siinä vaiheessa, kun alkaa testata "uutta hyvää ideaa", mutta siitä ei kirjallisuudesta löydy ennestään mitään, on hyvä miettiä, voiko siihen olla jokin syy. On hyvä kuulostella kokeneempien tutkijoiden mielipiteitä esimerkiksi jonkin seminaarin tai konferenssin yhteydessä. Siellä voi kuulla, että "joo me kokeiltiin sitä jo 20 vuotta sitten, mutta...".

Kun laboratoriosta siirrytään teolliseen sovellukseen, tulee ratkaista useita haasteita, kuten vesitase, ympäristökysymykset, turvallisuus, kustannukset, reagenssin myrkyttyminen ja kemiallinen kestäminen jne. Se on insinööriosaamista, jota tarvitaan, kun halutaan parantaa maailmaa, ja sehän on erotustekniikoiden perimmäinen tarkoitus.

Tähän lopuksi täältä tieteen päätykatsomosta neuvo: "sattumalle pitää antaa mahdollisuus". Sattuma on elämänuralla usein hyvänä apuna, kuten edelläkin on muutamassa esimerkissä ilmennyt.

Graduate School in Chemical Engineering (GSCE) 1995-2015

- Four-year full-time studies financed by Academy of Finland
- Participants:
- Åbo Akademi University (coordinator), LUT, HUT (now Aalto) and University of Oulu
- Board chairman prof. Mikko Hupa 1995-2014, Henrik Saxén 2015,
- LUT representative prof Erkki Paatero 1995-2008, doc. Marjatta Louhi-Kultanen 2008-2015
- Joint intensive courses, annual seminars, Annual Book with research reports by each GSCE student
- Total more than 150 and among those 30 LUT students received their degree of Doctor of Technology within the GSCE framework

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JUTTA NUORTILA-JOKINEN

Teollisuusprofessori (eläkkeellä), Dosentti

Membraanitekniikan ja teknillisen polymeerikemian laboratorio – niin kuin minä sen muistan

Lappeenrantaan?

Keväällä 1987, kun olin Helsingin yliopiston (HY) Puu- ja polymeerikemian laitoksella tekemässä gradua edeltävää erikoistyötäni ja siippani oli ilmoittanut muuttavansa Lappeenrantaan Kymi-Kymmene Oy:n palvelukseen, professorini Franciska Sundholm vihjaisi, että LTKK:lla oli aloitettu polymeerikemian opetus ja että FL Sirkka-Liisa Maunu Franciskan laitokselta ottaisi apulaisprofessuurin vuodeksi haltuun. Mitä jos sieltä löytyisi minullekin hommia?

Niinpä Franciskan kehotuksesta päätin soittaa professori Matti Lindströmille, LTKK:n fysikaalisen kemian professorille, joka vastasi asiasta. Puhelimeen vastasi kuitenkin osaston sihteeri Taina Haapasalo, joka toimistonsa ikkunasta parkkipaikan tarkistettuaan totesi, että Matti on varmaan kotona, soita sille sinne. Siis että minä onneton luonnontieteiden kandidaatti soittaisin professorille kotiin? Huh-huh, olipas täällä erikoiset tavat!

Uhkarohkeus kuitenkin kannatti ja myöhemmin syyskesällä Matin kotona tapahtuneen työhaastattelun jälkeen aloitin syksyllä teknillisen polymeerikemian, fysikaalisen kemian ja sähkökemian tuntiopettajana.

TkL Markku Laatikainen oli jo opettanut polymeerikemian alkeita (aineopintojakso) yhdelle vuosikurssille, joten nyt meidän oli Sirkka-Liisan kanssa lisäksi pikaisesti polkaistava käyntiin myös sitä seuraava erikoisopintojakso ja siihen liittyvät laboratorioharjoitukset. Onneksi joitakin harjoitustöitä pystyin soveltavin osin kopioimaan omista labroistani HY:ltä...

Tuohon aikaan työhuoneeni sijaitsi KETEn (kemiantekniikan) siiven 3. kerroksen päässä vastapäätä Matin huonetta. Viereisessä huoneessa työskenteli Marianne Nyström, joka oli tutkijana useassa Matin projektissa. Yksi Matin laitteita, jolla Marianne teki paljon mittauksia, oli ns. streaming- eli virtauspotentiaalilaite. Tieteellisesti kuvattuna laitteella mitattu streaming-potentiaali on verrannollinen kiinteiden rajapintojen varaustiheyteen eli ns. zeta-potentiaaliin Helmholtz-Smoluchowskyn yhtälön mukaisesti. Tästä kehkeytyikin myöhemmin yksi laboratoriomme tärkeimpiä työkaluja. Toinen Matin itserakentamista laitteista oli kvartsikidevaaka, jolla pystyttiin mittaamaan esimerkiksi adsorptiota pinnalle kvartsikiteen värähtelytaajuuden vaihteluiden perusteella.

Kalvotekniikka oli jo tuolloin astunut vahvasti kuvaan kemiantekniikan osastolla, kiitos professoreiden Seppo Palosaari ja Matti Lindström. Professori Palosaari oli jo heti LTKK:lle tultuaan alkanut puhua siitä, miten erotustekniikoita tullaan tarvitsemaan eri teollisuuden aloilla tulevaisuudessa yhä enemmän ja että kalvotekniikka, joka siihen asti oli ollut kovinkin tuntematon erotustekniikka Suomessa, tulisi olemaan yksi vahvasti nousevia tulevaisuuden tekniikoita. Ja miten oikeassa hän olikaan!

Tuohon aikaan kalvotekniikkaa käytettiin laajemmin lähinnä elintarviketeollisuudessa, mm. proteiinien erotukseen herasta (ultrasuodatus). Toisaalla, varsinkin Japanissa, mutta myös Yhdysvalloissa ja Lähi-idässä, suolanerotus käänteisosmoosilla merivedestä esim. juoma- ja teollisuusvesien valmistuksessa oli kasvamassa merkittävästi. Myös puunjalostusteollisuudessa ensimmäinen teollisen mittakaavan laitos oli otettu käyttöön Ruotsissa Iggesundin tehtailla sellun valkaisuvesien käsittelyssä.

Kaikissa ulkoisen paineen avulla ajetuissa kalvoprosesseissa tapahtuu kalvon likaantumista ajan saatossa. Tällöin hiukkaset, kolloidiset hiukkaset tai liuenneet makromolekyylit kerrostuvat ja/tai adsorboituvat kalvon huokosiin tai kalvon pinnalle fysikaalisten ja kemiallisten vuorovaikutusten tai mekaanisen vaikutuksen seurauksena, mikä johtaa pienempiin tai tukkeutuneisiin kalvon huokosiin. Tällöin puhutaan ns. fouling-ilmiöstä. Palautumattoman foulingin seurauksia voivat olla esim. prosessin vähentynyt tuotto, korkeampi prosessipaine, heikentynyt erotuskyky, lisääntyneet käyttökustannukset ja tihentyneet kalvojen pesuvälit, mistä seuraa yleensä lyhentynyt kalvojen käyttöikä. Yleisesti ottaen kalvosuodatusprosessien maine Suomessa oli eduistaan huolimatta huono, mikä johtui lähinnä juuri fouling-ilmiöstä ja sen seurauksista sekä teollisuudessa suuriksi koetuista investointi- ja käyttökustannuksista. Suomeen oli myös kiirinyt uutisia joistakin epäonnistuneista kalvosuodatuskokeiluista, mikä osaltaan vaikutti kielteiseen asenteeseen.

Nyt tutkiessaan kloroligniinin ultrasuodatusta eri pH:issa Marianne oli havainnut, että suodatuskalvosta mitatun zeta-potentiaalin ja kloroligniinin dissosiaatioasteen, saavutetun retention, vuon aleneman ja adsorption välillä vallitsi selvä yhteys. Saattoiko kalvon ja suodatettavan aineen varauksen muuttuminen pH:n suhteen olla yksi syy foulingiin?

Kuva 1 Professori Marianne Nyström ja streaming-potentiaalilaite mittauskenno avattuna.

Laboratorio kasvaa ja kehittyy

Kun keväällä 1990 palasin takaisin LTKK:lle vietettyäni pari vuotta Skotlannissa ja mammalomalla, Marianne hoiti silloin teknillisen polymeerikemian apulaisprofessuuria. Olimme saaneet pienen projektin kemiallisen monitoimitehtaan jätevesien puhdistuksesta, ja niin minäkin sain ensikosketukseni ultrasuodatukseen – ja kipinän. Syksystä lähtien hoidin sitten teknillisen polymeerikemian assistentuuria. Laboratorion vahvuuteen kuului myös laboratorioinsinööri Eero Kaipainen, jota ilman mikään ei olisi labrassa toiminut.

Pikkuhiljaa väki laboratoriossa lisääntyi, kun saimme, itseni lisäksi, ensimmäiset jatko-opiskelijamme (Neda Ehsani, Piia Järvinen, Arto Pihlajamäki, Lena Kaipia, Tiina Huuhilo, Mika Mänttäri, Pasi Väisänen, Pekka Olin...vain muutamia mainitakseni), ja tutkimustoiminta tietysti samalla vilkastui. Meillä oli myös yleensä yksi tai useampia ulkomaalaisvahvistuksia, joko opiskelijoita tai tutkijoita, sillä Marianne uskoi vahvasti kansainväliseen yhteistyöhön, siitä kun hyötyivät yleensä molemmat, niin lähettäjä kuin vastaanottajakin. Olihan Marianne itsekin pariin otteeseen Suomen Akatemian varttuneena tutkijana mm. Sydneyssä Australiassa professori Tony Fanen laboratoriossa (UNWS), jossa oli silloin maailman suurin membraanitekniikan tutkimusryhmä. Mariannen poissa ollessa minä sitten luotsasin meidän laboratoriotamme (1992–93 ja 1996–97).

Vuonna 1998 laboratorion nimi vaihtui virallisesti membraanitekniikan ja teknillisen polymeerikemian laboratorioksi (MemPo) ja Marianne nimitettiin membraanitekniikan professoriksi. Marianne oli, muuten, tuolloin maailmanlaajuisesti ensimmäinen nimenomaan membraanitekniikan professoriksi nimitetty.

Laboratorio oli tuolloin kasvanut jo niin paljon, että meitä oli neljä varttuneempaa tieteenharjoittajaa, jotka vedimme omia tutkimusryhmiämme ja -projektejamme. Nykyinen membraanitekniikan professori TkT Mika Mänttäri keskittyi nanosuodatukseen sokeri- sekä sellu- ja paperiteollisuudessa, TkT Samantha Kiljunen tutki mm. liuotin- ja happoresistenttejä suodatinkalvoja, TkT Arto Pihlajamäki yliassistenttina keskittyi pitkälti opetukseen ja minä sellu- ja paperiteollisuuden vesikiertojen sulkemiseen ja prosessien kehittämiseen tutkimusprofessorina Cleantech2000-projektissa Savonlinnassa.

Tutkimustoiminta

Fouling oli ilmiönä varsin keskeinen laboratorion tutkimuskohde alusta saakka: haluttiin ymmärtää syvemmin, mitä se on, mitkä tekijät johtavat sen syntymiseen ja miten sitä voidaan

Suodatuskalvojen karakterisointi	Ultrasuodatus	Erotustekniikat puunjalostusteollisuudessa
Kalvon varauksen määritys streaming potentiaalin avulla kalvon pinnan suuntaisesti ja huokosten läpi	Proteiiniliuosten ultrasuodatus	Puunjalostusteollisuuden kierto- ja jätevesien mikro-, ultra- ja nanosuodatus
Kalvojen rakenne FTIR ja SEM avulla	Proteiiniliuosten ja malliproteiinien fraktiointi	Paperikoneen kiertovesien puhdistus: kalvoteknisten menetelmien vertailu pilotmittakaavassa
Kalvojen hydrofobisuuden mittaus kontaktikulman avulla	Kriittinen vuo proteiinien ultrasuodatuksessa	Puunjalostusteollisuuden kierto- ja jätevesien puhdistus erilaisilla hybridiprosesseilla
Kalvojen huokoskokojakauman määritys PEG:n avulla	**Nanosuodatus**	Teollisten prosessien vedenkäytön vähentäminen
Kalvojen testaus äärimmäisissä olosuhteissa (korkea T, erittäin matala/korkea pH)	Sokerien, suolojen ja pienten molekyylien nanosuodatus	Täyteaineiden ja kuitujen sedimentaatio ja retentio
	Metallien erotus äärimmäisissä olosuhteissa (korkea T, erittäin matala/korkea pH)	Kriittinen vuo paperiteollisuuden kiertovesien nanosuodatuksessa
	Kriittinen vuo nanosuodatuksessa	
Fouling ja kalvojen pesu		
Kalvo/partikkelivuorovaikutusten karakterisointi	Proteiinien suodatuksessa likaantuneiden kalvojen puhdistus	Fouling-kerroksen analysointi (SEM-EDAX, FTIR, Raman)
Keraamisten kiekkosuotimien ja suodatinkankaiden fouling ja pesu	Humushappojen aiheuttama fouling	Pesun vaikutus kalvon pintaominaisuuksiin ja retentioon (SEM-EDAX, FTIR, Raman)

estää, olipa se sitten syntynyt esim. sokeri-, meijeri, kaivannais- tai sellu- ja paperinjalostusteollisuuden prosesseissa. Oheisessa taulukossa on esitetty MemPon keskeisimmät tutkimusalueet.

Kaikkeen tähän tutkimukseen tarvittiin paitsi tutkijoita myös erilaisia suodatuslaitteistoja mikrosuodatuksesta nanosuodatukseen ja laboratorioskaalasta pilot-skaalaan sekä kattava valikoima erilaisia mittaus- ja analysointilaitteistoja.

Vuosien saatossa Teknillisen polymeerikemian laboratorio saikin lisää välineitä tutkimustyöhön. KETEn omalla Pajalla rakennettiin polykarbonaatista laboratorioskaalaisia ultra- ja nanosuodatuskennoja, jotka olivat käteviä erilaisten perusilmiöiden tutkimisessa, esimerkiksi erilaisten partikkeleiden ja suodatuskalvojen välisen vuorovaikutuksen karakteroinnissa ja mm. proteiinien fraktioinnissa.

Pieniä semipilot-skaalaisia laitteita rakennettiin erilaisten kaupallisten putkisuodatuskalvomoduulien (Stork-Friesland, Carbosep, Paterson Candy Int. jne.) ympärille. Laboratorioon saatiin myös hankittua kaupallisia suodatuslaitteistoja, joissa kalvon pinnalla vaikuttavia leikkausnopeuksia kasvatetaan erilaisilla tekniikoilla, kuten roottorilla tai värähtelyllä (Valmet Raisio (nyk. Metso) CR-suodin ja New Logic VsSep). Sekä em. putkimoduulit että CR-suodin ja VsSep olivat oman paperitehtaan kiertovesien puhdistukseen keskittyneen tutkimukseni keskiössä. Kiertovesien kiintoaineet, kuten kuidut ja täyteaineet, muodostavat laminaarivirtausalueella kalvon pinnalle sekundaarikerroksen, joka useimmiten johtaa nopeaan palautumattoman foulingin syntymiseen kemiallisten ja/tai mekaanisten vuorovaikutusten kautta. Leikkausnopeuden kasvattaminen kalvon pinnalla on yksi tehokas ratkaisu foulingin hallitsemiseen.

Erityisesti sokeriteollisuuden tarpeisiin rakennettiin myös pilot-mittakaavainen nanosuodatuslaitteisto, jossa voidaan käyttää teollisen mittakaavan spiraalimoduuleja – Mikan ”lelu” ja silmäterä. Kaivannaispuolen tutkimuksiin oli saatu Laroxin Labox-moduuli sekä Outokumpu Mintecin minipilot (keraaminen suodin) ja flotaattori.

Näillä laitteistoilla pystyttiin tekemään testausta paitsi normaalisti laboratoriossa myös (semi) pilot-mittakaavassa tehdasolosuhteissa, mikä onkin erittäin tärkeää, kun halutaan nähdä, miten jatkuvatoiminen kalvoprosessi sopii erilaisiin kohteisiin. Esimerkiksi foulaantumisen kehittyminen on jatkuvatoimisessa prosessissa aivan erilaista kuin panosprosessissa laboratoriossa, koska tuoretta foulanttia on koko ajan tarjolla ja myös sen koostumus voi vaihdella merkittävästi prosessihäiriöiden tms. myötä.

Kalvojen karakterisointi puhtaina, foulaantuneina ja myöhemmin jopa suodatuksen aikana, vaati paljon mittausmenetelmäkehitystä. Keskeisiä tutkimuslaitteita olivat streaming-potentiaali, dynaaminen kontaktikulma, FTIR, SEM-EDAX ja myöhemmin myös Raman-spektroskopia. Nykyinen provostimme Mari Kallioinen-Mänttäri kehitti Ramanista työkalun, jolla pystytään identifioimaan kalvon pinnalle ja huokosiin adsorboituneita aineita ja siten avaamaan foulingin saloja.

Kansainvälinen toiminta

Kansainväliset suhteet membraanitekniikkaa tutkiviin tutkimusryhmiin ympäri maailman olivat Mariannelle erityisen tärkeitä. Kuten edellä totesin, MemPo-laboratoriossa oli miltei aina vierailijoita muista yliopistoista ympäri maailman, ja myös me vastavierailimme usein. Marianne osallistui aktiivisesti konferensseihin ja kannusti myös meitä tutkijoita lähtemään tuloksia esittelemään aina kun se vain oli taloudellisesti mahdollista. Siihen aikaan oli mahdollista anoa rehtorilta matka-apurahaa, jota kyllä usein anottiinkin ja saatiin. Pääsipä joskus melkein koko labramme osallistumaan, kuten esim. ICOM-konferenssiin Toulousessa, Ranskassa ja IMSTEC-konferenssiin Sydneys-

Kuva 2. MemPo-jengi ICOM-konferenssissa Toulousessa, Ranskassa, 7.-12.7.2002. Kuvassa vasemmalta Samantha Kiljunen, Niina Laitinen, Lena Kaipia, Sari Metsämuuronen, Svetlana Butylina, Jutta Nuortila-Jokinen, Mika Mänttäri, Arto Pihlajamäki, Mari Kallioinen, Eero Kaipainen ja Jukka Tanninen.

sä, Australiassa. Näillä reissuilla opittiin paljon uutta ja solmittiin uusia ja verestettiin vanhoja tutkijatuttavuuksia. Mieleen on jäänyt mm. Sydneyn eläintarhan valtava moniportainen kalvosuodatuslaitteisto, jolla koko eläintarhan vedet puhdistettiin ja puhdistettu vesi kierrätettiin takaisin uusiokäyttöön – juuri näinhän se pitääkin tehdä!

CST:n alla järjestettiin myös vuosittain kansainvälisiä konferensseja ja riippuen teemasta kyseinen laboratorio oli sitten vastuussa järjestelyistä. Ensimmäinen CST:n järjestämä konferenssi taisi olla "Fouling in Pressure Driven Membrane Processes" kesällä 1994 ja järjestelyvastuussa meidän laboratoriomme.

Tuohon aikaan meillä ei ollut järjestelyissä käytössä oikeastaan mitään ulkopuolista apua eikä kyllä paljon rahaakaan, kaikki piti saada katettua kohtuullisen vaatimattomilla osallistumismaksuilla. Niinpä me sitten pioneerihengessä laadimme budjetit ja ohjelman, teimme esitteet, järjestimme tilat ja kaiken muun, mitä tuollainen vaatii. Jopa Get-togetherin ja konferenssi-illallisen ruokatarjoilut me teimme itse kokkaamista myöten, ja reippaat nuoret miehemme hakivat juomat Alkosta.

Hyvien suhteidensa ansiosta Marianne sai koottua maailmalta Lappeenrantaan kaikki foulingia tutkineet kovat nimet – gurut: Dr. Pierre Aimar (Université Paul Sabatier, Toulouse, Ranska), Prof. Georges Belfort (Rensselaer Polytechnic Institute, Troy, USA), Dr. Bill Eykamp (Arlington, Boston, USA), Prof. Tony Fane (University of New South Wales, Sydney, Australia), Prof. John A. Howell, (University of Bath, Bath, UK), Prof. Gunnar Jonsson (Technical University of Denmark, Lyngby, Tanska) ja Dr. Gun Trägårdh, Lund University, Lund, Ruotsi).

Konferenssin ohjelma oli tosi hyvä, olihan meillä alan parhaat puhujat paikalla. Jännittävin kohta ohjelmassa oli ehkä Bill Eykampin suorittama likaantuneen spriraalimoduulin "ruumiinavaus" (autopsy). Oli varmaan monelle muullekin ensimmäinen kerta, kun pääsi oikeasti kurkistamaan kalvomoduulin sielunelämään.

Päivän ohjelman jälkeen me "nuoriso" eli Neda, Piia, Lena, Sinikka (Parkkinen), Svetlana (Vanhanen), Mika, Pekka, Eero, Arto ja mä, lähdimme sitten järjestämään iltatilaisuuksia ja kokkailemaan. Kaikki meni yleensä hyvin ja ruokakin maistui. Vieraiden lähdettyä sitten siivoamaan ja viemään tavaroita kylmiöön. Ja jos luulitte, että olisi siitä lähdetty keräämään voimia seuraavan päivän luennoille, niin ei, ei sinne päinkään. Osa meistä lähti tietysti jatkoille meille, ja aamuyöhönhän se venähti, varsinkin kun piti vielä pelastaa ulkoaltaassa asunut kuivilla ollut kultakala tai kasata kaatunut halkopino (omakotiasumisen riemuja!). Mutta seuraavana aamuna olimme ajoissa luennolla, ehkä ei aivan pirteinä, mutta kuitenkin, Mariannen tiukan katseen alla.

10 vuotta myöhemmin, vuonna 2004, kun järjestimme seuraavan CST fouling-konferenssin, tällä kertaa otsikolla ”Fouling and Critical flux: Theory and Applications”, järjestelyt eivät olleet enää yhtä pioneerihenkisiä. Mutta saimme koolle samat gurut ja asiasta kiinnostuneen yleisön, joten tunnelma oli aivan yhtä mukava ja mieleenpainuva kuin 10 vuotta aikaisemmin. Itselleni tilaisuus oli kuitenkin haikea, koska olin jättämässä MemPon ja siirtymässä Lappeenrannan toiselle laidalle UPM:n tutkimuskeskukseen.

MemPo-henki

Tämä kirjoitus saattaa lukijasta kuulostaa Mariannen muistokirjoitukselta, ja sitä se ehkä tavallaan onkin, koska MemPosta puhuttaessa häntä ja hänen vaikutustaan laboratorion kehitykseen ei tietenkään voi sivuuttaa. Professorina hän viitoitti tien, jota me muut sitten lähdimme toteuttamaan kukin omalla tavallamme omilla vahvuusalueillamme, mutta aina yhdessä.

Kuva 3 ”The Eykamp Cut” – käytetyn spiraalimoduulin avaus. ”Patologina” Dr Bill Eykamp.

Päällimmäisenä noista ajoista ovatkin mieleeni jääneet nuo mahtavat ihmiset, joiden kanssa sain olla rakentamassa MemPo-laboratoriota ja joiden kanssa edelleenkin on mahtavaa tavata. Samalla teimme uraauurtavaa tiedettä, jonka hedelmistä uusi membraanitutkijasukupolvi voi nyt nauttia, mutta muistimme myös, että välillä pitää relata ja pitää hauskaa. Jos LUTissa vallitsee yleisesti Skinnarilan henki, niin meillä MemPossa oli ihan oma membraanihenki. Kiitos siitä!

ILKKA TURUNEN

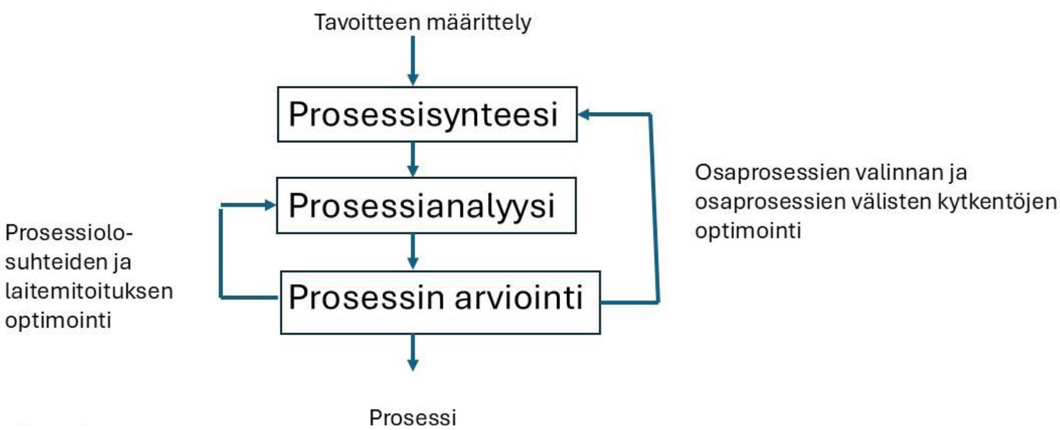
Professori (Em) Prosessi- ja tehtaansuunnittelu

Prosessitutkimuksen ja -suunnittelun laboratorio

Toimintaa ohjaavat periaatteet

Työskentelin professorina Lappeenrannassa vuosina 1999-2015. Laboratorioni nimi vaihteli hieman vuosien varrella. Mielestäni nimistä paras oli prosessitutkimus ja -suunnittelu, koska se parhaiten kuvasi laboratorion tutkimus- ja opetustoimintaa. Jotkut puhuivat tehdassuunnittelun laboratoriosta ja vastaavasta oppiaineesta. Tätä Otaniemestä periytynyttä nimitystä en pidä hyvänä, koska monet ymmärtävät tehdassuunnittelun niin, että se sivuuttaa kemiallisteknisen prosessikehityksen ja rajoittuu esimerkiksi lay-out-suunnitteluun ja muihin vastaaviin vähemmän tieteellisiin suunnittelun osa-alueisiin. Kuitenkin juuri kemiallistekninen prosessien tutkimuksen, suunnittelun ja kehityksen metodiikka oli aihepiiri, jota laboratoriossani tutkin ja opetin. Prosessien kehitys ja suunnittelu on juuri sitä, mitä olin ollut Kemira Oy:ssä tekemässä professorikauttani edeltävät 15 vuotta. Siihen liittyvä metodiikka tuli olemaan laboratorioni keskeisin tutkimus- ja opetuskohde. Olin erittäin innostunut päästessäni jatkamaan tätä toimintaa akateemisesta näkökulmasta.

Kuva 1. esittää yleisluontoisesti prosessien tutkimusta ja suunnittelua. Siinä ensimmäinen vaihe, prosessisynteesi, tarkoittaa aluksi yksikköprosessien valintaa, ja asteittain tarkentuen sitten laitetyyppien, laitteiden ja lopulta niiden yksityiskohtien valintaa. Seuraava vaihe, prosessianalyysi tarkoittaa valittujen yksikkö-



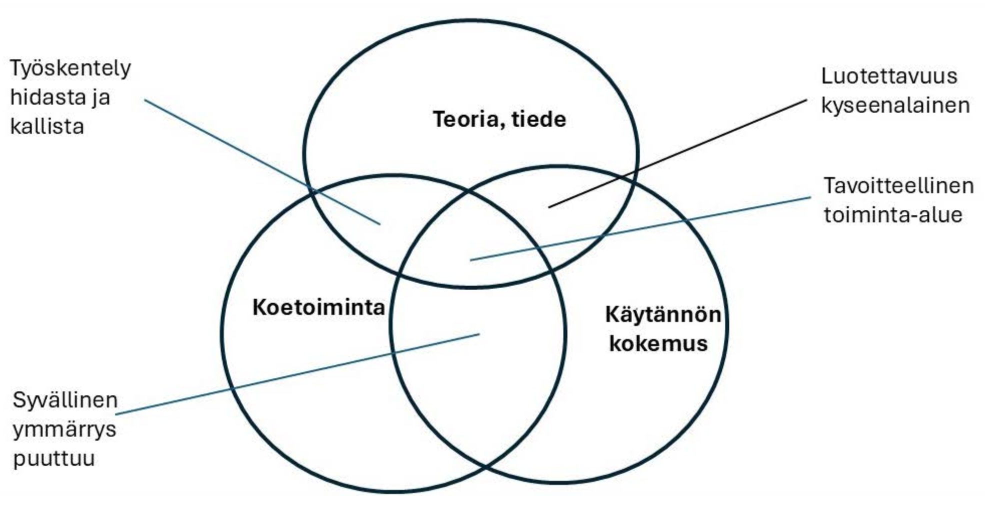
Kuva 1 Prosessitutkimuksen ja -suunnittelun sisältö.

prosessien ja laitteiden toiminnan tarkastelua, käytännössä prosessien mallinnusta ja simulointia. Kuvassa näkyvien takaisinkytkentöjen mukaisesti prosessia optimoidaan, kunnes viimeisenä vaiheena oleva prosessien arviointi antaa riittävän hyvän tuloksen. Arviointikriteereinä ovat etenkin kannattavuus, turvallisuus, sekä ympäristö- ja energianäkökohdat. Koko toiminta etenee asteittain tarkentuen alkaen konseptuaalisesta suunnittelusta lohkokaavioineen ja päättyen yksityiskohtaiseen laitesuunnitteluun sekä lopulliseen virtaus- ja PI-kaavioon.

Kuvattu toiminta on hyvin monitahoista ja laajasisältöistä. Sen vuoksi opetuksessa paneuduttiin koko toiminta-alueen pääperiaatteisiin, menemättä liikaa yksityiskohtiin muualla kuin esimerkeissä. Tutkimus sen sijaan kohdistui valittuihin osa-alueisiin ja melkoinen osa prosessitutkimuksen ja suunnittelun aihepiireistä jäi pakostakin sen ulkopuolelle.

Kuva 2. esittää yleisellä tasolla tiedon hyödyntämistä prosessikehityksessä. Erityisesti uusien tuotantoprosessien kehityksessä on osattava hyödyntää tieteeseen perustuvaa teoriaa, koetoimintaa sekä käytännön kokemusta, kaikkia näitä kolmea. Kuvan keskimmäinen alue, joka on yhteinen kaikille kolmelle tietolajille, on tavoitteellinen toiminta-alue. Mikäli teoreettinen tieto ei ole mukana, ei välttämättä ymmärretä, mitä ollaan tekemässä ja mihin toiminta perustuu. Koetoiminnan puuttuessa on luotettavuus kyseenalainen. Kaikkia esiintyviä fysikaalisia ja kemiallisia ilmiöitä ei välttämättä tunneta, tai tietämys niistä on puutteellista. Tästä voi seurata yllätyksiä ja kohtalokkaitakin erehdyksiä, jotka voidaan joskus koetoiminnalla välttää. Koetoiminnasta on huomattava, että sitä tapahtuu eri mittakaavoissa, esim. laboratorio-, pilot plant- ja tehdaskokein. Kolmantena tietolähteenä on käytännön kokemus. Mikäli se sivuutetaan, voi toteutus kestää liian kauan tai tulla liian kalliiksi. Kenelläkään ei ole aikaa ja rahaa toteuttaa koko projektia esim. molekyylitasolta lähtien, vaan uusienkin prosessien yhteydessä aikaisempaa kokemusta on hyödynnettävä, missä se on mahdollista.

Näiden periaatteiden pohjalta lähdin aikoinaan laboratorion opetus- ja tutkimustoimintaa kehittämään. Itseni lisäksi laboratorion toimintaa osallistui ansiokkaasti joukko muita henkilöitä. Heistä mainittakoon dosentti Arto Laari, jonka panos laboratorion toiminnassa oli merkittävä sen viimeisinä vuosina.



Kuva 2 Tiedon alkuperä ja hyödyntäminen prosessitutkimuksessa ja -suunnittelussa.

Opetus

Kun ryhdyin hoitamaan professuuriani vuonna 1999, ko. laboratoriossa ei ollut tehty yhtään diplomityötä. Varsin pian tilanne muuttui ja muutaman vuoden kuluttua siellä tehtiin niitä eniten Kemiantekniikassa. Kaiken kaikkiaan diplomitöitä valmistui 15 vuoden aikana reilusti toista sataa, lähes kaikki teollisuuden aiheista. Syynä suureen määrään lienee ollut se seikka, että laboratorion toiminta-alue oli varsin laaja ja varsin hyvin teollisuuden aiheille sopiva. Opiskelijat luonnollisesti halusivat näitä teollisuuden aiheita, joista yleensä maksettiin myös pieni korvaus.

Erittäin suosittu opintojakso oli prosessisuunnittelun suunnittelutehtävä. Sekin tehtiin teollisuusyritysten aiheista ja yrityksen edustaja oli myös läsnä kunkin ryhmän projektikokouksissa, joita pidettiin 5 kappaletta. Jokaiseen suunnitteluryhmään perustettiin projektiorganisaatio, johon kuului noin 5 opiskelijaa. Ainakin osa projektikokouksista pidettiin aiheen antaneen yrityksen tiloissa, jolloin opiskelijat pääsivät myös tehdasvierailulle. Aiheet vaihtelivat jonkin verran, mutta ideaalitapauksessa aiheena oli pienen tuotantoprosessin alustava suunnittelu. Tuloksena syntyi esim. suppea markkinaselvitys, prosessin lohkokaavio, prosessin kuvaus, virtauskaavio säätötarpeineen, laiteluettelo, kustannus- ja kannattavuusarvio jne. Koska osa projektikokouksista pidettiin aiheen antaneen yrityksen tiloissa, autoilu tuli tutuksi. Toimeksiantajia oli ympäri Suomen, Oulua ja Kokkolaa myöten.

Opettamista ja sen kehittämistä helpotti kuulumiseni eurooppalaiseen opetustyöryhmään (European Federation of Chemical Engineering, Working Party of Education). Kokouksia oli 1-2 vuodessa ja ne tarjosivat mahdollisuuden vaihtaa mielipiteitä ja ideoita muiden eurooppalaisten professorien kanssa.

Tutkimus

Tutkimustoiminnan tuloksena laboratoriossa syntyi 8 väitöskirjaa, satakunta tieteellistä julkaisua sekä yksi patentti. Rahoitus jakaantui suunnilleen tasan teollisuusyritysten ja julkisten lähteiden kesken. Viime mainittuja olivat lähinnä silloinen TEKES sekä Suomen Akatemia.

Tutkimuksen aiheet vaihtelivat, mutta ne kaikki liittyivät prosessien tai prosessilaitteiden kehitykseen. Mukana oli mm. prosessien mallinnusta, prosessikehityksen metodologiaa sekä katalyysin tutkimusta.

Erityisen mielenkiintoisena tutkimusaiheena mainitsen tässä prosessien tehostamisen (Process Intensification). Kyseessä on suhteellisen uusi, 1970-luvulla vauhtiin päässyt kemiantekniikan tutkimusalue. Sille on esitetty monenlaisia määritelmiä, seuraavassa brittiläisten tutkijoiden Reay, Ramshaw ja Harwey esittämä:

Any chemical engineering development that leads to a substantially smaller, cleaner, safer and more energy efficient technology is process intensification.

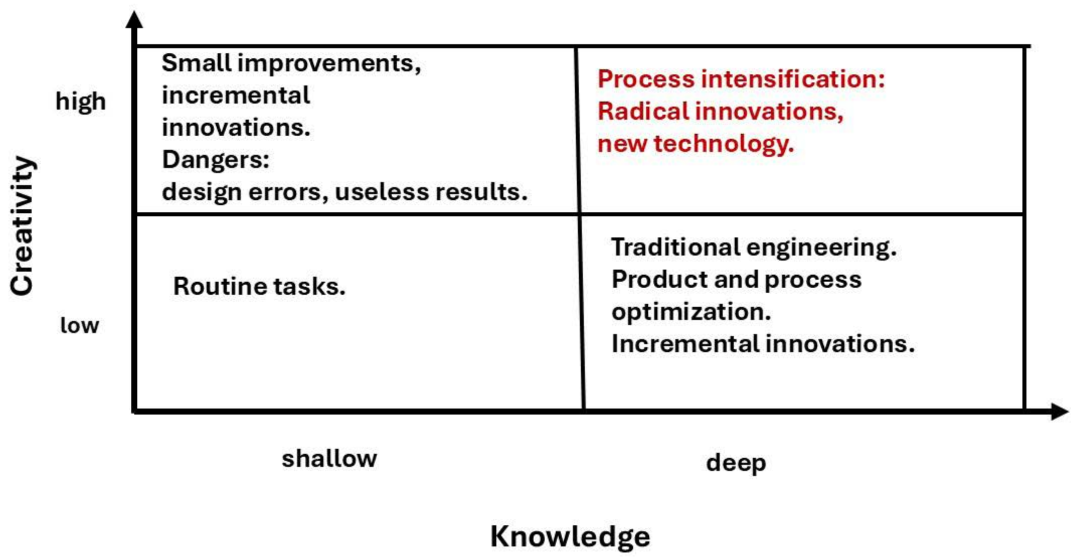
Ajatuksena intensifioinnissa on, että jokin prosessin osa toteutetaan radikaalisti uudenlaisella tavalla, jolloin saavutetaan merkittäviä etuja. Siinä käytettävät tekniikat ovat moninaisia. Niistä mainittakoon epätavanomaiset kemialliset reaktorit (esim. monoliittireaktorit, keskipakovoimaa hyödyntävät reaktorit, staattinen sekoitus reaktoreissa), reaktio ja muu yksikköoperaatio yhtaikaisesti samassa tilassa (esim. reaktiivinen erotus, reaktiivinen ekstruusio, reaktiivinen jauhaminen), yhdistetyt erotusoperaatiot (esim. membraanitislaus, membraaniadsorptio, adsorptiivinen tislaus), vaihtoehtoiset energialähteet (esim. ultraääni, aurinkoenergia, mikroaallot, sähkökentät) jne. Eräänä prosessien intensifioinnin osa-alueena voidaan vielä mainita mikroprosessitekniikka, jota myös tutkimme ainakin yhden väitöskirjan verran. Kiinnostuin prosessien intensifioinnista, koska sitä olin paljolti tehnyt Kemirassa ennen professorikauttani. LUT:ssa työskennellessäni kuuluin EFCE:n kansainväliseen intensifiointityöryhmään (European Federation of Chemical Engineering, Working Party of Process Intensification) ja olin useita vuosia sen puheenjohtaja. Kuvassa 3. on oma käsitykseni tiedon ja luovuuden roolista prosessien intensifioinnissa.

Mitä jäi käteen

Olin työurani aikana onnellisessa asemassa siinä mielessä, että sain tehdä samankaltaista työtä kahdessa eri ympäristössä. Ensin 15 vuotta käytännössä, sitten saman ajanjakson akateemisessa maailmassa. Tosin teollisuudessa tunsin itseni välillä toivottomaksi teoreetikoksi ja yliopistossa minua taidettiin välillä pitää yksinkertaisena perusinsinöörinä. Helposti ajattelee, että yliopistossa vallitsee akateeminen vapaus, jossa voi suhteellisen vapaasti toteuttaa itseään, ja että teollisuudessa on tyydyttävä pelkästään ratkomaan tarkoin määrättyjä ongelmia. Näin ei ainakaan minun kohdallani ollut, vaan melkeinpä päinvastoin. Yliopistossa tutkimuksen vapautta rajoittavat rahoittajat sekä erilaiset strategiat ja ns. painopistealueet, jotka tosin enemmän tai vähemmän yhteistyössä määritellään.

Takavuosina Helsingin Sanomissa ilmestyi haastattelu, jossa Oxfordin yliopiston professorilta kysyttiin, että mistä heidän erinomaiset tutkimustuloksensa johtuvat. Vastauksena annettiin kaksi syytä. Ensinnäkin opiskelijoiden valinnassa tehtiin todella tarkkaa työtä ja valittiin vain todella hyviä opiskelijoita. Toiseksi heille annettiin todella suuri vapaus valita tutkimuskohteensa. Ihan näin emme voi tietenkään Suomessa ja LUT:ssa toimia, mutta jotain opittavaa meillä siinä on.

Eräs maailmankuulu tiedemies on todennut, että liika ratkaisukeskeisyys tutkimuksessa vaatii vain hyviä laskennallisia ja kokeellisia valmiuksia. Jos halutaan luoda jotain todella uutta, on tärkeintä asettaa kysymykset oikein ja nähdä ongelmat uusista näkökulmista. Tästä olen samaa mieltä. Tavoitteet on asetettava riittävän korkealle, eikä yliopistossa tule tyytyä pelkkien rutiiniongelmien ratkaisuun.



Kuva 3. Tiedon ja luovuuden rooli prosessien intensifioinnissa.

DEPARTMENT OF SEPARATION SCIENCE 2019-2025

In 2019, it became evident that the primary focus within the Department of Chemical Technology was separation science, prompting the consideration of a name change to better reflect this specialization.

The department was reorganized concurrently with the name change to better align with its focus areas and operational approach. Its philosophy is twofold: one dimension relates to the types of, and internationally recognized knowledge on, separation technologies (research groups), and the other to societal themes (application of the technology knowledge on huge global societal challenges). Many groups contribute to multiple societal themes, with each theme supported by several groups, demonstrating a highly collaborative and multidisciplinary approach.

The Department of Separation Science is engaged in pioneering research within chemical engineering. It is supported by a team of 120 staff members across 12 research groups and operates at four locations: Lappeenranta, Lahti, Mikkeli, and Kouvola. Below is a brief overview of the research groups.

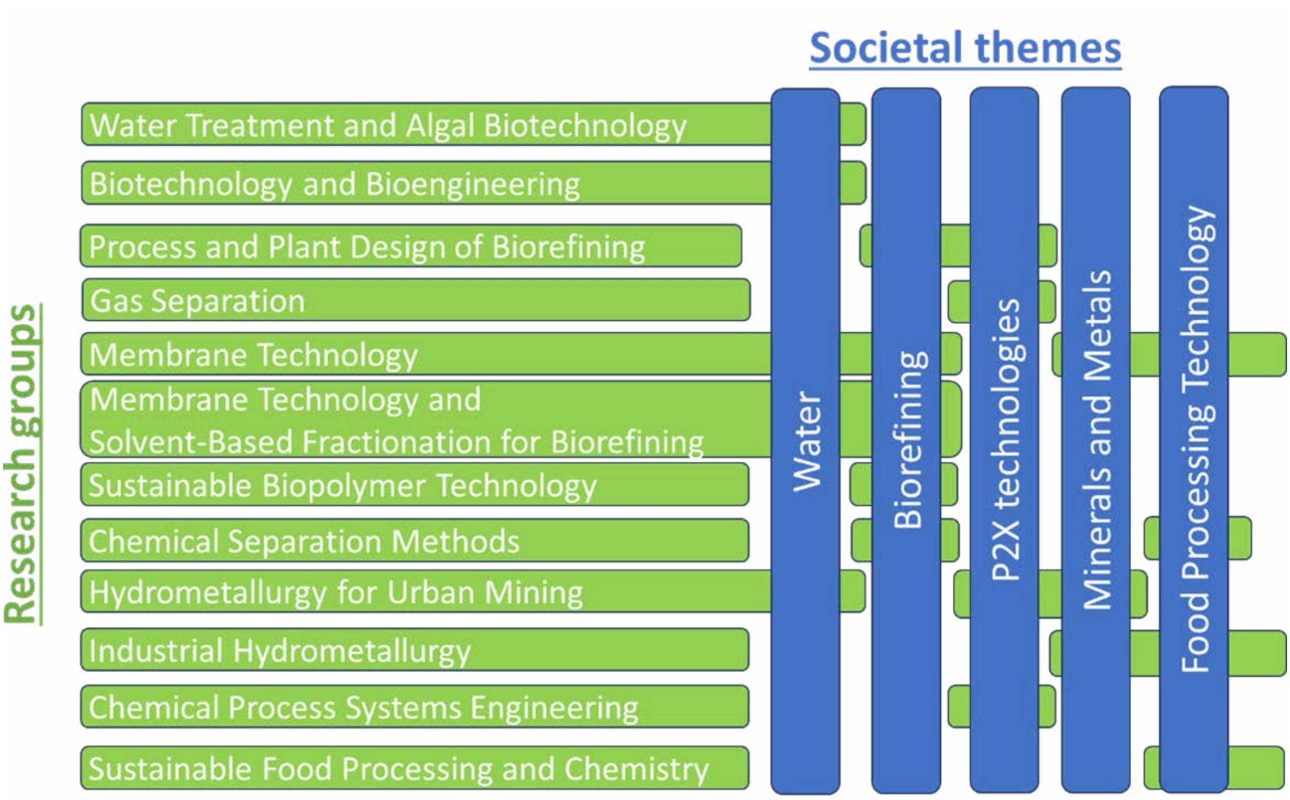


Figure 1 Two-dimensional philosophy of the research in Department of Separation Science.

The Water Treatment and Algal Biotechnology group, led by Professor Amit Bhatnagar, explores the potential of Nordic microalgae and microalgal consortia for wastewater treatment, nutrient recovery, carbon capture, and biofuel production. The group also develops functional materials such as biochar, nanocellulose, aerogels, and nanocomposites for pollutant removal from water.

The Biotechnology and Bioengineering research group, headed by Professor Susana Rodriguez-Couto, focuses on biotechnological methods for treating wastewater containing hazardous organic pollutants from various industries. The group aims to develop cost-effective, environmentally friendly processes for wastewater treatment and resource recovery, including valorization of lignocellulosic waste.

The Membrane Technology group, led by Professor Mika Mänttäri, concentrates on developing new membrane materials, modifying existing membranes, and reusing waste membranes. Their work supports applications in water treatment, biorefining, food processing, and mining, emphasizing waste reduction and cost efficiency. Membrane technology also aligns with upcoming European wastewater regulations.

The Hydrometallurgy for Urban Mining group, under Professor Eveliina Repo, specializes in recovering valuable elements from secondary resources such as ashes, slags, e-waste, and brines using electrochemistry, metal-organic frameworks, and 3D-printed separation materials. The group develops advanced materials for water and air purification, hydrogen production, antimicrobial applications, and batteries, promoting a circular economy for side streams.

In the Mining and Metals sector, the Industrial Hydrometallurgy group, led by Associate Professor Sami Virolainen, studies hydrometallurgical separation techniques like bioleaching, ion exchange, solvent extraction, and solid-liquid separation to address challenges in the industry.

The Chemical Process Systems Engineering group, headed by Professor Tuomas Koiranen, focuses on process research, design, and optimization through modeling and experimentation, aiming to reduce carbon emissions and develop renewable energy-based chemical products (P2X).

The Gas Separation group, led by Associate Professor Nima Rezaei, plays a vital role in P2X processes by providing gas separation and purification solutions, enabling large-scale implementation of circular economy principles.

The Chemical Separation Methods for Biorefining group, under Professor Tuomo Sainio, investigates chemical conversion, fractionation, and purification of biomass using techniques such as adsorption, ion exchange, chromatography, and extraction, from fundamental phenomena to process optimization.

The Process and Plant Design Group for Biorefining, led by Associate Professor Kristian Melin, explores how biomass-related processes can be scaled industrially using modeling and simulation, with a focus on electrification, hydrogen economy, and low-emission pulping methods, among others.

The Sustainable Biopolymer Technology research group, headed by Associate Professor Rama Layek, aims to valorize lignocellulosic biomass into high-performance biopolymers, composites, and biobased adhesives. The group also investigates biobased side streams, surface chemistry of 2D materials, and their integration into biocomposites to promote a circular bioeconomy.

A new Master's program in Food Technology commenced in Kouvola in Autumn 2024. The plan is to grow a regional research hub in Kouvola with local research groups aligned with local industry needs. The program leverages expertise in separation technologies to support food processing innovations, with key researchers including Assistant Professor Samuel Perez and Post-doctoral Researcher Marjo Pöysä.

As part of LUT University's multidisciplinary strategy, the Department actively collaborates internally and externally to address societal challenges comprehensively.

The internal collaboration is organized, for example, through LUT Research Platforms, which bring together expertise from all LUT Schools to focus on specific thematic areas. Developing an effective separation process requires more than just technological advancements; it must also incorporate environmental, societal, and economic sustainability considerations. For example, the SCI-MAT platform integrates these critical aspects into mineral and metal separation technologies, ensuring that the processes are not only efficient but also sustainable and responsible from a broader perspective. Additional nformation about LUT Research Platforms can be found under Chapter Collaboration in research and education.

The Chapter further elaborates on the Centre of Separation Technology (CST), which is headed by Dr. Katja Lahikainen. CST was established with the primary goal of bridging the gap between industrial requirements and academic expertise. The center emphasizes close collaboration with industrial partners to develop innovative solutions and facilitate knowledge transfer, thereby enhancing practical applications of separation technologies in various industries.

The Department's infrastructure is a significant strength, comprising approximately 3000 m2 of laboratory space and over 350 analytical and research instruments across four cities: Lappeenranta, Lahti, Mikkeli, and Kouvola, supporting diverse research activities. The maintenance and analytical services are run by the Support team led by laboratory engineer Markku Rahikainen having ca. 10 experts working in all the four cities.

The Department's commitment to fostering innovation and advancing technological research is evident through its diverse research groups and platforms. These entities play a crucial role in addressing complex engineering challenges and promoting sustainable development. By integrating entrepreneurial and global perspectives, the department aims to prepare students and researchers to contribute effectively to the evolving technological landscape. The collaborative efforts across various research initiatives not only enhance academic excellence but also ensure that the Department remains at the forefront of engineering advancements. Looking ahead, continued investment in research and education will be vital in maintaining its leadership position and in driving impactful solutions for societal needs.

The subsequent Chapters provide an in-depth overview of the research groups and platforms discussed earlier, offering detailed insights into their activities and contributions. Additionally, the Chapter Collaboration in research and education introduces various platforms, networks and partnerships, highlighting their roles in fostering cooperation and advancing research initiatives.

In case you have any thoughts or problems that we could help you with, please, do not hesitate to contact us.

Email address: First name.Surname@lut.fi

Figure 2 Department of Separation Science

CIRCULAR ECONOMY: PURIFICATION AND UTILIZATION OF INDUSTRIAL SIDESTREAMS

SAMI VIROLAINEN
Associate Professor of Industrial hydrometallurgy, Docent

Metals separations for industrial and anthropogenic side streams and wastes - Research in the group of Industrial Hydrometallurgy

Metals separations for industrial and anthropogenic side streams and wastes - Research in the group of Industrial Hydrometallurgy

In early 2010, after the long-lasting and successful leadership of Professor Erkki Paatero in Laboratory of Industrial Chemistry (see article by Prof. (Em) Paatero on page 23) Senior Teaching Assistant Kimmo Klemola and later Professor Tuomo Sainio took over the leadership in research and teaching of topics related to chromatographic separation, ion exchange and liquid-liquid extraction in hydrometallurgy and biomaterial separations. Later the research group, under the leadership of Prof. Sainio, became to be known as Chemical Separation Technologies. I will now lead the reader from 2013 to the present and future by introducing PhD Theses done in the group reflecting the directions of the research in the group.

The last dissertation of Prof. Paatero as a custos was undersigned's Hydrometallurgical recovery of valuable metals from secondary raw materials (Virolainen, 2013). This was one of the first dissertations globally focused heavily on metals recycling. Also, in this matter Prof. Paatero was at the forefront presenting the idea on this topic already in 2006. The Thesis contained, for example, novel separation processes for recovering pure indium from used LCD screens, and recovery of germanium from secondary sources.

The next dissertation of the group was supervised by Prof. Sainio. Fedor Vasilyev (2018) made ground-breaking work about modeling and simulation in hydrometallurgical liquid-liquid extraction. The Thesis contained state-of-the-art, and beyond, publications about equilibrium modeling and simulation of mixer-settler cascades. Especially the latter one was totally novel in academic liquid-liquid extraction literature, and still today it remains to be the most advanced document in the field.

In Jussi Tamminen's Thesis (2022) the effect of mixing properties to kinetics and dynamics of liquid-liquid extraction was studied. Among different kinds of contactors, emphasis was especially on rotor-stator-type high-sheer mixers, allowing for very fast mass transfer leading to intensified extraction process and possibility to use smaller reactors with high productivity. Also, in addition to his Thesis, Dr. Tamminen had a significant impact on the liquid-liquid extraction research in the group for almost twenty years. During that time, he became a world glass expert in fundamentals and practical applications of industrial hydrometallurgical liquid-liquid extraction.

Niklas Jantunen's Thesis (2023) was the first one having undersigned as the first supervisor (co-supervised by Prof. Sainio). The Thesis focused on studying different kinds of advanced methods and fundamentals for liquid-liquid extraction process design for particularly highly concentrated metal solutions. The topic is very relevant to industrial liquid-liquid extraction since solutions as concentrated as possible are used. And that leads to much more complicated aqueous chemistry and process design challenges compared to dilute solutions, for which typically the research for liquid-liquid extraction theories is done. The societal impact of the Thesis was in recycling side streams in metallurgical plants (As and H2SO4 separation) and battery metals recycling from industrial side streams as well as from waste lithium-ion batteries. Dr. Jantunen is currently working as a post-doctoral researcher in the group.

Fig 1. Tobias Wesselborg in running simulated moving bed experiment for his PhD work with LUT's self-designed and –built (under Prof. Tuomo Sainio) continuous ion exchange workstation.

The latest dissertation from the group of Industrial Hydrometallurgy was by Tobias Wesselborg in early 2025. In Dr. Wesselborg's Thesis very advanced process designs and configurations were used to recycle pure battery metals from waste lithium-ion batteries. Especially, the articles describing design and use of multicolumn simulated moving bed-type configurations are absolute ground-breaking in the field of hydrometallurgical ion exchange. These configurations are typically used in fine chemical and pharmaceutical industry but bringing them now to the world of industrial hydrometallurgy has a huge potential to enhance efficiencies in many challenging separation problems.

The group of Industrial Hydrometallurgy has a sub-team for development of novel ion exchange materials, which has been doing world class research and publications in the field. The key people are post-doctoral researcher Youssef El Ouardi and Visiting Professor Katri Laatikainen. Prof. Laatikainen (dissertation in 2009 with a surname Sirola) and Dr. Markku Laatikainen (dissertation in 2011) have been key researchers in the group in the field ion exchange, and theories and modeling behind, also after 2013. A good example of the quality of the work is the review article on ion exchange recovery of rare earth element from secondary sources (El Ouardi et al., 2023), which has been the most downloaded article of Hydrometallurgy -journal for a long time. The latest dissertation on the ion exchange material development was authored by Alessio Giove (2024) and supervised by Prof. Laatikainen. The topic was the development of novel-type of ion imprinted polymers for battery metals separations. A new flavor in the group's work is biohydrometallurgy and this subtopic is studied by Postdoctoral Researcher Manivannan Sethurajan with his PhD and Master students. Today, the research group consists of three postdoctoral researchers, three junior researchers, one project researcher, and four Master Thesis students.

As can be seen, the research topics within ion exchange and liquid-liquid extraction technologies have been various, but the covering theme has been to use intelligent methods and process configurations, to design novel and advanced unit processes and separation materials for societally essential separation problems. Recycling battery metals and rare earth elements from various secondary sources has been the topic in major part of the publications in the past ten years. Also, the fundamentals of process chemistry, including, for example, studies in aqueous chemistry, have been a crucial part of many publications. The vision of the research group is to continue with these successful major lines and to further deepen the fundamental understanding of ion exchange and liquid-liquid extraction unit processes in all aspects; aqueous chemistry, organic and solid phase chemistry, physical and flow phenomena, process configurations, reactors, etc.

Company collaboration has been, and will be in the future, an essential part of the group's work. This has been facilitated, for example, in several Business Finland (formerly TEKES) projects, exampl e.g., the three projects under BATCircle umbrella (Recycling and circular economy of battery metals), and the two TOCANEM projects (Reducing carbon footprint of metals recovery processes by novel process designs). Also, the confidential direct contract research projects with the industrial partners have been a regular part of the groups' work during the decades. The key collaborators include, to name a few, Metso (previously Outotec and Metso:Outotec), Jervois Finland Oy, Terrafame, Fortum Battery Recycling, and Boliden (Harjavalta and Kokkola), but the undersigned wishes to express gratitude to all the many companies that are and have been involved. Success would not have been possible without you!

Fig 2. Members of the Industrial Hydrometallurgy heading for a river course in Perth, Western Australia, during ALTA conference 2023. From the left: Santeri Kurkinen (LUT), Sami Virolainen (LUT), Associate Professor Don Ibana (Curtin University), Professor Aleksandar Nikoloski (Murdoch University), Tobias Wesselborg (LUT), Niklas Jantunen (LUT), Reza Aref (LUT).

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EVELIINA REPO

Professor (tenure) of Hydrometallurgy for urban mining

Turning Secondary Resources into Opportunities – Research by the Hydrometallurgy for Urban Mining Group

The global demand for metals, particularly critical metals such as rare earth elements (REEs), platinum group metals and battery metals, has increased due to their crucial role in modern technologies like electric vehicles, renewable energy systems and electronics. However, traditional mining practices to extract these metals are resource-intensive, environmentally damaging, and increasingly unsustainable due to depleting high-grade ore reserves. This challenge can be addressed by the utilisation of secondary resources such as waste or byproducts from industrial processes or e-waste from consumers and companies. Recovering metals from secondary resources, i.e. urban mining, reduces dependence on primary mining and decreases environmental pollution caused by improper waste disposal.

Secondary resources

Here is one example I have used when explaining the importance of urban mining for different audiences: "Each mobile phone requires 36 mg of gold, necessitating the extraction of roughly 7 kilograms of high-grade gold ore." This example highlights the importance of recycling, but we also need to keep in mind the variety of existing secondary resources.

- **Electronic waste (e-waste):** Discarded electronics rich in precious metals and REEs. Waste circuit boards hold up to 800 mg/kg of gold and 35 mg/kg of platinum. Permanent magnets are made from REEs, especially neodymium (up to 32%), praseodymium (up to 10%), and dysprosium (up to 10%), yet only 1% of used magnets are effectively recycled.

- **Industrial ashes and slags:** Byproducts from incineration or metallurgical processes that often contain residual metals like zinc, copper or REEs. Fly ash, in particular, contains from 100 to 600 mg/kg of REEs

- **Mine tailings:** Waste materials left after mineral extraction, which still contain metals such as cobalt, nickel, zinc, lithium, gold and REEs, even reaching several grams per kilogram depending on the mine.

- **Wastewaters:** Effluents from industrial processes containing dissolved metals that can be recovered rather than released into the environment. Metal and mining industry wastewaters contain copper, zinc and nickel, with concentrations up to 1000 mg/L. Desalination brines, produced as residuals from seawater desalination operations, contain magnesium that, with global brine volumes, could reach 280,000 tonnes per day.

- **Sludge:** Organic and inorganic residues from wastewater treatment or industrial activities. Municipal sludge from a typical wastewater treatment plant might contain around 20–30 kg of phosphorus per tonne of dry matter, and in the EU, if efficiently recovered, it could cover approximately 24–28% of the total phosphorus demand.

Key methodologies

Emphasising the development of cost-effective, energy-efficient and environmentally friendly technologies to extract metals from secondary resources decreases the need for virgin raw materials and minimises the environmental impact of metal production. Suitable results can be achieved by the integration of expertise in electrochemistry, material science and advanced separation techniques. In our research group, we are focusing particularly on the optimisation of the processes described below.

Electrifying resource recovery

Electrochemistry is one of the core metal recovery strategies that we have studied in our research group. Actually, the goal of our very first project was to develop an electrochemical process for REE recovery from secondary resources. The main achievement was a one-step electro-leaching process of spent NdFeB magnets, resulting in simultaneous leaching and recovery of up to 93% pure REE oxalates. This method offered an environmentally friendly alternative to conventional acid leaching, which often relies on harsh conditions.

While electrochemical processes are considered environmentally benign, their energy efficiency remains a notable concern. Therefore, optimising electrochemical reactors became an important research direction in our group. Additive manufacturing, i.e. 3D printing, provided an innovative way to fabricate optimised components, especially electrodes for novel reactors targeted at metal recovery. In the project funded by the Research Council of Finland, 3D-printed electrodes reached over 40 times higher electroactive surface areas compared to the conventional plate electrodes and, in general, showed excellent potential for gold recovery from liquid streams.

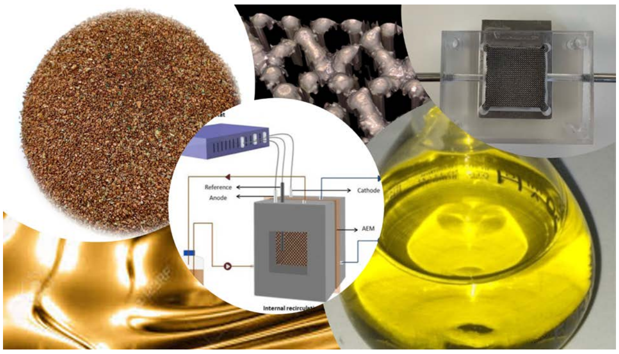

Figure 1. Electrochemical gold recovery.

Optimising metal capture by architectural designs

Metal-organic frameworks (MOFs) are ordered architectural structures composed of metal ions or clusters coordinated with organic ligands, forming crystalline, porous frameworks that extend in one, two or three dimensions. They are highly promising adsorption materials due to their large surface areas, porosity and tunability with functional groups that enhance their efficiency and selectivity. For example, we have proved that a post-synthetic modification of MIL-101(Cr) with organophosphorus compounds enhanced the material's adsorption capacity and selectivity for REEs. Particularly, Cyanex-272 and tributyl phosphate functionalised MOFs showed 90% selectivity towards heavy rare earth elements (here: erbium) and excellent stability during multiple adsorption-desorption cycles.

3D printing offers an excellent tool for structural optimisation. The desired structure offers the highest amount of adsorption sites in a small volume and effortless availability of these sites. Keeping this in mind, we have applied selective-laser-sintering (SLS) to fabricate adsorption materials using optimised designs combined with selected functional groups. For example, commercial ion-exchange resins, lithium titanate and nickel-iron bimetallic particles mixed with the printing polymers have been used as starting materials to produce 3D-printed structures able to recover copper from the tailings, scandium, vanadium, molybdenum, indium and boron from the seawater desalination brines, lithium from the diluted side streams and arsenic from the simulated wastewater. Collaboration with Finnish start-up company Weeefiner enabled us to conduct pilot experiments in a moving lab environment for recovering valuable elements from real desalination brines during the Horizon project Sea4value.

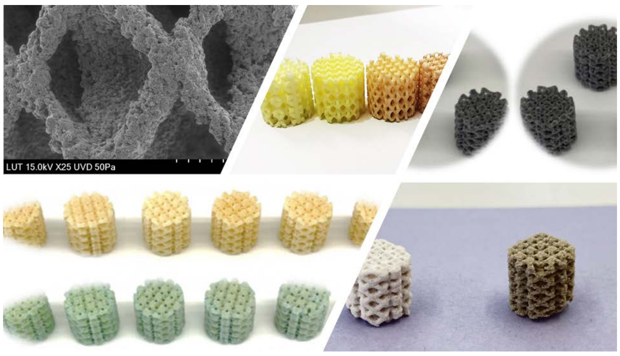

Figure 2. 3D-printed adsorption materials.

Catalysis for clean environment and energy

In addition to their adsorption capabilities, MOFs exhibit remarkable catalytic properties. However, their composition as ultrafine powders makes their separation from liquid phases challenging. To address this, our team is developing solutions by coating MOFs onto the surfaces of various support materials. Across multiple projects, we have successfully applied MOF coatings to fabrics, face masks, activated carbon, carbon fibres, metal electrodes and 3D-printed structures while also developing a new, reliable and efficient microwave-assisted coating technique.

Photocatalytic activity is a material's ability to catalyse reactions using light energy. In MOFs, light excites electrons in metal centres or organic linkers, generating electron-hole pairs that drive redox reactions. In our research, we coated fabrics and activated carbon with photocatalytic MOFs, like MIL-53(Fe) and ZIF-8, which successfully degraded pharmaceuticals in simulated wastewater. ZIF-8 was also used to give antimicrobial properties to face masks, destroying coronavirus efficiently even under visible light, although UV radiation enhanced the virus inactivation. Furthermore, photocatalytic activity for water splitting was established using cobalt-modified NH2-MIL-125(Ti) in collaboration with TU Delft and supported by the Research Council of Finland.

MOFs are also ideal electrocatalysts in water electrolysis to produce green hydrogen. In our recent study, we developed a scalable method to produce electrocatalytic coating on a nickel electrode using MOF templates, microwave heating and laser treatment. Electrocatalytic properties were superior compared to conventional iridium dioxide, and currently we are utilising the same idea for the electrochemical synthesis of green ammonia. By substituting valuable metal-based catalytic materials with more abundant ones, we aim to support the goal of reaching self-sufficiency.

Nutrients from side streams

It is well known that municipal sludge contains phosphorus and nitrogen, which remain highly underutilised. Our efforts in this area resulted in a concept of comprehensive sludge recycling where nutrients were valorised as pure struvite that can be used as fertiliser. This concept also allowed the production of high-value carbon materials, which have already been applied as efficient water purification materials and can replace graphite in lithium-ion batteries.

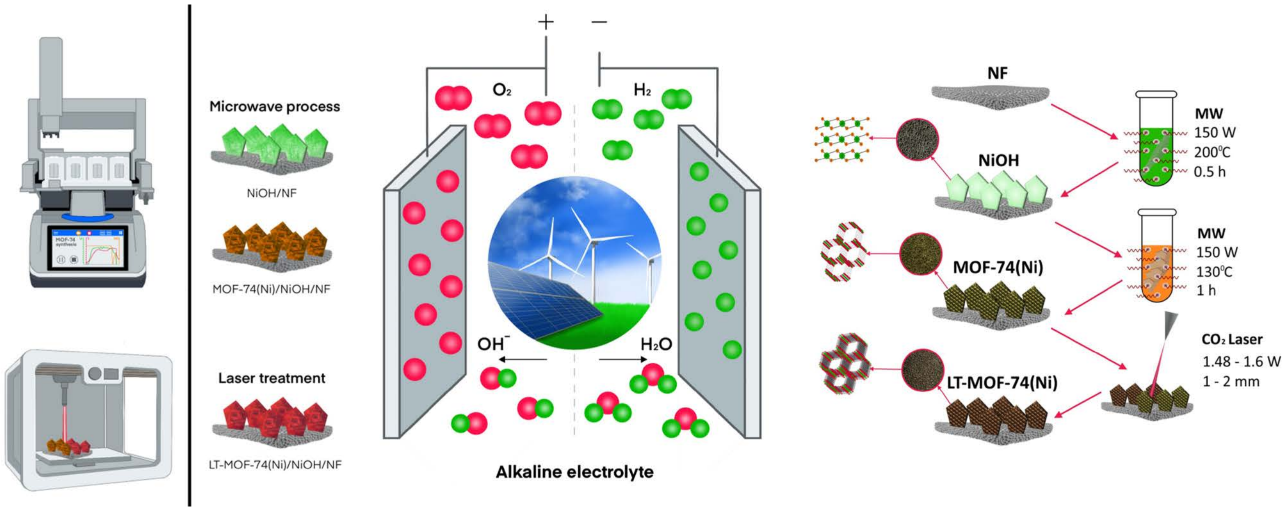

Figure 3. Electrocatalytic water splitting.

Our other novel approach for nutrients recovery relies on capacitive deionisation, also referred to as electrosorption, where porous carbonous electrodes capture ions under applied voltage. This process separates anions and cations into oppositely charged electrodes and then, after reversing the current, releases them back to the solution phase, allowing the production of concentrated streams. Electrodes studied in our group have been oxygen-functionalised carbon, polypyrrole/(nano)cellulose, and 3D-printed graphite/nylon structures. Finally, we were also able to functionalise 3D-printed filter materials with MOFs that efficiently capture phosphate ions from the liquid streams, enabling phosphate recovery and its further utilisation.

The future – from laboratory scale to pilots

Our research has advanced the field of hydrometallurgy by developing optimised processes and materials for resource recovery. However, several obstacles must be addressed. Primarily, the matrix complexity, characterised by low concentrations of metals or nutrients and the presence of interfering compounds, complicates selective extraction. Additionally, scalability is challenging since translating laboratory-scale processes to industrial applications requires further optimisation and economic evaluation. Lastly, although electrochemical techniques show high potential, for example, their energy consumption must be reduced to ensure practical, widespread implementation.

Our goal in the future is to scale 3D printing and coating processes, allowing us to build pilot-scale prototypes for both recovery of valuable elements and green energy applications. As the pressure for carbon neutrality and recycling increases, we see the greatv potential of our research directions to solve several current environmental challenges.

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MIKA MÄNTTÄRI

Professor of Membrane technology

LUT Membrane: Solutions for Industrial and Environmental Challenges

Membrane research at Lappeenranta began in the late 1980s, and the Laboratory of Membrane Technology and Technical Polymer Chemistry was established in the early 1990s. The first professor in the field of membrane technology was Professor Marianne Nyström. Since then, LUT membranologists have published approximately 300 scientific peer-reviewed papers, been inventors on 15 granted patents, and 28 doctors have graduated. The membrane research group focuses on addressing diverse separation and purification challenges across industries such as biorefining, water treatment, mining and food production. With decades of expertise, we investigate membrane fouling, performance enhancement and sustainable material development, including biopolymer-based membranes and reuse of end-of-life (EoL) membranes. We create hybrid processes combining oxidation, adsorption and crystallisation with membranes for effective wastewater treatment, pharmaceutical removal, solute fractionation and resource recovery.

Why membranes?

One advantage of membrane separation is the ability to tailor separation efficiency based on the membrane type and filtration conditions (Fig. 1). Therefore, membranes can be used to separate suspended solids or dissolve table salt, among other substances. Membrane filtration is also a separation technique with a relatively low energy consumption since no phase change takes place, which makes it suitable for temperature-sensitive materials. Purification for specific purposes, fractionation, recovery and concentration are potential processes that can often be performed simultaneously. Consequently, membranes are applied in diverse fields, including gas separation, CO2 capture, desalination, process water purification, safe drinking water production, production of ultra-pure water, juice and protein concentration, clarification of wine, beer and juices, catalyst recovery and more.

International research group

Currently, the membrane research group consists of two professors, an associate professor, three postdoctoral researchers, 12 active doctoral students, as well as several visitors and undergraduate students. The team is more international than ever, with researchers representing nine nationalities. Researchers are based in Lappeenranta, Mikkeli and Lahti. We have facilities to carry out research in both liquid and gas phases. Our filtration units have the capacity to treat streams from millilitres to m3/h. In spring 2025 a brand new P2X-chemical process lab was opened where membrane technology is harnessed for the separation of gases with a state-of-art membrane gas separation test unit. The power-to-x lab opens up new possibilities to exploit membranes to use industrial waste gaseous streams for e-fuels, for example.

The oxidation team, led by Dr Kinga Skalska-Tuomi, is part of the membrane research group. We investigate ways to enhance oxidation processes such as cold plasma oxidation and ozonation using catalysts, and how these processes can complement membrane technologies. Oxidation is important for degrading pharmaceutical compounds and treating membrane concentrates, and it has also been explored as a pretreatment for membrane filtration to reduce fouling. Oxidation is also an important part of membrane modification processes.

Research in membrane group

Our research focuses on solving various separation and purification challenges related to biorefining streams, water and wastewater treatment, the mining and metallurgic industry including the battery industry, the food industry and so on. To achieve this, it is necessary to enhance our understanding of separation and fouling phenomena and develop better membranes and pre- and post-treatment processes. Improving membranes requires examining and understanding their properties, making membrane characterisation technologies crucial to research. LUT membranologists have been developing these methods since the late 1980s, starting with pioneering work on charge analysis from membrane surfaces.

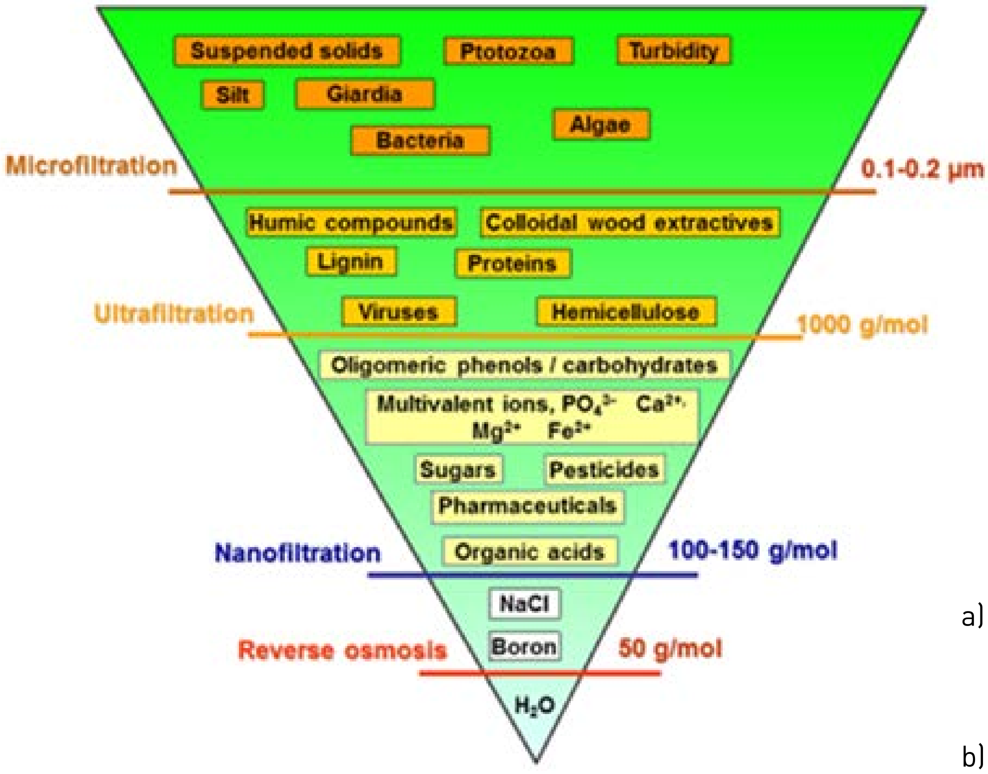
A process is more than a membrane

We integrate membrane processes with oxidation, adsorption, crystallisation, chromatographic or biological processes to achieve optimal solutions. For instance, membrane bioreactors are investigated to purify municipal wastewaters. By incorporating microalgae with bacterial biomass, we have successfully achieved a significant reduction in membrane fouling. Specifically, it has been demonstrated that aeration, typically employed in conventional (bacterial) bioreactors to manage fouling, can be reduced by 60% without an increase in fouling. An example of a hybrid process is the oxidation of hot water extract of wood prior to membrane fractionation. Oxidation has shown to improve the flux by as much as several hundred per cent. In many applications, combining technologies often yields more efficient solutions. Therefore, collaboration with other research teams at LUT and externally is an important part of our work.

Material development

Recent research has emphasised membrane materials, particularly biobased materials and reuse of end-of-life (EoL) membranes and their use in different applications. Extremely hydrophilic biopolymers are utilised for membrane preparation, and sources like wood, sawdust and waste textiles (e.g. cotton bed sheets and t-shirts) are investigated for membrane fabrication. An important research area is making biopolymer-based membranes resistant to microbial degradation, which currently limits their use. Phenolic compounds and polyelectrolytes are utilised to enhance the antibacterial properties of membranes. Polyelectrolyte modified NF membranes have also been utilised for extracting critical minerals from seawater.

Efforts are also focused on recirculating industrial EoL membranes and modules by developing new surfaces for them. By coating the EoL membrane surface with polyelectrolytes, it has been possible to create even nanofiltration membranes with a capacity that is 50–100% higher than commercial reference membranes. It is estimated that approximately two million membrane modules are discarded annually from desalination plants. Recirculating these EoL membranes could significantly reduce waste, lower the costs associated with membrane processes, and enhance sustainability.



a)

b)

Fig. 1 Pressure-driven membrane processes and their selectivity (a), membrane modules (b)

Research on industrial streams

LUT membranologists have explored the application of membranes in various industrial sectors. Acidic and alkaline streams from mining, metallurgical industries and recently the battery chemical industry, are potential targets for nanofiltration and reverse osmosis membranes. Nanofiltration can effectively separate metal ions from acids. Biorefining relies heavily on separation processes where membranes can simultaneously fractionate, concentrate and purify solutions. Different kinds of biomass extraction liquors have been shown to have strong fouling capability for commercial membranes. Therefore, we have developed different pretreatments and improved commercial membranes to manage fouling. One patented invention was to use residual biomass from the biomass extraction to purify hemicellulose extract and to reduce membrane fouling. Novel solvents, such as ionic liquids, deep eutectic solvents and cellulose-dissolving solvents (NMMO), are also potential targets for membrane separation.

A significant portion of our work involves contract research projects with industry. These collaborative projects typically focus on preliminary testing of the usability of membrane processes for specific separation and purification challenges. Although continuing these collaborations is advantageous, attaining greater impact necessitates concentrating on long-term research initiatives. A notable example of successful long-term industrial collaboration is the partnership with "Finnish Sugar-Danisco-DuPont", which led to several patents and the establishment of an industrial-scale membrane filtration plant for recovering xylose from spent sulphite pulping liquor.

Wastewater purification

In the water treatment sector, better purification of wastewater is needed. The new Urban Wastewater Treatment Directive (Directive

EU 2024/3019) demands better removal of pharmaceuticals than can be achieved in the current wastewater treatment plants. Therefore, quaternary treatment stages are being examined, including options like oxidation, adsorption and membrane filtration. Wood-based adsorbents, such as sawdust or extracted lignin, have demonstrated excellent adsorption capacities for pharmaceuticals, sometimes even surpassing activated carbon. Cold plasma oxidation has been studied and its efficiency enhanced by catalysts. Both methods have shown sufficient pharmaceutical removal, but only membrane filtration can comprehensively purify biologically treated municipal wastewater by simultaneously removing nutrients, pharmaceuticals, PFAS, viruses, bacteria and nano- and microplastics.

Municipal wastewater treatment plants face the challenge of implementing one process now and another later, or adopting membrane technology immediately to meet increasingly stringent purified water quality standards. How to treat membrane concentrate is also a significant challenge to solve. We have conducted research into the oxidation of persistent compounds to render them biodegradable and the crystallisation process to recover nutrients. The integration of membrane filtration with wastewater purification has demonstrated that approximately 50% of phosphorus can be recovered as precipitates without the need for chemical additives. Nutrients can also be recovered from municipal waste waters by self-sustainable microbial nutrient recovery cells (MNRC), which is developed from microbial fuel cells. It utilises ion-exchange membranes to work almost completely without electricity from outside. Bacteria produce the necessary electricity in MNRC in electrodialysis, which is investigated by the LUT membrane group.

Future wastewater treatment

One future aim is to develop a membrane-based wastewater treatment process for untreated municipal wastewater (Fig. 2). This involves direct membrane filtration after proper pretreatments to separate and concentrate suspended solids and solutes, followed by treating concentrates in compact biological processes. Improved membranes are being developed to enable this treatment approach. This would allow for the recovery and utilisation of substances in wastewater rather than merely degrading and disposing of them, potentially revolutionising wastewater treatment and creating new business opportunities. Research into hospital wastewater suggests that this concept could yield superior water quality compared to existing activated sludge treatment processes. However, challenges remain, including membrane resistance, fouling and cost. Advancing membrane materials and utilising EoL membranes may make direct membrane filtration

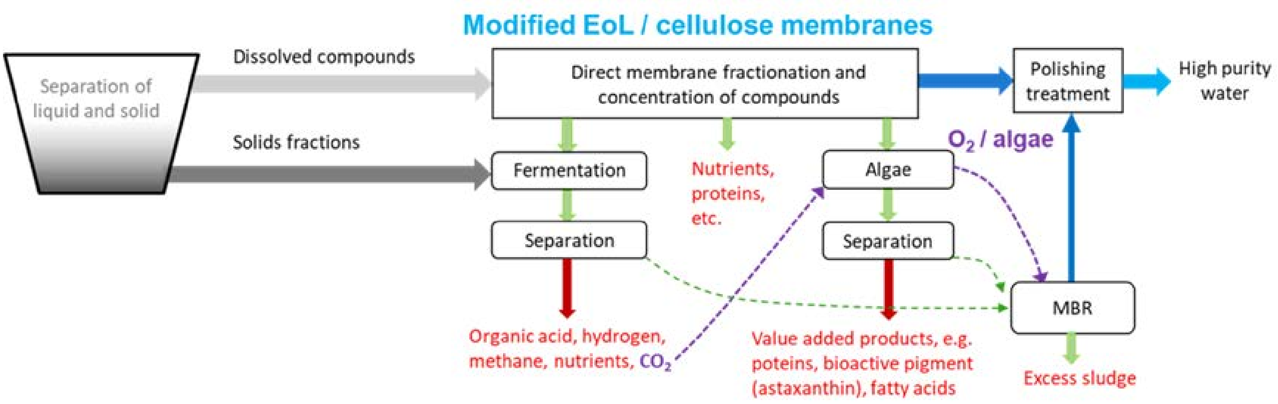


Fig. 2. Revolutionisation of wastewater treatment

with resource recovery and utilisation feasible in the future.

Membrane technologies are one key group of technologies where societies change from a linear economy to a circular economy. Membranes are often BAT technology (best available technology) for a process. Today the punchline "Your Waste Is Our Raw Material" is truer than ever.

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IKENNA ANUGWOM
Associate Professor, Docent

A Green Twist to Biomaterials Separation and Valorisation

The main inspiration for the work of our group is to present a new approach aimed at the deconstruction of lignocellulosic biomaterials using green and benign solvents, followed by the valorisation of the main fractions into valuable bio-functional materials. This endeavour investigates the use of different classes of ionic liquids and deep eutectic systems as extraction or deconstruction solvents for biomaterials, aiming to reduce the environmental impact usually associated with conventional chemical biomaterials processing.

Fractions of lignocellulosic biomaterials such as lignin, hemicelluloses and cellulose have been vastly underutilised, despite their wide range of potentially valuable applications and products. The envisioned outcome of this endeavour is to produce various types of products from the derived fractions obtained through solvent extraction/deconstruction of lignocellulosic biomaterials, and to propose new and sustainable routes to valorise these polymers obtained from the deconstruction process. We hope to continue developing this approach and envision scaling the process to an industrial level, becoming renowned in the field of green solvents for biomaterial valorisation and revitalisation.

Our group has been working towards the development of novel and sustainable solvent pathways for the extraction of valuable materials from biomass, aiming to achieve the goals of a sustainable future. Our main emphasis is on developing technology and business models to improve resource efficiency in the use of lignocellulosic biomaterials and bio-based waste. We have experience in recovering biomass compounds from various process waters and wood extracts, which are often discarded in landfill or incinerated.

Here, we present a pathway for the usability of agave bagasse waste biomass and silver birch (Betula pendula) to produce cellulose acetate (CA) using our proposed green solvent-based process. The feasibility of the novel green solvent-based fractionation process aimed at purifying cellulose for further synthesis of CAs from waste biomass was evaluated. We demonstrated that waste biomass could be valorised into CAs. Furthermore, we have been working on the development of biodegradable membranes from biomass and their utilisation in wastewater purification and solvent recycling. Additionally, we have developed a green solvent route for waste textile recycling and revitalisation.

Regarding the revitalisation of waste textile fractions, the primary goal is to demonstrate the potential of using reclaimed polyester (PET) from recycled cotton/polyester blends as a source with zero-carbon footprint credentials to produce ultrafiltration membranes using the non-solvent induce phase separation (NIPS) technique. The use of recycled raw materials in membrane fabrication presents an opportunity to improve sustainability within the water and wastewater treatment market. This work further enhances the understanding of manufacturing PET-based UF membranes.

Currently, our research also focuses on the preparation and surface modification of cellulose-based membranes and hydrogels to remove contaminants of major concern, such as microplastics, dyes and pesticides from water. This endeavour aims to determine effective ways to combine hydrophobic eutectic solvents with cellulosic materials while maintaining their stability in aqueous phases, to enhance the removal and recovery of these contaminants from wastewater streams.

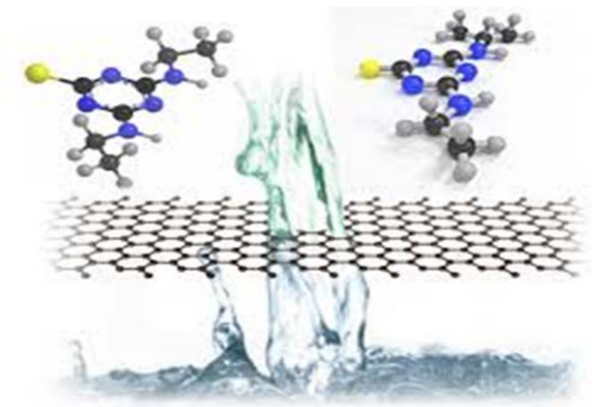

Figure 1: *Membrane filtration - selective permeability of particles and ions across membranes.*

In terms of waste materials valorisation, another aspect of this research involves envisioning and fabricating a biodegradable biocomposite material using green solvent-extracted lignin. The benign process used to modify the lignin was employed as a bio-based additive in the manufacturing of biocomposites. The biocomposites were produced from polylactic acid (PLA) and wood. It is noteworthy that the lignin used in this endeavour was extracted from construction and demolition waste (CDW) using a green solvent-based process, and part of the recovered lignin was modified. The implementation of lignins in biocomposite filament extrusion was tested, and the influence of lignin on the composite manufacturing process and mechanical characteristics of the produced biocomposite was evaluated. Results showed that lignin compounds can be used as part of biocomposites based on PLA and wood material. Lignin was found to act more as a coupling agent than a lubricant, and the coupling agent strength effect of esterified lignin was comparable to the commercial coupling agent used in these experiments. The use of green solvent-based processes makes it an interesting option for producing a bio-based lignin additive for composites from waste wood fractions such as sawdust and CDW.

Pharmaceutical blister packages usually comprise aluminium and plastic layers. Due to their multi-material structure, recycling discarded packages is typically challenging. However, when separated, both metallic and polymeric fractions are recyclable. The proposal involves separating the aluminium and polymeric layers of waste pharmaceutical blisters by exploiting a green solvent-based process. Complete separation was achieved with both studied solvents, and the results showed that the green solvent-based process offers a viable green separation methodology for aluminium and plastic from blister packages. The aim of this study is to investigate the viability of green solvent-based processes as separation mediums for separating aluminium and plastic from waste pharmaceutical blisters (WPBs) without affecting the integrity of the separated materials.

Lignocellulosic non-wood biomass was treated in highly diluted green solvents. The aim was to demonstrate the power of green solvent-based processes as treatments for non-wood biomass as a sustainable, environmentally friendly and cost-efficient approach. The primary fractions obtained were hemicelluloses and cellulose-rich pulp with very low lignin content. A simple model was used to describe the weight loss obtained for the treated wood. Chemical analysis results revealed substantial removal

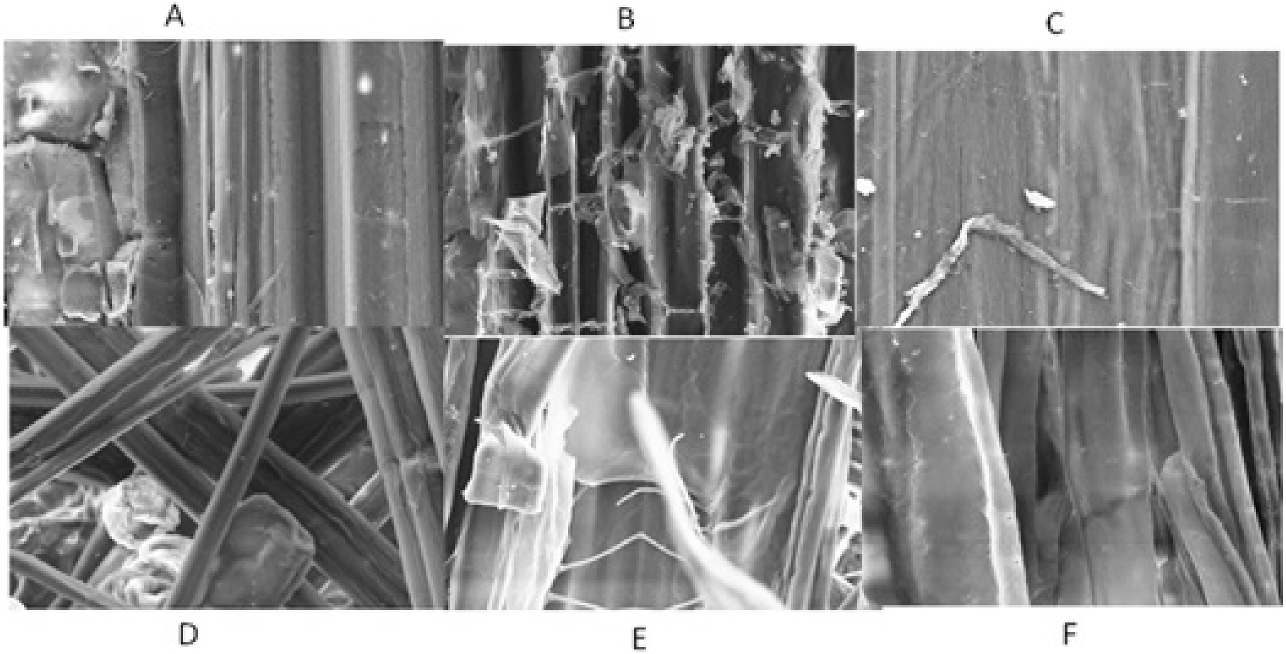

Figure 2: *SEM images of the A) native bamboo, B) eucalyptus bark, C) wheat straw. D, E, F depict the corresponding SIL treated samples. (For all samples magnification: 1KX, size 20µm).*

of lignin, consistent with results of switchable ionic liquids (SIL) treatment of wood. The goal was to assess the potential of this type of poorly explored biomass as a source of potentially valuable raw materials. The aim of the present investigation relies on taking advantage of the versatility of the short-time high-temperature (STHT) procedure and verifying its suitability for other types of lignocellulosic biomass than soft or hardwood. These other types of biomass are fast-growing and abundantly available. Additionally, lignin extraction capacity was quantified, as well as possible changes in the crystallinity of cellulose.

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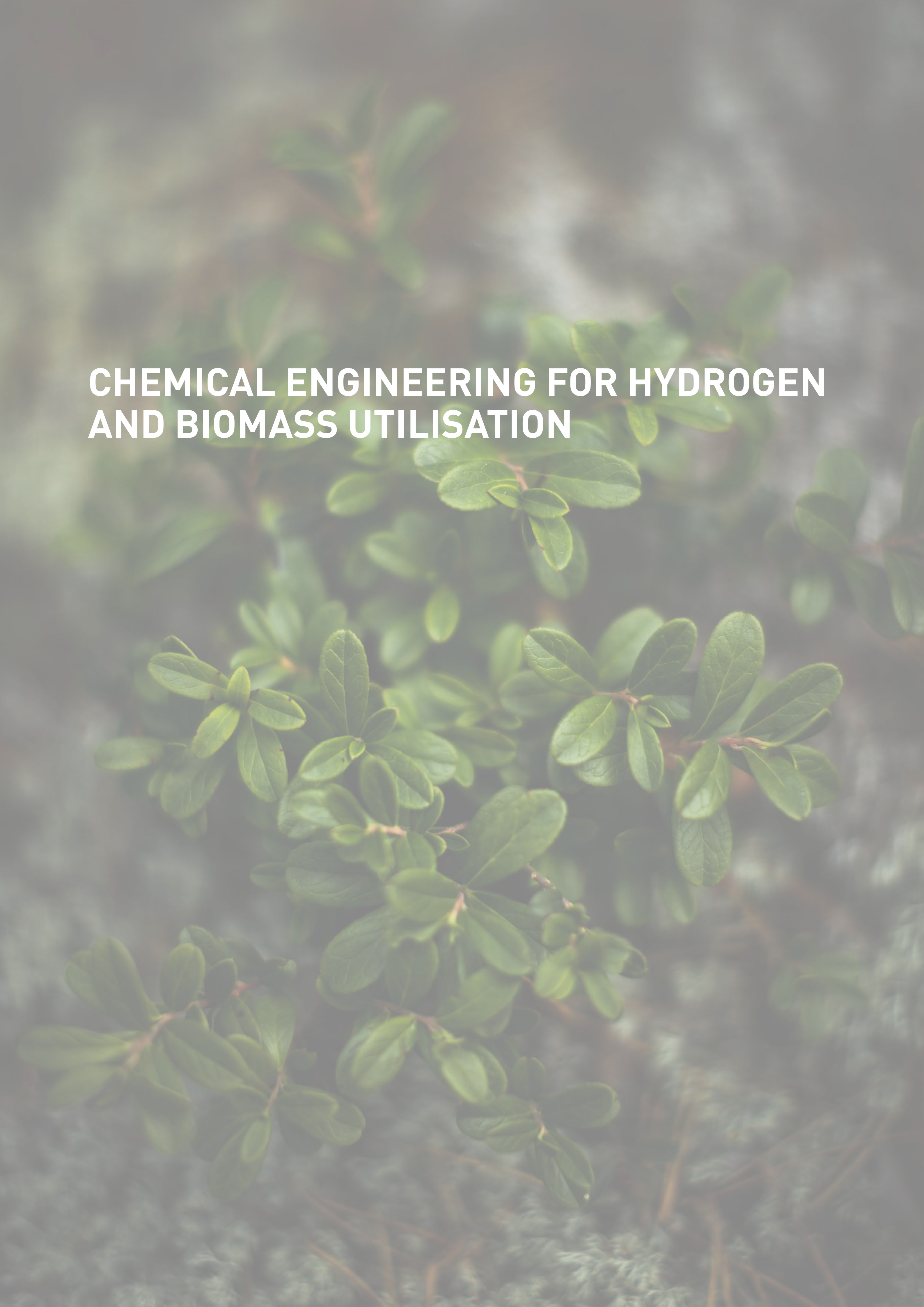

CHEMICAL ENGINEERING FOR HYDROGEN AND BIOMASS UTILISATION

TUOMO SAINIO

Professor of Separation Technology for Biorefining

All you need is interactions (on the molecular level)

Chemical engineering for biomass processing offers adventures for anyone who wishes to challenge themselves. For more than a century, the Finnish forest industry has refined its core processes, especially chemical pulping and integrated energy production. Modern biorefineries expand the product range and thus require various types of novel processes, including separations. As a professor in separation rechnology for biorefining and leader of the Chemical Separation Methods (CSM) research group, I have the privilege of working on such challenging topics. Our research group continues the work of the former Laboratory of Industrial Chemistry (Teknillisen kemian laboratorio, Prof. Erkki Paatero) with a stronger focus on biobased molecules. Since 2020 we have been based at LUT's campus in Lahti, with a few researchers operating at the Mikkeli and Kouvola regional units and the Lappeenranta campus.

The main themes of the CSM group's research are the chemical conversion of biomass, separation of valuable compounds from complex mixtures, and purification of effluent streams and individual compounds. As the group's name suggests, we specialise in separation methods that are based on molecular-level interactions between dissolved biomass and separation materials. We are interested in production-scale applications of adsorption, ion exchange, chromatography and liquid-liquid extraction. Chromatography is often regarded as the most selective separation method suitable for the large-scale processing of dissolved biomass.

The CSM group's approach to new research problems is illustrated in the figure [above]. High-quality experimental data is acquired to get an understanding of the fundamental phenomena (mass transfer, phase equilibria) and the properties of the separation materials. The observations are interpreted with relevant theories, often using advanced mathematical models. These form the basis on which development and optimisation of unit operations can be built. Typically, we use numerical simulations to optimise processes and to assess the performance of alternative process configurations. Predictions are validated using bench or mini-pilot scale equipment. A mismatch between experiments and simulations sends us back to studying the fundamental phenomena more closely, revisiting the theories and improving the models. I suppose that is why someone chose to call our business *re-search…*

Separation and purification of biobased molecules

In just two or three centuries, chemists have learnt to build almost any industrially relevant compounds from a handful of elements. If there is a way to do it economically, chemical engineers will come up with a process to implement it on a commercial scale. While we appreciate the work of synthesis chemists, we adopt a different approach when working with biomass. Nature spent some 300 million years perfecting the synthesis of lignocellulose and other complex chemical structures in plants. To exploit them in a sustainable manner, we need separation and purification processes that preserve such structures to the highest meaningful extent and ensure our processing technologies are efficient and minimise emissions.

Examples of biomass-derived compounds in our research include monosaccharides and polysaccharides of various origins, polyphenols such as flavonoids and lignin, glucosidic phytochemicals, organic acids, and to a lesser extent proteins. Industrial streams include alkaline pulping liquors ('black liquor'), acidic lignocellulose hydrolysates, molasses, vinasse, high-fructose corn syrup, wort, berry juices, potatoes, whey, as well as wastewaters and sludges. Ongoing doctoral research projects deal with interactions between phenolic compounds and cross-linked dextran separation materials [Lehtilä & Sainio, 2025], and the use of cellulose as a separation material in biorefineries.

Chemical conversion

Despite the aim of preserving the structures nature has created, it is sometimes better to make an omelette than let the eggs spoil. We have applied this principle to cellulosic wastes that cannot be recycled as fibres by valorising them as monomeric carboxylic acids. Disintegrating the polysaccharide chains under alkaline conditions at 190 °C yields bifunctional molecules that can be used, for example, as building blocks for biopolymers. The behaviour of the complex reaction network was accurately described over a wide temperature range with a novel kinetic model [Fallahmehneh & Sainio, 2024]. As a practical demonstration, we recently converted 'zero fibres', a cellulosic waste dug from a deposit at the bottom of Lake Näsijärvi, into hydroxy carboxylic acids [Mattila et al., 2025]. A purification process for such acids was developed earlier [Heinonen & Sainio, 2019]. The hydroxy acids were finally converted into biobased surfactants in a solvent-free mechanochemical process [Crigna et al., 2025].

Other examples include our work on controlled acid catalysed hydrolysis of oat beta glucan. The aim was to produce a narrow molar mass fraction that has, according to the literature, great potential to be fermented into beneficial short-chain fatty acids in the colon [Nguyen et al., 2021]. The key to achieving this was found to be integrating the chemical reactor and separation units into a hybrid process that decouples the residence time of the polysaccharide molecules in the reactor and their feed rate [Sainio & Kaspereit, 2021].

Theoretical work on separation process development

For some, the only interesting operating point of any process is the optimum that maximises selected key performance indicators. Finding optima is often a matter of computing power and persistence; it does not necessarily lead to a deeper understanding of the process being studied. In our view, identifying the *boundaries* of the feasible operating parameter space is at least an equally intriguing task. In this regard, our main result is the unified design method, which transforms the operating parameters of different chromatographic separation processes into such a form that they can be compared [Siitonen & Sainio, 2015]. The method allows for a visual comparison of the feasible operating parameter ranges and, under certain limitations, the transfer of an operating point from one process scheme to another. We have applied the method to single column batch chromatography, steady-state recycling chromatography, several variants of simulated moving-bed chromatography (SMB), binary and ternary separations [Sainio, 2016], complete and incomplete separations [Sainio, 2021], and even to centrifugal partition chromatography where both phases are liquids (not yet published).

Artificial intelligence

As I am writing this, the rapid development of generative AI is a cause of both excitement and uncertainty. We already see students using AI to cheat in impressive ways. To level the playing field, we recently developed an AI Grader tool that orchestrates commercial large language models (LLMs) to automatically evaluate and grade students' exam answers on adsorption and chemical reaction engineering courses (for internal use at LUT, not published).

There are only speculations about how AI will affect separation technology research in the long term. To stay informed, we have dipped our toes into AI-driven process development by building a tool for automated SMB chromatography design [Sainio & Kawajiri, 2024]. The user only needs to provide a chromatogram from a batch column experiment, the desired process configuration, and the design constraints (target purities of the products). The tool processes the input data using a recurrent neural network (long short-term memory, LSTM) and makes a prediction of the optimal operating parameters with a deep neural network (multilayer perceptron, MLP). With our conventional numerical simulation tools, such design problems are typically solved in an hour or so. The AI-driven design tool makes the prediction in just milliseconds with high accuracy. Where's the catch? We burnt thousands of hours of CPU time to generate millions of SMB chromatography data points and quite a bit of GPU time to train the neural networks. Just like the generative AI tools of the present day, our tool learnt from a massive number of examples to predict which result the user is most likely to be happy with.

The question remains whether a machine can learn to *understand* the fundamental phenomena of the separation process so well that it could *create* novel solutions? If yes, what will the role of a human chemical engineer be in that reality? I trust the answer will be found by the time the centenary edition of this publication is available.

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TUOMAS KOIRANEN

Professor of Chemical Processes Systems Engineering

Chemical process systems engineering has its roots in chemical engineering and plant design

> Research and teaching activities are concentrated in **process research, design and intensification (PI)** by physicochemical modeling, prediction and experimentation.
>
> Computerized tools are central in these activities.

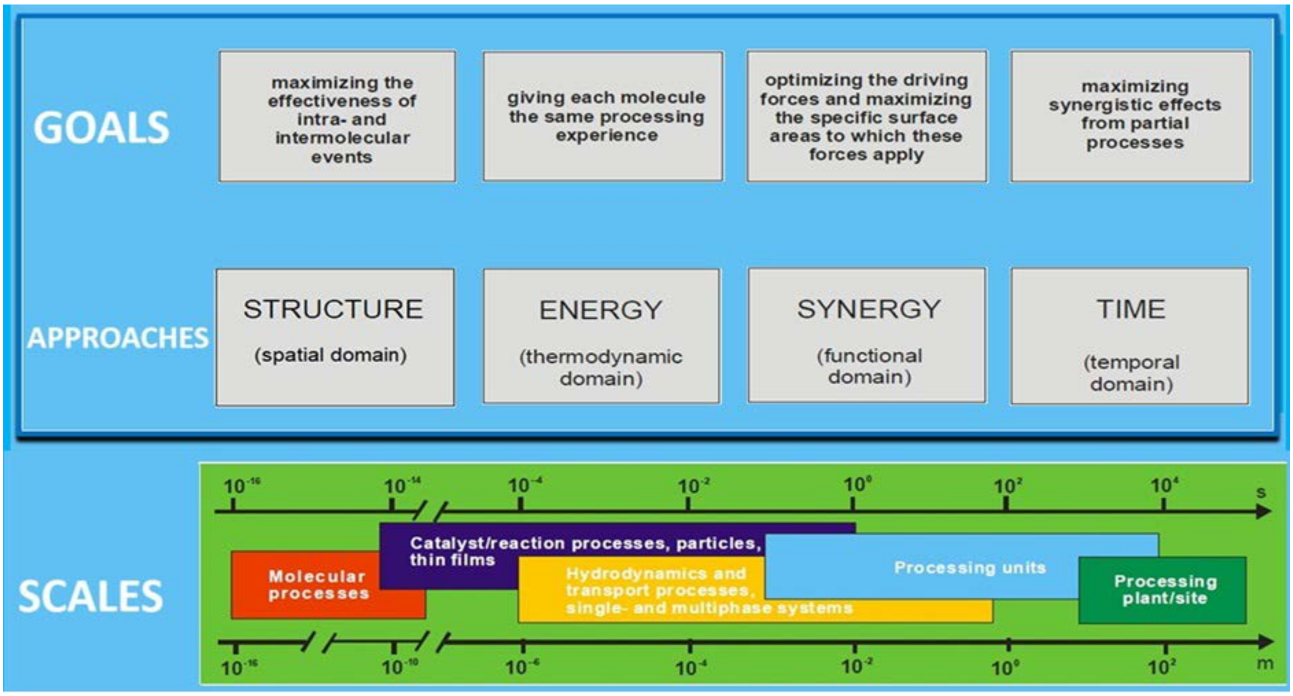
In-depth understanding of physico-chemical phenomena

The work of a technical university has two functions:

1. Teaching
2. Research

The connecting theme of teaching and research is thorough understanding of chemical systems, and the fundamental balances involved. We aim to educate talented new professionals who can solve technical problems and design new processes. Graduates of master's and doctorate of science programmes are capable of taking on challenges in the process industry and co-operating with their colleagues. Research, on the other hand, is about understanding the problems at hand and creating new solutions that also include comprehending different theories in depth.

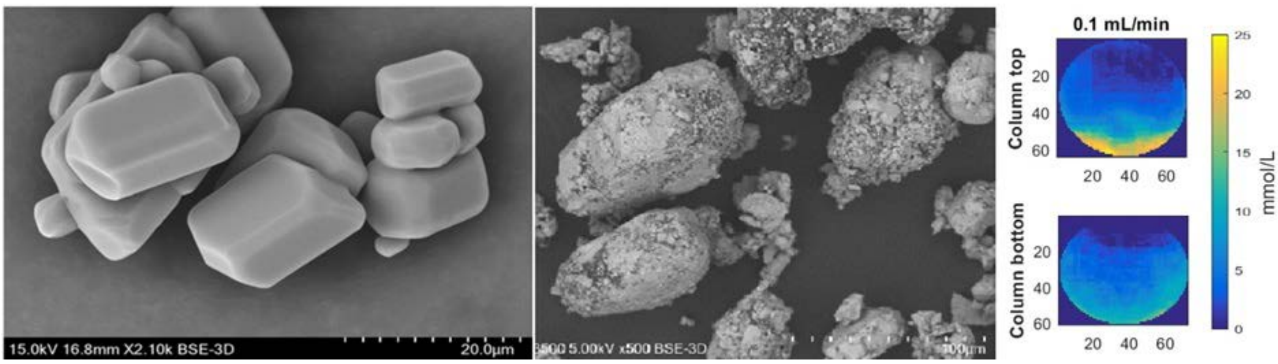
Chemical process systems engineering (CPSE) involves understanding different scales from a molecular level to a chemical process plant level. Again, we need to understand mass, momentum and energy balances as well as chemical reactions and chemical reactor technologies. Currently, and fortunately, we have excellent mathematical tools for solving balances: multiphysics-based computational fluid dynamics and chemical process plant simulators. Today, it is possible to solve e.g. electrolyser operations as a three-dimensional fluid flow model, or an ultrasound-assisted chemical reactor model by combining fluid flow models with other laws of physics. Chemical production facilities can be modelled as continuous flow processes, allowing for the analysis of mass and energy streams, as well as the optimisation of chemical equipment sizing. In addition to this, we can solve process dynamics involved in variable feed flows or the tuning of process controls, for example.

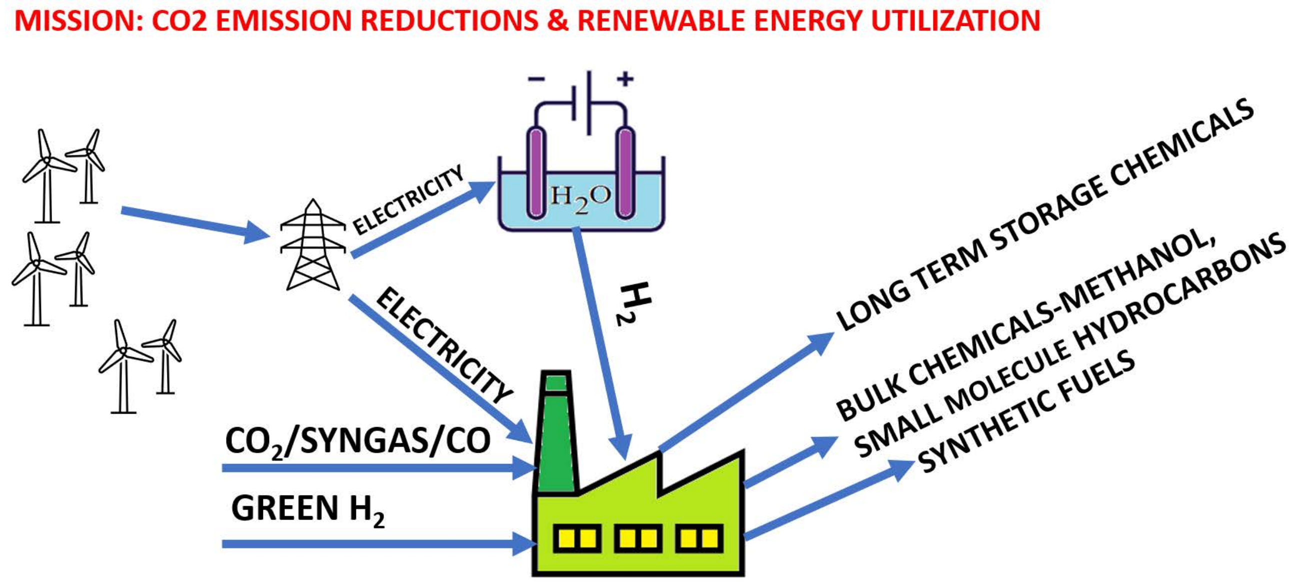


CPSE has long traditions in chemical plant design and also in chemical process intensification (PI), which was started by Ilkka Turunen and was related to the spatial domain approach using micrometer-scale reactors. Substantial improvements were related to intensified heat and mass transfer. PI paradigm-based approaches are also thermodynamic, functional and temporal domains that all aim for radical improvements in yields, selectivities and efficiencies.

PI has been applied to different applications, for example ultrasound-assisted crystallisation, ultrasound-assisted extraction processes, or hollow-membrane absorption in carbon capture studies. In PI-based crystallisation and extraction, the targets were to combine several unit operations into one unit and to improve yields. Hollow membranes, on the other hand, enable miniaturisation of huge CO2 absorption columns without sacrificing process efficiencies.

The experimentation is fundamental in this research field because models need to be validated and tuned to be used in real-world applications. Experimentation can be related to microscopic phenomena such as the polishing of crystal surfaces, sustained release of fertiliser nutrients, mass transfer from liquid droplets, or chemical reaction kinetics.





Example problem

Interdisciplinary platform work combining energy technology, chemical technology and business school competencies was started in 2015, with the aim of developing a fully renewables-based CO2 neutral energy system. Renewable energy-based electricity is utilised mainly using sun and wind power. The global perspective is climate change control and approaching carbon-neutral or even carbon-negative processes throughout the consumer chain from raw materials to products. Different forms of collaboration with energy and fuel production companies, as well as chemical and pulp producers, from contract research to consortium-based work, has been intensive because of the current topic. Several studies of process simulations and techno-economics have been worked out for different manufacturing chains of power-to-X processes.

Substantial research has been done in methanol synthesis from CO2 and green hydrogen. Liquid- and gas-phase reaction studies involved with water sorption enhancement (SE) to improve reactor performance have been a particular research focus. It is noted that SE is involved in all CO2 hydrogenation reactions of P2X.

It is clear that P2X, climate control and raw material recycling will be research topics for the coming decades. Global temperature rise control and especially replacement of fossil raw materials will set the green transition in chemical technology, and therefore there will be an urgent need to educate new professionals in this field.

NIMA REZAEI

Associate Professor (tenure) of Gas Separation

Gas Separation Research using Advanced Materials and Process Concepts

The Gas Separation research group is currently focusing on the application of advanced materials and process concepts in gas separation processes including separation, purification, storage, and utilisation of gases for energy and material use. We are conducting experimental and simulation research studies within the framework of climate action and is focusing on applications such as:

- Carbon capture, utilisation, and storage
- Hydrogen production and purification
- Biogas
- Air pollution control
- Industrial gas separation
- Atmospheric water harvesting
- Confined transport and phase equilibria

Significant issues in carbon capture using sorbents are the result of 1) long adsorption-desorption cycle time and (2) inefficient energy input that must be given usually to an entire adsorption column so that the CO_2 molecules in the sorbent are removed (after capturing them on sorbent). We tackle both problems by directly depositing the sorbents onto a thin conductive surface and by heating them with electricity. We use metal-organic frameworks (MOFs) because of their high capacity to hold CO_2. The MOFs are deposited as thin films onto a thin conductive surface (Aluminium or Copper). Figure 1(d) shows a printed circuit board heater concept that includes a conductive thin serpentine on Kapton tape. By applying a small voltage, the conductive base layer reaches the conditions that are needed for separating CO_2 from sorbent. In Figure 1(a)-(c), images of sorbents that are deposited directly onto electronic aluminium waste are shown. Our initial simulation study shows a desorption time of less than one minute, which is usually several hours using conventional methods. The electrically heated sorbent can also be used in other applications such as sensors and

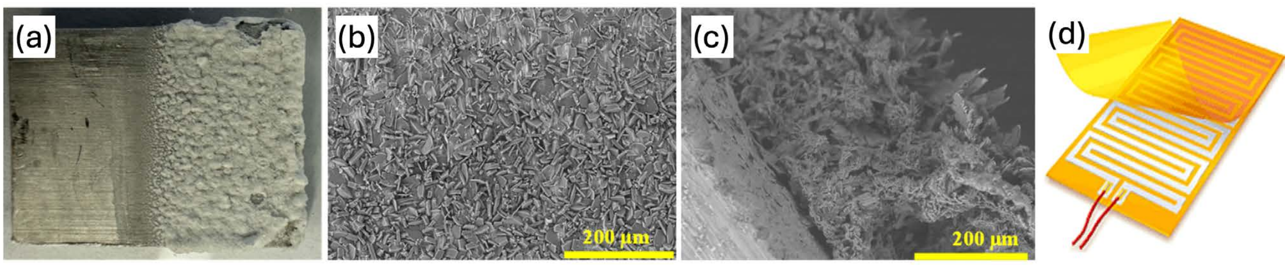


Figure 1: Thin-film MOF sorbents on (a) waste aluminium partly deposited with sorbent; (b) surface coverage of sorbent under SEM; (c) cross-section of aluminium with sorbent under SEM; and (d) a thin-film metal heater on Kapton tape.

self-sterilising filters. Our research group is collaborating with Prof. Eveliina Repo (LUT), Dr. Fatemeh Keshavarz (LUT), and Prof. Piero Macchi (Politecnico di Milano, Italy).

The gas separation research group is also focusing on intensifying separation processes passively and using capillarity as an inherent driving force. In Figure 2(a), a gas bubble is shown that is confined in a liquid. Let us assume the gas is CO_2 confined in water at room conditions. If the diameter of the gas bubble is 50 nm, the gas bubble can have an internal pressure of approximately 60 bar while the liquid is still at room temperature. The difference between the gas and liquid is called capillary pressure and brings benefits such as higher gas solubility in liquid and internal mixing due to the interfacial surface tension changes gradient, which eventually intensify CO_2 dissolution in water without consuming significant energy. These benefits are in addition to the extended exposed surface area (for a given amount of gas in liquid) when bubble size decreases. We apply the concept of confined phase equilibria and transport in Figure 2(b) to separate mostly CO_2 from a gas mixture for carbon capture. In this project, we are collaborating with Prof. Clayton Radke (University of California Berkeley, USA).

Our research group has also initiated a large-scale project where we aim to calculate the carbon footprint of WWII, in collaboration with Prof. Lassi Linnanen (LUT) and Prof. Joyce Chaplin (Harvard University, USA). The idea is to estimate the CO_2 emission due to war efforts during- and after the war to rebuild damaged infrastructure. Aside from scientific values, this carbon footprint can help to increase the social awareness of greenhouse gas emissions and can serve as an infamous reference. Because most people can connect with the devastation scale of WWII, it would be more meaningful to compare, for example, the carbon emissions from a given activity (such as transportation) with the total carbon emissions during WWII. From a political and international law perspective, this study can also aid in including accountability for environmental remediation (such as carbon capture and storage costs for CO_2 emissions due to war efforts) with regard to countries that initiate large-scale wars.

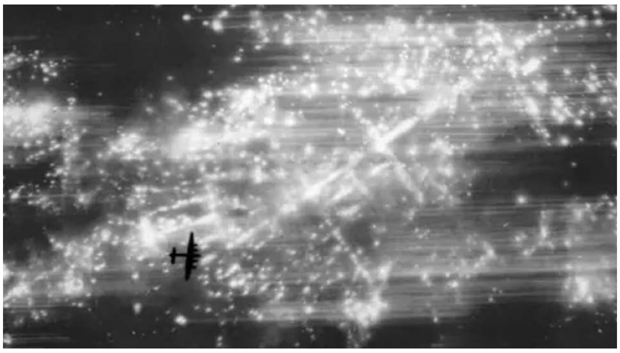


Figure 3: Bombing of Dresden during WWII (picture from Getty Images).

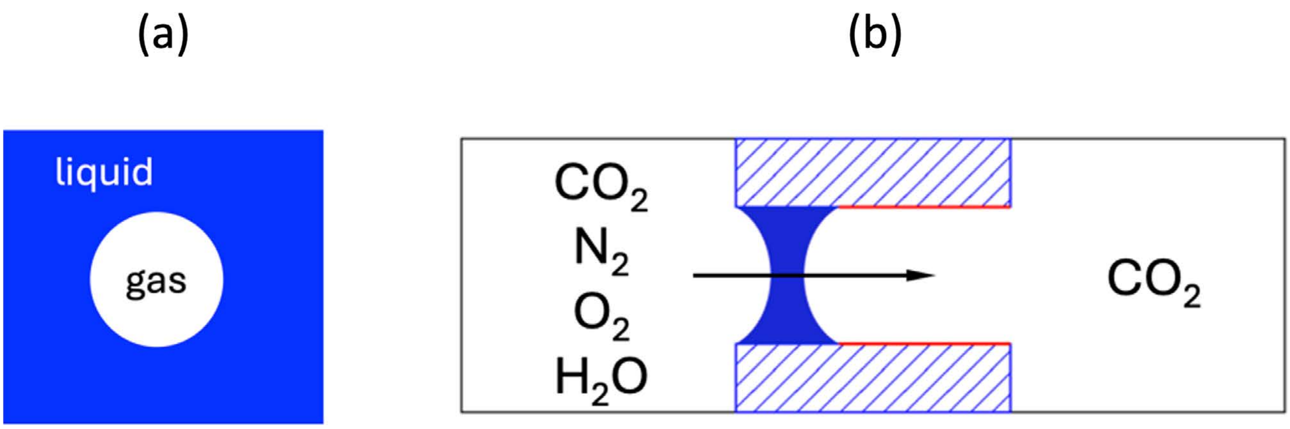


Figure 2: Schematic of (a) a gas droplet confined in a liquid medium, and (b) a thin sorbent confined in a membrane tube used for separating CO_2 from a mixture.

KRISTIAN MELIN

Associate Professor of Process and Plant Design

From a new biomass-based product in the lab to profitable commercial plant

What is behind the new ideas of biobased products and new processes?

Using biomass instead of oil, preferably in combination with wind and solar electricity, opens up fascinating opportunities for greener processes that can benefit the local economy and result in new business opportunities.

New ways to valorise biomass are typically found in experimental work in the laboratory. The better affordable solvent that can dissolve cellulose has been found, enabling production of new products from biomass, for example, pulp for textiles. New ways to produce high-value biobased materials, such as graphene anode material for electric cars, are discovered, and more green products are found for traditional oil-based chemicals, such as lignin replacing phenolics in resins.

These are all fascinating developments, but one key question is how to develop the ideas into to commercial, well-functioning industrial-scale plant. When the great idea from the laboratory is turned into a business, it also has a much higher impact on society. As in the discovery of new medicines, the new promising idea of a molecule can one day become a life-saving medicine.

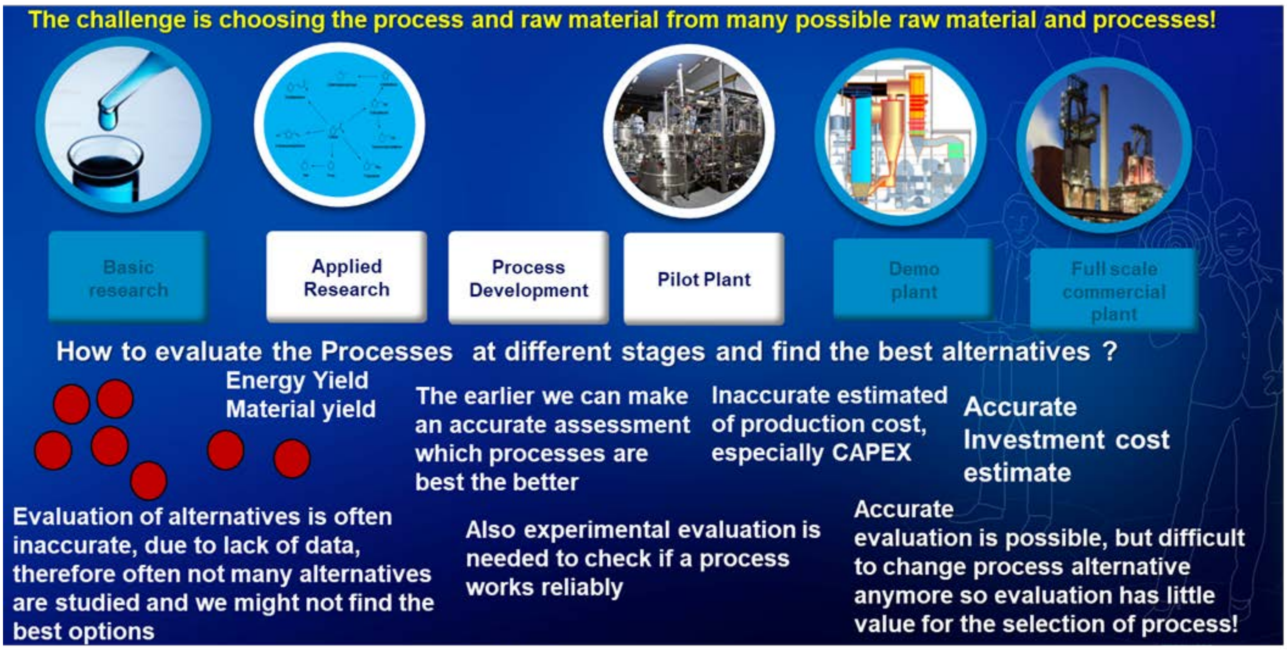
We also do not always have to start in the lab when developing a new, better process, we can also find a new, more efficient production pathway for an existing product like ethanol by combining existing unit processes in a novel way. We might also have ideas how a traditional process with energy-consuming separation part, such as evaporating a huge amount of water, can be improved by using different separation technology, for example, by utilizing membranes to separate products. There are also several options to turn biomass-based processes greener and more efficient, for example by electrification. Instead of using a traditional boiler, which is typically based on burning part of the biomass residues from the process, we can employ a heat pump or use electrical heating. Furthemore, biomass-based processes can be complemented with green hydrogen production through water electrolysis, and/or biomass-derived components such as carboxylic acids could be upgraded for example into kerosene fuel using renewable electricity.

How do we transition a new process from the lab to a commercial plant, and what challenges do we face?

Transforming new technology from the laboratory into a commercial application typically involves both basic and applied research, where the fundamental principles of a new invention are explored. Once these principles are established, an experimental proof-of-concept test is conducted to verify that the new method functions as intended. Following this, extensive validation occurs in the laboratory before piloting and demonstration take place in an industrially relevant environment. After confirming that the technology operates effectively at a sufficiently large scale, the design and construction of a commercial production plant can commence.

This entire process, from laboratory to commercial plant, can take over a decade and requires substantial funding. Initially, there are often numerous ideas for new processes, but only a select few evolve into commercial-scale plants. This is primarily because not all new ideas are technically or economically viable. Some processes may yield insufficient output, or they may produce a product at a significantly higher cost compared to existing methods.

How can we determine which alternatives are the most promising? This can be a challenging task, often referred to as the 'process design paradox'. At the outset of developing a new product, it is relatively easy to pivot and explore alternative options if one of the selected processes proves unfeasible. However, we often have limited data to conduct a detailed comparison, particularly regarding costs. Initially, there may not be enough information to design the process in detail and estimate its costs based on the capacity of each piece of equipment. Conversely, after years of development, we typically possess very accurate data to assess the process technology. If we discover that the chosen alternative performs significantly worse than other options, it becomes increasingly difficult to select a different process. In such cases, we may have invested considerable time and resources into develo-



ping a solution that ultimately proves unviable. Additionally, the time to market for new inventions is often critical; companies that make better technological choices can successfully introduce competitive processes and secure advantageous positions in emerging markets.

The urgency to introduce new technologies to the market is also driven by the pressing need for climate change mitigation and energy transition. We require hundreds of new green plants utilizing green hydrogen or biomass, yet the technology for these solutions is often not yet commercially viable. Consequently, there is a significant delay between the decision to phase out fossil fuels and the introduction of new green process technologies at a commercial scale. Furthermore, there are inherent risks and pitfalls for investors in new technologies, which may only become apparent after demonstration, revealing that some seemingly promising technologies encounter issues with materials or operability.

How can we accelerate the development of new processes and enhance our chances of selecting alternatives that are both sustainable and exhibit high economic and technical performance?

One effective approach is to conduct techno-economic analyses concurrently with experimental tests at various stages. We can have multiple stages in the development of new processes leading to a full-scale plant. After each stage, we assess the feasibility of the process based on the data collected thus far. We utilize specific criteria grounded in key performance indicators, such as the yield of the main product, which must be met. Once this criterion is satisfied, we progress to the next stage, where we conduct investigations in a pilot plant and again evaluate the feasibility of the process post-testing. At these stages, we allocate more resources, manpower, and funding towards development, which allows us to gain a more accurate and comprehensive understanding of the process's feasibility. The ultimate goal is to refine the most promising ideas into commercial plants while discarding those that are not viable.

What role do process design and computer-aided methods play?

As we transition towards more commercial plants, it is often necessary to specify or even design the process, especially when constructing a production plant, to accurately predict the technology's performance. Thus, process design is essential not only during the design of the first full-scale plant but also in the early stages of development when we are still in the laboratory. It is crucial to consider how the process can be scaled up for full-scale production, including identifying the necessary process steps, realizing the required reaction and separation stages, and connecting process streams to minimize heating and cooling requirements.

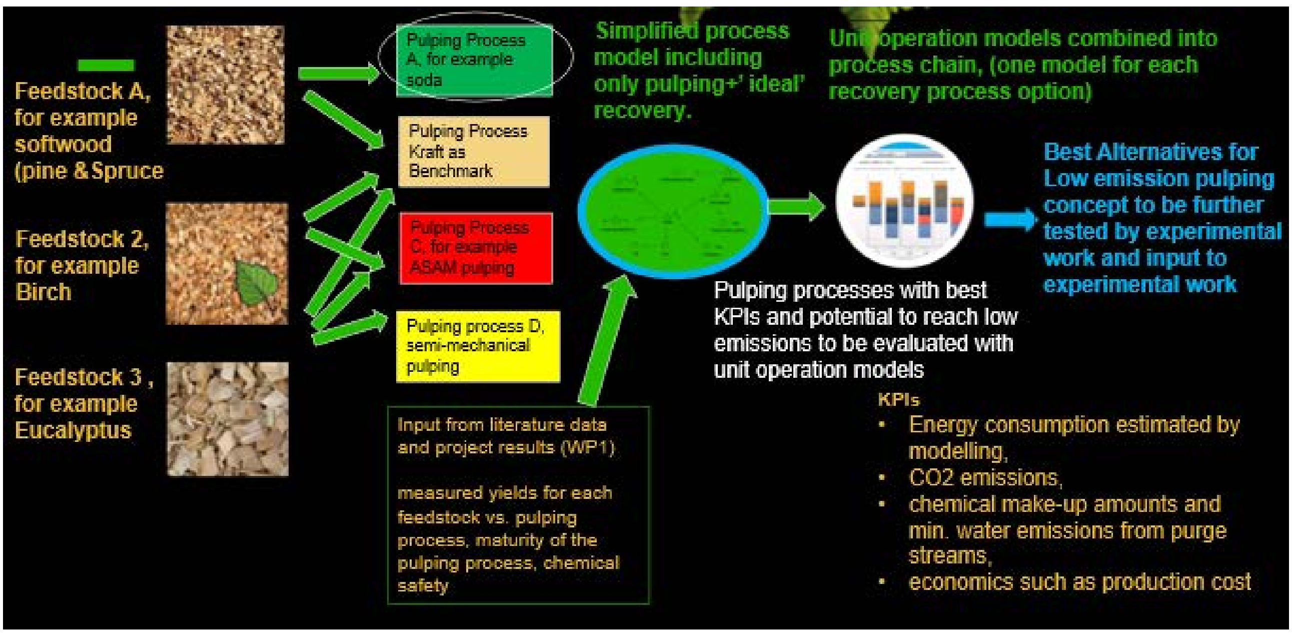
During this phase, we can utilize process simulation software, such as Aspen Plus, to simulate the full-scale process. This allows us to easily modify the process and explore various configurations. Consequently, we can significantly optimize the process on-screen, ensuring that the improved design achieves maximum performance and profitability. Additionally, these software tools can integrate economic databases, enabling us to estimate the investment costs associated with various process options. Furthermore, Life Cycle Assessment (LCA) analysis can be conducted alongside techno-economic evaluations to identify the most sustainable options.

In research, advanced methods have been developed to facilitate process development. Multilevel evaluation methods can be employed to initially assess numerous process alternatives and raw materials using shortcut models, subsequently selecting the one with the highest performance for more rigorous analysis with detailed models. The computer models used for process development and design are continually evolving, allowing for the prediction of material properties without the need for extensive, time-consuming experiments. While AI and machine learning can accelerate process development, the representation of process design data, such as diagrams, and the synthesis of new processes are not as advanced as AI applications in text generation. In the future, AI may be leveraged to expedite simpler design tasks, such as piping design. Accelerating process development will also enable us to explore a broader range of potential options.

How does the research group of Process and plant design in biorefining apply these concepts in collaboration with various projects?

A significant portion of our current work is focused primarily on national Research and Development projects, with plans to expand into more international collaborations in the future. Our aim is to develop innovative ideas that lead to commercial solutions while providing insights into the feasibility and sustainability of production methods or products when implemented at full production scale. These projects are typically conducted in partnership with companies, research organizations, and universities. One area of exploration involves biomass-based processes that utilize electrification. By employing electrical heating, we aim to minimize the reliance on combustion within these processes. Additionally, electricity is harnessed to split water into green hydrogen, which can be co-fed into the process, effectively doubling the yield in applications such as methanol production via gasification. Several projects are dedicated to investigating sustainable alternatives to oil-derived plastic packaging and exploring the potential of replacing cotton with textile fibers derived from wood. Our goal is to develop products that outperform fossil-based alternatives. For instance, we have identified that casein and cellulose can be utilized to create biodegradable films and textile fibers, although we are still in the early stages of refining this method and its associated processes.

An illustrative example of a challenging project that employs various modeling and evaluation methods is the Emission Free Pulping project, funded by Business Finland, in which LUT is actively involved. The objective is ambitious: to achieve a significantly higher yield than the current Kraft process while drastically reducing biogenic CO2 emissions. In other words, the typically combusted components should be



transformed into products that simultaneously reduce biogenic emissions. This goal cannot be accomplished merely by fine-tuning the Kraft Pulping process; we must explore new pulping methodologies. A large consortium, primarily based in Finland and Sweden, is engaged in this effort, with numerous doctoral students and postdoctoral researchers conducting experimental work on a laboratory scale to test these new pulping processes. Many pulping methods have already been evaluated at pilot or laboratory scales. We begin with simplified models to assess a range of pulping processes, after which we can select the most promising option for further detailed evaluation using more rigorous models that describe each step of the process. We are utilizing computer-aided tools in this project, such as Aspen.

How can things change over 10-15 years and what are the new directions for research?

In the next 10-15 years, we will continue to learn how to valorize biomass more effectively, producing higher value products similarly to how oil refineries have evolved to utilize each fraction of crude oil efficiently. Additionally, computer-aided methods are advancing, allowing us to accelerate process developments and evaluate the performance and sustainability of new processes with reduced experimental work, thanks to improved modeling and simulation tools. We may design processes that contribute to balancing the future energy system, which will have a high share of wind and solar energy, by utilizing inexpensive electricity when it is available. The raw materials of oil and natural gas can transition to biomass, biogenic CO2, and green electricity.

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RAMA LAYEK

Associate Professor (tenure) of Biopolymers

Transforming Lignocellulosic Biomass into High-Performance Biopolymers and Composites

The Sustainable Biopolymer Technology (SBT) Group at LUT University, Lahti campus started in 2021, and from the beginning to the present date the group has been dedicated to finding new solutions to reduce the environmental problems caused by our use of fossil-based materials. The group considers that it is important to reduce pollution, protect resources and build a further sustainable future. The main focus of the group is on utilising renewable resources, such as lignocellulosic biomass (plant-based materials), to develop eco-friendly substitutes that still perform efficiently. The goal of the group is to renew the field of polymer science and offer solutions that benefit both the environment and bring new sustainable solutions for industries as well as society. With the challenges of climate change and environmental damage becoming more serious, there is a strong need for materials that are sustainable. The SBT group focuses on the replacement of fossil-based materials/products with renewable materials like bio-based and biodegradable polymers, biocomposites and natural fibres, which are good for the environment but still work well.

The group is looking to develop novel bio-based polymers, and the surface modification of natural biopolymers/natural fibres for the fabrication of biocomposites to replace fossil-based materials/products like plastics, adhesives and composites. These materials are designed to be not only high-performance but also eco-environmentally friendly. The goal of the group is to develop high-performance, sustainable materials from renewable monomer/macromer resources that can help to solve environmental issues while meeting/exceeding the functionality of fossil-derived materials. Fossil-based materials, once seen as cheap and efficient, have caused significant environmental harm. From plastic pollution to carbon emissions, these materials are now recognised as major contributors to the environmental crisis. The group aims to reduce the environmental impact by providing sustainable chemical and polymer solutions while making sure the developed materials are durable, have sustainable and affordable resources, and are of high-quality.

The big problem the SBT group is trying to solve

The issues that the SBT group is addressing are crucial. Fossil-based materials, such as synthetic polymers, binders, adhesives and lightweight composites, are commonly used across industries, including packaging, engineering wooden products, furniture, plywood, construction, sports goods and automotive sectors. We are surrounded by these materials in our daily lives, but their environmental impact is hazardous. They are made from petroleum-based raw materials, are toxic, and do not break down naturally, leading to pollution and long-lasting damage to ecosystems and human health. For instance, in the packaging industry, plastic waste has become a global issue. While plastics are versatile, they are also harmful to the environment because they are made from petroleum-based raw materials and take centuries to decompose. Conventional fibre-based packaging also often requires plastic coating (e.g. polyethylene) for moisture and grease resistance, making recycling difficult. To solve this, the SBT group is working on the development of biodegradable, bio-based polymers to replace oil-derived plastic in the fibre-based packaging and development of bio-based coatings that can replace fossil-based polymer coating while maintaining essential properties. Similarly, the adhesives and binders used in manufacturing often contain harmful chemicals that contribute to pollution in both the air and water. Even in industries like the engineering of wooden products, furniture, plywood, automotive and construction, the reliance on petroleum-based products is unsustainable and causes long-term harm to the environment. Replacing these materials is crucial, but it needs to be done in a way that does not compromise performance and functionality. The SBT group is working on the synthesis of novel biobased binders/adhesives solutions to replace these harmful materials with renewable alternative materials that are not only sustainable but also show high performance when compared to existing fossil-based solutions.

Another growing issue is the extensive use of synthetic fibres, which are used in applications from sports equipment to automotive parts and construction materials. Fibreglass and other synthetic fibres are made from fossil fuels, take centuries to degrade, and contribute to landfill waste and microplastic pollution. Furthermore, the production of these fibres requires a lot of energy and releases harmful greenhouse gases, making climate change worse. The SBT group works to develop solutions to replace synthetic fibres with natural fibres like flax, hemp and wood fibres, which are renewable, biodegradable and environmentally friendly. These natural fibres offer excellent mechanical properties, such as strength and flexibility, and can be integrated into reins/polymer matrixes to fabricate biocomposites, which are lightweight, strong and sustainable. By combining natural fibres with sustainable polymers/resins, the SBT group develops fibre-reinforced biocomposites that are durable, lightweight and strong while dramatically reducing our dependence on fossil-derived materials. These biocomposites offer promising alternatives to traditional plastics and composites, making them ideal for applications in industries like engineering composites, sports goods, and automotive and construction.

Our approach: transforming biomass into sustainable solutions

To transform biomass into sustainable solutions, the SBT group works in the interdisciplinary area of lignocellulosic biomaterial chemistry, polymer chemistry, and material and polymer engineering. Lignocellulosic biomass is a plant material like wood and agricultural waste. These materials are rich in useful components such as lignin, hemicellulose and cellulose, which are promising resources for sustainable product and solution development as these materials are great alternatives to traditional petroleum-based materials. The SBT group uses these materials as starting/raw materials and processes them to create high-performance chemicals/materials that are both sustainable and eco-friendly. By using these natural materials as raw material, the group aims to reduce the dependency on fossil fuels for creating chemicals, polymers and adhesive/binders and create a greener future.

Valorisation of lignin: a key component of sustainable materials

Lignin is a complex, aromatic polymer found in plant cell walls. It has often been regarded as a waste product, but recent advancements have shown that it has huge potential as a bio-based resin for adhesives, coatings and binders (Figure 1). The SBT group has been engaged in developing novel methods to modify lignin chemically, making it a viable and sustainable alternative to synthetic adhesives and resins used in the production of plywood, composite wood products and coatings. Using advanced chemical modification and polymerisation techniques, the group has been engaged in creating high-quality biobased binders and adhesives. These lignin-based resins are not only biodegradable and non-toxic, but they also offer superior thermal stability, mechanical strength and chemical resistance. These properties make them ideal for use in a variety of industrial applications. Additionally, the group is exploring ways to turn the lignin into biobased polyurethanes, which will further expand its potential as a replacement for petroleum-based materials in coatings, adhesives and composites.

Valorisation of hemicellulose: unlocking the potential of a renewable resource

Hemicellulose is another important component of lignocellulosic biomass that is also considered to be a very promising resource for sustainable product and solution development. The SBT group's research focuses on graft copolymerisation of hemicellulose to create sustainable alternatives to synthetic adhesives commonly used in industries like plywood, construction, furniture manufacturing and packaging. By modifying the hemicellulose and hemicellulose-based copolymers, the SBT group optimises the physico-chemical functionalities and adhesion performance of hemicellulose-based adhesives. The group also works on improving the water-resistance properties and overall bonding performance of the formulated hemicellulose-based adhesives, ensuring they are as strong and effective as petroleum-based ones while being safe and biodegradable.

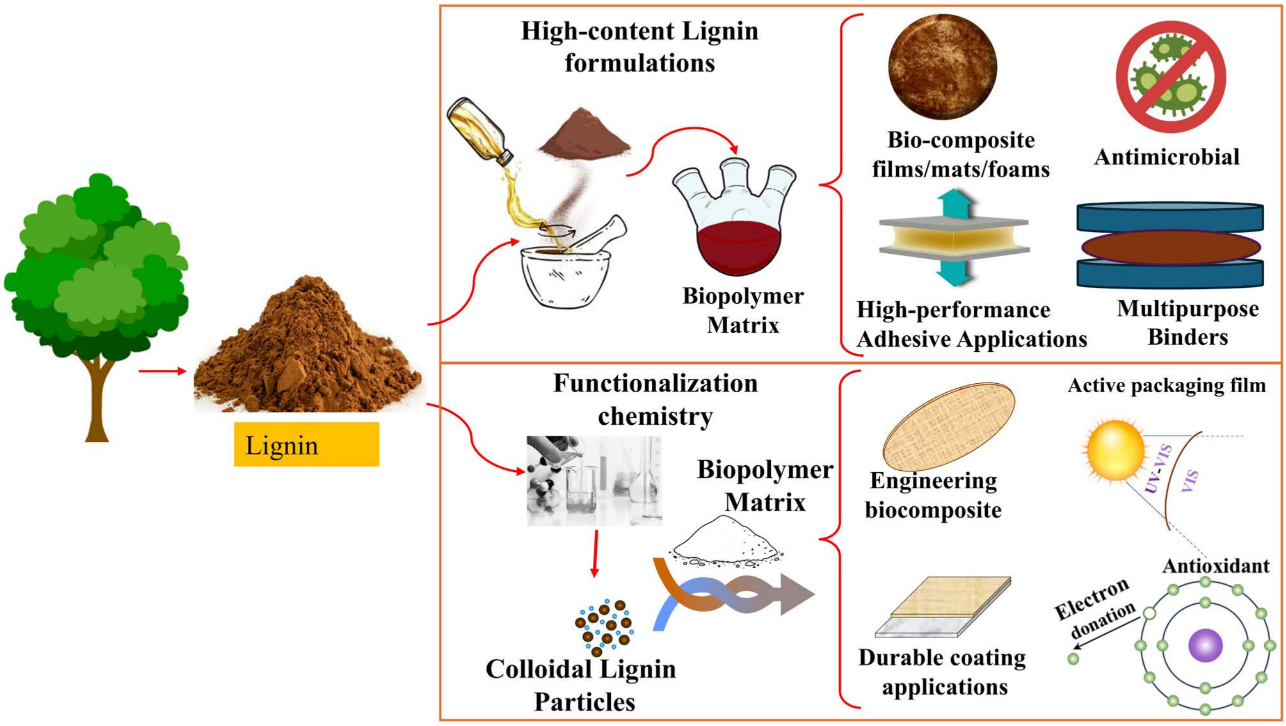

Figure 1. Valorization of lignin in adhesives, coatings, and composites applications

Natural fibre and nanocellulose-reinforced biocomposites: strengthening materials with nature's building blocks

In addition to valorising individual biomass components, the group works on combining natural fibres like flax, hemp and wood fibres with biopolymers to create fibre-reinforced biocomposites. These materials offer excellent mechanical properties, such as strength, flexibility and impact resistance, making them ideal for use in a wide range of industries, including automotive parts, construction and packaging. The group also uses nanocellulose fibres, a highly advanced material derived from wood fibres that offers exceptional mechanical strength, lightweight properties and high surface area. Through fundamental and scientific research, the SBT is working to correlate the structural-property relationship of nanocellulose composite papers and fabricate advanced biocomposites materials that are not only stronger but also have better ductility (Figure 2). This makes them a viable alternative to traditional plastics and engineering composites, offering sustainable options that perform well in demanding engineering applications where excellent mechanical strength and ductility are essential. A key part of the work of the SBT group is to ensure that the biopolymers and biocomposites that they create have satisfactory performance. The group conducts extensive tests to evaluate their strength, flexibility, impact resistance and thermal stability, ensuring they meet the functionality required for use in industries like packaging, sports good, automotive parts and construction. By testing the materials in a variety of environmental conditions, the group refines their formulations to achieve comparable results with fossil-based materials. These tests are critical for ensuring that the biopolymers and composites that they develop are durable and sustainable alternatives to petroleum-based products.

Collaborations with industry

To bridge the gap between research and practical application, the SBT group actively collaborates with companies across multiple sectors. These partnerships include adhesive and binder manufacturers, packaging companies and raw material suppliers. By working closely with industry partners, the group proves that their innovations align with company needs and facilitate the development of sustainable biopolymer technologies of the future. The goal of the group is to translate their cutting-edge research into technology that can be adopted by various industries, thereby contributing to a more sustainable economy.

Future vision

In the next five to ten years, the research will position the SBT group at the forefront of bio-based material innovation. The group visualises a future where lignocellulosic biomass serves as the backbone of a sustainable materials economy, replacing fossil-based materials across multiple industries. Within five years, the SBT group plans to develop

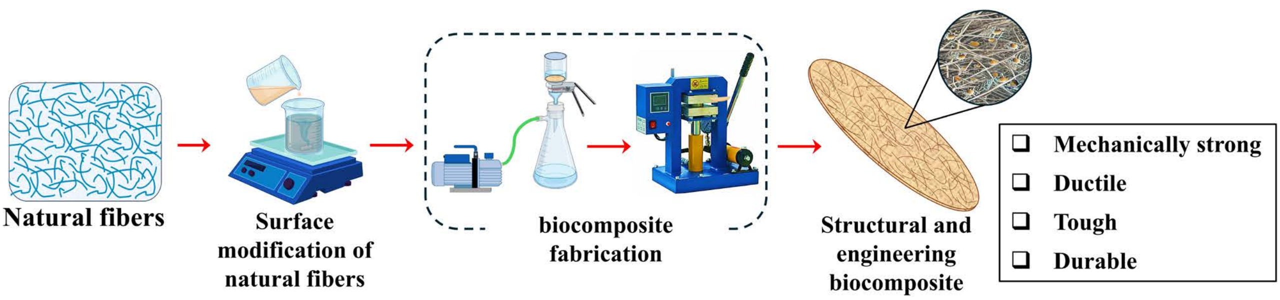

Figure 2. Durable and mechanically strong advanced biocomposite

high-performance adhesives/resins, and biocomposites derived from lignin, hemicellulose and nanocellulose that meet various industrial standards such as engineering wooden products, furniture, plywood, sustainable packaging, sports goods and automotive applications. The group's research will focus on optimising material properties, improving scalability, and fostering industry collaborations to accelerate commercialisation.

In ten years, the goal of the SBT group is to see extensive industrial acceptance of their sustainable materials, significantly reducing reliance on fossil-derived polymers. The group expects their research to contribute to a bioeconomy where biodegradable and high-performance alternatives replace traditional plastics and composites, reducing carbon emissions, plastic waste and resource depletion. Advances in biopolymer chemistry, fibre-reinforced composites and nanocellulose technology will expand the potential of sustainable materials, ensuring they offer performance comparable to traditional materials.

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GREEN SOLUTIONS FOR WATER TREATMENT

AMIT BHATNAGAR

Professor of Water treatment

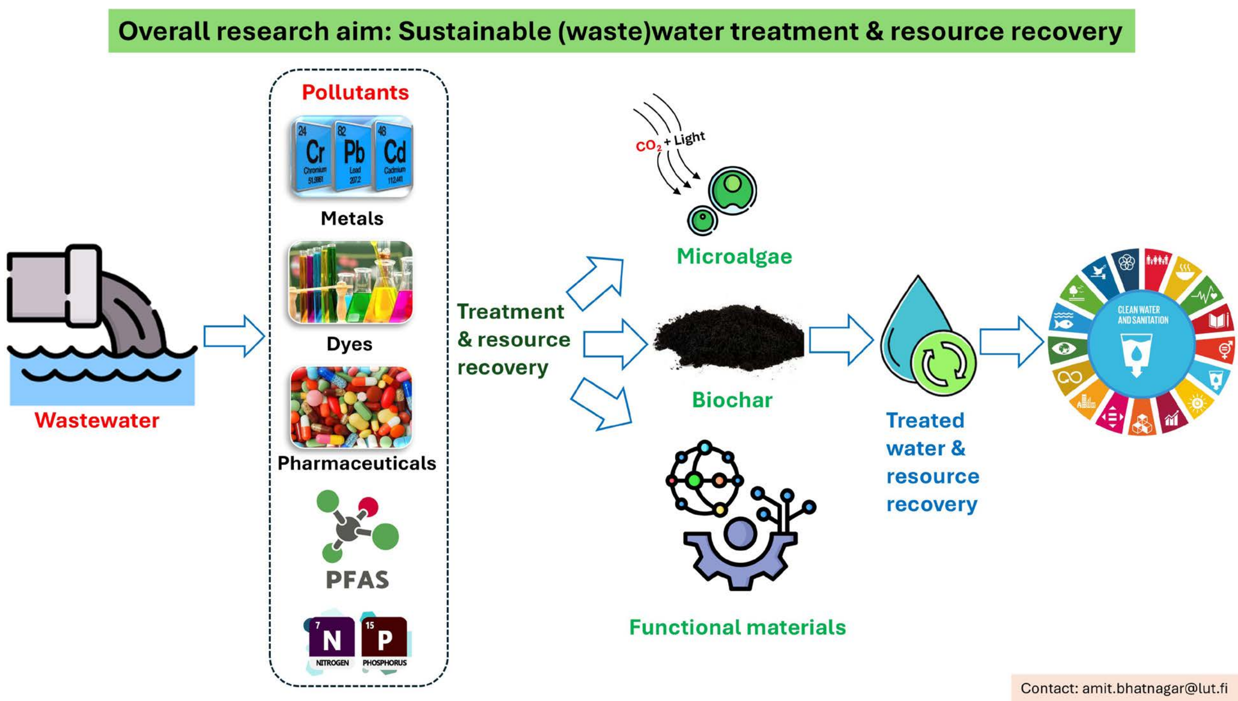
Greener and Sustainable Water Treatment Solutions

Introduction – The big problems we are tackling

Water pollution and climate change are among the most significant environmental challenges we face today. Water pollutants, including residues of pharmaceuticals and personal care products, microplastics, and persistent industrial chemicals like PFAS (per- and polyfluoroalkyl substances), make our water unsafe and pose risks to human and environmental health. Over the years, many countries have been facing challenges in providing clean water for their population, and the problem is getting worse due to growing water demand, pollution and overuse. At the same time, greenhouse gases are building up in the atmosphere, making climate change worse and requiring immediate action. Therefore, my team has been investigating affordable, eco-friendly and effective ways to treat water, recover nutrients and other valuable resources from wastewater, and capture CO_2, which can also be applicable in low-income countries.

Ongoing research

My team's research focuses on developing eco-friendly wastewater treatment methods



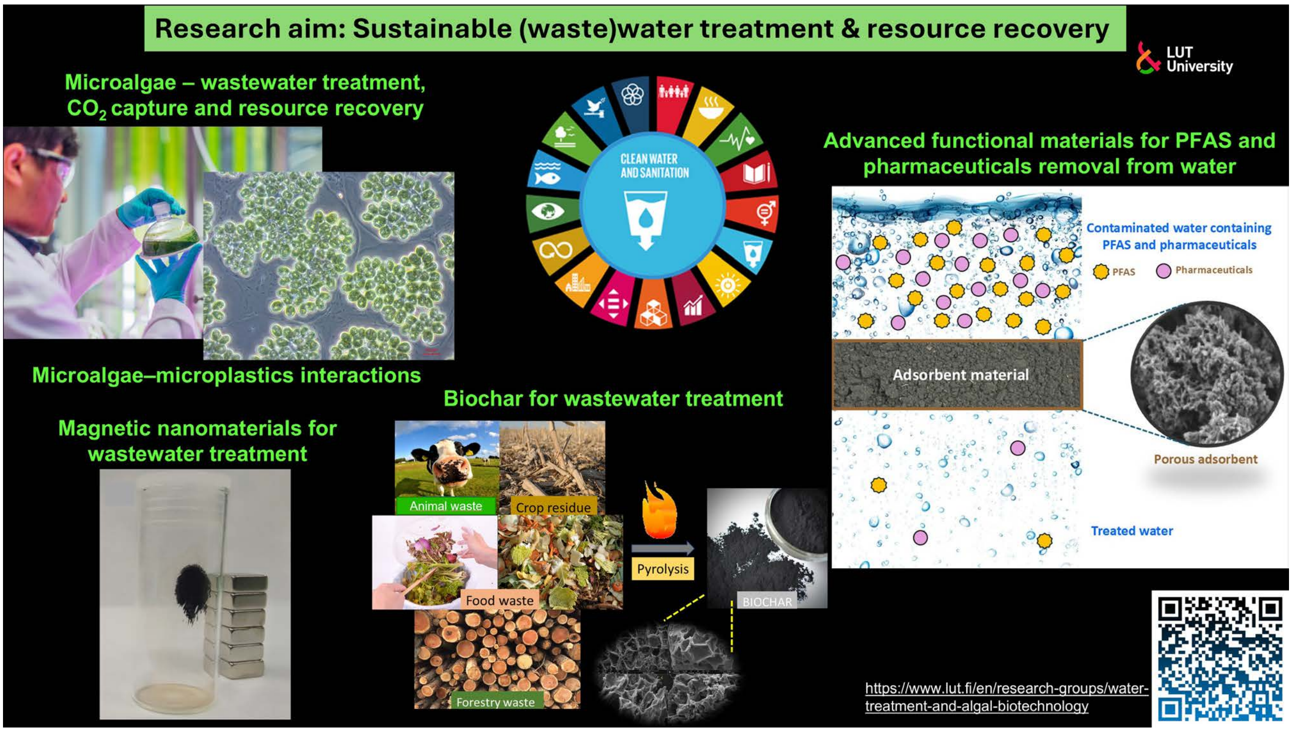
using microalgae, biochar, nanomaterials and advanced functional materials. Besides treating wastewater, we also work on recovering valuable resources such as nutrients from wastewater. The main goal is to develop affordable and effective solutions for wastewater treatment and carbon capture that not only treat water and reduce climate impact but also transform waste into useful bioproducts for various industries. This approach supports the circular econom.1y by repurposing waste into valuable materials and promoting sustainability.

1. Microalgae for wastewater treatment and carbon capture

Microalgae are tiny plant-like cells that are naturally found in freshwater and seawater. They can also grow well in different types of wastewaters by using nutrients such as nitrogen and phosphorus compounds, which cause harmful algal blooms if these nutrients are present in excess in water bodies. As microalgae grow, they capture carbon dioxide and release oxygen while also producing useful biomass. Because of these abilities, microalgae are a perfect eco-friendly option for tackling environmental problems and supporting sustainable development. When used in wastewater treatment, microalgae offer a greener and more affordable alternative to many traditional purification methods. Some key benefits of microalgae-based treatment include the removal of toxic pollutants, nutrient recovery and energy savings, while lowering CO_2 emissions. Microalgae-based treatment plays a key role in the circular bioeconomy, where waste is converted into valuable resources. The algae biomass collected from wastewater treatment can be used to make biofuels, bioplastics, and even fish and animal feed. We are also investigating the interactions between microalgae and microplastics and how they influence the potential of microalgae for biofuel production.

2. Advanced functional materials for water treatment

We develop and test not only biobased materials like biochar and nanocellulose, but also nanomaterials and advanced functional materials for the efficient removal of mi-



cropollutants such as pharmaceuticals and persistent pollutants like PFAS from water using the adsorption process. **Biochar** is a carbon-rich material that can be prepared from natural and waste biomass, animal waste, and residues of forest and agricultural industries, etc. Because of its unique features, biochar has gained attention in wastewater treatment as a low-cost adsorbent, an alternative to commercial activated carbon, which is very expensive. My group has developed modified (designer) biochar, such as magnetic biochar, utilising a variety of waste materials for the removal of different pollutants present in wastewater. Apart from biochar, we have also synthesised **carbon aerogels**, **nanocellulose**- and **clay**-based adsorbents as well as **nanomaterials** and **nanocomposites** for water treatment, which have shown excellent performance for the removal of diverse aquatic pollutants. Besides this, research is underway in our lab on synthesising different advanced functional materials for PFAS removal from water. PFAS, commonly referred to as 'forever chemicals', are being increasingly detected in water bodies worldwide. My group has recently started systematic studies on PFAS removal from water. The overall aim of my research is to enhance treatment efficiency while reducing environmental impact.

Collaboration with companies and other stakeholders

Collaboration with companies is crucial in securing effective solutions that can make a real difference for global society. Currently, my team is collaborating with Operon Group Oy, Finnforel Oy, Finnsementti Oy, Blue Economy Mikkeli (BEM), etc., in our ongoing projects. One of the demonstration sites for our research is the Mikkeli wastewater treatment plant, where we plan to test new, compact and advanced hybrid microalgal photobioreactors. These bioreactors are designed to work with decentralised water and wastewater management systems. We plan to install pilot-scale algae bioreactors at the R&D test site to achieve sustainable wastewater treatment, focusing on removing, recovering, recycling nutrients and capturing carbon. This will be an important step in demonstrating how algae-based technology can be used in wastewater treatment and nutrient recovery. I am looking for further collaboration with industries that aim to improve wastewater treatment, reduce carbon emissions, or find sustainable ways to reuse resources. By working together, we can develop eco-friendly solutions that help businesses, communities and the environment.

Vision for the future

Over the next few years, our research group plans to set up pilot systems that combine algae-based water purification and carbon capture with industrial processes. We will also focus on building strong partnerships with companies to scale up our lab research to address real-world challenges. My team's long-term goal is to develop fully circular wastewater treatment systems that not only treat contaminated water but also generate valuable bioproducts such as biofuels, biofertilisers or biodegradable plastics. Our work on microplastics and PFAS removal will continue to evolve, leading to groundbreaking solutions for these emerging pollutants.

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SUSANA RODRIGUEZ COUTO

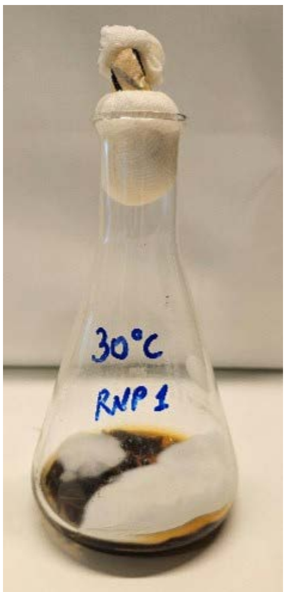
Professor of Biological water treatment

Sustainable and environmentally friendly removal of xenobiotics from wastewater: a solution that comes from the forests

Industrialisation, urbanisation and increasing population have resulted in the generation of a huge quantity of xenobiotic pollutants worldwide. Such compounds are synthetic, toxic, hardly biodegradable, and they have complex chemical structures containing aromatic rings. These features make them 'bio-resistant', causing their persistence and accumulation in the environment to have detrimental effects on wildlife and human health. Therefore, their removal from wastewater before being discharged into the environment is imperative. However, conventional wastewater treatments are ineffective in the removal of xenobiotics, and emerging approaches are either expensive or non-environmentally friendly. This has led to the search for new cost-efficient and green technologies to replace or complement conventional ones such as those based on the use of microorganisms. Among different existing microorganisms, white-rot fungi, so named because of the whitish colour of

(A)

(B)



(B)

Figure 1. Fruiting bodies of white-rot fungi growing on the trunk of a birch tree in Repovesi National Park, Finland (A); White-rot fungi grown in our laboratory (B).

the delignified wood, are outstanding since they are the only known organisms able to mineralise the recalcitrant and bulky heterogeneous biopolymer lignin.

The chemical structure of numerous xenobiotic pollutants is similar to that of lignin and, hence, white-rot fungi is able to degrade a wide variety of environmental pollutants such as synthetic dyes, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and emerging pollutants, which are hardly degraded by conventional wastewater treatment methods. The enzymatic system of white-rot fungi is mainly composed of peroxidase and laccase enzymes. The latter have been the subject of increased research interest due to their oxidative versatility and low catalytic requirements – they only need molecular oxygen to exert their catalytic action instead of the hydrogen peroxide required by the peroxidases. In addition, enzymatic treatment has a minimal environmental impact with low energy consumption. Very promising results have been achieved at laboratory scale under controlled operating conditions. The challenge remains to apply this approach under real industrial conditions at an affordable cost. To achieve this goal, we are researching different strategies at our laboratory.

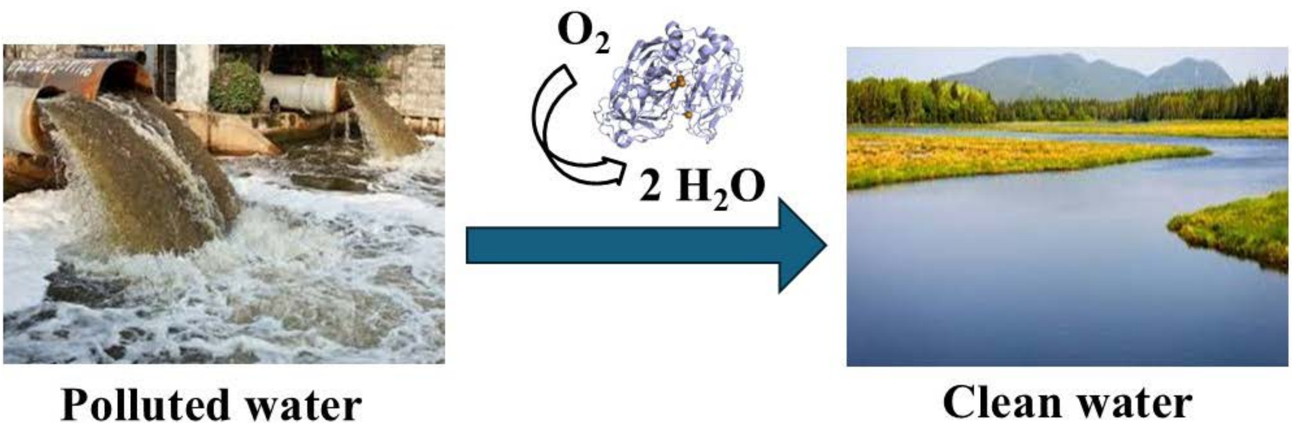


Figure 2. Enzymatic process for wastewater treatment.

SYSTEMIC FOOD PROCESSING

SAMUEL PEREZ VEGA
Assistant professor (tenure), Food process engineering

Moving Finland into Sustainable and Profitable Food Systems

In recent years, the world has experienced extraordinary events that have significantly impacted society, the environment, and the economy. Examples include global warming and the COVID-19 pandemic. These events are direct consequences of living in an era marked by the unpredictable effects of human activity on Earth. Among these adverse effects are climate change, eutrophication, overuse of water and land, and biodiversity loss. These issues, closely linked to food production activities, threaten the biosphere and highlight the urgent need to redesign food systems for sustainability.

Current Food System Behavior

Today, food systems face two unavoidable pressures: population growth and increasing income levels. Without technological innovations or mitigation strategies, incremental environmental pressures will push Earth beyond ecological stability. There is a lack of awareness about critical leverage points within food systems that could facilitate a transition toward sustainability. At LUT, we see a significant opportunity to identify key areas where sustainable practices can make a substantial impact.

Addressing complex problems requires thorough analysis of their main factors and interactions. Food production systems are no exception. Considerations such as raw material selection, processing technologies, nutritional quality, economics, environmental impact, and social factors must be comprehensively evaluated to develop sustainable solutions. Therefore, new holistic tools are needed — ones that integrate environmental, nutritional, economic, social, and contextual aspects.

Our Research Group

Our research group is committed to fostering innovation and sustainability within the food sector. We are passionate about tackling challenges in food production and processing through systemic and scientific approaches that prioritize minimal environmental impact, nutritional value, economic viability, and resilience. Our work holds the potential to transform the food industry and promote a sustainable future.

We aim to generate transformative knowledge and solutions by integrating engineering science, technology, and a holistic perspective. A key focus is developing new processing frameworks that reduce environmental pressures, enhance economic performance, and improve value without compromising nutritional quality.

Our Mission

Our mission is to conduct high-quality research that assists industry, society, and government in understanding, evaluating, and implementing sustainable, value-added actions from a systemic and scientific perspective in the food sector.

As part of LUT's Separation Science department, our group relies heavily on separation technologies. Our long-term goals include breakthroughs in food processing and separation methods, exploring novel ingredients from circularity perspectives, customizing processing techniques, and translating cutting-edge research into practical applications. Collaboration with industry and research partners is essential to achieving these objectives, enabling us to contribute significantly to the sustainability and innovation of the food industry.

Future Research

Previous studies have identified leverage points within typical food systems where strategic changes can benefit the environment, society, and economy. For example, utilizing underexploited raw materials with high nutritional value and low environmental impact presents a promising avenue.

A central focus of our future research is developing sustainable, value-added ingredients for the food industry. There is considerable interest within the European Community in replacing ingredients with high environmental footprints, low nutritional value, or non-European origins. This creates opportunities to adapt technologies to produce similar commodities from locally resilient raw materials, such as oats, hemp, rye, wheat, flax, wild berries, fish, herbs, mushrooms, root vegetables, peas, faba beans, buckwheat, and seaweed—resources abundant in Finland with low environmental impacts and adaptability to climate variability.

Our goal is to develop applicable roadmaps and multidisciplinary tools that adopt a holistic approach and can be implemented globally to transition the food sector toward sustainability.

Fig 1 Rahul Biswas and Savindi Wanninayake conducting laboratory experiments.

Critical Research Areas

Our research involves advancing separation techniques to fractionate value-added components from novel raw materials and studying their functionalities to improve food properties. We utilize mathematical modeling and simulation tools to optimize processing conditions and evaluate alternative methods efficiently. Additionally, we focus on creating new ingredients and functionalizing existing ones to replace environmentally impactful conventional ingredients. Understanding physicochemical structures allows us to tailor ingredient properties effectively.

We also evaluate the nutritional and environmental impacts of food processing and systems, integrating circular economy principles to minimize resource use and waste while supporting sustainable product development.

Finland as a Leader in Sustainable Food Systems

Our research aims to support Finland's strategic goals over the next decade:

- Promoting healthy, safe, and sustainable diets accessible to all in Finland.
- Ensuring that food and feed production in Finland remains sustainable, competitive, and resilient.
- Prioritizing resource efficiency and zero waste in the Finnish food system.
- Positioning Finland as a pioneer and testbed for innovations in sustainable food systems.

We strive to develop innovative solutions that facilitate the transition from conventional to sustainable food systems. Our efforts include transforming local raw materials, maintaining high nutritional standards, and reducing environmental impacts while increasing economic returns. We also aim to expand processing options and explore new markets to enhance Finland's food security.Furthermore, we seek to foster collaboration across Nordic countries, the European Union, and other regions with similar agricultural conditions, such as Canada. Our partnerships include EU countries like Spain, Ireland, and Portugal, focusing on developing new food alternatives from low-impact algae sources. We also collaborate with US universities and European companies to develop sustainable processing strategies that consider environmental and nutritional impacts across food sectors.

Whole Crop Utilization Approach

Future research will emphasize utilizing the entire crop, including edible and non-edible parts, through a whole crop biorefinery approach. This involves chemical, mechanical, and biological processing to produce a variety of commodities such as oils, proteins, fibers, bioactive compounds, and locally produced food additives like thickeners, emulsifiers, and colorants, as well as biochemicals, biofuels, and bioplastics.

Implementing this concept requires selecting resilient local raw materials, adopting innovative extraction and separation technologies, evaluating logistics, identifying market opportunities, analyzing economic viability, and estimating environmental impacts. These strategies aim to create a more sustainable food system in Finland.

The advent of new processing technologies, combined with computational and AI tools, heralds a new era of societal, educational, and technological transformation. LUT University is committed to leading this change, developing methodologies that will embed sustainability into future food systems, yielding societal and economic benefits for Finland.

Overall, we focus on developing scalable, eco-friendly processing technologies, such as green chemistry-based extraction and separation methods, to reduce environmental footprints and improve efficiency. In addition, we promote the adoption of circular economy principles within the food industry, focusing on minimizing waste, optimizing resource use, and generating value from by-products. These practices aim to build a resilient, sustainable food system capable of facing future challenges.

Educational Outreach and Capacity Building

Educating future scientists, engineers, and policymakers is vital for long-term sustainability. We develop educational programs and workshops to equip participants with the knowledge and skills needed to address complex food system challenges.

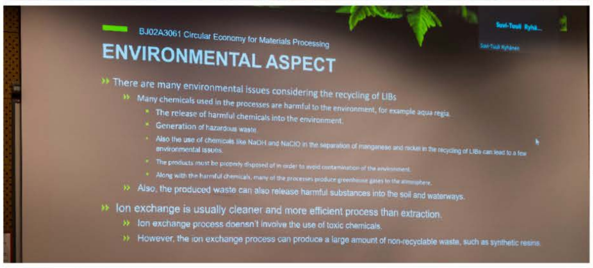
Public engagement activities, including seminars, webinars, and community events, are integral to raising awareness and fostering dialogue among researchers, industry stakeholders, and the public, promoting collective action toward sustainability.

Looking to the future

Transitioning to sustainable and profitable food systems is complex but essential. At LUT University, we are dedicated to driving this change through innovative research, collaboration, and education. Our holistic approach addresses environmental, social, and economic aspects, aiming to benefit society at large.

Our group strives to generate transformative knowledge and solutions that help industry, society, and government adopt sustainable practices. Through expanded research and collaborations, we aim to lead the transition toward sustainable food systems, creating a more sustainable future for Finland and globally.

EDUCATION


BJ02A3061 Circular Economy for Materials Processing
ENVIRONMENTAL ASPECT
There are many environmental issues considering the recycling of LIBs
Many chemicals used in the processes are harmful to the environment, for example aqua regia.
The release of harmful chemicals into the environment.
Generation of hazardous waste.
Also the use of chemicals like NaOH and NaClO in the separation of manganese and nickel in the recycling of LIBs can lead to a few environmental issues.
The products must be properly disposed of in order to avoid contamination of the environment.
Along with the harmful chemicals, many of the processes produce greenhouse gases to the atmosphere.
Also, the produced waste can also release harmful substances into the soil and waterways.
Ion exchange is usually cleaner and more efficient process than extraction.
Ion exchange process doensn't involve the use of toxic chemicals.
However, the ion exchange process can produce a large amount of non-recyclable waste, such as synthetic resins.

RITVA TUUNILA

Associate Professor of Solid-Liquid separation
Deputy Head of Department
Head of Degree programs

Fifty Years of Chemical Engineering Education in Lappeenranta

Seppo Wilska was invited in 1974 to plan the start of chemical engineering education at Lappeenranta University of Technology (LTKK). He developed the first curriculum following the idea that a Master of Science degree in Chemical Engineering needs a strong basis in chemistry combined with engineering knowledge and skills to be able to work successfully in the chemical and process industry. Seppo Wilska was nominated as the first professor of technical chemistry, and the new programme started in 1975. A laboratory for doing some basic chemical experiments was built and teaching was carried out by Seppo Wilska and assistant Helinä Pihlaja. At the beginning of the second academic year in 1976, Pentti Minkkinen started as an associate professor of inorganic and analytical chemistry. After that, new teaching staff, for example Professor Seppo Palosaari, Associate Professor Matti Lindström, PhD Salme Koskimies and MSc Riitta Mennola were hired to teach new chemical engineering students. From the very beginning it was clear that laboratory staff members were also required, so during the first years MSc Markku Levomäki started as laboratory engineer and Pekka Järvi as laboratory technician. In the 1980s and 1990s the department grew constantly with the arrival of new staff members. Tapio Miettinen started as lecturer in organic chemistry, Lars Nyström as a professor of process engineering, Erkki Paatero as a new professor of technical chemistry and Marianne Nyström as an associate professor of technical polymer chemistry (1993). Later, in 1998, Marianne was appointed as professor of membrane technology, in fact the first in the world with the title "membrane technology".

In that time there were three major subjects that a chemical engineering student could study: applied chemistry, process engineering and chemical engineering. Paper technology started as a new major subject with a new professorship of paper technology. Thus in 1990 Jouko Lehto was "borrowed" from Kymi-Kymmene Kaukas Research Centre to quickly set up the teaching and laboratory courses for the first students. After a year Jouko was followed by LicTech Matti Stén, the retired research director of Enso Research Centre, who then took the lead as professor of paper technology (acting). Due to his personal interest Matti brought paper and colloid chemistry strongly into the studies, which differed significantly from the paper technology studies at Helsinki University of Technology at the time, as they focused mainly on the mechanical side of papermaking. When Matti retired after three years in 1994, Hannu Manner was appointed as professor of paper technology. Paper technology became very popular among students because at that time there were a lot of work opportunities for new engineers in the pulp and paper industry. At the end of the 1990s, process and plant design got their own professorship, in which Ilkka Turunen started as full professor in 1999. He started to develop education strongly in that field. At the same time, the first professorship of Separation Science was established with the financial help of Larox.

The Department of Separation Science (Chemical Engineering) has cooperated closely with industry from the very beginning, but this first company-funded professorship underlies the fact that the department was seen as a reliable partner in both research and education.

The new millennium started an internationalisation of chemical engineering education. The new university law brought separate BSc and MSc degrees (three and two years) with their own degree programmes to technical universities, which enabled the development of two-year international MSc programmes. Professor Ilkka Turunen immediately started to develop the first double degree programme – the MSc in Chemical and Process Engineering jointly with the State Mining University St Petersburg. This DD programme was the first in chemical engineering totally taught in English. After several years, it was time to take the next step and change this DD programme to a regular MSc in Chemical Engineering with an open international call. That was followed in 2018 with the modern 100% online MSc in Biorefineries, which was originally developed at the request of the pulp and paper industry to offer continuing education for adult people in working life. Currently, the biorefineries programme is taught in a blended mode – about 50% online and 50% contact teaching, organised with a few intensive days per month at the Lahti campus. This enables good and flexible study opportunities for both young and adult students.

There are also similar blended learning opportunities in chemical engineering in Mikkeli and Kouvola. The MSc in Water Technology started in Mikkeli in 2023 and the MSc in Food Processing Technology in 2024 in Kouvola. In Lappeenranta we have the BSc in Chemical Engineering taught in Finnish and the MSc in Chemical Engineering for Energy Transition, both taught in person at the campus.

LUT Chemical Engineering was a trailblazer, being the first degree programme among technical university programmes in Finland to be accredited by an international organization (ASIIN). The benefit of starting the accreditation process in 2014 was the determination of learning outcomes (what a graduate should know after studying) for all BSc and MSc programmes. The process also required very detailed study of the teaching and evaluation methods used, and the workload of the courses. During this process many meetings with fruitful discussions were organised with the main industrial partners. At the same time, EFCE (European Federation of Chemical Engineering) guidelines for core study contents of chemical engineering programmes were studied and those requirements were fulfilled. With this accreditation, which we now have for all our regular programmes excluding food processing technology, given it is a very recently started programme, our programmes have international EUR-ACE quality labels, which are very important in all international cooperation in education. Even more important is to guarantee our students internationally high-quality degree programmes.

Besides our regular study programmes, in education we cooperate with several European universities. The most visible are the joint double and triple degree MSc programmes, in which a student studies at two (DD) or three (TD) universities, with one or two semesters at each, and finally conducts a jointly supervised master's thesis that leads to an MSc diploma from each partner university. Current DD and TD programmes focus on the chemical engineering, biorefining and mining sectors. Besides the whole programmes, nowadays there is also an increasing number of joint online courses with international partner universities.

Today, about 35 bachelors and 75 masters graduate yearly from chemical engineering, of which about 50% are Finnish and another 50% from all over the world. It can be said that increasing internationalisation is a trend of the day in chemical engineering studies and education.

EVELIINA REPO

Professor (tenured) of Hydrometallurgy for urban mining.
Head of Doctoral Programme in Green Chemical Technology

Shaping Tomorrow: PhD in Green Chemical Engineering for Future Innovators

The PhD program in Green Chemical Engineering at LUT University is part of the Doctoral Programme in Engineering Sciences and offers a rigorous, research-intensive path focused on sustainable chemical technologies. Doctoral studies combine structured coursework with the development of an original dissertation, carried out within active research groups aligned with LUT's strategic goals especially related to clean energy, water and air, as well as sustainable development. Every year, six to eight students are graduated as Doctor of Science (Technology) from the Department of Separation Science.

Figure 1. ELMO-LION PhD course summer school.

Candidates are selected through international recruitment or academic networking, with research topics proposed by supervising professors based on available funding and refined collaboratively with the student. Before formal admission, candidates prepare a postgraduate study plan that includes a detailed research and study plan, as well as a supervision plan, all of which are approved and regularly updated. Each doctoral student is guided by at least two supervisors, with a LUT professor serving as the primary supervisor and a qualified co-supervisor supporting the process.

Students are deeply involved in experimental work and are expected to publish their findings, which form the core of their dissertation. Most doctoral candidates are employed as junior researchers, allowing them to integrate into research teams and participate in collaborative projects, industry meetings, and steering groups—enhancing their professional networks and project management skills. They are also encouraged to engage in teaching and thesis supervision, gaining valuable academic experience.

The LUT Doctoral School supports students with joint courses, workshops, and access to broader doctoral education networks, allowing for multidisciplinary and tailored learning. Additional training in university pedagogy and project management is available, and informal academic practices—such as seminars, weekly meetings, and collaborative events—foster an energetic research community. This comprehensive program prepares graduates for impactful careers in academia, industrial R&D, and leadership in environmental innovation.

CAREER PATHS

LAURA TEITTINEN

Bachelor's student

Image courtesy of Laura Teittinen.

My journey toward becoming a chemical engineering student has been unconventional. Initially, I enrolled at a different university as a chemistry major. However, my interest in chemical engineering grew after I met a few students from that field during a university anniversary celebration. Their insights and experiences sparked my curiosity, leading me to apply for transfer to LUT University's chemical engineering program. Although I was unfamiliar with chemical engineering at the outset, my exposure to the field and the enthusiasm of current students motivated me to pursue this path. This decision marked a significant turning point in my academic career, reflecting my willingness to explore new disciplines and adapt to new challenges. My experience underscores the importance of networking and firsthand interactions in shaping academic and career choices, especially when venturing into less familiar fields.

Currently pursuing my bachelor's degree, I find my academic journey to be highly fulfilling and insightful. It has allowed me to discover my specific field of interest and develop a deeper understanding of how theoretical concepts translate into practical applications. This integration of theory and practice has been particularly advantageous during my summer employment, where I gained firsthand experience in understanding the operation of process equipment and the types of analyses conducted in laboratory settings, along with their underlying purposes. Although the coursework can be challenging, the supportive environment within the department fosters collaboration and encouragement among students. This camaraderie enhances the learning experience, making complex topics more approachable and motivating continuous growth in my field of study.

Occasionally, I find myself overwhelmed with emotion when reflecting on the numerous doors and summer job opportunities that have become accessible through my studies. It is remarkable to consider how these academic pursuits have expanded my horizons in ways I had not previously envisioned. The field of chemical technology offers a diverse array of career paths for students, and I am grateful to have discovered my niche within this industry. My aspiration is to become a professional in the heavy industry sector, and I am confident that the knowledge and skills gained from my studies will enable me to realize this goal. These educational experiences are influencing my career path and strengthening my desire to contribute to the industry in the future.

ANNE NURMINEN

MSc graduate June 2025

The most motivating aspect of my previous professional experience was engaging with water and water treatment processes, which inspired my decision to pursue studies in Water Technology. LUT University resonated with me due to my prior work experience on a west coast island, where many LUT graduates and trainees were familiar figures. The flexibility of blended learning enabled me and many other students to continue our education while balancing work and personal commitments. However, the most rewarding part was the opportunity to connect with fellow students and faculty members, fostering a collaborative learning environment. Throughout my studies, I met inspiring professionals from diverse backgrounds, as well as ambitious students at the beginning of their careers, each contributing valuable insights. This experience has equipped me with a scientific approach to problem-solving and a comprehensive understanding of current water-related challenges and future needs. With this degree, I am now positioned to explore new and exciting career opportunities in the water sector, contributing to innovative solutions and sustainable practices.

As I approach my graduation, I experience a profound sense of relief and happiness for having successfully completed this significant journey. However, I also feel a touch of nostalgia, as I am reluctant to leave the Land of the Curious that has fostered my growth and learning. Throughout this period, I am deeply grateful for the unwavering support I received—from the warm welcome at the start of the program to the invaluable guidance provided as I finalized my degree. This experience has not only enriched my knowledge but also strengthened my confidence and passion for continuous exploration and discovery.

KATRI LAATIKAINEN

Head of the Energetics and CBRN technology Division

Image courtesy of Katri Laatikainen.

I am a researcher affiliated with the Finnish Defence Research Agency, where I serve as the Head of the Energetics and CBRN technology Division. My journey at the agency began in 2022 when I was appointed Deputy Head of the same division. Demonstrating my expertise and leadership, I was promoted to Head of Division effective January 1, 2025, and I was also appointed as a Professor on April 4, 2025.

Before my tenure at the Finnish Defence Research Agency, my academic and professional journey was primarily associated with the Lappeenranta-Lahti University of Technology LUT, where I pursued my higher education and built my career. I completed my matriculation exam in 1997, after which I was admitted to study chemical technology at LUT. My academic path was temporarily interrupted by my voluntary military service, which I fulfilled at the Air Force C3 Systems School in Tikkakoski before relocating to Lappeenranta to continue my studies.

I earned my Master of Science in Technology in 2003 and subsequently completed my Doctor of Chemical Technology in 2009. Following my doctoral research, I initially worked as a postdoctoral researcher funded by the Academy of Finland, and later as an Academy Research Fellow. My research was primarily focused on developing metal-selective separation materials, which are crucial for the mining industry and environmental water purification processes. My interest in research was sparked early in my academic journey, specifically during my third year, when I joined Prof. Erkki Paatero's research group as a research assistant. This experience played a significant role in shaping my career path; without it, I might have chosen to enter the industry directly after completing my Master's degree. However, the stimulating environment and the innovative nature of the research group inspired me to pursue doctoral studies, driven by a passion for discovering new phenomena and contributing to scientific knowledge.

During my earlier years, I balanced a passion for sports with academic pursuits. I played floorball at a competitive level in the Finnish Championship, dedicating significant time to training and matches. Simultaneously, I spent much of my time in the laboratory conducting experiments, which I found to be a highly effective combination that complemented my overall development. While pursuing my Master's degree in technology, my enthusiasm was primarily focused on chemistry, and I was less interested in other subjects. However, my current role as the head of the Energetics and CBRN technology Division has deepened my appreciation for the broader scope of my studies. In this position, I work alongside chemists, biochemists, and physicists, utilizing advanced modeling and simulation tools that are integral to our research efforts. Reflecting on my academic journey, I recognize the importance of courses in mathematics, physics, and statistical mathematics. Although, in the early 2000s, as a young student, I struggled to see their immediate relevance, I now understand that these subjects have been fundamental to my professional success. They have provided essential analytical skills and a solid scientific foundation that support the complex research and technological innovations in my Department. Overall, my diverse experiences have contributed significantly to my growth, both personally and professionally, illustrating the value of interdisciplinary knowledge and practical application in scientific research.

Establishing a comprehensive international cooperation network is essential for a successful academic career. My own experience includes extensive international work during my postdoctoral and Academy Research years. I have spent three months in Poland, a year in France, and participated in several shorter research periods in South Africa. Beyond these specific engagements, my professional network encompasses numerous researchers from various nationalities. Engaging in international research collaborations not only advances scientific knowledge but also enriches personal development by providing valuable life experiences and cultural insights. Such interactions foster a broader perspective, enhance adaptability, and promote cross-cultural understanding, which are increasingly important in today's interconnected academic landscape. Building and maintaining a diverse international network can open doors to collaborative projects, funding opportunities, and innovative ideas, ultimately contributing to a more dynamic and impactful research career.

JARMO REUNANEN

MSc (Eng.), Chief Specialist (Retired)

Image courtesy of Jarmo Reunanen.

I attended Lappeenranta University of Technology (LUT) as an undergraduate student from 1980 to 1986. I graduated from the Department of Chemical Technology with a specialization in Chemical Engineering. During my studies, I worked as a part-time teacher from my third year, guiding laboratory work in analytical and organic chemistry, as well as programming and laboratory exercises in chemical engineering.

My Master's thesis was conducted at Valke that was part of United Paper Mills. Despite Valko's relatively research-oriented approach, I decided not to pursue a career in this traditional industry. Instead, I chose to continue my studies. I started working as full-time teacher and later served as an assistant and senior assistant in the Laboratory of Chemical engineering until 1994. Between 1989 and 1991, I had the opportunity to study at Kyoto University in Japan, supported by a scholarship from the Japanese Ministry of Education. During this period, I engaged in intensive academic research, which culminated in the approval of my licentiate thesis in 1992. This experience significantly contributed to my academic development and provided valuable insights into Japanese higher education and research environments.

In 1994, I was recruited to Kemira's Oulu Research Center, leveraging my expertise in process engineering. During my tenure there, which lasted until the center's closure in 2009, I was responsible for developing innovative processes and planning and executing pilot experiments to test new concepts and technologies. Between 1999 and 2001, I gained valuable experience at Kemira's Kokkola factories, where I focused on understanding and mastering the local industrial language and operational practices. Notably, during this period, I successfully doubled the production capacity of the feed phosphates plant through a strategic, small-scale, and short-term investment. This improvement was crucial in meeting the increased demand driven by the mad cow disease crisis.

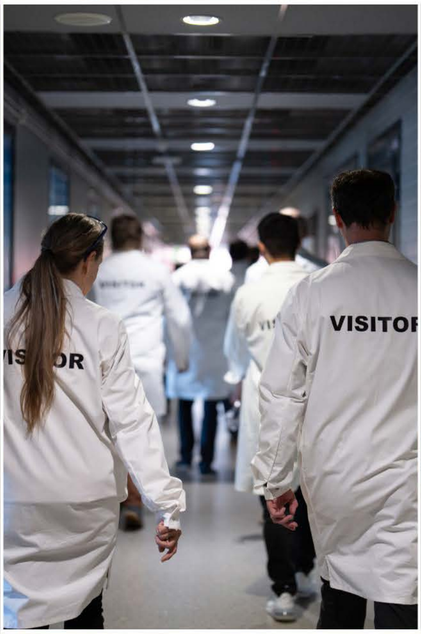
The research center's closure prompted my decision not to relocate to the Helsinki metropolitan area. Following my dismissal, Kemira extended an offer for a position at the Siilinjärvi gypsum pigment plant, which was preparing for substantial investments aimed at expanding its production capacity. Despite these plans, the shutdown of two customer paper machines and the failure to attract new clients ultimately led Kemira to discontinue its gypsum pigment operations in 2011.

In 2011, I transitioned to Talvivaara, which later became Terrafame, with the goal of initiating uranium recovery processes. During this period, I was involved in the development and operational planning of the uranium extraction activities. However, as financial challenges arose and funds for Talvivaara were depleted, the nearly operational plant was placed on hold in 2013. Subsequently, I shifted my focus to managing water treatment at the site, which had accumulated millions of cubic meters of contaminated water due to ongoing mining and processing activities. My responsibilities included overseeing the construction of a centralized water treatment facility, which was essential for ensuring environmental compliance and operational efficiency. I also worked on stabilizing the water balance and bioleaching operations, which are critical for sustainable mineral processing. In 2019, I requested a transfer to a metals processing plant, where my responsibilities more closely aligned with my academic training and professional expertise. This move allowed me to contribute more effectively to the company's core operations, leveraging my background in metallurgical processes and environmental management.

In my role, I led the metal recovery process and contributed to the initial design phase of a battery chemicals manufacturing facility. Subsequently, at the end of 2022 I transitioned away from the metals plant to focus on finalizing the uranium processing plant and applying for a startup license from the Radiation and Nuclear Safety Authority for the new facility that had finally obtained a positive investment decision related to uranium recovery. This was already a second license for this facility and process I had applied for, as the first one had expired during Talvivaara's bankruptcy. The uranium recovery plant was commissioned in summer 2024, and in early 2025, I trained my successor to lead the plant before my retirement in the summer.

As seen above, my career path has led me to various and interesting positions in the field of chemical engineering. The education I obtained at LUT has been highly effective in equipping me with essential technical skills. In particular, the research training I received has aligned exceptionally well with my chosen career trajectory, providing a solid foundation for my professional development. Throughout my student years, I did not pursue formal coursework in personnel management. However, I developed essential skills in this area through practical experience while working. As my team expanded from fewer than ten to 150 employees, I gained valuable insights into team leadership, organizational development, and personnel coordination, which significantly enhanced my management capabilities. Engaging with government authorities and navigating the permit application process—ranging from individual pilot projects to extensive mining area licenses—has constituted a substantial aspect of my professional career. Fortunately, LUT now offers specialized training programs for professionals in this domain. Collaborating with these young professionals has been particularly rewarding, as I am able to concentrate on technical aspects while they effectively translate my work into formal, official language, ensuring clarity and compliance in all documentation. Overall, I am pleased with my professional journey and the quality of education I obtained at LUT, which has significantly contributed to my personal and career development.

COLLABORATION IN RESEARCH AND EDUCATION



PLATFORMS AND NETWORKS

KATJA LAHIKAINEN

D.Sc. (Econ. & Bus. Admin.)
Director, Centre for Separation Technology (CST)

CST – Empowering companies to achieve breakthroughs in separation technology R&D

The **LUT Centre for Separation Technology (CST)** was established in 1997 to coordinate the research and industrial collaboration in the field of separation technologies at the Department of Chemical Technology at Lappeenranta University of Technology. The key objectives of CST were:

- Promoting high-level research in the field of separation technology
- Transferring the knowledge generated at the university to the industry
- Promoting collaboration between different laboratories and research groups in the field of separation technology and networking with domestic and international research groups
- Developing the capabilities needed for experimental activities
- Promoting education in the field in Finland

Now, 28 years later, the core idea of CST's activities remains the same: transferring the knowledge generated at the university to industry and promoting corporate collaboration in research and education.

CST's activities cover all the key focus areas of the Department of Separation Science, which are:

1. Biorefining
2. Food processing technologies
3. Minerals and metals
4. P-to-X chemicals
5. Water treatment technologies

The main aim of CST is to bridge the gap between industry and academia by facilitating collaboration and innovation. This is done through establishing joint R&D projects and enabling access to expert knowledge and events.

CST supports companies in securing funding for R&D projects from various sources such as Business Finland, EU Horizon, EIT RawMaterials and other funding instruments that encourages industry participation in joint actions. One of the latest examples of successful project consortium building is *Circularity-Integrated Mining (CINTEM)* project. The project is funded by Business Finland, and it connects four research organizations and nine companies. The main aim of CINTEM is to integrate the mining projects into the circular economy already in the planning stage.

Moreover, CST offers extensive analysis and laboratory services through the department's research infrastructure, which includes a 3,000 square meter laboratory space for product development and testing. Moreover, CST provides opportunities for collaboration with students on course projects, thesis works and internships. For example, Masters' Programmes on Water Technology and Food Processing technology include a four-week internship period that offers excellent opportunities for companies to get to know future employees.

In addition to facilitating joint projects and R&D expertise, CST plays a pivotal role in organizing conferences and events that serve as a nexus between industry and academia. These gatherings provide a platform for academic professionals, industry leaders, and students to exchange ideas, present research findings, and forge collaborative partnerships. The conferences and events are particularly designed to address current challenges and opportunities in the field of separation science, thereby enhancing the impact of research and its practical applications.

Figure 1: The current CST Board: Jukka Koskela, CTO, Roxia; Kimmo Järvinen, Head of EU Governmental Affairs, SSAB; Sari Mannonen, Senior Vice President of New Business and Hydrogen, Helen; Tero Tupakka, CEO, Ekomuovi & KMV Tuotteet

LUT Resource

LUT RE-SOURCE platform (2016-2020) addressed the need to transition from a LINEAR ECONOMY to a CIRCULAR ECONOMY with novel separation and purification processes that achieve a new level of raw material efficiency and optimised use of water and energy, enabling the cost-efficient and sustainable use of waste as a resource. At the platform special attention was given to that that also sustainable business models and an understanding of customer needs and market knowledge for the future were developed in the same work packages and research teams than the process and product development. Platform boosted the creation of multidisciplinary projects and it had an open structure, which meant that different research groups from LUT could join in the platform projects whenever their knowledge was needed and they had an interest to implement the research in the projects. Altogether there were 19 research groups from different research areas participating in different platform actions.

Provost Mari Kallioinen-Mänttäri, the leader of the RE-SOURCE platform, states:

> As the platform leader I saw that the main goal of the platform was to facilitate the interdisciplinary collaboration between LUT research teams and through that to develop and utilize the intellectual resources we have to generate new skills, knowledge and innovations, which enable improved resource efficiency in the use of both biomass and rare metals. As a result of this work we developed and analysed new fractionation and recovery routes for both biomass and critical metals. The increase in collaboration boosted by the platform can be seen still today when the teams, who found each other at the platform work together in new projects.

SAWE 2015-2020

The Platform leader Professor Mika Mänttäri explains:

> The Safe Water for All (SAWE) platform strived to revolutionize wastewater treatment by focusing on the recovery and utilization of wastewater compounds, rather than solely their degradation and disposal. The objective was also to achieve water quality superior to current standards. The research platform was dedicated to developing advanced water treatment methods and processes, as well as comprehensive assessment techniques to evaluate the benefits of these processes from economic, environmental, and societal perspectives.

Xplorer Network

Towards Zero Impact Mining

The Xplorer Network was established in 2020 within LUT University's Department of Separation Science. Initially, it operated as part of an international mining competence center recognized by UNESCO (and headed by the St. Petersburg Mining University). Since 2022, the network has functioned as an independent Finnish entity, with members including LUT University, the University of Oulu, the University of Eastern Finland, Lapland University of Applied Sciences, Kajaani University of Applied Sciences, and the company Sofi Filtration.

The network promotes sustainable mining and raises awareness by organizing conferences aimed at a broad audience. The first conference, held in Lappeenranta in 2024, focused on security—specifically how geopolitical developments and the sustainability transition impact the mining industry. The next conference will take place in Oulu in 2026, under the theme *Redesign Mining*.

SCI-MAT Research Platform

Sustainable Circularity of Inorganic Materials
2020–2025

SCI-MAT is a multidisciplinary flagship research platform at LUT University that advances the circular economy of inorganic raw materials. The platform hosts several international projects focused on recovering valuable metals from industrial side streams and waste. It brings together research in engineering, business, and the sustainability transition.

Sami Virolainen, Head of the Department of Separation Science, Director of SCI-MAT and Xplorer:

> SCI-MAT has brought sustainability and business researchers into high-quality research on mineral and metal separation technologies. These researchers have embraced challenges traditionally seen as purely technical. They have found answers—and posed new, complex research questions. Interdisciplinary collaboration is a success and proven to be essential.

GreenRenew Research Platform

Green Hydrogen and CO2 for Industry Renewal

2021–2025

GreenRenew Research Platform with its predecessor platform REFLEX "Recycling carbon in a flexible competitive energy system" operates in the field of Power-to-X (PtX or P2X). P2X describes the technology that converts electricity, often from renewable sources, into other forms of energy, like hydrogen or synthetic fuels. It is interdisciplinary platform where LENS, LBS and LES work together to understand, to study and to propose novel production chains of renewable energy (RE) based electrification into CO_2 neutral or even to CO_2 negative products. This productive and active platform brings energy industry, chemical industry and novel P2X industries together with academia. And now our new LUT P2X Laboratory will intensify fruitful co-operation among all stakeholders.

Tuomas Koiranen, professor at Department of Separation Science, WP leader" Emerging PtX Technologies & Concepts: Chemical synthesis processes"

> REFLEX and GreenRenew Research Platforms have operated at scientific frontline of Green Energy Transition almost 10 years, and the Platform work has been a valuable piece of ever-evolving energy transition already towards non-fossile raw materials. GreenRenew has been able to propose solutions to controlling the Climate Change.

PARTNERSHIPS

Yhdessä enemmän - Vartiaisen perheen ja LUT:n 50 vuotinen kumppanuus.

Kuva: Timo Vartiainen.

Miksi Vartiaisen perhe aloitti yhteistyön Kemiantekniikan osaston kanssa?

Larox perustettiin vuonna 1977 entisen Lappeenrannan konepajan tiloihin. Alusta alkaen isälleni, Nuutti Vartiaiselle, oli selvää, että Lappeenrannan Konepaja, joka toimi alihankintakonepajana, muuttuisi vientiyritykseksi, keskittyen nesteen ja kiintoaineen erotuksen kapeaan osaamisalueeseen. Laroxin tavoite oli tietää erittäin paljon vähästä. Oli haettava hyviä yhteistyökumppaneita yrityksen maailmanvalloitukseen. Luonnollinen yhteys löytyi Lappeenrannan teknillisestä korkeakoulusta, jossa oli osaamista monella eri alueella. Laroxin potentiaaliset asiakkaat toimivat eri prosessiteollisuuden alueilla, kuten kaivos-, kemian- ja elintarviketeollisuudessa. Alusta alkaen oli selvää, että Kemiantekniikan osasto tarjosi juuri sitä asiantuntemusta ja teknologista tukea, jota tarvittiin erotustekniikassa. Yhteistyö alkoi pienimuotoisesti, mutta kasvoi nopeasti molempia osapuolia hyödyttäväksi kumppanuudeksi, joka on jatkunut lähes viisikymmentä vuotta perheemme eri yritysten kanssa.

Entinen korkeakoulun rehtori Juhani Jaakkola totesikin osuvasti: *"Meistä tuli Laroxin tutkimus- ja kehitysosasto, ja Laroxista meidän käytännön sovellusosastomme."*

Millainen on ollut Kemiantekniikan osaston rooli liiketoimintanne kehittymisessä vuosien varrella?

Kemiantekniikan rooli perustamiemme yritysten, Laroxin, Flowroxin ja Roxian liike- toimintojen kehittymisessä on ollut merkittävä. Vuosien varrella on saatu teknistä tukea, prosessiosaamista, arvokkaita näkemyksiä ja innovatiivisia ratkaisuja, jotka ovat auttaneet yrityksiämme pysymään kilpailukykyisinä alati muuttuvilla markkinoilla. LUT:n asiantuntijat ovat olleet mukana kehittämässä uusia tuotteita, valmistustekniikoita, innovaatioita ja prosesseja, jotka ovat vieneet yritysten kehitystä eteenpäin.

Yhteistyö on liittynyt erityisesti nesteen ja kiintoaineen erotukseen sekä virtaustekniikkaan. Näihin liittyvien ilmiöiden ymmärtäminen ja tehostaminen on ollut avainasemassa. Itse suodattimien sekä niissä käytettävien kankaiden ja keraamisten elementtien, mitoitus, kulutus- ja kemiallinen kesto sekä puhtaana pysymisen tutkiminen on tuonut merkittäviä parannuksia osien kulutuskestävyyteen ja suodattimien toimintaan.

Suodatusprosessin optimointi ja sen vaikutus eri prosessituloksiin on lisännyt kilpailukykyä eri markkina-alueilla. Esimerkiksi Clever Filter -projektin kautta tehostettiin suodatusprosessin osa-alueita optimoimalla koko suodatusjaksoa. Pumppauksen ja virtaustekniikan alueella selvitettiin eri lietteiden reologian- ja viskositeetin vaikutuksia pumppujen ja venttiilien toimintaan, mikä johti selkeisiin parannuksiin tuotteiden ominaisuuksissa.

Monet edellä mainitut tutkimus- ja kehityshankkeet ovat osa kokonaisuutta, jonka avulla on parannettu myytävien tuotteiden kilpailukykyä pitkäjänteisesti. Vuosien varrella teetetyt diplomityöt ovat olleet kytköksissä liiketoiminnan haasteisiin. Näitä töitä on tehty vuosien varrella useita kymmeniä, ellei satoja.

Mikä on saanut Vartiaisen perheen panostamaan osaston laite- ja henkilöresursseihin merkittävästi?

Sanontahan on *"Yksi plus yksi on enemmän kuin kaksi"* ja se pitää varmasti paikkansa meidän ja yliopiston yhteistyössä.

Minusta on aika selvää, että pitkäjänteinen yhteistyö tuo varmasti parempia tuloksia molemmille. Näin ollen olemme halunneet perheenä panostaa Kemiantekniikan osaston resursseihin niin rahallisesti kuin myös tutkimushankkeiden ja diplomitöiden kautta. Vuosien varrella olemme lahjoittaneet kolme professuuria osastolle. Yliopiston tukisäätiön yhteyteen perustetun Nuutti ja Tyyne Vartiaisen rahaston kautta on tuettu kymmenillä tuhansilla euroilla vuosittain erotus- ja virtaustekniikan hankkeita ja sen myötä erotustekniikan keskusta.

Olemme edesauttaneet omalta osaltamme yliopiston kehittymistä erotus- ja virtaustekniikan alueella merkittäväksi tekijäksi jopa globaalisti. Panostukset ja yhteistyö ovat vaikuttaneet laajemmin kuin pelkästään yliopistolle. On mainitsemisen arvoista, että yli 300 työpaikkaa on syntynyt Lappeenrantaan perustamiemme yritysten kautta.

Pitkäaikaisena CST:n puheenjohtajana miten näet tämänkaltaisen toiminnan tukevan yritystoimintaa?

Usean vuosikymmenen ajan Erotustekniikan keskuksen (CST:n) puheenjohtajana olen nähnyt, kuinka tällainen yhteistyö voi tukea yritystoimintaa monin eri tavoin. Se luo synergiaa, josta molemmat osapuolet oppivat ja kehittävät yhdessä uusia ratkaisuja. Tämä ei ainoastaan paranna liiketoiminnan tehokkuutta, vaan myös luo uusia mahdollisuuksia innovaatioille ja uudelle yritystoiminnalle.

Esimerkiksi sähkösaostuksen ja erilaisten vedenkäsittelytekniikoiden, kuten plasmahapetuksen, tutkiminen johti myöhemmin Roxian ympäristöliiketoiminnan syntymiseen, joka sittemmin yhtiöitettiin omaksi yritykseksi; Vuoxi Oy:ksi.

Millaisia konkreettisia hyötyjä yhteistyöstä CST:n kanssa voi olla?

Yhteistyö on auttanut meitä pysymään ajan tasalla alan uusimmista trendeistä ja teknologioista. CST:n toiminnassa on mukana useita merkittäviä alan teollisuusyrityksiä ja yhteistyökumppaneita. Monet heistä ovat asiakkaitamme, jolloin on ollut mahdollisuus vaihtaa tietoja prosesseista ja niiden haasteista.

Millaisena näet Erotustekniikan osaston tänä päivänä?

Erotustekniikan osasto näyttäytyy dynaamisena ja innovatiivisena yksikkönä, joka on valmis vastaamaan tulevaisuuden haasteisiin. Vuosien varrella siitä on kehittynyt merkittävä osa Lappeenrannan-Lahden teknillisen yliopiston huippuosaamista. Erotustekniikan henkilöstön osaaminen on oman alansa huippua. Heillä on kyky sopeutua ja kehittää uusia ratkaisuja erotustekniikan kehittymiseen niin Suomessa kuin globaalisti. Uskon, että heillä on valoisa tulevaisuus edessään.

Kuva 1. Timo Vartiainen (vas.), Roxian toimitusjohtaja Matti Riihimäki ja teknologiajohtaja Jukka Koskela suodatuslaboratoriossa. Suodatus on oleellinen osa perheen yrityksen toimintaa ja tarkoittaa myös LUT kemian tekniikan ja erotustekniikan yhteistyön jatkuvuutta. Kuva: Timo Vartiainen.

Millainen on Vartiaisen perheen ja Erotustekniikan osaston yhteinen tulevaisuus?

Meidän ja Erotustekniikan osaston yhteinen tulevaisuus näyttää lupaavalta. Tulemme jatkamaan yhteistyötä ja etsimään uusia tapoja kehittää liiketoimintaamme yhdessä. Uskon, että yhdessä voimme saavuttaa enemmän kuin yksin. Tulevaisuuden yhteistyöstä on hyvänä esimerkkinä uuden partikkelitekniikan professuurin rahoituksen järjestyminen erotustekniikkaan. Tämän rahoituksessa olemme mukana perheemme kolmannen sukupolven omistaman Capillary Oy:n kautta.

Lopuksi haluan kiittää kaikkia, jotka ovat olleet mukana tällä matkalla. Yhteistyö ja yhteiset ponnistelut ovat tehneet tästä mahdollisen, ja odotan mielenkiinnolla, mitä tulevaisuus tuo tullessaan.

Timo Vartiainen
Roxia Oy:n hallituksen puheenjohtaja
Lappeenrannan teknillisen yliopiston kunniatohtori

Celebrating 50 years of Excellence in Separation Science – Reflections from ANDRITZ

ANDRITZ and LUT University have built a long-standing, forward-looking partnership grounded in scientific excellence and mutual trust. Over time, this collaboration has deepened—particularly in the field of separation science—and now includes a shared, state-of-the-art laboratory on the LUT campus in Lahti.

LUT's academic expertise supports ANDRITZ's research and innovation efforts in numerous ways. A key strength of the collaboration lies in LUT's ability to integrate fiber technology research with separation science. This interdisciplinary approach enables the development of new, environmentally friendly solutions—for example, more energy-efficient recycling of process chemicals. These joint efforts drive technological innovation while supporting our ambition to remain at the forefront of sustainable engineering.

The partnership also broadens our expert network and opens new avenues for joint innovation. It provides a platform to explore emerging research topics, access a wider range of scientific and technical disciplines, and leverage the complementary strengths of both organizations.

As a long-time member of the Centre for Separation Technology (CST), we view this collaboration as a vital driver of innovation and competitiveness. We look forward to continuing this journey—pushing boundaries, creating impact, and shaping the future of separation science.

Markus Paananen
Research and Development Manager,
Fiberline Product Group
ANDRITZ

Collaboration with LUT Separation Science on Battery Recycling

Since 2020, Fortum Battery Recycling Oy (FBR) has been collaborating with LUT Separation Science on battery recycling, focusing on the evaluation of ion exchange and membrane technologies for the separation of key battery metals—nickel, cobalt, and lithium.

FBR has developed a unique hydrometallurgical process to recover metals and graphite from end-of-life lithium batteries. A core innovation of this process is the on-site electrochemical production of key chemicals, combined with aqueous-based separation techniques.

The collaboration with LUT has validated FBR's initial findings. LUT's expertise has been instrumental in verifying and refining the process. FBR aims to scale up this technology to an industrial level by the end of the decade.

This partnership has been highly productive and will continue throughout the scale-up phase. The joint objective is to enhance the separation efficiency, yield, and product purity to meet battery-grade material standards. FBR places high value on LUT's technical contributions, which are essential for overcoming the challenges of industrial-scale implementation.

Pasi Kauppinen, Manager,
Concept and Technology Development

Kenneth Ekman, Director,
Concept and Technology Development

Fortum Battery Recycling Oy

Metso's collaboration with LUT Chemistry

> Metso and its predecessors have maintained a long-standing research collaboration with the LUT Chemistry Department. This collaboration has focused for example on studying separation phenomena in hydrometallurgical processes. The expertise and experience of LUT Chemistry in ion exchange and solvent extraction processes have been highly valued, resulting in significant and valuable outcomes.
>
> **Eero Kolehmainen**
> Development Manager
> Metso, Pori Research Center

Testimonial from Ekomuovi

> At Ekomuovi, we are committed to advancing the sustainability of our plastic products. Our collaboration with LUT University has been instrumental in achieving this goal. Working with a talented bachelor's student has provided us with invaluable insights into the ageing and degradation of plastics. This partnership has not only enhanced our understanding but also demonstrated the immense potential of academic-industry collaborations. We highly recommend other companies to leverage the expertise and innovative thinking that universities like LUT have to offer. The ease and effectiveness of this collaboration have truly opened our eyes to new possibilities.
>
> **Tero Tupakka**
> Managing Director
> Ekomuovi

Lappeenranta – kaivos- ja erotustekniikan kansainvälisen luokan osaamiskeskittymä

Lappeenrannan-Lahden teknillisellä LUT-yliopistolla on vuosien varrella ollut merkittävä rooli kaupungin kasvussa ja kehityksessä. Yhtään kotiin päin vetämättä kemian ja erotustekniikan osaamisen voidaan sanoa olevan Lappeenrannassa eurooppalaista huipputasoa. Energiamurroksen myötä harvinaisten mineraalien hyödyntämisestä on Suomessa ammennettavissa uutta elinvoimaa. Tulevaisuudessa rooliamme voitaisiin hyvin kasvattaa koko EU:n T&K-osaamisen keskittymänä sekä puhtaan siirtymän ja kiertotalouden vauhdittajana.

Kaupungille erotustekniikan osaston merkitys näyttäytyy eritoten alueen yritystoiminnan välityksellä. Laroxin perinteitä jatkava Metso on investoinut suodatinteknologiakeskukseen ja tukeutuu kehitystyössään LUT:n osaamiseen ja yliopiston tuottamiin ammattilaisiin.

Kaupunki edistää osaltaan yritysten demoympäristöjen rakentamista ja toteutti viisi vuotta sitten yhdessä silloisen Flowrox Oy:n kanssa mielenkiintoisen kokeilun lääkejäämien erottelusta sairaalan jätevesistä. Tässäkin perustana oli yliopistolla kehitetty innovaatio veden plasmapuhdistuksesta sähkön avulla.

Kaupungin Greenreality- ja yritysyhteistyössä arvokasta on, että erotustekniikan osaamisella vesien kierrätys tehostuu, veden ja energian kulutus sekä päästöt pienenevät. Näin paikallisten yritysten kautta levittyvät maailmalle sekä LUT:n että kaupungin asettamat ilmastonmuutoksen hillinnän isot tavoitteet.

Kaupungin vedenpuhdistuksessa on tehty vuosikymmenten ajan yhteisiä selvitys- ja opinnäytetöitä. Viimeisimmän diplomityön tuloksena laitoksen alkalointikemikaali tullaan vaihtamaan kierrätyskemikaaliin. Uusi vedenpuhdistuslaitoksen megaluokan investointi tulee mahdollistamaan uudenlaisen tilan ja ympäristön tuleville tutkimus- ja pilotointitarpeille.

Suomen ilmastopääkaupungille on strategisen tärkeää puhtaan sähköistämisen globaalien tavoitteiden saavuttaminen sekä Power to X-alan työpaikkojen kasvu. Parhaillaan vireillä on maakunnassamme useita vetyteollisuuden investointeja ja kasvunäkymät ovat erityisen lupaavat.

Erotustekniikan osaaminen on 50 vuoden aikajänteellä löytänyt omat erityisosaamisen alueet koko LUT-yliopiston kasvun tavoin: Show the way – never follow.

Lappeenrannan kaupunki onnittelee erotustekniikan 50-vuotismerkkipaalun saavuttamisesta ja toivottaa navakkaa myötätuulta seuraaville viidelle vuosikymmenelle. On ollut ilo kuulla, miten yrityksistä kiitellään LUT:n ketteryyttä ja kykyä räätälöidä palvelujaan yritysten tarpeisiin.

Tuomo Sallinen
kaupunginjohtaja

Markku Heinonen
kehitysjohtaja (kesään 2025 saakka)

Lahden kaupungin onnittelut LUT-yliopiston 50-vuotiaalle erotustekniikalle

Lahden kaupunki esittää lämpimät onnittelunsa LUT-yliopiston erotustekniikan 50-vuotisjuhlan kunniaksi. Puolen vuosisadan mittainen työ erotustekniikan tutkimuksen ja koulutuksen parissa on osoitus pitkäjänteisestä ja kunnianhimoisesta työstä, tieteellisestä huippuosaamisesta sekä yhteiskunnallisesti merkittävästä vaikuttavuudesta.

Lahdessa olemme valtavan ylpeitä siitä, että Lahti on LUT-yliopiston toinen kotikaupunki. Yliopiston vahva läsnäolo ja innovatiivinen tutkimustoiminta ovat keskeisiä alueemme elinvoiman ja kasvun rakentajia. Erotustekniikan tutkimus on vahvistanut Lahtea osaamiskaupunkina, tuonut alueelle kansainvälisiä huippuosaajia ja rakentanut tiivistä yhteistyötä elinkeinoelämän kanssa. LUT-yliopiston yhteislaboratoriot yrityksien kanssa, tiivis vuoropuhelu yrityksien ja tutkijoiden välillä sekä iloiset opiskelijat ja henkilökunta ovat tuoneet kaupunkiimme kauan kaivattua akateemista paloa ja eloa. Johtavana ympäristökaupunkina haluamme kaikin keinoin tukea ja kannustaa yliopistoamme eteenpäin ponnistuksissa puhtaamman ja kestävämmän tulevaisuuden eteen.

Toivotamme LUT-yliopiston erotustekniikalle menestystä myös tulevina vuosikymmeninä.

Lämpimin onnentoivotuksin,
Henna Eskonsipo-Bradshaw
Kasvupalvelujohtaja, Lahden kaupunki

Kuva: Henna Eskonsipo-Bradshaw

Yhteistyötä puhtaampien vesien puolesta

Mikkeli on strategiansa mukaisesti puhtaan veden pääkaupunki. Sellaiseksi ei kannata julistautua ilman hyviä perusteita.

Mikkeli on herättänyt valtakunnallista ja myös kansainvälistä huomiota uuden jätevedenpuhdistamon ansiosta. Projektin kalleuden kanssa tuskailun vastapainoksi olemme saaneet huippulaadukkaan laitoksen ihailua. Rohkeaa teknologiavalintaa, MBR-prosessin hankkimista edelsi vuosien tutkimus- ja testausyhteistyö LUTin erotustekniikan osaston kanssa. Ilman tätä teknologialoikka olisi varmaankin jäänyt Vesilaitokselta ottamatta.

Puhdistamoprojektissa varauduttiin myös TKI-työhön. Luolastoon syntyi oma osasto T&K-toimintaa ja pilotointia varten. Yrityksiä ja tutkimuslaitoksia palveleva uniikki TKI-ympäristö rakentuu hyvässä yhteistyössä LUTin asiantuntijoiden kanssa. Merkit ovat sellaiset, että lähivuosina siellä nähdään yritysprojektien ohella myös LUTin pilotteja; laboratoriosta ulos kasvaneita jätevedenkäsittelyn testilaitteistoja.

Lisääntynyt yhteistyö ja usko tulevaan saivat aikaan merkittävän askeleen koulutuspuolella. Mikkeliin kytketty vesiteknologian diplomi-insinöörien koulutus avasi uuden polun, joka hakijamäärien perusteella näyttää vievän hyvään suuntaan. Kasvavien vesihaasteiden myötä kiinnostus alaa kohtaan on arvatenkin nousujohteinen.

Kaupunkistrategian toteutus kaipasi lisää kansainvälistä toimintaa. LUTissa kiinnostuttiin kaupungin ehdotuksesta rakentaa yhteistyössä Mikkeliin kansainvälinen, uutta vesiteknologiaa käsittelevä tapahtuma. Vuosia aiemmin aloitettu Finnish Lakeland Forum -seminaarisarja saikin syksyllä 2025 rinnalleen LUTin johtaman Emerging Trends in Water Treatment -konferenssin. Yhteistyössä Xamkin ja muiden kynnelle kykenevien kanssa luotiin kokonainen tapahtumaviikko, Mikkeli Water Week. Mainiosti onnistunut startti rohkaisi jatkamaan konferenssin ja tapahtumaviikon kehittämistä. Jatkoa onkin tulossa.

Edellä kuvattu yhteistyö on kiinteä osa kaupungin koordinoimaa Blue Economy Mikkeli -osaamiskeskusta. LUT:n ohella yhdessä Xamkin, Vesilaitoksen, MikseiMikkelin ja paikallisten yritysten Operonin ja Mipron kanssa rakennetun verkoston tavoitteena on kasvattaa veteen liittyvää liiketoimintaa, tutkimusta ja koulutusta. Ja, eikä enempää tai vähempää kuin luoda uusia ratkaisuja maailman vesiongelmiin.

Hyvästä syystä voidaan sanoa, että Mikkeli ei olisi puhtaan veden pääkaupunki ilman LUTia. Uskottavuuden ja aseman kehitys vaatii yliopistoyhteistyötä ja kansainvälisesti kiinnostavaa osaamista. Yhdessä voimme rakentaa elinvoimaisen ekosysteemin, johon yhä useammat yritykset haluavat asettua.

Erotustekniikan osaston kanssa kohti entistä puhtaampia vesiä!

Juha Kauppinen, FT
Koordinaattori, Blue Economy Mikkeli

LUT edistää Kouvolan kehittymistä

Kouvolan kaupunki onnittelee 50-vuotiasta Erotustekniikan osastoa. Yhteistyömme LUT-yliopiston kanssa pohjautuu pitkäaikaiseen kumppanuuteen jo yli kahdenkymmenen vuoden ajalta. Olemme saaneet hyödyntää LUT Kouvolan yksikön osaamista tutkimuksen, erityisesti rautatielogistiikan tutkimuksen saralla. Meille kaupunkina on ollut erittäin tärkeää saada myös yliopistotason koulutusta jälleen Kouvolaan. Olemme ylpeitä ja iloisia sen käynnistymisestä niin logistiikan kuin elintarviketekniikan alalla.

Elintarvikealan Food Processing Technology -maisteriohjelman käynnistyminen on erinomainen esimerkki siitä, miten korkeakoulutus voi kehittyä vastaamaan paikallisiin tarpeisiin. On ollut hienoa olla rakentamassa uudenlaista koulutusta Kouvolaan yhdessä LUT-yliopiston ja alueen yritysten kanssa. Se on syntynyt yhteisestä tahtotilasta ja vastaa tämän päivän ja tulevaisuuden elintarvikealan osaamistarpeisiin. Tämä ohjelma ei ainoastaan tuota uusia diplomi-insinöörejä – se rakentaa tulevaisuuden kestävää ruoantuotantoa, jossa Kouvolalla on vahva ja näkyvä rooli.

Kouvolan kaupungin strategisena tavoitteena on vahvistaa korkeakoulutusta erityisesti omilla vahvuusaloillamme. Elintarvikesektori, jonka juuret ulottuvat syvälle Kouvolan maataloushistoriaan, on yksi näistä. Elintarviketekniikka yhdistää käytännönläheisen tutkimuksen, kestävän kehityksen ja innovaatiot – asioita, jotka ovat yhä keskeisemmässä roolissa myös alueellisessa elinvoimassa ja huoltovarmuudessa.

Kaupungin tavoite on, että yhteistyömme syvenee ja tiivistyy – haluamme kasvattaa sekä opiskelija- että TKI-toimijoiden määrää alueella. LUT-yliopisto toimii Kouvolassa koulutuksen ja yritysten kilpailukyvyn edistäjänä ja on merkittävä vaikuttaja elinvoimanäkökulmasta. Yhteinen tavoitteemme on myös opiskelijoiden ja yritysten törmäyttäminen. Kansainvälisten opiskelijoiden määrä on lisääntynyt viime vuosina. He tuovat mukanaan uusia näkökulmia, osaamista ja kulttuuria, jotka rikastuttavat paitsi tutkimusta ja opetusta myös koko Kouvolan elinympäristöä.

Globaalit ympäristöhaasteet sekä terveys- ja ravintosuositukset vaativat uusien teknologioiden ja innovaatioiden kehittämistä myös elintarviketeollisuudessa. Maailman turvallisuustilanne korostaa kotimaista huoltovarmuutta ja sitä kautta elintarvikealan kehittämisen tärkeyttä Suomessa, erityisesti maan suurimmassa maatalouskaupungissa, Kouvolassa.

Näkymät 5–10 vuoden päähän ovat lupaavat. Uskomme, että elintarvikealan tutkimus ja kehitys tuottaa konkreettisia innovaatioita paikallisille yrityksille, lisää työpaikkoja ja vahvistaa alueen vetovoimaa. Samalla se tukee koko Suomen ruokaturvaa ja vientipotentiaalia – Kouvolasta käsin.

Yhteistyöllä eteenpäin – lämpimät onnittelut!

Marita Toikka
Kouvolan kaupunginjohtaja

Katse kohti seuraavaa menestyksekästä vuosikymmentä

Kollin Säätiön asiamies Esko Kolli, provosti Mari Kallioinen-Mänttäri ja apulaisprofessori Kristian Melin. Kuva: Kollin Säätiön luvalla.

Kollin Säätiön yhteistyö LUT-yliopiston Erotustekniikan osaston kanssa käynnistyi vuonna 2019, kun lähdimme merkittävällä panostuksella rahoittamaan neljää uutta professuuria. Tämä päätös tehtiin vakaalla uskolla siihen, että yhteistyöllä voidaan vauhdittaa Lahden alueen yliopistokoulutuksen ja tutkimuksen kehitystä – ja näin todella tapahtui.

Professuuripanostukset ovat olleet keskeisessä roolissa yliopiston toiminnan nopeassa kasvussa Lahdessa. Yhteistyön konkreettisia tuloksia nähdään erityisesti kampusalueella, jossa on syntynyt uusia tutkimuslaboratorioita tiiviissä yhteistyössä elinkeinoelämän kanssa. Näistä tiloista on tullut tärkeitä alustoja niin akateemiselle tutkimukselle kuin yritysyhteisöille, joilla rakennetaan tulevaisuuden metsäalan ratkaisuja.

Yhteistyöhön Erotustekniikan osaston kanssa on tähän mennessä panostettu jo useiden miljoonien eurojen edestä, ja olemme iloisia siitä, että yhteinen matka jatkuu. Yhteistyön jatkumisesta vuosille 2025–2030 on sovittu ja näemme tulevien vuosien avaavan uusia mahdollisuuksia – erityisesti metsäalan sivuvirtojen hyödyntämisessä ja korkean jalostusasteen osaamisen kehittämisessä. Metsä, suomalaisen kansantalouden peruskivi, tarjoaa tässä keskeisen pohjan uusille innovaatioille.

Myös Kollin Säätiön rahoittama Metsä360-tunnustuspalkinto on vakiinnuttanut asemansa metsäalan innovaatioiden näyteikkunana. Palkinto nostaa esiin merkittäviä tekoja ja se myönnetään innovaatiolle, ratkaisulle tai teolle, joka kasvattaa metsien jalostusarvoa.

Kollin Säätiölle on ollut tärkeää olla tukemassa osaamisen kasvua ja juurtumista Lahden alueelle, jossa yliopiston läsnäolo on jo osoittanut merkittävän myönteisen vaikutuksen alueelliseen kehittymiseen.

Yhteistyö Erotustekniikan osaston kanssa on ollut antoisaa, innostavaa ja ennen kaikkea tuloksellista. Kollin Säätiö uskoo vahvasti, että tämän yhteistyön myötä olemme pystyneet – ja pystymme myös jatkossa – vaikuttamaan merkittävästi maamme uuden, korkean jalostusasteeseen perustuvan metsäosaamisen syntyyn ja menestykseen.

Lämpimät onnittelut osastolle 50-vuotisesta taipaleesta – yhteistyö, osaaminen ja rohkea kehittäminen vievät kohti seuraavaa menestyksekästä vuosikymmentä.

Esko Kolli, talousneuvos
Marjatta ja Eino Kollin Säätiön asiamies

Paljon onnea 50-vuotiaalle Erotustekniikan osastolle!

Kouvolassa kotipaikkaansa pitävä Kymin Osakeyhtiön 100-vuotissäätiö sr myöntää Etelä-Karjalan alueelle apurahoja tieteelliseen toimintaan. Säätiö on toiminut yhteistyössä LUT-yliopiston kanssa jo pitkään.

Säätiö on myöntänyt Lappeenrannan-Lahden teknilliselle yliopistolle vuosien 2022–2024 aikana yhteensä 450 000 euroa erityisapurahaa tieteelliseen toimintaan Kouvolaan sijoittuvan elintarvikeprosessitekniikan apulaisprofessuuriin. Kouvolassa alkoi elintarviketekniikan maisteriohjelman koulutus syksyllä 2024. Kouvolassa säätiö on tukenut myös alempia koulutusasteita elintarvikekoulutusten toteuttamisessa.

”Kymin Osakeyhtiön 100-vuotissäätiö pitää tärkeänä tukea ammatillista opintotoimintaa ja tiedettä Kymenlaaksossa ja Etelä-Karjalassa. Näissä kysymyksissä säätiö haluaa toimia pitkäjänteisesti ja siten, että apurahojen vaikuttavuus on alueellisesti merkittävä. Erityisesti arvostamme aktiivista yritysyhteistyötä. Lappeenrannan–Lahden teknilliselle yliopistolle myönnetyt apurahat täyttävät nämä kriteerit erinomaisesti. Paitsi että tuet oppilaitokselle mahdollistavat laadukasta opetusta ja tieteentekoa säätiön toiminta-alueella, ne edistävät myös alueen elinvoimaisuutta muilla tavoin. Korkeakoulut katsovat eteenpäin, synnyttävät kehitysajatuksia ja uudenlaista energiaa koko alueelle”, sanoo Kymin Osakeyhtiön 100-vuotissäätiön hallituksen puheenjohtaja Pirkko Harrela.

Kymin Osakeyhtiön 100-vuotissäätiö onnittelee Erotustekniikan osastoa merkkivuoden johdosta.

DEPARTMENT IN TABLES AND FIGURES 1974-2025

Department personnel 1975-2024

The table has been assembled using data sourced from LUT. However, it is important to note that the dataset may not be entirely comprehensive, primarily due to the presence of outdated or inaccessible data formats. Consequently, some entries might be absent from the table. We sincerely apologize for any omissions and appreciate your understanding regarding these limitations.

a) Teaching and research personnel

Professors (tenured and non tenured)

Backfolk	Kaj
Bhatnagar	Amit
Farrash Bamoharram	Fatemeh
Henricson	Kaj
Häkkinen	Antti
Kajanto	Isko
Kallas	Juha
Kallioinen-Mänttäri	Mari
Koiranen	Tuomas
Kraslawski	Andrzej
Käyhkö	Jari
Lindström	Matti
Louhi-Kultanen	Marjatta
Manner	Hannu
Minkkinen	Pentti
Mänttäri	Mika
Nyström	Lars
Nyström	Marianne
Oja	Marja
Paatero	Erkki
Palosaari	Seppo
Reinikainen	Satu-Pia
Repo	Eveliina
Rodriguez Couto	Susana
Sainio	Tuomo
Sillanpää	Mika
Siren	Heli
Tang	Zhonghong
Turunen	Ilkka
Wilska	Seppo
Österberg	Monika

Acting Professors and Associate professors (1975-1999)

Halme	Erkki
Levomäki	Markku
Pohjola	Veikko
Silventoinen	Ilpo
Sten	Matti
Grönroos	Ari
Kaijaluoto	Sakari
Karlsson	Markku
Karvonen	Vesa
Laatikainen	Markku
Laine	Jouko
Maunu	Sirkka-Liisa
Nuortila-Jokinen	Jutta
Passiniemi	Pertti

Associate Professors (Tenure)

Layek	Rama
Melin	Kristian
Rezaei	Nima

Other Professorships

Häkkinen	Antti	Professor endowed
Käyhkö	Jari	Research Professor FiberTech 2010
Nuortila-Jokinen	Jutta	Research Professor Cleantech 2000
Nuortila-Jokinen	Jutta	Industry Professor
Oja	Marja	Professor endowed
Wolkersdorfer	Christian	Professor FiDiPro

Associate professors (non tenure), Post-doctoral researchers and University teachers

Anugwom	Ikenna
Heinonen	Jari
Jernström	Eeva
Kinnarinen	Teemu
Klemola	Kimmo
Kolehmainen	Eero
Laakso	Ekaterina
Laari	Arto
Mäkinen	Martti
Niemi	Harri
Partanen	Jaakko
Pihlajamäki	Arto
Ramasamy	Deepika
Rueda Marquez	Juan
Srivastava	Varsha
Tuunila	Ritva
Virolainen	Sami
Zhao	Feiping
Aghajanian	Soheil
Alatalo	Hannu
Ayati	Ali
Balasubramaniam	Arul
Bediako	John
Ben Hammouda	Samia
Boy	Virginie
Butylina	Svetlana
Daneshvar	Ehsan
Demesa	Abayneh
Doshi	Bhairavi
Dwivedi	Amarendra
El Ouardi	Youssef
Emebu	Samuel
Fontmorin	Jean-Marie
Gao	Bo
Givirovskiy	Georgy
Gurung	Khum
Han	Bing
Hatakka	Henry
Hautaniemi	Marjaana
Hiltunen	Salla
Hokkanen	Sanna
Jantunen	Niklas
John	Miia
Koljonen	Krista
Kuosa	Markku
Laasonen	Emma
Laatikainen	Katri
Lahtinen	Markus
Li	Xiuxi
NaviriFallah	Rahimeh
Nieminen	Harri
Pinar	Orkun
Pöysä	Marjo
Rawat	Anuj
Rissanen	Tiina
Rousu	Päivi
Sethurajan	Manivannan
Sirin	Sema
Skalska-Tuomi	Kinga
Tanhaei	Bahareh
Viitala	Mirka
Kuukka	Katja
Paakkunainen	Maaret
Preis	Sergei
Pulkkinen	Mika
Turku	Kati
Vahteristo	Kari
Tellinen	Juhani

Lecturers

Hakuli	Virpi
Koskimies	Salme
Mennola	Riitta
Miettinen	Tapio
Mäkelä	Klaus
Männynsalo	Jarkko
Oja	Marja
Penttinen	Kyösti

Senior assistants, Assistants and Assistant professors (tenure)

Bulsari	Abhay
Haakana	Timo
Jussila	Raija
Kapanen	Mika
Kervinen	Antti-Jussi
Kärki	Ari
Lahtinen	Leila
Lehmonen	Pertti
Muukka	Jyrki
Nevalainen	Anssi
Penttilä	Ilkka
Pykäläinen	Jukka

Rong	Benguang
Ryösö	Kati
Soleymani	Azita
Yrjölä	Kari
Aho	Kaisa
Alatalo	Tuula
Ali-Hokka	Aila
Ali-Hokka	Seppo
Alppisara	Maria
Dai	Zhongde
Ehsani	Neda
Hagman	Anja
Halme	Erkki
Hauhia	Heikki
Heikka	Riitta
Hiironen	Juha
Hirvonen	Ismo
Huuhilo	Tiina
Jussila	Raija
Järvinen	Pia
Kainulainen	Mikko
Kantanen	Leena
Kilpeläinen	Veli
Kiviniemi	Anne
Koivisto	Matti
Kolhonen	Katriina
Kortelainen	Helena
Koski	Ilkka
Kosonen	Marja-Leena
Kärki	Merja
Laakso	Tapio
Laamanen	Riku
Lahti	Tuula
Laitinen	Vuokko
Liimatainen	Katriina
Lyytinen	Maija-R
Mäkelä	Petri
Necibi	Mohamed
Park	Yu Ri
Parkkonen	Virpi
Peltomäki	Elina
Perez Vega	Samuel
Pihlaja	Helinä
Puumalainen	Raili
Reunanen	Jarmo
Riikonen	Päivi
Rinne	Anne
Ruohio	Vesa
Ruokokoski	Veli-M
Silenius	Petri
Silvennoinen	Kari
Silventoinen	Ilpo
Summanen	Hannu
Suoanttila	Päivi
Suurinkeroinen	Teija
Sääksjärvi	Eija
Turku	Irina
Venäläinen	Kaija
Verraes	Virginie
Ylinen	Kati

Project managers

Gradov	Dmitry
Pöntinen	Ville
Salmimies	Riina
Ruuska	Timo

Visiting Scientists

Gharieb	Ali
Laatikainen	Katri
Korpinen	Risto

Researchers and Project researchers

Aaltonen	Minna
AbdelWahed	Mahmoud
Afzali	Shokufe
Aghababaei	Aylin
Airaksinen	Leo
Aksenova	Anna
Almassi Tighi	Karo
Andre	Laurie
Arif	Maham
Aromaa	Tiia
Asumalahti	Siiri
Balshakou	Siarhei
Bec	Sabina
Ben Hamida	Sarra
Bessaies	Hanen
Bilesan	Mohammad
Buzuku	Shqipe
Cervantes Rincon	Nancy
Chauhan	Deepesh
Elo	Timo
Esmaeili	Mohammadamin
Ezeanowi	Nnaemeka
Fallah Fini	Mojtaba

Franco del Pino	Ana
Friman	Eetu
Frindy	Sana
Ghasemi	Ensieh
Ghosh	Tuhin
Hasan	Mehdi
Heinonen	Ulla
Hietanen	Teemu
Holappa	Janne
Honkonen	Jani
Hukkamäki	Jarkko
Humppi	Tarmo
Huseynova	Shahla
Huttunen	Manu
Huusari	Ellimaaria
Isosaari	Pirjo
Jain	Monika
Juusola	Pekka
Jääskeläinen	Eduard
Kabugo	James
Kaijanen	Laura
Kaipia	Lena
Kamali	Mohammad
Kang	Ning
Kaur	Parminder
Kavun	Vitalii
Khalighi	Mahmood
Kiljunen	Samantha
Kilpeläinen	Jarmo
Kilpeläinen	Tuija
Kohonen	Jarno
Kokko	Kalle
Kärki	Satu
Kärmeniemi	Titta
Kääriäinen	Marja-Leena
Kääriäinen	Tommi
Laapas	Nina
Lahdenperä	Esko
Laine	Pertti
Lappalainen	Tom
Leikoski	Tuomo
Leinonen	Jani
Li	Yang
Lindell	Jutta
Linnanen	Teijo
Lohi	Tiina
Luukkonen	Juha
Makkonen	Esko
Malinen	Heli
Mani	Rajaboopathi
Mansikkaviita	Satu
Massima Mouele	Emile
Mattila	Milla
Maydannik	Philipp
Metsälä	Antti
Metsämuuronen	Sari
Mohamed	Ghada
Moradi	Mohammad
Moslova	Karina
Musiienko	Denys
Muurman	Henna
Myllylä	Ilkka
Nevalainen	Minna
Nguyen	Ngan Ho Kim
Nikolaev	Egor
Olin	Pekka
Ora	Ari
Paavilainen	Juha
Paltmann	Egon
Panorel	Iris
Parvan	Majed
Pastushok	Olga
Patala	Samuli
Ponomarev	Nikolai
Pussinen	Krista
Puton	Jaroslaw
Pääkkönen	Iiris
Qu	Haiyan
Rantala	Jari-Pekka
Rassokhin	Aleksandr
Rautiainen	Risto
Razavizadeh	Sayedjalal
Rehman	Aafaq
Riepponen	Marko
Roosta	Aliakbar
Rotich	Nicolus
Roy	Manta
Rumky	Jannatul
Rytkönen	Arsi
Saad	Mustafa
Safonov	Dmitry
Salmenhaara	Heikki
Salmi	Perttu
Sayinli	Burcu
Selvaraj	Rengaraj
Sha	Zuoling

Sharma	Jyoti
Shcherbakov	Ilya
Shestakova	Marina
Sihvo	Iida-Maija
Sihvonen	Tuomas
Sinisaari	Tuomas
Sivén	Seppo
Sivenius	Miira
Sokolov	Alexander
Soleyman	Azita
Soto Salcido	Luis
Suoanttila	Marjukka
Tamminen	Jussi
Tamper	Juha
Tanninen	Jukka
Turku	Irina
Vehmaanperä	Paula
Velts	Olga
Verma	Shilpi
Viinanen	Kai
Virkki-Hatakka	Terhi
Virtanen	Suvi
Vornamo	Timo
Zeng	Huabin
Zhang	Yulan
Zhukov	Vladimir
Ängeslevä	Marina

Research and Project engineers

Halonen	Pasi
Hamara	Ville
Harju	Erja
Heinonen	Tiia
Huhtanen	Mikko
Kalliovaara	Esa
Karhu	Antti T M
Koponen	Lasse
Kurkinen	Santeri
Laasonen	Hanna
Laatikainen	Markku
Lahti	Jussi
Lehtonen	Kaisa
Musin	Eduard
Paananen	Jari
Ringman	Kaisa
Sarlomo	Laura
Suppula	Ilkka
Särkkä	Heikki
Trogen	Mikaela
Tyster	Mikko

Junior Researchers

Aghaee	Morteza
Ajo	Petri
Alatalo	Sara-Maaria
Almanasrah	Mohammad
Amin	Parsa
Ani	Elisabeta-C
Arefzadeh	Seyedmohammadreza
Arola	Kimmo
Babu	Indu
Bandina	Ekaterina
Baral	Asmit
Bolourieh	Nazila
Boström	Henna
Botar-Jid	Claudiu
Bresolin	Bianca
Burgos Castillo	Rutely
Crigna	Giorgia
Dahal	Bigyan
Deb	Anjan
Do	Minh
Dong	Yujiao
Ebrahimi	Fatemeh
Ekberg	Bjarne
Fallahmehneh	Farangis
Filianin	Kirill
Gafiullina	Anastasia
Giove	Alessio
Givirovskaia	Daria
Golmaei	Seyedmohammad
Gudarzi	Davood
Haapasaari	Sampo
Han	Mei
Heinonen	Jari
Hellsten	Sanna
Hesampour	Mehrd
Hietanen	Erika
Hietanen	Tomi
Hokkanen	Sanna
Holopainen	Sanna
Hurskainen	Asiia
Iakovleva	Evgenia
Iftekhar	Sidra
Ippolitov	Vadim
Jafari	Shila

Jafari	Shirin
Jakhwal	Parul
Jalilian	Yasaman
Joseph	Jessy
Kaartinen	Sini
Kachina	Anna
Kallio	Emmi
Kalliola	Simo
Karpova	Tatjana
Kayani	Fareeha
Khan	Usman
Koivula	Elsi
Ktit	Ahmad
Kucuk	Mehmet
Kumar	Tarun
Kumarov	Alisher
Lares	Mirka
Laukala	Teija
Lehtilä	Reko
Levchuk	Irina
Li	Changbai
Liukkonen	Alma
Lopatina	Anastasiia
Luong	Tan Vu
Lyytikäinen	Katja
Mahajan	Shreya
Makarava	Iryna
Maksimov	Pavel
Maliuk	Olga
Mannila	Marju
Merin	Sara
Mero Plaza	Mario
Mielonen	Katriina
Mohammadi	Rubaba
Mohammadisepasi	Sepideh
Mäkinen	Pekka
Nakari	Olli
Nakarmi	Kanchan
Narayanasamy	Mohankumar
Nariyan	Elham
Nekoueian	Khadijeh
Nevstrueva	Daria
Nguyen	Si Huy Hoang
Nguyen	Thanh Phuong
Nguyen	Lam
Nguyen	Viet Hung
Nieminen	Harri
Nieminen	Joona
Oleksiienko	Olga
Ovaska	Sami-Seppo
Pakarinen	Jouni
Pennanen	Toni-Petteri
Pham	Thuy Duong
Popovic	Tamara
Puhakka	Ville
Puranen	Johanna
Qu	Bin
Radmehr	Shahla
Raiskio	Elisa
Rantalankila	Mikko
Ratchananusorn	Warin
Rauvanto	Irina
Rosendo Lopes	Daniela
Safaei	Zahra
Saren	Andrey
Saukkonen	Esa
Saukkonen	Lauri
Semenov	Denis
Sha Mercy	Anitta
Shahid	Kanwal
Shakhanova	Marina
Sharma	Tushar
Siitonen	Jani
Singh	Srishti
Sjöman	Elina
Smith	Aaron
Song	Jianzhi
Srithammavut	Waroonkarn
Stade	Sam
Strand	Elsi
Suerbaeva	Asiia
Theuri	Shelmith
Tirkkonen	Aini
Tsering	Tenzin
Turkia	Heidi
Vanhala	Sini
Vasilyev	Fedor
Virtanen	Tiina
Vishtal	Alexey
Vroman	Marju
Vuokko	Matti
Wang	Zhao
Wesselborg	Tobias
Wicker	Rebecca
Woldemariam	Mihret
Yaghoubi	Khashayar

Yan	Fangping	Zafeer	Mohd
Yerkinbekova	Yerkezhan	Zhang	Yunfan
Yousuf	Alharith	Zhang	Nianhua

b) Technical personnel

Laboratory managers

Laakso	Timo
Patala	Pirjo-Riitta

Analysis engineers/chemists, Chemists

Hyvönen	Sari
Kuivanen	Jarkko
Kurri	Anni-Kaisa
Porkka	Veijo
Puro	Liisa

Technical expert

Pynnönen	Tero

Laboratory engineers

Asikainen	Kari
Huhtanen	Tommi
Jokela	Ville
Kaipainen	Eero
Kervinen	Antti-Jussi
Korhonen	Esa
Levomäki	Markku
Lindqvist	Petri
Maijanen	Markku
Nevalainen	Tuomas
Nurminen	Paavo
Peltonen	Soile
Rahikainen	Markku

Laboratory supervisors

Korhola	Markku
Varpenius/Alamehtä	Marja-Liisa

Laboratory technicians

Ahtola	Kirsti
Alhoranta	Anu
Hart	Ilona
Hovila	Päivi
Huuhilo	Timo
Hyrkkänen	Anne
Hyvönen	Maria
Järvi	Pekka
Kokko	Anne
Kuntsi	Jorma
Kälviäinen	Esa
Laukkanen	Hanna
Lehtoaro	Juha
Lipitsäinen	Solja
Ollila	Sara
Pihlajaniemi	Anu
Raitavuo	Mari
Ruokonen	Jaana
Ruokoniemi	Harri
Ryhänen	Ari
Seppänen	Tarja
Taina	Maria
Taipale	Helena
Tanskanen	Kirsi
Tervo	Minna
Thomander	Jenni
Turkia	Helvi
Väkiparta	Toni
Makhotkina	Olga
Pekkanen	Jari

c) Administrative personnel

Directors of CST

Nyström	Lars	1998-1999
Nyström	Marianne	2000-2007
Paatero	Erkki	2005-2007
Mänttäri	Mika	2008-2008
Louhi-Kultanen	Marjatta	2008-2008
Karvonen	Vesa	2008-2013
Tuunila	Ritva	2012-2013
Jernström	Eeva	2013-2017
Kiljunen	Samantha	2017-2021
Lahikainen	Katja	2022-

Reseach Directors

Käyhkö	Jari
Ullakko	Kari

Development managers

Lampinen	Matti
Mamelkina	Maria
Reisto	Timo

Coordinators

Ryynänen	Jaana
Kekäläinen	Janne
Kuparinen	Anne

Software engineer

Avramenko	Yury

Head of administration

Korhonen	Kati

Office secretaries

Kailanpää	Minna
Kulhoranta	Kirsi
Hyvönen	Judy

Project secretary, CST

Peuha	Eeva-Liisa

Marketing assistant

Sillanpää	Tseyang

Department secretaries

Haapasalo	Taina
Marttinen	Anne

Secretaries

Hokkanen	Raija
Ketvell	Heljä
Kojo	Ritva
Neuvonen	Inka
Puolakka	Marja
Toitturi	Mari
Ylämäki	Carita

Student affairs

Damsten	Sari	Head of Studdy affairs
Karhinen	Kaisa	Student advisor
Vahvanen	Piia	Secretary of International Study Affairs

Degrees and graduations over the years

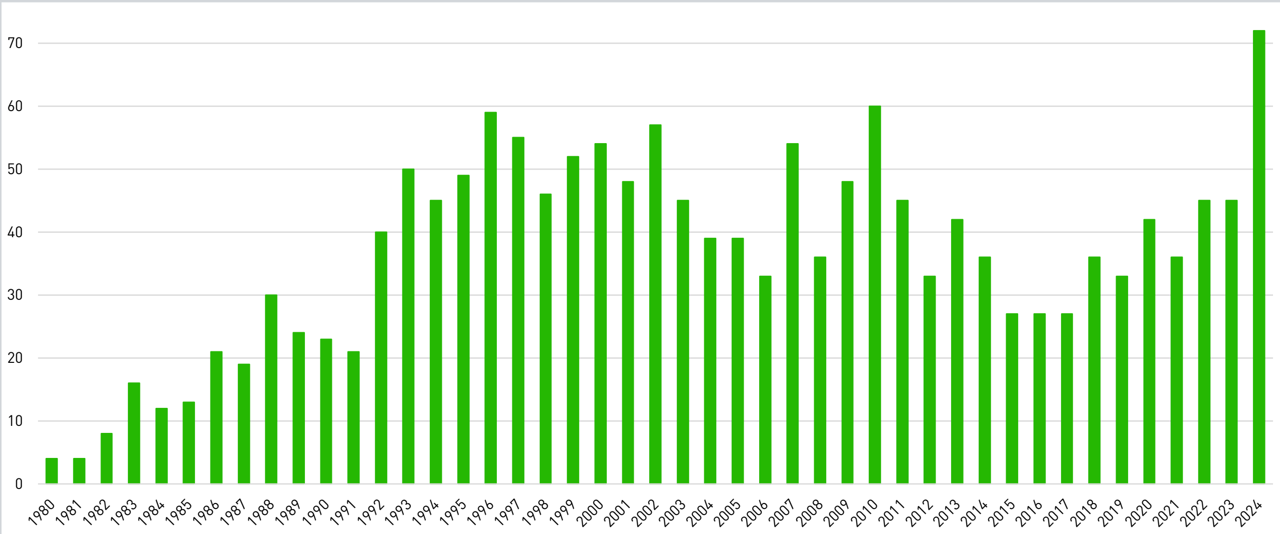


Figure 1. The number of Master of Science (DI) degrees has varied between 1980 and 2024. Source: Extra-Vipunen – Finnish National Education Administration's statistical service.

166 candidates earned the Doctor of Science (Technology) degree between 1989 and 2024.

Source: Extra-Vipunen – Finnish National Education Administration's statistical service.

External funding

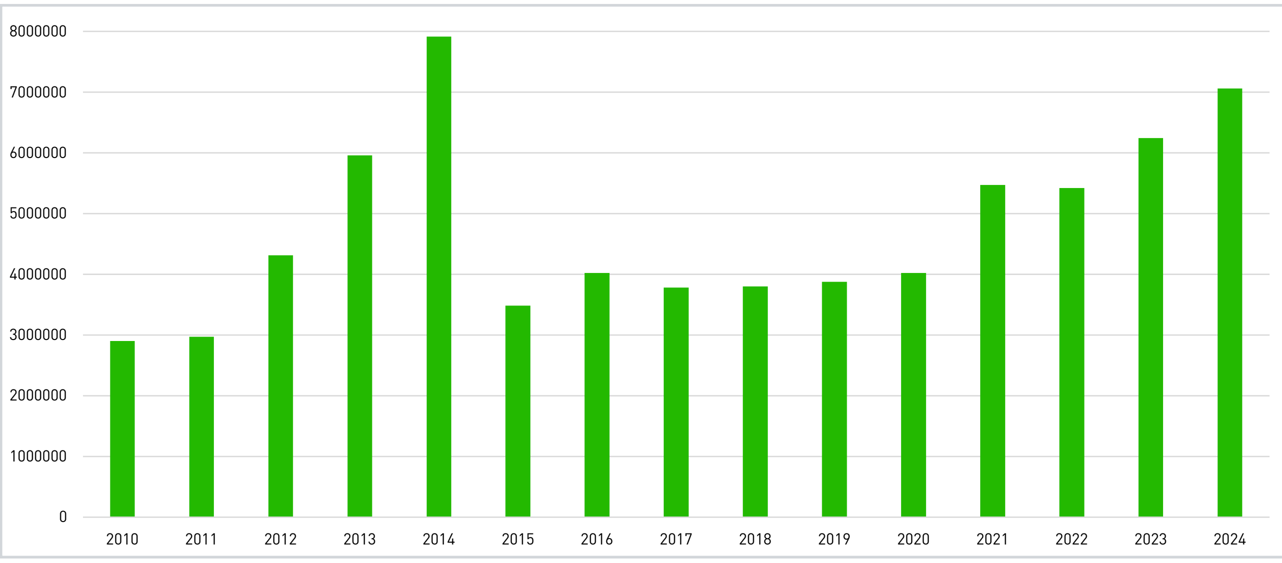


Figure 1. External funding of the Department of Separation Science. Source: LUT Financial Planning and Reporting

Statistics on personnel as per 1.9.2025

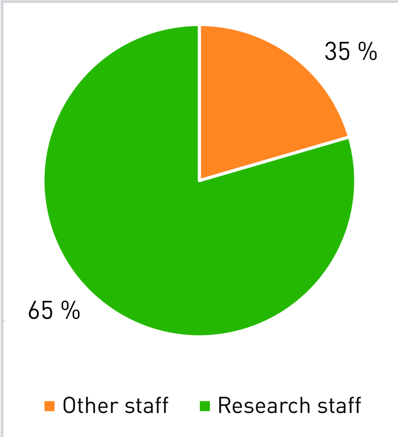


Figure 1. Distribution of personnel between research personnel and other personnel

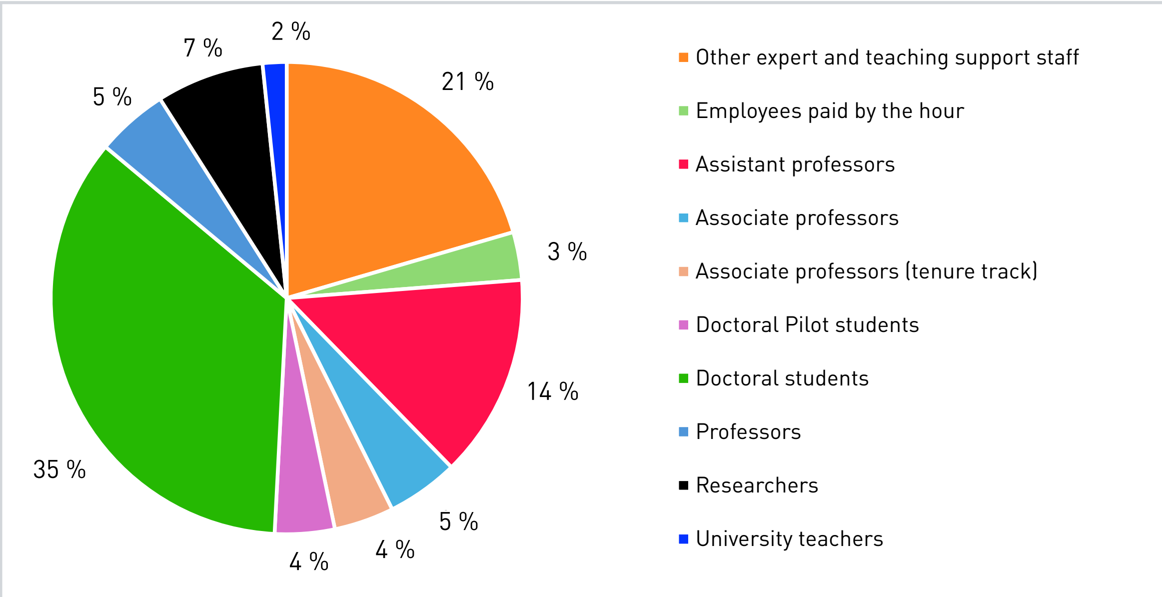


Figure 2. Distribution of research personnel by job title

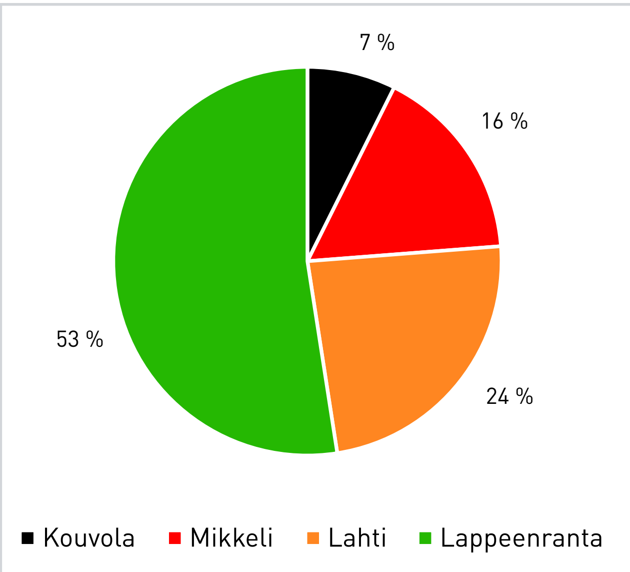


Figure 3. Distribution of personnel across campuses and regional units

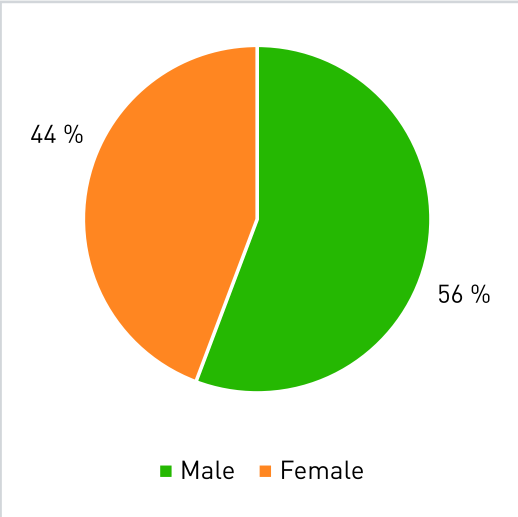


Figure 4. Gender distribution of personnel

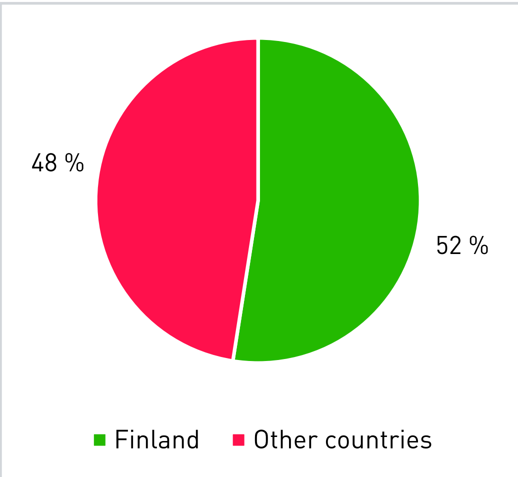


Figure 5. Nationalities of personnel in the department in 2024. The personnel comes from 28 different countries.

Examples of articles

Wicker, R., Daneshvar, E., Patel, A., Dhar, B.R., Bhatnagar, A. (2024). "Production of biomethane, biohydrogen, and volatile fatty acids from Nordic phytoplankton biomass grown in blended wastewater." Chemical Engineering Journal, 479, 147809.

El Ouardi, Y., Virolainen, S., Massima Mouele, E., Laatikainen, M., Repo, E., Laatikainen, K. (2023). "The recent progress of ion exchange for the separation of rare earths from secondary resources – A review." Hydrometallurgy, 218, 106047. DOI: 10.1016/j.hydromet.2023.106047

Daneshvar, E., Wicker, R.J., Show, P.-L., & Bhatnagar, A. (2022). "Biologically-mediated carbon capture and utilization by microalgae towards sustainable CO_2 biofixation and biomass valorization – A review." Chemical Engineering Journal, 427, 130884. https://doi.org/10.1016/j.cej.2021.130884

Virolainen, S., Fallah Fini, M., Laitinen, A., & Sainio, T. (2017). "Solvent extraction fractionation of Li-ion battery leachate containing Li, Ni, and Co." Separation and Purification Technology, 179, 274–282. https://doi.org/10.1016/j.seppur.2017.02.010

Van der Bruggen, B., Mänttäri, M., & Nyström, M. (2008). Drawbacks of applying nanofiltration and how to avoid them: A review. Separation and Purification Technology, 63(2), 251–263. https://doi.org/10.1016/j.seppur.2008.05.010

Helminen, J., Helenius, J., Paatero, E., & Turunen, I. (2001). "Adsorption equilibria of ammonia gas on inorganic and organic sorbents at 298.15 K." Journal of Chemical & Engineering Data, 46(2), 391–399. https://doi.org/10.1021/je000273+

Mänttäri, M., Puro, L., Nuortila-Jokinen, J., & Nyström, M. (2000). "Fouling effects of polysaccharides and humic acid in nanofiltration." Journal of Membrane Science, 165(1), 1–17. https://doi.org/10.1016/S0376-7388(99)00215-X

Patents granted for the members of the Department 2000-2025

The list does not contain patents granted for companies where SepSci personnel are co-inventors.

Record Number	Inventors	Name of Patent
FI127777B	MANTTARI MIKA (FI); KALLIOINEN MARI (FI)	EXTRACTED LIGNOCELLULOSIC MATERIAL AS AN ADSORBENT
FI127778B	KALLIOINEN MARI (FI); MANTTARI MIKA (FI)	EXTRACTED LIGNOCELLULOSIC MATERIAL AND USES THEREOF
EP3600650B1	KALLIOINEN MARI (FI); MANTTARI MIKA (FI)	METHOD OF USING EXTRACTED LIGNOCELLULOSIC MATERIAL AS AN ADSORBENT
FI129866B	KALLIOINEN MARI (FI); MANTTARI MIKA (FI); ANUGWOM IKENNA (FI)	A METHOD OF FRACTIONATING A LIGNOCELLULO-SIC MATERIAL AND PRODUCTS OBTAINED BY SAID METHOD
FI20165885A7	KOIRANEN TUOMAS (FI); EKBERG BJARNE (FI); HAKKINEN ANTTI (FI); VARIS JUHA (FI); LOUHI KULTANEN MARJATTA (FI)	ULTRASONIC CRYSTALLIZER AND ULTRASONIC CRYSTALLIZER SYSTEM
FI20175656A7	AHOLA JERO (FI); KARVONEN VESA (FI); EKBERG BJARNE (FI); LINDH TUOMO (FI); HUTTUNEN MANU (FI); KINNARINEN TEEMU (FI); NYGREN LAURI (FI); HAKKINEN ANTTI (FI)	A METHOD AND A SYSTEM FOR ESTIMATING RESI-DUAL LIQUID CONTENT AFTER A LIQUID REMOVAL PROCESS
FI20205673A1	PONOMAREV NIKOLAI (FI)	METHOD FOR PRODUCING ACTIVE CARBON
FI127626B	KINNARINEN TEEMU (FI); HUTTUNEN MANU (FI); NYGREN LAURI (FI); LINDH TUOMO (FI); AHOLA JERO (FI); HAKKINEN ANTTI (FI); KARVONEN VESA (FI); EKBERG BJARNE (FI)	A METHOD AND A DEVICE FOR REMOVING LIQUID FROM MATERIAL
FI126207B	KARVONEN VESA (FI); AHOLA JERO (FI); HAKKINEN ANTTI (FI)	A METHOD AND APPARATUS FOR STABILIZING AND OPTIMIZING A VACUUM IN A VACUUM PROCESS
FI20175032A7	HUTTUNEN MANU (FI); NYGREN LAURI (FI); KINNARINEN TEEMU (FI); LINDH TUOMO (FI); AHOLA JERO (FI); HAEKKINEN ANTTI (FI); KARVONEN VESA (FI); EKBERG BJARNE (FI)	METHOD AND SYSTEM FOR DETERMINING LEAKA-GE FLOW IN A NEGATIVE PRESSURE SYSTEM FOR A NEGATIVE PRESSURE FILTER
FI130889B1	MANTTARI MIKA (FI); ANUGWOM IKENNA (FI); KALLIOINEN MARI (FI); LOPATINA ANASTASIIA (FI)	A METHOD OF SEPARATING ONE OR MORE POLY-MER FRACTIONS FROM A MATERIAL COMPRISING TEXTILES AS WELL AS SPECIFIC POLYMER FRAC-TIONS AND USES THEREOF
FI130028B	VARIS JUHA (FI); KOIRANEN TUOMAS (FI); TAMMINEN JUSSI (FI); GRADOV DMITRY (FI)	AN ULTRASOUND PROCESSING DEVICE
FI20175773A1	HUTTUNEN MANU (FI); KINNARINEN TEEMU (FI); NYGREN LAURI (FI); HAKKINEN ANTTI (FI); AHOLA JERO (FI); KARVONEN VESA (FI); EKBERG BJARNE (FI); LINDH TUOMO (FI)	A METHOD AND A SYSTEM FOR ESTIMATING RESI-DUAL LIQUID CONTENT AFTER A LIQUID REMOVAL PROCESS
FI20175411A1	HUTTUNEN MANU (FI); KINNARINEN TEEMU (FI); LINDH TUOMO (FI); AHOLA JERO (FI); HAKKINEN ANTTI (FI); KARVONEN VESA (FI); NYGREN LAURI (FI)	A METHOD AND A CONTROL SYSTEM FOR CONT-ROLLING A VACUUM PUMP
FI20185987A1	MANTTARI MIKA (FI); AROLA KIMMO (FI); KALLIOINEN MARI (FI)	A METHOD AND APPARATUS FOR TREATMENT OF SALINE WATER
FI124365B	SIREN HELI (FI); KAARTINEN SINI (FI); MAI-JANEN MARKKU (FI); DAHLBERG KJELL (FI); KOIVISTO HARRI (FI); ESKELINEN EELIS (FI)	METHOD, SYSTEM AND EQUIPMENT FOR REDU-CING AND / OR REMOVING COMPOUNDS FROM SOURCE MATERIAL
FI128625B	PONOMAREV NIKOLAI (FI); SILLANPAA MIKA (FI)	METHOD FOR PRODUCING ACTIVATED CARBON
FI20146163A7	KARVONEN VESA (FI); HAKKINEN ANTTI (FI); LOUHI KULTANEN MARJATTA (FI); KOIRANEN TUOMAS (FI)	METHOD AND DEVICE FOR CONTINUOUS CRYSTAL-LIZATION AND OPERATION THEREOF

LUT University

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