Mistra TerraClean
Annual Report 2019

MISTRA
TERRACLEAN

EXECUTIVE SUMMARY

Mistra TerraClean develops smart and safe engineered materials and devices for clean air and water.

To ensure clean and safe air and water for all is an integral challenge for a sustainable future and directly addressed by the United Nations 2030 Agenda for Sustainable Development. The global and domestic need to more effectively capture pollutants released into the air, water and industrial effluents is continuously increasing. Climate change, exponential population growth, and man-generated emissions threaten our supply of water resources with severe implications for the economy, environment, and human health. Also, emissions to air and insufficient cleaning technologies pose threats to social, economic, and environmental sustainability. Innovation and technologies that support the improvement of water and air quality, resource and waste management are urgently needed. Knowledge is the key to progress and to reach the 2030 goals. Contaminations in effluent water and air are issues that cut across the industry and society. Our partners represent a variety of sectors and have complimentary experiences; they span from academia, institutes, trade organizations, start-up companies, SMEs to multinational industries.

Regardless of the source, current purification technologies must be improved to sufficiently address current and future challenges concerning energy efficiency and sustainability (reuse, recycle, waste reduction, raw materials…). Yet a limitation with today's solutions is that they cannot adapt to variations in operating conditions. Another challenge is that traditional filters and membranes will not be able to capture all types of pollutants, especially substances that occur in minute quantities.

In essence: we need smart solutions to help industry and society address these issues!

Mistra TerraClean aims to develop innovative new materials from the bottom-up and validate them under both laboratory and field conditions. The latter is done within case studies where our materials are tested under realistic conditions together with partner companies to drive the research and development within this program towards real-world problems.

This report presents an overview of the Mistra TerraClean programme, our achievements, and progress from April 2019 to March 2020. During this past year, we have brought the material production activities up-to-speed and prepared the first "smartified" device specimens. We have combined material candidates and are constantly learning more about the capacity of our base materials to adsorb target contaminants, such as heavy metal ions, NOx gases, and PFAS compounds. Some of the developed materials were observed to have additional features, such as non-fouling properties. The first wave of toxicology and life cycle analyses of the materials we produce was launched and performed during the past year and generated input on how to refine our strategies for improved sustainability.

With the hope of the coming year becoming as fruitful and rewarding as the past, I thank all partners and supporters of Mistra TerraClean for your contributions: expertise, funding, dedication, and the collaborative spirit that enables a transdisciplinary research programme to advance far beyond the borders of each discipline. Not in the least, we thank Mistra for their support and the confidence put in us to advance research and innovation in the field of smart materials.

Ulrica Edlund, Program Manager

Q&A

ANY SPECIFIC ACHIEVEMENTS DURING THIS PAST YEAR?

Our work packages are soaring with activity and we established collaborations that cut across work packages, groups and institutions. Partners gather around hypotheses and combine various expertise, instrumentation and materials to achieve a solution to the problem or achieve an improvement of current technologies. Interdisciplinary collaboration is a key to successfully solve complex problems and a true strength of the Mistra TerraClean consortium.

Materials with high and selective adsorption capacities are being produced. We demonstrated the first hybrid materials with embedded sensors, for instance, cellulose membranes with printed electronics, and materials with photocatalytic activity. We have conducted the first tests with a photovoltaic rig for capturing airborne contaminants, using NOx gas as a model compound. We have achieved some very promising results when applying a material device to capture PFAS compounds from a water solution. The first round of life cycle assessment was conducted and evaluated and we have a much better understanding of the chemistry of our material candidates from a sustainability and toxicology point of view. The LCA data is key in the selection of relevant materials and solutions which will proceed into the specific case studies.

ANY CHALLENGES THAT YOU HAVE ENCOUNTERED?

A continuous challenge for the program is to move from promising laboratory-scale trials to working products in larger scales. The volumes of polluted air or wastewater to be purified are considerably larger in a real industrial setting, and the controlled conditions prevailing at the lab never become the same in industry. We aim to put promising material and devices to the test in case studies set up at partner companies. We are currently working hard on identifying appropriate test sites and conditions and elaborate realistic and relevant test protocols.

WHAT IMPACT DO YOU THINK THE RESEARCH WITHIN THIS PROGRAMME WILL HAVE ON OUR SOCIETY?

Our materials may improve environmental conditions in Sweden: better air and water quality, and support the growth of Sweden's smart materials industry. The products that are developed have the potential to significantly improve current technologies and solutions, which would have a positive effect on competitiveness. We hope and believe that Mistra TerraClean will foster a long-term national hub capable of providing competence and expertise required to keep Sweden in the forefront with respect to research and enterprise in new materials for cleantech applications.

HOPES FOR 2020?

Our next challenge is to test selected materials on a larger scale and with real effluents under more authentic conditions. I hope that the first case studies at the partner companies will start soon. Within the Mistra Fellow programme (https://www.mistra.org/forskningsprogram/mistra-fellows-programme/), Mistra enabled Mistra TerraClean to send a partner for an internship at World Health Organization (WHO) in Geneva. Our fellow will work strategically with water policy issues. We hope that the Mistra Fellowship will bring our programme knowledge transfer, a strategic outlook, deeper insight in global water management policies and processes that govern the same, and a valuable network.

WORK PACKAGE 1
MATERIALS DEVELOPMENT AND STRUCTURING

In Mistra TerraClean WP1, materials are developed, with the following tasks:

1.1 Materials for removal of heavy metal ions

1.2 Synthesis of up-scaled surface modified mesoporous magnesium carbonate for pilot testing for water purification, including heavy metal/arsenic removal, and for gas purification

1.3 Surface modification of cellulose versions and hybrids with hemicellulose

1.4 Interactive filters based on wet-stable aerogels and foams to selectively remove metal ions and bacteria from water, and bacteria and other airborne particles, such as pollen and viruses, from air

1.5 Activated carbons and porous polymers derived from relevant biomass and waste. Refined hydrochars.

1.6 Biomass-derived activated carbons and porous polymers with magnetic features

1.7 Synthesis of zeotype materials suitable for biogas upgrading

Materials for removal of heavy metal ions, i. Materials for selective adsorption of heavy metal ions, ii. Modification of activated carbon for enhancement of capacitive device performance

Researchers at UU have tested mesoporous magnesium carbonate (MMC) for azo-dye adsorption. Also surface modified MMC. They found that modification can significantly enhance the performance of the sorbent. Uptake of Reactive black 5 and Amaranth on modified MMC was very high. Results published in ACS Omega 4 (2), 2973-2979. They also tested highly porous amorphous calcium carbonate with high specific surface area (as a precursor for CaO) for high temperature CO_2 sorption, and found that MMC (and the MgO that is obtained with calcination) can be used to enhance the cyclic stability of the CaO. Uptake amount is unaffected by the presence of MgO. Published in RSC advances 9 (35), 20273-20280. They have also tested MMC for heavy metal and pharmaceutical adsorption, performance on heavy metal is good but underwhelming for pharmaceuticals.

On the KTH side, the electrodes seem to have been modified now and the device is continued to be tested with respect to real implementation for water purification.

Synthesis of up-scaled surface modified mesoporous magnesium carbonate for pilot testing for water purification, including heavy metal/arsenic removal, and for gas purification

Disruptive Materials (DM) has worked a lot on production process optimization of Upsalite to improve process times and reduce cost-of-goods. Since 2017, more than 7 tons have been manufactured at two different CMO's in Germany. In addition, a lot of data has been compiled for the REACH application, and they now have approval to manufacture and sell up to 10 tons/year. Up-scaled post synthesis modification in kg scale will be carried out at DM's facility once the method has been verified in small-scale at Uppsala university. Up-scaled dye adsorption experiments will be planned afterwards. Up-scaled tests on adsorption of heavy metals from L scaled wastewater is to be carried out together with Uppsala university researchers.

Surface modification of cellulose versions and hybrids with hemicellulose

Work with the chemical modification, by polymer grafting, of cellulose nanocrystals (CNC) has been executed. By decorating CNC with zwitterionic polymers, it was developed a material with improved non-fouling and antibacterial properties. With the findings of this work, one manuscript is sent for submission. Furthermore, the knowledge has enabled further improvements in the ongoing project revolving about using zwitterionic polymer grafted CNC for the preparation of membranes with enhanced adsorption of metal ions as compared to other related membranes. One PhD student is involved in this task, who is supervised by Prof. Mathew at Stockholm University and Prof. Edlund at KTH. This student's main activities are within WP2.

Self-organized wet-stable nanocellulose functionalized aerogels

2019, started with a thorough literature study on the different techniques, which have been used to create novel and efficient materials for water purification. According to the previous works, which had been done on aerogels and the interesting results which had been achieved, we chose to work with the aerogels as the starting point. The main focus was to make shapeable wet stable aerogels based on CNF and to convert them into appropriate filtering materials by applying specific surface modification techniques.

A molecular layer by layer (m-LBL) technique was then chosen and applied to modify the CNF-based aerogels. By using different monomers in this technique, it is possible to tailor the surface with different functional groups and preparing a toolbox for removing different types of contaminants from water. We used trimesoyl chloride (TMC) and m-xylylenediamine (MXD) as the reacting monomers and significant changes in the properties of the aerogels were achieved and the aerogels turned from hydrophilic to hydrophobic which made them interesting for oil-water separation. Next step was to fully characterize both the deposited molecular layer on the surface and also the structure of the aerogels before and after modification.

The first step in characterizing our new material was to measure the thickness of each bilayer, which was deposited on the surface and estimating the accessible surface area of the aerogel according to the weight increment of the aerogels after each bilayer deposition. For this purpose, model cellulose surfaces on silicon wafers were prepared and coated with 5 and 10 bilayers and the thickness of the coated layers was measured via a scratching technique with AFM. Further characterization of the aerogel and the deposited layers are ongoing.

At the same time, different types of aerogels were fabricated trying to select the one that best fitted our demands. For instance, periodate oxidized freeze linked aerogels, ion linked aerogels and freeze-dried aerogels were tested. Eventually, aerogels which were freeze linked in the presence of Ca^{+2} ions were chosen. The reason for this choice was that these aerogels were the easiest to fabricate (no need for any chemical reaction and also very low energy consumption since they don´t need any freeze drying) but still having promising properties and totally wet stable after m-LBL modification.

To summarize, the focus in 2019 was to fabricate and characterize different type of aerogels, m-LBL modification of the aerogels with TMC and MXD, and eventually characterization of the deposited layer, which is still in progress.

Activated carbons and porous polymers derived from relevant biomass and waste. Refined hydrochars

The primary task has been to deliver on the preparation of activated carbons from waste milk and waste biomass. Milk is a product that is produced on an enormous scale and in Europe, 13% of the milk is wasted, and in North Africa and West and Central Asia, the value is 20%. It was possible to use the milk in a hydrothermal carbonization method to prepare hydrochars, which were subsequently refined into activated carbons by physical activation in a flow of CO_2. The activated carbons had properties that were proper for the removal of gaseous molecules in gas mixtures. For example, in the removal of CO_2 from N_2. One paper was published. Scientific Reports volume 9, Article number: 16956 (2019).

Another focus has been the activation of hydrochars derived from waste biomass, being critical in some countries. Activated carbons from hydrothermally carbonized prickly pear seed waste were prepared and a factorial design approach was applied to assure that as much hydrochar as possible could be prepared during the hydrothermal carbonization. One manuscript has been drafted and will be submitted during 2020.

Biomass-derived activated carbons and porous polymers with magnetic features

The details of iron impregnated activated carbons for the preparation of magnetically activated carbon for water purification applications has been revealed. A focus has been on the hydrochars, which has a golden-like luster. Under specific conditions, thin films are deposited on the assembly of hydrochar particles and give one side of the agglomerated particles a shiny luster, typically that is golden, but he has also observed other colors such as blue. Furthermore, the different effects of adding the iron as Fe^{2+}/Fe^{3+} or in the form of solid Fe-oxides have been studied. More time is needed however, to prepare a consistent manuscript, as the dependencies on the Fe-concentration and Fe-type are complex. Vahid works 100% in WP1.

Synthesis of zeotype materials suitable for biogas upgrading

From late 2019 and throughout most of 2020, Dr Hao will work in the programme at Stockholm University. He is a lecturer from Taiyuan University of Technology, China, and is funded 50% from his home university and by Mistra TerraClean and to some minor degree a Vinnova project. He is working on a project using the control of extra-framework cations in the archetypical zeolite A to select CO_2 over gases such as N_2 and CH_4, which is relevant for the upgrading of biogas. In specific, he has prepared a set of different zeolite A compositions with varying Na-to-K ratio that were prepared either by direct ion exchange from zeolite NaA or by a back-ion exchange from zeolite KA. He has observed some differences when it comes to gas separation tendencies for zeolites with identical compositions but prepared in these two different manners. The work is continuing and a manuscript will likely be submitted during late 2020.

Surface modification of cellulose versions and hybrids with hemicellulose

The research work in this task has involved the preparation, characterization, and functionalization of lignocellulose nanoparticles. Nanoparticles were extracted with high-pressure homogenization from the residue of a bioethanol pilot plant. The effects of residual lignin, the presence of zwitterionic grafts, or a combination of those features, were thoroughly investigated. The resulting materials were observed to have additional features other than the targeted adsorption of heavy metal ions. Non-fouling and anti-bacterial performance were recorded.

Bi-layered membranes were prepared with cellulose microfibers as support layer and the zwitterionic lignocellulose as the functional layer.

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WORK PACKAGE 2
SMART FILTER DESIGN AND VALIDATION

In Mistra TerraClean WP2, building devices utilizing the smartness of materials is a key activity, with the following tasks:

2.1 Sensory filter material and actuators development
2.2 Smart material filter design and manufacturing
2.3 Photocatalyst materials. Photocatalytic fuel cells
2.4 Validation of fluidics, mechanics and scalability
2.5 Benchmarking of filter material smartness
2.6 Active capacitive deionization device

Electrochemical sensors in filter devices

Electrochemical sensors were printed (RISE Bio- and Organic Electronics) onto filter membranes (MoRe Research) and these were placed in a device for testing filter performance (Stockholm University, Aji-lab).

Here, the aim is to build a sensor absorbent in the form of membranes, and to utilize electrochemistry to probe the state of health of the filter material. Electrochemical sensors were print-

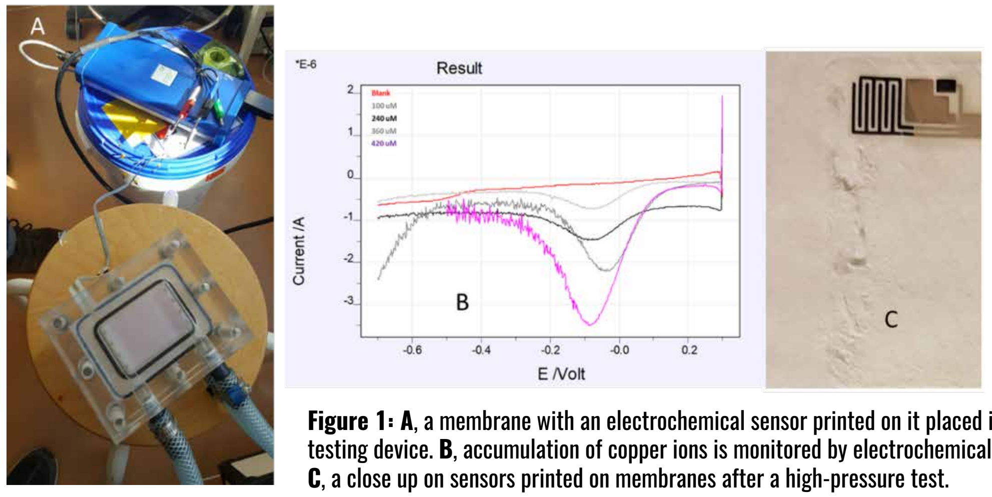
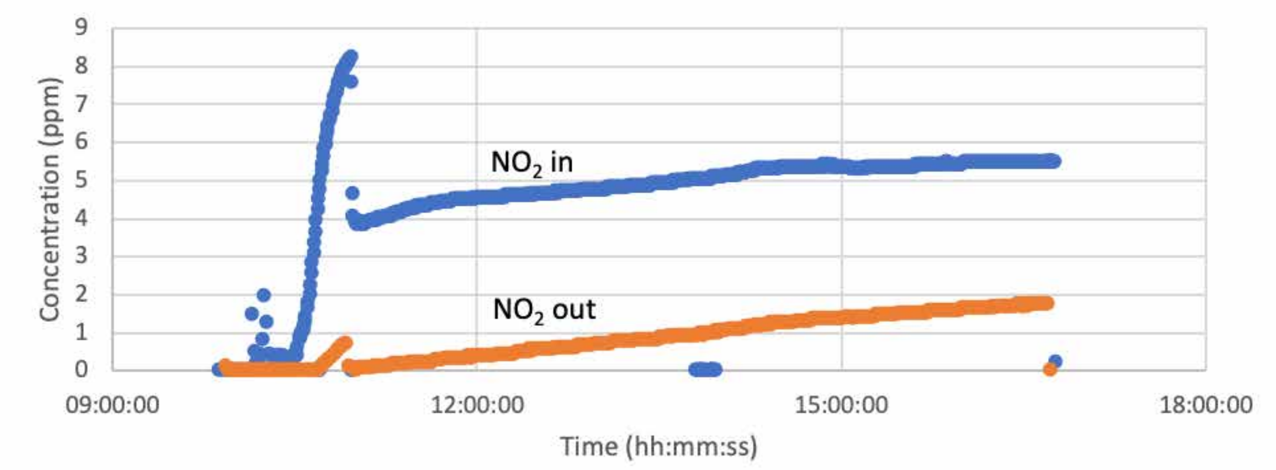


Figure 1: A, a membrane with an electrochemical sensor printed on it placed in a membrane testing device. **B**, accumulation of copper ions is monitored by electrochemical stripping methods. **C**, a close up on sensors printed on membranes after a high-pressure test.

Figure 2: NO_2 concentration in the inlet and outlet of the test rig. The UV lamp was turned on during the entire experiment.



ed onto membranes and these were mounted in a flow device and connected to an electrochemical reading station (Fig. 1A). Solutions of 100 mM KCl in the presence or absence of increasing concentrations of Cu were pumped, at different speeds (50 to 400 L/min) through the filter. To prove the possibility of using the printed sensor to detect analytes in the solution electrochemical detection of Cu in the flowed solution was attempted. As it can be seen from Fig. 1B, a clear electrochemical response was recorded when Cu was present in the solution. Fig 1C shows a sensor membrane after test with high pressure.

Photocatalytic remediation of NO_2 in a test rig

A test rig previously constructed (RISE Bio- and Organic Electronics) to evaluate photocatalytic sheets and coatings was used to evaluate a paper machine manufactured (RISE Bioeconomy and Health) ZnO-cellulose composite papers.

Two efficiency was evaluated at two concentration ranges. The first test performed (IVL) using a relatively high concentration of NO2 gas, aimed at 4 ppm. This represents air near a source of NO2 pollution. In a second experiment (Camfil), NO2 at a lower concentration, less than 100 ppb was evaluated. This is near the NO2 concentration ranges in heavily polluted places such as underground garages.

Tests with highly concentrated NO_2

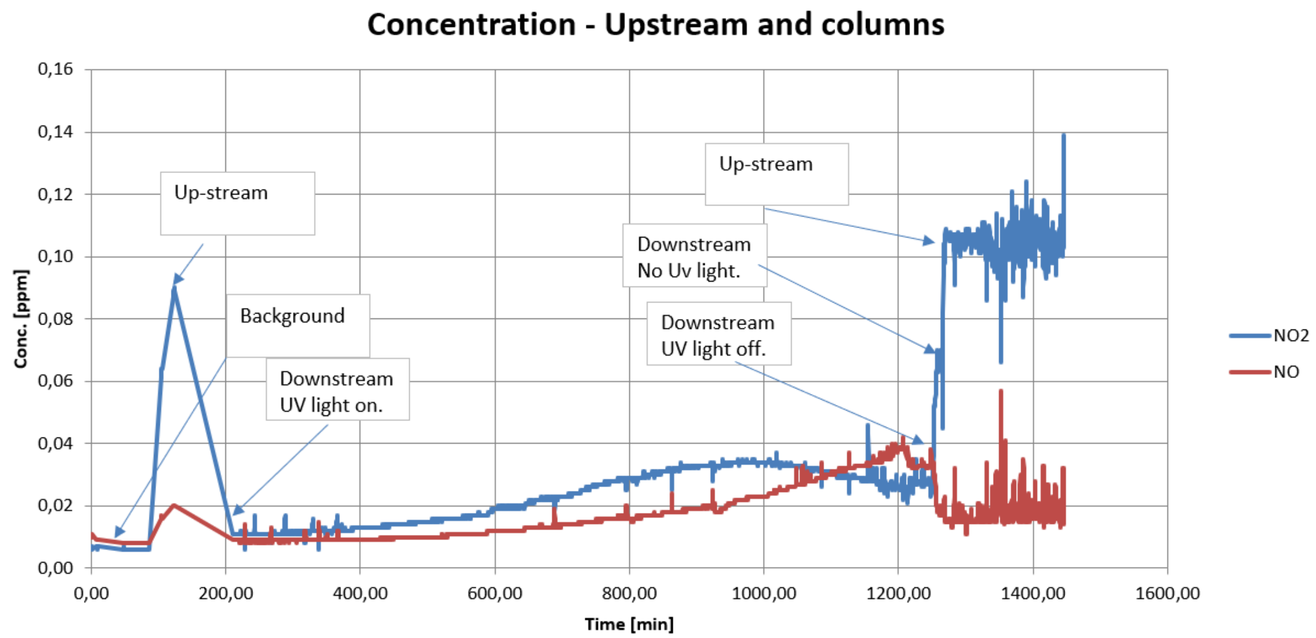
As seen in Fig. 2, the photocatalytic reactor removes 3 ppm NO2 from the inlet gas during the experiment.

Tests with low concentrated NO_2

The tests with NO2 abatement demonstrate the efficiency of the tested photocatalyst, as well as the utility of the test rig for this type of evaluation. The loss of efficiency after long running times, likely caused by nitrate saturation of the catalyst, and generation of NO, calls for further research and development of photocatalytic materials.

Figure 3: The test rig for photocatalysts at the labs of Camfil, Trosa.

Figure 4: The test rig for photocatalysts is fed with a mix of 90 ppb NO2 and 20 ppb NO. After the UV-aggregate is turned on concentration of both compounds decreases to circa 10 ppb



Capacitive Deionization

This was carried out in task 2.6 by KTH FNM and concerns deliverables 2.12 and 2.13.

An innovative capacitive deionization device which stores energy while cleaning ionic, microbial and other charged (and some uncharged) contaminants from water was designed, manufactured and tested by the KTH FNM group for various kinds of water samples and material modifications. Three different form factors were developed (Figure 5a-c) for testing purposes and based on fluid dynamics modelling results, the cylindrical architecture was used for further testing. The cylindrical CDI prototype was successfully applied for cleaning several kinds of ions of interest from three different mine effluents (Fig. 5d) and other wastewater samples supplied by IVL, which includes flue gas condensates. The prototype efficiently removed salts including heavy metals salts with low power consumption for all the samples tested. The prototype was also successfully applied for the removal of 10 different PFAS molecules from synthetic water (supplied by IVL), with more than 95% removal for all molecules: in effect reaching contaminant levels well below the required standards. The results (measured at IVL) indicated that in addition to electric field mediated removal, some PFAS molecules were also disintegrated by the process. This could be a route for permanently mitigating the PFAS issue.

In addition to the above, the FNM group successfully tested novel CDI electrode materials comprising of nanostructured Boron Nitride coated activated carbon cloth (carried out by RISE Bioscience and Materials) for high voltage CDI operation targeted at removing organic and other toxic pollutants (like pharmaceuticals) in water (Figure 1e). In another work, new boron nitride-based spacers integrated into microfibrillated cellulose (MFC) papers provided by RISE-Biosciences were evaluated for improving the capacitance and hence efficiency of ion removal in the CDI prototypes. The results showed some success with further efforts being put to get a better understanding of the effects.

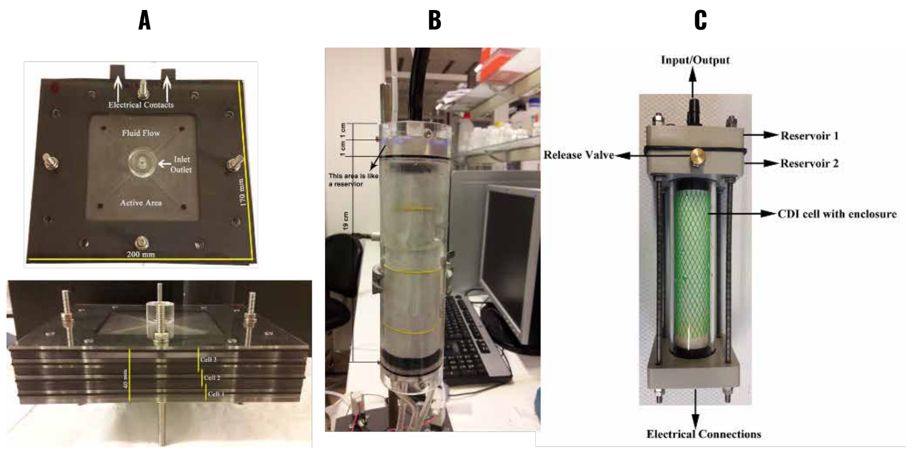
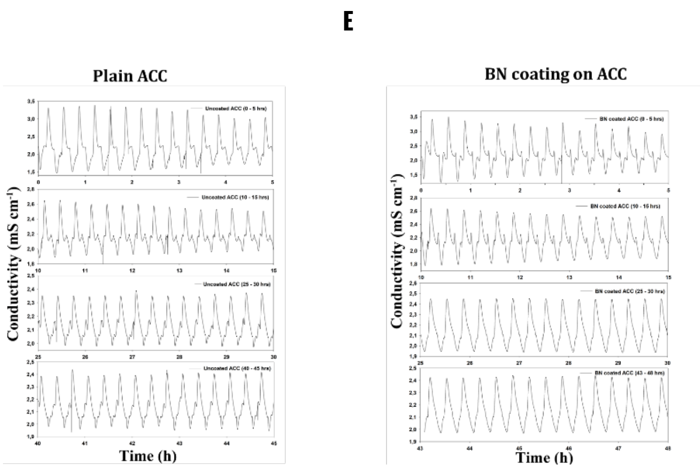


Figure 5: (a) Flat surface CDI unit with three series connected CDI cells; (b) Cylindrical CDI cell with same capacity as the flat surface cell; (c) Cylindrical CDI cell with input-output reservoirs for sensing elements; (d) result of one of the mine effluents after CDI treatment and (e) comparison of high voltage deionization results for boron nitride coated and plain ACC electrodes showing better integrity for BN coated ACC with time.

D

Mine Effluent – 0.73 kWh/m³

Ion Type	Initial Conc (ppm)	% Removed
Ca^{2+}	39	98
K^{+}	6	95
Na^{+}	15	89
Zn^{2+}	0,03	35
Cu^{2+}	0,002	69
Sb	0,001	12
As	0,004	59
Fl^{-}	0,8	68
NO_3^{-}	0,1	100
Br^{-}	-	-
Cl^{-}	5	98
SO_4^{2-}	30	100



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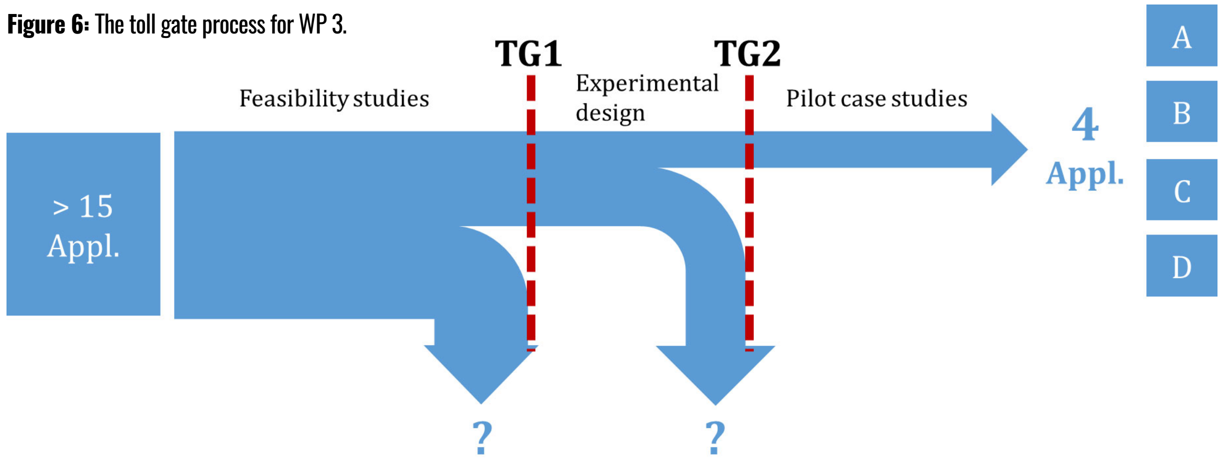
WORK PACKAGE 3
APPLICATION PLATFORM

Figure 6: The toll gate process for WP 3.



In Mistra TerraClean, WP3 is our application platform. After focusing on conducting basic experiments during the first two years of the project, focus shifted in 2019 to preparing for pilot scale experiments. To do so, a tollgate system was proposed (Figure 6).

The purpose of the process is to bring clarity to how and why different materials get the chance to become a subject for pilot studies. This is needed both internally among project partners as well as externally. The decision of when a technology is ready for any of the toll gates lies with the steering group. There are several criteria that needs to be fulfilled before an application is ready for any of the two toll gates. An attempt to formulate these can be seen below.

Toll gate 1

1. Basic chemistry works
   a. Function demonstrated in lab-scale test
   b. Sufficient material can be available for testing
   c. Equipment and method for application (WP2 matters) can be designed for tests.
2. Full scale application can be economically viable
   a. Upscaling is feasible and expected to reduce cost to reasonable level
   b. Upscaling is possible within a reasonable timeframe if the method is proven to be applicable for full scale implementation
3. The industry shows an interest in the effect a positive result would have
   a. Interest both from end user as well as supplier of material and equipment.

Material group	Material	Case A – Flue gas condensate		Case B – Gas		Case C – Mining effluents		Case D – Drinking water	
		Stat us	Comm	Status	Comm	Status	Comm	Status	Comm
MMC and porous carbonates									
	Upsalite			Planned/ongoing					
Cellulose hybrides (MFC/NFC)									
	Exilva	TG0				TG0			
Activated carbon and porous polymers				TG0	SO2				
	Granulated activated carbon	TG0							
	CDI	TG0				TG0		TG1	PFAS
	Biochar	TG0							
	SX100 (GAC)	TG0				TG0			
	Magnetic carbon	TG0							
Zeolites		TG0				TG0			
ZnO – photocatalysis				TG0	NO2				
Silicates				TG0	SO2				
	Aerogel w chelating agent	TG0				TG0			
	Aerogel	TG0				TG0			
Reverse osmosis		TG0							

4. The LCA has not pointed at any unsolvable environmental aspects

Toll gate 2

1. We are able to agree upon an experimental design that, when it has been performed, leaves little doubt about the performance of the technology in full scale
   a. Function demonstrated in pilot test
   b. Sufficient amount of material is available for testing
2. Equipment and method for application (WP2 matters) is designed for tests.
3. Full scale application estimated to be economically viable and competitive compared to other methods
   a. Agreement between supplier and user on test design and technical support
4. The cost of the experiment fits within the budget
5. The testing can be performed within the time frame of the project

Until today, the situation with respect to toll gates can be seen in the table below. One of the technologies have passed through TG1, but none has passes through TG2.

WORK PACKAGE 4
HUMAN AND ENVIRONMENTAL SAFETY, LIFE CYCLE ASSESSMENT, SCIENCE AND SOCIETY

In Mistra TerraClean, WP4 addresses and assesses human and environmental safety, Life Cycle Assessment, science and society, with the following tasks:

4.1 Toxicological appraisal of material production, application, post-consumer fate and management
4.2 Toxicological appraisal of material performance in individual case studies in WP3
4.3 Societal stakeholder interactions with the program
4.4 Long-term/post-program viability

A Life Cycle Assessment (LCA) describes environmental aspects and impacts throughout the whole life cycle of a product, i.e. raw material extraction, production, use and end-of-life management. In addition, knowledge about the function of the product is central for comparisons between materials.

When initiating the TerraClean project, it was decided to introduce LCA thinking into the workstreams of both novel chemical synthesis within WP1 and the WP2 device design processes. The aim is to ensure that the new materials and devices for water and air cleaning do not entail less benefit for environmental and human health than conventional solutions. This LCA "light", coupled with toxicological evaluation, will either reveal a lack of foreseeable issues, or where applicable, help to suggest alternatives to circumnavigate potential issues.

During 2019, WP4 has initiated the work with LCA screening of the filter materials and devices. The LCA and toxicological evaluations are based on collection of information and data from the projects. All chemistry and device groups in WPs 1 and 2 have been contacted and offered LCA screening. Most have agreed to this and screening has been performed. WP4 is currently producing material-specific reports covering life cycle analyses of the production, use and regeneration/discard processes as well as toxicological evaluation of process chemicals. These will be used to provide feedback to each group and a time-table for review of eventual consequences and impact on chemistry and device design developed. Individual meetings will be initiated during Q1 of 2020.

Plans are also in place to introduce a full LCA/Life Cycle Cost (LCC) analysis on one to two of the material(s)/device(s) deemed closest to commercialization (TRL5-6), by passage through the toll gate set up by WP3 for case study performance. Focus will be on chemically-modified materials from the initial LCA screen. WP4 also plans for overall risk assessments at a later stage. In such risk assessments, the decreased levels of contaminants resulting from use of the new filter materials and devices in the biosphere will be evaluated. Here the focus will be both on environmental impact and potential effects on human health.

In a parallel work stream, WP 4 has begun to interact with specific case studies in WP3. Initial efforts have focused on guidance in the development of the case concerning remediation of PFAS contaminated water. Planned work here includes input on setting standards for removal of PFAS and related compounds, with respect to optimizing impact on environmental sustainability and human exposure. Similar approaches will be applied to other developing case studies within the Mistra TerraClean portfolio.

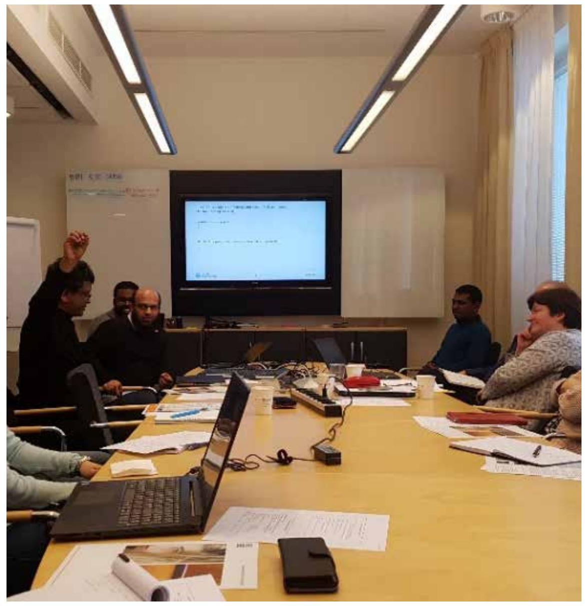
Finally, a key recruitment has been made within WP4, Francesco Bignami MSc, who has a background in urban water quality assessment, as well as application of LCA to this and other aspects of environmental risk assessment. Francesco will serve as dedicated liaison both within WP 4 and with other WPs in the program.

WORK PACKAGE 5
MANAGEMENT, IP HANDLING, AND COMMUNICATION

In Mistra TerraClean, WP5 handles management, IP handling, and communication. To increase the awareness among the program partners, we strive to arrange meetings and visits at different sites. Some of these are described below.

MISTRA TERRACLEAN ACADEMY / ACTIVITIES

Mistra TerraClean Academy is an initiative to give added value in terms of competence and insights in issues related to the program's overarching aim, to the team members. The goal is to organize a site visit in connection with the annual consortium meeting. Every work package is also invited to arrange a special workshop, for other team members to attend. With this initiative, the program will foster an open and learning environment.



March 18, 2019

WP2 meeting on surface chemical characterization techniques and site visit at RISE Surface, Process and Formulation, Stockholm

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May 7, 2019

Site visit to Hammarby Sjöstadsverk, IVLs experimental water treatment plant test bed

June 14, 2019

WP2 and WP3 joint Workshop, methodology and experimental set-up for capturing PFAS compounds in water, technical session at KTH in Kista

January 2020

The Royal Academy of Engineering Sciences, IVA, launched an ambitious project on sustainable water management and strategies in urban environments, aiming to map Swedish challenges, opportunities and elaborate an action plan for the future, https://www.iva.se/projekt/hallbar-vattenforsorjning/. Ulrica Edlund will serve as a working group member at IVA throughout this project and facilitate knowledge transfer to the consortium.

Annual Consortium meeting – September 11–12 Tekniska museet / National Museum of Science and Technology, Stockholm

At the meeting we discussed present findings and future goals for the Mistra TerraClean program. We also engaged in strategy discussions with the programme board, planning for Stage II application, problem-owner perspectives from partner companies, and work package discussions. Topics: Achievements and Challenges – Where are We Today? The Problem Owner Perspective – Where are We Heading, and Why? What are the major challenges?

December 5, 2019

Consortium workshop, planning for stage II, KTH

OUTREACH

OUTREACH ACTIVITIES

New companies have approached the program during the year, and at least two new industrial partners will join Mistra TerraClean, either directly or in the preparation of phase II. There are ongoing discussions with Tekniska Museet, National Museum of Science and Technology, on collaboration for more extensive outreach.

The program Mistra TerraClean has been selected to IVA´s "100 List" for 2020. The list aims to highlight researchers and research teams with high scientific quality and with interest in increased contacts with the business sector and surrounding society. The selection is not only based on scientific excellence but primarily on the research´s potential for business development, innovation and benefit for users, companies and society.

PUBLICATIONS

J. Yan, A. Karlsson, Z. Zou, D. Dai, U. Edlund, Contamination of heavy metals and metalloids in biomass and waste fuels - characteristics and trends, Sci. Total Environ. 2020, 700, 134382.

DOI:10.1016/j.scitotenv.2019.134382

J. Rostami, A.P. Mathew, U. Edlund, "Zwitterionic Acetylated Cellulose Nanofibrils", Molecules, 2019, 24(17), 3147.

DOI:10.3390/molecules24173147

V. Saadattalab et al, a mini review "Effects of Metal Ions, Metal, and Metal Oxide Particles on the Synthesis of Hydrochars", ACS Omega 10.1021/acsomega.9b03926, accepted.

D. Georgouvelas, B. Jalvo, L. Valencia, W. Papawassiliou, A.J. Pell, U. Edlund, A.P. Mathew, "Effect of residual lignin and zwitterionic polymer grafts on the non-fouling and antibacterial performance of cellulose nanocrystals", Manuscript sent to ACS Applied Polymer Materials journal, no DOI.

Laxman, K., D. Kimoto, A. Sahakyan and J. Dutta (2018). "Nanoparticulate Dielectric Overlayer for Enhanced Electric Fields in a Capacitive Deionization Device." ACS Applied Materials & Interfaces 10(6): 5941-5948, DOI: https://doi.org/10.1021/acsami.7b16540

Laxman, K., A. Husain, A. Nasser, M. Al Abri and J. Dutta (2019). "Tailoring the pressure drop and fluid distribution of a capacitive deionization device." Desalination 449: 111-117, DOI: https://doi.org/10.1016/j.desal.2018.10.021

Nordstrand, J. and J. Dutta (2019). "Dynamic Langmuir Model: A Simpler Approach to Modeling Capacitive Deionization." The Journal of Physical Chemistry C 123(26): 16479-16485, DOI: https://doi.org/10.1021/acs.jpcc.9b04198

Nordstrand, J., K. Laxman, M. T. Z. Myint and J. Dutta (2019). "An Easy-to-Use Tool for Modeling the Dynamics of Capacitive Deionization." The Journal of Physical Chemistry A 123(30): 6628-6634, DOI: https://doi.org/10.1021/acs.jpca.9b05503

Nordstrand, J. and J. Dutta (2020). "Simplified Prediction of Ion Removal in Capacitive Deionization of Multi-Ion Solutions." Langmuir 36(5): 1338-1344, DOI: https://doi.org/10.1021/acs.langmuir.9b03571

Master theses

Minchao Ann: Ion removal trends in capacitive deionization and its application for treating industrial effluents. Available from urn:nbn:se:kth:diva-266820

Siddharth Sahu: Optimizing methods and materials for maximizing energy recovery and energy generation in the Capacitive Double Layer Expansion cycle. Available from: urn:nbn:se:kth:diva-266819

Student reports

Algot Rickman: Validation of a novel water purification technology, urn:nbn:se:kth:diva-254795

(http://uu.diva-portal.org/smash/record.jsf?dswid=-8524&pid=diva2%3A1320928&c=1&searchType=SIMPLE&language=en&query=Laura+Pacoste&af=%5B%5D&aq=%5B%5B%5D%5D&aq2=%5B%5B%5D%5D&aqe=%5B%5D&noOfRows=50&sortOrder=author_sort_asc&sortOrder2=title_sort_asc&onlyFullText=false&sf=all

Conferences

D. Georgouvelas, B. Jalvo, U. Edlund, A.P. Mathew, "Modified lignocellulose nanoparticles for water treatment applications", European Polymer Congress, Crete, Greece, June 2019. Poster presenter: Dimitrios Georgouvelas

D. Georgouvelas, U. Edlund, A.P. Mathew, "Cellulose nanocrystals with zwitterionic polymer grafts - a material with enhanced antifouling and antibacterial properties", Conference on Nanotechnology for renewable materials (TAPPI), Helsinki, Finland, June 8-11, 2020.

V. Saadattalab, N. Hedin, "Hydrothermal carbonization of glucose in the presence of iron ions", 5th Green & Sustainable Chemistry Conference, Dresden, Germany, 8-11 November 2020. Accepted. Presenter: Vahid Saadattalab

Prof. Mathew and Prof. Edlund organized in collaboration with colleagues in Finland and Austria, a symposium on Cellulose and Renewable Materials for Gas, Air & Water/Liquid Purification. The symposium aimed to provide a forum for the dissemination of cutting-edge research on the utilization of lignocellulosic building blocks and their assemblies in the area of air/gas and water/liquid purification. The topics include approaches to construct innovative biobased materials solutions, e.g. with high selectivity and capacity, involving for example bottom-up construction of multifunctional materials from renewable resources for membrane and filter technologies, adsorption processes and as anti-fouling surfaces. Special emphasis is put on physicochemical aspects taking place in such systems as well as novel characterization methods needed to evidence the performance and to reveal the mechanisms. The symposium was arranged as part of the American Chemical Society (ACS) National Meeting, an annual event with 10-15000 delegates from all over the world. A number of contributions from Mistra TerraClean partners was planned as dissemination of programme results.

The symposium was scheduled for March 22-26, 2020, in Philadelphia, U.S.A. Due to the outbreak of Covid-19 virus, the conference was postponed.

U. Edlund, "Toward smart and safe engineered materials and devices for clean air and water", Abstracts of Papers, 259th ACS National Meeting, Philadelphia, PA, Unites States, March 2020, CELL

D. Georgouvelas, B. Jalvo, U. Edlund, A.P. Mathew, "Zwitterionic functionalized nanolignocellulose for removal of metalloids from industrial effluents", Abstracts of Papers, 259th ACS National Meeting, Philadelphia, PA, Unites States, March 2020, CELL

Z. Karim, D. Georgouvelas, A. Svedberg, A. Mathew, "Nanoscopically engineered microfibrillated cellulose composite membranes for removal of charged impurities", Abstracts of Papers, 259th ACS National Meeting, Philadelphia, PA, Unites States, March 2020, CELL

J. Yan, A. Karlsson, C. Nordenskjöld, U. Edlund, "Fuel Contamination in Renewable Energy Production – Demands of Materials Development for Sustainably Reducing of Emissions to Air, Water and Soils", Abstracts of Papers, 259th ACS National Meeting, Philadelphia, PA, Unites States, March 2020, CELL

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MISTRA TERRACLEAN ANNUAL REPORT 2019

FINANCIAL REPORT

Contribution from Mistra			
	INCOME		**12 564 637**
EXPENSES			
Personnel			7 312 763
Travel			105 737
Consumables			369 788
Depreciations			160 711
Other costs			404 986
Services			322 352
	DIRECT COSTS		**8 676 337**
Indirect costs incl. facilities			2 192 095
	TOTAL COSTS		**10 868 432**
	BALANCE		**2 819 025**
	PROGRAMME CONTRIBUTION	**IN-KIND**	**1 508 276**
In-kind part of total cost			14%

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