TBMCE2020

Book of Abstracts

3rd International Conference on Technologies & Business Models for Circular Economy

15 December 2020

"Naložbo sofinancirata Republika Slovenija in Evropska unija iz Evropskega sklada za regionalni razvoj"

"This investment is co-financed by the Republic of Slovenia and the European Union Fund for Regional Development"

About the Conference

The TBMCE (International Conference on Technologies and Business Models for Circular Economy) is devoted to presentations of circular economy concepts, technologies and methodologies that contribute to a shift of business entities and society as a whole towards a more responsible, circular management of resources.

Due to the COVID-19 pandemic, the TBMCE 2020 conference was held virtually on 15 December 2020. The conference program included panel discussions, plenary lecture, and oral and poster presentations on the following topics:

- Sustainable energy,
- Biomass and alternative raw materials,
- Circular business models,
- Secondary raw materials and functional materials,
- ICT in Circular Economy,
- Processes and technologies.

The TBMCE 2020 was organized by the Faculty of Chemistry and Chemical Engineering, University of Maribor. The event was under the patronage of the Ministry of Economic Development and Technology.

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Power-to-Solid Solution for High Efficiency Seasonal Grid Energy Storage

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Abstract: Currently, no feasible seasonal grid energy storage technology exists that would enable balancing of energy production and consumption over a long period, e.g. summer-to-winter compensation. The only solution today is a pump hydro storage, which requires some specific geographical conditions; mountains that provide the gravitational fall. Vast regions of the planet cannot provide it. For that reason, huge amounts of electricity surplus are wasted or curtailed to avoid grid destabilization. Globally speaking, the problem is not a shortage of energy; it is primarily one of energy storage. This is especially critical for electricity from renewable sources that are very intermittent. The problem is so acute that it is already slowing down the incorporation of more renewable energy into the grid.

Here we will present a completely new electric energy storage technology that can store the grid's energy in the oxidative-reductive potential of solid metal. It has the potential to store energy with a much higher density than the power-to-gas or power-to-liquid approaches.

This new storage technology will be able to capture all the surplus electrical energy, and then release it when required without any self-discharge. As such, it will have a massive impact on the management of electrical energy in the future. It is able to resolve the fundamental problems of current storage technologies because it exhibits a combination of unique characteristics such as: high energy density, a small land footprint for the new storage stations, no geographical constraints for the storage plants, no emission or waste due to a closed working cycle and no self-discharge during long-term storage.

Keywords: energy storage, electrolysis, hydrogen, electric grids, renewable energy.

Influence of Homogenization of Alkali-Activated Slurry on Mechanical Strength

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Abstract: ZAG national building institute* leads several projects dealing with upcycling of waste materials. Waste materials from different industries are used as precursors in alkali activation for different building and civil engineering products. Although alkali activated materials are not new, some of the parameters in the technological process are not yet fully understood and tested.

Therefore, the preparation of alkali-activated pastes by using a three-roll mill homogenization method was tested on several different waste materials: fly ash, fly ash with metakaolin, slag mixture (electric arc furnace slag and ladle slag), glass wool, waste green ceramics. All were activated with different alkali activators (NaOH, commercial sodium silicate solutions, laboratory-produced alkaline activators based on waste cathode-ray tube glass), treated with different curing regimes (60 °C and 70 °C) and different drying methods (drying at room temperature, drying at 105 °C). The only parameter that was in common with all experiments was homogenization procedure.

The viscosity of the slurry before homogenization was higher than after homogenization, the distribution of elements was more uniform and the compressive strength higher in all homogenized alkaline activated materials, regardless of other parameters.

Keywords: alkali activated material, secondary raw material, foaming, homogenization, mechanical strength.

Acknowledgement: Project No. C3330-17-529032 "Raziskovalci-2.0-ZAG-529032" was granted by Ministry of Education, Science and Sport of the Republic of Slovenia. The investment is co-financed by the Republic of Slovenia, Ministry of Education, Science and Sport and the European Regional Development Fund.

Electrocoagulation Implementation for Textile Wastewater Treatment Processes

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Abstract: Electrocoagulation (EC) has been employed recently to treat tannery, textile, and coloured wastewater. Three main processes are gathered in EC process, namely electrochemistry, coagulation, and flotation. This technique uses DC currents source between metal electrodes immersed in the textile effluent, which causes the dissolution of electrode plates into the effluent. The main advantage of EC compared to chemical coagulation technique is that EC generates less sludge. The objective of the present manuscript is to review the potential of electrocoagulation for the treatment of textile effluent. The most influential factors on removal efficiency, such as initial pH, time of EC, conductivity, current density, initial dye concentration and periodically reversal current on electrodes were discussed (Baner, 2019). Beside monomeric also polymeric species could form in dependence of pH, such as $Fe(H_2O)_6^{3+}$, $Fe(H_2O)_5(OH)^{2+}$, $Fe_2(H_2O)_8(OH)_2^{4+}$and $Fe(H_2O)_6(OH)_4^{4+}$(Hendaoui et al, 2018). This paper focuses on reviewing recent advances in electrocoagulation with the aim of identifying the current state of the technology and its potential as an effective textile wastewater treatment method. Industrial applications of electrocoagulation represent the major challenges to the textile sector. Considering the circular economy concept, which focuses on positive society-wide benefits, manufacturing brick or ceramic materials is feasible method for disposing sludge.

Keywords: electrocoagulation, textile effluent, metal removal, costs.

References:

1. Bener S., Bulca O., Palas B., Tekin G., Atalay S., Ersoz G., Electrocoagulation process for the treatment of real textile wastewater: Effect of operative conditions on the organic carbon removal and kinetic study, Process Safety and Environmental protection 129 (2019) 47-54.
2. Moussa D.T., M.H. El-Naas, M. Nasser, M.J. Al-Marri: A comprehensive review of electrocoagulation for water treatment: Potentials and chalanges, Journal of Environmental Management 186 (2017) 1, 24-41.
3. Hendaoui K., F.Ayari, I. BenRayana, R.BenAmar, F. Darragi, M. Trabelsi-Ayadi: Real indigo dyeing effluent decontamination using continuous electrocoagulation cell: Study and optimization using Response Surface Methodology, Proces Safety and Environmental Protection 116 (2018) 578-589.

Top-level Analysis of New Business Models to Support the Decarbonisation of Industrial Clusters

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Abstract: Recent climate change commitments have created the need for deep decarbonisation across all sectors of the economy. EII accounts for a third of annual greenhouse gas emissions and there have not been any deep decarbonisation solutions implemented for this transition. Literature also lacks research on how industry can decarbonise in a way that mitigates many of the challenges associated with decarbonisation. Industries have long existed in proximity in what is called an industrial cluster. These clusters benefit from collaboration in materials and resources through industrial symbiosis. This can be utilised for decarbonisation, in order maintain the competitiveness of the industrial products post decarbonisation. The decarbonisation pathways outlined in this work include fuel switching, CCS/CCUS and energy efficiency. For the case study, CCS and hydrogen were chosen as the main pathways.

Business model innovation (BMI) is an analytical tool that defines the competitive strategy of a business and has played a key role in increasing the uptake of a new technology. This work aims to develop two methodologies: to create novel BMIs for the decarbonisation of industrial clusters and to qualify and quantify the impact of these novel business models. The BMIs would be qualified by defining their value proposition, value creation and delivery and value capture, in addition to analysing their strengths, weaknesses, opportunities and threats. The BMIs will be quantified financially to assess their impacts.

This work presents 10 novel BMI for the decarbonisation of industrial clusters: industrial decarbonisation pooling, open industrial decarbonisation model, industrial decarbonisation as a service, industrial decarbonisation system orchestrator, peer-to-peer industrial decarbonisation model, cluster/provider-side industrial decarbonisation model, industrial low carbon technology leasing, sustainable industrial low carbon equipment, decarbonisation advocating cluster and low carbon industrial equipment refurbishment. These BMIs models were also quantified using the developed methodology both qualitatively (through financial equations) and

quantitatively (through SWOT analysis). The models were applied to a case study for the Merseyside cluster in the UK.

The study concludes that whilst some BMI may be the best financially, they may have limitations logistically which do not make them the most appropriate. It also finds that through BMI, many savings may be harnessed, which makes existing technologies uncompetitive in future decarbonised markets. This iterates the important of both methods of quantification. Industrial decarbonisation through BMI is a huge research topic that is yet to be explored, and this research will hopefully initiate many more works in the future.

Keywords: Business model innovation, Industrial decarbonisation, Net zero, Climate targets.

Circular Economy in the Food Industry

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Abstract: Food is one of the three main pillars of the water-energy-food (WEF) nexus. The links among the three are responsible for the sustainability of society. While this nexus is a current trend analyzed and implemented in the chemical and power industries [1] food production companies are product oriented [2,3] that do not typically work as chemical complexes. However, total site integration [4] is an example from the chemical industry that can bring benefits allowing energy savings, improving the sustainability and the economics of the facility. By integrating the residues, it is possible not only to produce added value chemicals, but also to reduce the consumption of utilities while managing and valorizing the waste generated in their operation. By reusing the waste, the principles of circular economy are implemented within the food industry.

To illustrate the possibilities of circular economy on the food industry a methodology is developed for the identification of the portfolio of products, based on the development of key performance indexes, KPI, (i.e. economic, process operation and energy, process safety). Next, the process is design following a hybrid heuristic-mathematical optimization approach. After a prescreening of the technologies, a mathematical optimization approach is used to formulate a superstructure. Three representative cases of European interest products are shown such as the oranges [5], the olive oil [6] and the coffee [7] are presented to show the possibilities of obtaining high added value products such as essential oils, antioxidants, extracts and dyes was well as providing a fraction of the power and thermal energy required non only for the section of the facility but to the entire integrated process.

Keywords: circular economy, Process Integration, Food industry, igh added value products.

Acknowledgement: The authors acknowledge the funding received from the European Union's Horizon 2020 research and innovation programme IPropBio, under the Marie Sklodowska-Curie grant agreement No 778168

References:

1. Bauer, D.; Philbrick, M.; Vallario, B. U.S. Department of Energy. The Water-Energy Nexus: Challenges and Opportunities. 2014
2. Fito, P.; LeMaguer, M.; Betoret, N.; Fito, P.J. Advanced food process engineering to model real foods and processes: The "SAFES" methodology. J Food. Eng. 2007, 83 (2), 173-185

3. Schanes, K.; Doberning, K., Gözet, B. Food waste matters. A systematic review of household food waste practices and their policy implications. J Clean Prod. 2018, 182, 978-991.
4. Liew, P.Y., Theo, W.L., Wan Alwi, S.R., Lim, J.S., Manam Z.A., Klemes, J.J., Varbanov, P.S. (2017) Total Site Heat Integration planning and design for industrial, urban and renewable systems. Renew. Sust. Energy. Revs. 68 (2) 964-985
5. Criado, A., Martín, M (2020) Integrated multiproduct facility for the production of chemicals, food and utilities from oranges. Ind. Eng. Chem. Res. 59, 16, 7722-7731
6. Lidia Sánchez, Manuel Taifouris, Debalina Serangupta Marcos Corazza and Mariano Martín, Mahmoud El-Halwagi, Methodology for the design of multiproduct facilities: Case of the olive tree 14th Mediterranean Congress of Chemical Engineering. Virtual Conference 16-20 Nov https://doi.org/10.48158/MeCCE-14.DG.06.04.
7. Manuel Taifouris, Arantza Criado1, Marcos Corazza and Mariano Martín, Integrated Food Facilities: Circular Economy Applied to the Food Industry AIChe Annual Meeting. Virtual 14-20 Nov 2020 Oral Presentation

Towards Integrated BIM Based Circular Construction Workflow

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Abstract: In this research paper we summarize an inductive case study of construction project where SRM-based building materials are being utilized, to construct a small facility. In the first theoretically oriented part of the study, we present the economic opportunities arising from the introduction of recycled materials in construction sector. Furthermore, our work includes a case study of building information modelling (BIM) of a small facility where recycled construction and demolition waste is being used as a substitute for natural aggregate to produce more sustainable green concrete. The topic of sustainable construction is addressed in a multidisciplinary manner, namely from the economic, organizational, environmental and engineering perspective. We analyze the challenges and opportunities of BIM, when used to model a circular construction project. Our assessments suggest that the benefits of using information solutions outweigh the burden of the challenges we inevitably face when changing well established work practices.

Keywords: circular economy, construction, BIM, digitalization.

The Influence of Different Fibres Quantity on Mechanical and Microstructural Properties of Alkali-Activated Foams

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Abstract: Alkali activated foams (AAFs) present a promising material to be used as an insulating material in the building and construction area. They are produced from different aluminosilicate sources (i.e. slags, fly-ashes, calcined clays) mixed with alkali activator and foaming agent (such as H_2O_2, metal powder) [1]. The resulting hardened structure contains air voids and is thus very fragile, therefore the additional stabilization of the structure by the addition of different types of fibers represents one possible way to its mechanical properties improvement [2].

In this study, electric arc furnace steel slag (EAF) and ladle furnace basic slag (LS), obtained from two metallurgical companies in Slovenia, were activated with the mixture of 31.5 mass % of Na_2SiO_3 and 0.5 mass % of solid NaOH and foamed with 2.5 mass % of H_2O_2. Pores were stabilized with the addition of 1.5 mass % of Triton (T) as a surfactant. Four types of fibres were separately added to the studied mixtures (polypropylene (PP), polyvinyl-alcohol (PVA), basalt (B), and glass wool (GW)) in five different quantities: 0.5, 1.0, 1.25, 1.5 and 2.0 vol %. The results of mechanical properties showed, that compressive strength was increased in all 20 specimens, partially due to the increased density as well as to the fiber addition. Flexural strength on the other hand was the most improved in the samples where PP and PVA fibres were added. The samples with the addition of B and GW fibres showed only small or no improvement in flexural strength in comparison to the referenced sample (specimen with no added fibres). Additionally, the microstructure of used fibres and selected foams was also investigated by the means of SEM and EDS analysis.

Keywords: alkali activated material, microstructural analysis, mechanical strength, slag.

Acknowledgment: Development of AAFs is part of the ERA-MIN FLOW project which has been financed by the Ministry of education, science, and sport (acronym: MIZS) under grant agreement No. C 3330-18-252010.

References:

1. V. Ducman and L. Korat: "Characterization of geopolymer fly-ash based foams obtained with the addition of Al powder or H_2O_2 as foaming agents" *Materials Characterization*, vol. 113, pp. 207-213, (2016), doi: 10.1016/j.matchar.2016.01.019.

2. M. Mastali, P. Kinnunen, H. Isomoisio, M. Karhu, and M. Illikainen: "Mechanical and acoustic properties of fiber-reinforced alkali-activated slag foam concretes containing lightweight structural aggregates" *Construction and Building Materials*, vol. 187, pp. 371-381, (2018) doi: 10.1016/j.conbuildmat.2018.07.228.

Fibre Reinforced Alkali Activated Rock Wool

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Abstract: Mineral wool, i.e. rock and glass wool, represents considerable challenge after its functional-time runs out due to its small density leading to large volume consumption during transport and in landfills where it usually ends. Rock wool chemically consists mostly of Si (almost 20 m%), Al (almost 10 m%), a smaller amount of elements from 1st group (less than 2 m%) and a considerable amount of elements from 2nd group (almost 20 m%). Mineralogically almost whole material is in the amorphous phase. Therefore, chemically and mineralogically rock wool represents a promising material to be used as a precursor in alkali activation for building and civil engineering industry. In this way, the waste material from the building industry is upcycled into a product with added value that could be returned into the building industry.

Mineral wool, no matter from which minerals is made, consists of few centimetres to few decimeters long fibres, which are milled to the powder form to be used in alkali activation as the precursor. Alkali activated materials with fibres generally show an increase in mechanical strength, especially the bending strength. To reach even higher strength several other fibres were used as additives to the rock wool's micron-sized fibres, i.e.: steel, cellulose (2 types), basalt, polypropylene and polyvinyl alcohol fibres. All prepared alkali slurries were curred at 40 °C for 3 days. Time dependence of their mechanical strengths was followed. Maximal increase of compressive and bending strength after 28 days was reached with polypropylene fibres, i.e. it was 20% and 30% higher than compressive and bending strength of alkali activated material without additional fibres respectively.

Keywords: alkali activated material, mechanical strength, waste mineral wool, fibre, upcycling.

Acknowledgement: Project No. C3330-17-529032 "Raziskovalci-2.0-ZAG-529032" was granted by Ministry of Education, Science and Sport of the Republic of Slovenia. The investment is co-financed by the Republic of Slovenia, Ministry of Education, Science and Sport and the European Regional Development Fund.

Waste Trading for Recovery in the Circular Economy Transition

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Introduction: Circular Economy has been a highly discussed model for recent system design (Hopkinson et al., 2020), aiming at eliminating waste and continual usage of resources. It prioritises Redesign/Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose and Recycle, where waste is viewed as a post-consumer product, whenever Refrain is not possible. Recover, and Re-mine (Reike et al., 2018) are the least preferable approaches. The building of new waste treatment plants has not been closely following the Circular Economy hierarchy, and the incurred cost and social acceptance have been challenging. Waste trading, under an appropriate and mutually agreed strategy can provide a complementary solution in the Circular Economy transition. As in the transition period, waste can yet be reduced significantly, but waste needs to be diverted from landfill. This study overviews the pros and cons of waste trading and proposes a potential waste trading design. An extended Pinch Analysis-based targeting method is proposed and applied to a case study amongst Central Europe.

Methods: The method proposed is an extension of PA into Waste Trading Pinch Analysis (Fan et al., 2020). The main adaptions of the PA in this study are the application purpose, the definition of the amount and the constraint, which is insignificant in the case of carbon emission capture and storage. The waste amount (horizontal axis) of this study represents the waste amount needed to be treated, and the waste amount can be treated in the waste treatment facilities. The purpose is to facilitate waste trading within the countries and internationally. The constraint of such allocation is that the available waste treatment capacity cannot be brought forward to the other time (month), and the waste cannot be stored for a long duration. The proposed Pinch Analysis based method in targeting prior to explicit waste trading design has been demonstrated through a case study of Austria (AT), the Czech Republic (CZ), Denmark (DE), Poland (PL) and Slovakia (SK). The problem is decomposed into separated stages for better insights and analytics for optimisation.

Results: The pessimistic estimation indicated that the GHG emission of 1 t waste is reduced by 20 kg – 30 kg compared to the baseline scenario. To prevent pollution

haven and to consider the economic feasibility, the landfill fees have to be increased significantly. A significant increment in the landfill taxes or gate fees is needed to encourage environmentally friendly waste trading. The minimum for AT, CZ, PL, SK in the assessed condition are 155.42 €/t, 92.60 €/t, 184.66 €/t and 197.87€ /t.

Conclusions: The graphical nature of the proposed method could facilitate communication with the final decision-makers. The decomposed problem is easier to understand where the targets (theoretical limit) are identified for the following optimisation. In future work, the potential pitfall of taxation should be further assessed. Social behaviour analysis could be useful in prediction to improve the practicability of the waste trading design.

Keywords: circular economy, waste management, Landfill Fees, extended Pinch Analysis.

Acknowledgement: The financial support from the EU supported project Sustainable Process Integration Laboratory – SPIL funded as project No. CZ.02.1.01/0.0/0.0/15_003/0000456, by Czech Republic Operational Programme Research and Development, Education, Priority 1: Strengthening capacity for quality research

References:

1. Fan, Y.V, Jiang, P., Klemeš, J. J., Liew, P. Y., Lee, C. T. (2020). Integrated regional waste management to minimise the environmental footprints in circular economy transition. Resources, Conservation and Recycling, 105292.
2. Hopkinson, P., De Angelis, R., Zils, M. (2020). Systemic building blocks for creating and capturing value from circular economy. Resources, Conservation and Recycling, 155, 104672.
3. Ooi, R. E., Foo, D. C., Ng, D. K., Tan, R. R. (2013). Planning of carbon capture and storage with pinch analysis techniques. Chemical Engineering Research and Design, 91(12), 2721-2731.
4. Reike, D., Vermeulen, W. J., Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resources, Conservation and Recycling, 135, 246-264.

Maximizing Net Present Value of Solar Heat Network for Low Temperature Industrial Operations

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Abstract: The world is currently significantly dependent on fossil energy sources (Al-Mansour, 2011). In industries, fossil fuels used for process heat and electricity are currently large contributors to greenhouse gas (GHG) emissions (Mahmoud and Sunarso, 2018). Industrial sector represents a significant part of the global energy consumption and has considerable contribution to global GHG emissions. Energy efficiency and switching to renewable fuels are thus essential to achieve better environmental quality, sustainability, and a more lasting solution to the global threat of climate change. Solar energy is a type of renewable energy that could potentially offset a significant amount of energy from conventional fossil fuels (IPCC, 2018).

This study extends the work of a synthesis of solar heat network for low temperature industrial operations (Abikoye et al., 2019) to assess economic viability of such a network and to account for both spatial and temporal variations. Economic viability of solar thermal is evaluated based on the net present value across an entire solar network's lifetime. The multi-period Mixed Integer Non-Linear Programming (MINLP) model is applied to an industrial case study of a dairy plant (Atkins et al., 2010) for the three different locations. Sensitivity analysis is further performed based on collector's area and heat requirements of industrial process stream(s), and the results are compared with those obtained when maximizing the attainable quantity of solar heat.

Keywords: Solar thermal, industry, low temperature operations, multi period optimization, net present value.

Acknowledgments: The authors wish to acknowledge the support from the Slovenian Research Agency (research core funding No. P2-0412 and project N2-0138).

References:

1. B. Abikoye, L. Čuček, A. J. Isafiade, Z. Kravanja, 2019, Integrated design for direct and indirect solar thermal utilization in low temperature industrial operations, Energy, 182, 381-396 F.
2. Al-Mansour, 2011, Energy efficiency trends and policy in Slovenia, Energy, 36, 4, 1868-1877 M. J. Atkins, M. R. W. Walmsley, A. S. Morrison, 2010, Integration of solar thermal for improved energy efficiency in low-temperature-pinch industrial processes, Energy, 35, 5, 1867-1873 IPCC, Intergovernmental

3. Panel on Climate Change. Special Report, (2018), https://www.ipcc.ch/report/sixth-assessment-report-cycle/, (27.11.2020). A. Mahmoud, J. Sunarso, 2018, A new graphical method to target carbon dioxide emission reductions by simultaneously aligning fuel switching, energy saving, investment cost, carbon credit, and payback time, International Journal of Energy Research, 42, 4, 1551-1562

Cascade Table Analysis for Targeting and Design of Material Resource Recycling and Reuse Networks featuring Multiple Contaminants

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Introduction: Chemical Engineering and Process Integration have complemented each other in identifying resource conservation solutions for process waste minimisation and reduction of environmental impacts and implementing Circular Economy principles. In the field of water and wastewater minimisation, Process Integration methods for single-contaminant problems have been proposed having Pinch-based targeting and design phases. However, the power of Pinch Analysis is not well applied to multi-contaminant resource recycling problems, due to issues with formulating an efficient problem encoding.

Methods: The Water Cascade Table and water Pinch with graphical visualisation used for targeting and designing single contaminant material recycling networks are evolved to handle multiple constraints. Based on previous analysis, multiple cascades with individual contaminant/quality indicators are analysed sequentially. Each contaminant is assigned a cascade table. Each sink is classified into the proper contaminant cascade based on their limiting contaminant, and the sources are prioritised based on the contaminant. This work also proposes a new way of arranging the streams in the Cascade Table to adapt for the multiple contaminants, which is by determining whether they belong to the high quality (Below the Pinch) region and the probable Pinch-causing source. The overall framework is to first identify a preliminary resource target for each sink, then to follow certain heuristics for further reduction of the fresh resource.

Results: The proposed method is validated with two illustrative examples and one real case study from a Brazilian pulp and paper industry. The obtained freshwater targets for the illustrative examples agree well with the literature. The freshwater requirement results for 2,822 kg/h for the Brazilian paper mill. The result obtained agrees with the solution from previous work.

Conclusion: The Cascade Table Analysis or the graphical representations provide a step-by-step procedure for multiple contaminants material network design and provides a user-friendly interface to the solutions. This is beneficial for engineers as the method shows the exact allocation of each source for each sink

Keywords: Process Integration, Enhanced Material Cascade Table Analysis, Multi-contaminant Water Pinch Analysis, Material Recycle/Reuse, Water Network Design.

Acknowledgement: The EU supported project Sustainable Process Integration Laboratory—SPIL funded as project No. CZ.02.1.01/0.0/0.0/15_003/0000456, by Czech Republic Operational Programme Research and Development, Education, Priority 1: Strengthening capacity for quality research, based on the SPIL project, is gratefully acknowledged under a collaboration agreement with the Universiti Technology Malaysia.

Water Based Electrochromic Devices as Low-Cost Multi-Color Screens

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Abstract: Electronic paper devices also known as electrochromic devices are known for their ability to change color with option to remain in certain color state even after the electrical power has been lifted. Traditional devices such as electrochromic windows used mechanisms like electrophoresis or intercalation and use special materials such as water-less electrolyte, and transparent conductive materials (TCM). As such, these devices can sometimes be relatively difficult to assemble, especially in developing countries, where such materials are harder to come by. Recently, certain improvements have been made by using alternative electrode positioning, that they do not require TCM. Presented here is a novel type of electronic paper that is recyclable, can be constructed as a monochrome or multi-color device and can be scaled accordingly to desired screen size. Presented electronic paper, is a semi-open electrochemical device, which uses pH indicator dyes and water-salt solution, combined with easily obtained sheet steel.

Keywords: pH indicator, electronic paper, stainless steel, alternative electrode positioning.

Use of Recycled Plastic Waste in Concrete

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Abstract: The increase in plastics consumption over the last decades has contributed to an increasing amount of plastic waste being deposited in landfills and in natural environments such as the oceans. The production of new materials from recycled plastics appears to be one of the best solutions for the management of plastic waste. The aim of this paper is to investigate the adequacy of using various recycled plastic wastes in cementitious composites. Concrete is the most widely used material and is available at low cost. The main raw materials consist of cement, water and aggregates. Approximately 65-80 % of the concrete volume is taken up by aggregates, which strongly influence the general workability, durability, permeability and strength of concrete. The use of recycled plastics as fine aggregates can eliminate large amount of waste material and at the same time solve problems related to aggregate mining, waste disposal and lack of natural aggregates on construction sites (Almeshal et al., 2020). The use of a lightweight plastic aggregate as an alternative to natural aggregates reduces the weight of concrete and offers many advantages, such as lower costs, enhanced thermal insulation performance, and better handling (Záleská et al., 2018). However, the inclusion of plastic in concrete does not effectively improve the mechanical properties of concrete. The strength of concrete should be balanced with reactive materials such as silica fume, metakaolin and iron slag to create an additional pozzolanic reaction (Sharma and Bansal, 2016). To make recycled plastic waste in concrete more attracted and accepted by the construction industry, future studies should focus on the economics, social acceptance, material properties such as: composite strength, triaxial failure, abrasion and impact resistance, rheological properties, thixotropy behavior, durability properties such as sulfate resistance and general long-term resistance to environmental influences. The results of this paper show that the use of recyclable plastics in concrete leads to more sustainable building materials in the construction industry.

Keywords: recycling plastic, concrete, physical properties, mechanical properties, durability.

References:

1. Almeshal, I., Tayeh, B.A., Alyousef, R., Alabduljabbar, H., Mohamed, A.M., Alaskar, A., 2020. Use of recycled plastic as fine aggregate in cementitious composites: A review. Construction and Building Materials 253, 119146.
2. Sharma, R., Bansal, P.P., 2016. Use of different forms of waste plastic in concrete–a review. Journal of Cleaner Production 112, 473-482.

3. Záleská, M., Pavlikova, M., Pokorný, J., Jankovský, O., Pavlík, Z., Černý, R., 2018. Structural, mechanical and hygrothermal properties of lightweight concrete based on the application of waste plastics. Construction and Building Materials 180, 1-11.

Anaerobic Co-digestion of Sewage Sludge and Wine Production By-products

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Abstract: Since sludge production in Europe is increasing as a result of more stringent requirements for water treatment, there is an increasing pressure to find appropriate treatment and disposal methods for this waste (Cieślik et al., 2015). Sewage sludge could be used for solid fuel and agriculture purposes, but also it is known as a promising source for biogas production in anaerobic digestion process. However, because sewage sludge has a low C/N ratio, it should be co-digested with other carbon rich organic substrate to increase the C/N ratio and improve biogas yield (Awe et al., 2018). The most sustainable co-substrates are industrial and agricultural residues and waste. For example, the grape pomace, a by-product from wine production has shown quite good performance in biogas mono-digestion studies due to high cellulose and hemicellulose content (Da Ros et al., 2016). Another potential candidate is grape seeds press cake, which is a by-product from grape seeds after oil extraction. The literature review showed that studies on mono-digestion of grape by-products and their co-digestion with sewage sludge are rare. To the best of authors knowledge, grape seeds biogas potential has not been studied yet.

The aim of this study was to investigate co-digestion potential of sewage sludge and two by-products from wine production, grape pomace and grape seeds press cake (both from red grapes) for biogas production. In addition, mono-digestion performance of each of these substrates was tested for the comparison. The anaerobic digestion experiments were performed with sewage sludge from a biological municipal wastewater treatment plant with a capacity of 68,000 PE. Grape pomace was gathered during grape harvesting in the Štajerska wine region and grape seeds press cake was obtained after the oil extraction. The anaerobic digestion studies were conducted under mesophilic conditions (42 °C) in 250 mL batch reactors, with a retention time of 40 days. Inoculum for the digestion was obtained from a biogas plant mainly using poultry manure. Besides, cattle rumen fluid was added to digestate mixtures to enhance fermentation, especially of lignocellulosic materials (Xing et al., 2020). Before anaerobic digestion experiments, basic characteristics of substrates such as total carbon (TC) and nitrogen contents (TN), C/N ratio and dry matter content were determined. Several parameters were measured in the digestates during anaerobic digestion: total organic carbon (TOC), chemical oxygen demand (COD), NH4-N and PO4-P contents, pH value and other. The volume of biogas produced was

measured by a water displacement method, while the composition of biogas was measured with a gas analyzer Optima7 Biogas.

The results of research showed that co-digestion of sewage sludge and grape pomace significantly enhanced biogas production, while less biogas was produced by co-digestion with grape seeds press cake. Similarly, grape pomace showed the best performance among the substrates tested in the case of mono-digestion studies, and biogas production was the lowest using grape seeds press cake, lower than in the case of sewage sludge mono-digestion.

Keywords: Sewage sludge, anaerobic co-digestion, rumen fluid, grape pomace, grape seeds press cake.

References:

1. Awe, O.W., Zhao, Y., Nzihou, A., Minh, D.P., Lyczko, N. 2018. Anaerobic co-digestion of food waste and FOG with sewage sludge – realising its potential in Ireland. International Journal of Environmental Studies, 75 (3), 496 - 517.
2. Cieślik, B.M., Namieśnik, J., Konieczka, P. 2015. Review of sewage sludge management: standards, regulations and analytical methods. Journal of Cleaner Production, 90, 1-15.
3. Da Ros, C., Cavinato, C., Bolzonella, D., Pavan, P. 2016. Renewable energy from thermophilic anaerobic digestion of winery residue: Preliminary evidence from batch and continuous lab-scale trials. Biomass and Bioenergy, 91, 150-159.
4. Xing, B.-S., Han, Y., Wang, X.C., Wen, J., Cao, S., Zhang, K., Li, Q., Yuan, H. 2020. Persistent action of cow rumen microorganisms in enhancing biodegradation of wheat straw by rumen fermentation. Science of The Total Environment, 715, 136529.

Development and Assessment of Alkali Activated Paving Blocks

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Abstract: Great attention has been placed over the last years by the building sector on the alkali-activated technology. Most of the solutions so far are based on well-known precursors, like metakaolin, fly ash and ground granulated blast furnace slag (GGBFS), but emerging and promising alternative precursors do exist; one example is the by-products from non-ferrous metallurgy, such as copper slags and vitrified bauxite residue. Considering this, the focus of the present work lies on the development of alternative alkali-activated binders from such non-ferrous metallurgy slags. Two slags, one from primary and one from secondary copper production were finely milled, blended with GGBFS and activated with K-based alkali silicate solution of 1.7 SiO2/K2O molar ratio and 65 wt% water content. The aggregates to paste mass ratio was kept at 2. The resulted mortars were cast in a mould and cured for the designated time at RT and 60% RH. The developed paving blocks were then tested regarding their intended use, following the provisions of standard EN 1338: Concrete paving blocks - Requirements and test methods. The following have been measured: splitting tensile strength, abrasion resistance, slip and skid resistance, resistance to freeze-thaw, resistance to freeze-thaw in the presence of de-icing salts, chemical resistance,... The results were compared with commercially available concrete pavers and it was confirmed that the performance of the alkali-activated pavers was comparable and for certain properties notably better than those of the concrete pavers.

Keywords: waste management, alkali activated material, recycling, slag.

Acknowledgement: "This activity has received funding from EIT RawMaterials, a Knowledge and Innovation Community (KIC) of the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. Project Agreement No. 16365 (RECOVER), project website: https://recover.technology."

From Plastic Debris in the Ocean to Sustainable Solutions

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Abstract: The global annual production of plastics has increased significantly in recent years, paving the way for more plastic waste to be released into the environment and consequently into the oceans via land-based sources or from marine-based operations. It is estimated that there are currently over 150 million tons of plastic waste in the sea (MacArthur, 2017). The results showed large differences between European countries in ocean debris per head, with Slovenia surprisingly having the highest ocean debris per head at 1.5 kg·head−1 year−1 followed by Belgium with ocean debris per head at 0.9 kg·head−1·year−1. The reasons for this are long and complex flows of plastic waste trade within and outside Europe. For example, Slovenia imports the majority of its plastic waste from the four surrounding countries, from where the majority is exported outside Europe (Bishop et al., 2020). It is therefore essential to change the current practice of disposing of plastic waste and implement sustainable solutions for the prevention and collection of macro and microplastics from the oceans. Prevention technologies include miscellaneous leakage prevention and the incorporation of filters to remove plastics from wastewaters and stormwater. However, these technologies have proven to be insufficient to protect the oceans from improper waste management, losses after catastrophic events, or during shipping. Therefore, boats, booms, waste traps, robots, drones, filters, and vacuum technologies are currently used to collect plastic waste from the oceans (Schmaltz et al., 2020). Regardless, these technologies alone cannot solve the problem of marine waste. The solutions are primarily based on the inclusion of renewables and the elimination of problematic or harmful plastic objects, as well as on achieving circularity by keeping the plastic within the economy and outside the environment (Fadeeva and Van Berkel, 2021).

Keywords: waste management, microplastics, plastic debris.

References:

1. Bishop, G., Styles, D., Lens, P.N.L., 2020. Recycling of European plastic is a pathway for plastic debris in the ocean. Environment International 142, 105893.
2. Fadeeva, Z., Van Berkel, R., 2021. 'Unlocking circular economy for prevention of marine plastic pollution: An exploration of G20 policy and initiatives'. Journal of Environmental Management 277, 111457.

3. MacArthur, E., 2017. Beyond plastic waste. American Association for the Advancement of Science.
4. Schmaltz, E., Melvin, E.C., Diana, Z., Gunady, E.F., Rittschof, D., Somarelli, J.A., Virdin, J., Dunphy-Daly, M.M., 2020. Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environment International 144, 106067.

Optimization of Waste Heat and Solar Thermal powered Organic Ranking Cycle: A Case Study of Aluminium Industry

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Abstract: Production of primary aluminum is among energy most intensive industrial processes, where around half of the energy consumed during electrolysis is lost as a waste heat. In this study, flue gas from aluminium production process and solar thermal are used as a combined low-temperature heat source for Organic Rankine Cycle optimization. Optimization is performed with GAMS by maximizing the net present value of the proposed system by considering revenues from electricity and heat production reduced by capital and operating cost. Three different organic fluids, R245fa, R1234yf and R1234ze, are used as working fluids. The data regarding solar irradiance and low-temperature flue gas are provided from aluminium company and the data regarding working fluid properties are obtained from Aspen Plus. Sensitivity analysis is further performed regarding solar collector area and price of heat.

Keywords: Solar thermal, Organic Rankine Cycle, Waste heat recovery, Aluminium Production, Mathematical Programming.

Topology Optimization of Steel-Lined Rock Caverns for Underground Storage of Chemical Energy

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Abstract: The paper presents the topology optimization of lined rock caverns designed for underground storage of chemical energy. This type of storage can store a high amount of hydrogen, methane, natural gas or carbon dioxide. The caverns are made of concrete shells and lined with thin sheets of steel to seal a content. The optimization is performed by the mixed-integer non-linear programming (MINLP) approach. GAMS/Dicopt is used. The model includes the cost objective function, which is subjected to geomechanical and design constraints. The stability and safety of the system in terms of rock mass strength is ensured. The optimization is proposed to be performed for the phase of preliminary design. In the near past, the non-linear programming optimization of a single gas cavern was introduced by Kravanja and Žlender (2010), extended to the optimization of the entire underground storage (Žlender and Kravanja, 2011) and performed for different rock environments (Kravanja and Žlender, 2012). MINLP optimization of the discrete dimensions of the cavern was later introduced by Kravanja and Žula (2018).

In this attempt, the topology calculation is included into the optimization of the underground storage. A numerical example at the end of the paper shows the overall MINLP optimization of an underground gas storage. The optimal discrete design with the optimal number of caverns of the storage is explicitly determined. Additional investment savings are achieved.

Keywords: Cost optimization, Mixed-integer non-linear programming, MINLP, Underground storage, Topology optimization.

References:

1. A. Brooke, D. Kendrick, A. Meeraus, "GAMS - A User's Guide", Scientific Press, Redwood City, CA, 1988.
2. S. Kravanja, B. Žlender, "Optimal design of underground gas storage", in: WIT Transactions on the Built Environment, 112, pp. 389–399, 2010. https://doi.org/10.2495/HPSM100361
3. S. Kravanja, B. Žlender, "Optimization of the underground gas storage in different rock environments", in: WIT Transactions on the Built Environment, 125, pp. 15–26, 2012. https://doi.org/10.2495/OP120021
4. B. Žlender, S. Kravanja, "Cost optimization of the underground gas storage", Eng. Struct. 33, pp. 2554–2562, 2011. https://doi.org/10.1016/j.engstruct.2011.05.001

5. S. Kravanja, T. Žula, "MINLP optimization of the underground lined rock", in: Conference proceedings, International Conference on Technologies & Business Models for Circular Economy, 1, Portorož, 1st ed. Maribor: University of Maribor Press, 2018. http://press.um.si/index.php/ump/catalog/view/367/345/590-2

Sustainability Profit Gained by the Optimized Clamped Beams

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Abstract: The paper presents the optimization of the sustainability profit achieved by the production of clamped beams in civil engineering. It is proposed to design a series of beams using three different material alternatives: structural steel, reinforced concrete and glued laminated timber. For this reason, three optimization models of beams are developed for the three materials. In addition, three different objectives are defined for each material alternative: for economic profit, for greenhouse gas emissions and for sustainability profit (which includes the ecological costs of global warming). The proposed objective functions are subject to the design, resistance and deflection constraints of the clamped beam, which are determined in accordance with the specifications of Eurocodes 2, 3 and 5. The optimizations of the beam alternatives are performed using the mixed-integer non-linear programming (MINLP) approach. GAMS /Dicopt is used. The task of the optimization is to find the most advantageous material alternative for the clamped beams. The numerical example presented at the end of the thesis clearly shows that the reinforced concrete beams have the highest economic profit, but the timber beams have the highest sustainability profit.

Keywords: Mixed-integer non-linear programming, GHG emissions, Sustainability profit, Optimization, MINLP.

References:

1. Brooke, A., Kendrick, D., Meeraus, A. (1988). "GAMS - A User's Guide", Scientific Press, Redwood City, CA.
2. Eurocode 2. (2004). "Design of concrete structures", European Committee for Standardization, Brussels.
3. Eurocode 3. (2005). "Design of steel structures", European Committee for Standardization, Brussels.
4. Eurocode 4, (2004). "Design of timber structures", European Committee for Standardization, Brussels.
5. Kravanja, S., Žula, T., Klanšek, U. (2017). "Multi-parametric MINLP optimization study of a composite I beam floor system", Engineering structures, 130, pp. 316-335.
6. Žula, T., Kravanja, S., Klanšek, U. (2016). "MINLP optimization of a composite I beam floor system", Steel and composite structures, 22(5), pp. 1163-1192.
7. Jelušič, P., Kravanja, S. (2017). "Optimal design of timber-concrete composite floors based on the multi-parametric MINLP optimization", Composite structures, 179, pp. 285-293.

8. Yoon, Y.C., Kim, K.H., Lee, S.H., Yeo, D. (2018). "Sustainable design for reinforced concrete columns through embodied energy and CO 2 emission optimization", Energy & Buildings, 174, 44-53.
9. Zhang, Q., Wei, Z., Ma, J., Qiu, Z., Du, T. (2019) "Optimization of energy use with CO2 emission reducing in an integrated iron and steel plant", 157, 113635.
10. Alonso, C.M. Berdasco, L. (2015). "Carbon footprint of sawn timber products of Castanea sativa Mill. in the north of Spain", Journal of Cleaner Production, 102, pp. 127-135.
11. Camp, C.V., Huq, F. (2013). "CO2 and cost optimization of reinforced concrete frames using a big bang-big crunch algorithm", Engineering Structures, 48, pp. 363-372.

First-Principles Comparison of Structural and Electronic Properties of TiO_2

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Abstract: Titanium dioxide has in recent decades received significant attention due to its wide range of applications [1]. One of the most promising and studied uses for TiO_2 has been its photocatalytic activity. However, it can be found in many phases, the most common being rutile, anatase and brookite. While brookite is rarely studied for photocatalysis, rutile and anatase have been very popular due to their photocatalytic activity. However, it can be fairly impaired by charge recombination and high band gaps; nevertheless these properties can be enhanced by means of doping, defects integration and the deposition of co-catalysts.
Density functional theory calculations were done in GPAW [2] with the projector augmented wave method (PAW). We used the Perdew Burke Ernzerhof (PBE) functional due to a good agreement with experimental structural data. Nonetheless, it fails to properly describe the electronic structure of semiconductors, which has been a known deficiency of DFT [3]. The simplest solution is the introduction of a Hubbard [4] (DFT+U) correction on *d* and *f* orbitals due to the strong Coulomb interactions. The DFT+U method is computationally on par with the vanilla PBE functional. However, U has to be uniquely determined. The alternative are much more computationally expensive hybrid functionals.

The effect of long range van der Waals forces was considered, thus Grimme's D3 correction on top of PBE+U was employed. Rutile and anatase were subsequently studied with PBE, PBE+U, PBE+U+D3, HSE06, PBE0 and B3LYP functionals, with U values of 4, 6 and 8 eV. The lower values yield better structures, whereas higher values better predict electronic properties. The efficiency of different functionals in structural optimization and electronic properties was compared, discussed and benchmarked against HSE06, PBE0 and B3LYP. To accurately describe the photoexcitations during photocatalysis, a proper electronic structure description is of pivotal importance, hence this study provides significant insight not only into structural but also electronic properties of TiO_2.

Keywords: Density functional theory, hybrids, DFT+U, TiO_2.

References

1. Haider, A. J.; Jameel, Z. N.; H.M., A.-H. I. "Review on Titanium Dioxide Applications," *Energy Procedia*, vol. 157, pp. 17–29, 2019.
2. Mortensen, J. J.; Hansen, L. B.; Jacobsen, K. W. "Real-Space Grid Implementation of the Projector Augmented Wave Method," *Phys. Rev. B - Condens. Matter Mater. Phys.*, vol. 71, pp. 1–11, 2005.
3. Morales-García, Á.; Valero, R.; Illas, F. "An Empirical, yet Practical Way to Predict the Band Gap in Solids by Using Density Functional Band Structure Calculations," *J. Phys. Chem. C*, vol. 121, pp. 18862–18866, 2017.
4. Hubbard, J.; A, P. R. S. L. "Electron Correlations in Narrow Energy Bands," *Proc. R. Soc. London. Ser. A. Math. Phys. Sci.*, vol. 276, pp. 238–257, 1963.

Optimisation and Performance Analysis of Downstream Oil Supply Chains Considering Emissions

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Abstract: The aim of this study is to develop a novel framework for the optimisation of downstream oil supply chains with emission-cost nexus and performance analysis. A P-graph based model has been developed to support the decisions of the distribution plan in the supply chain. This created the possibility to consider constraints, including the material balance, the sending capacity of refineries and storage depots, and the transport capacity of railways, barges and pipelines. Three scenarios, covering standard conditions, pipeline disruption, and demand increase, are analysed. The proposed novel method supports the decision-making of downstream oil supply chains and provides insight into the reduction of environmental influences. The results reveal that priority should be given to measures for reducing NOx emission (both Greenhouse and dangerous pollution gas) and the emission factors of barge transport, as this can bring great environmental benefit. When NOx emission for railways and barges is reduced by 5 %, 1,435 kCNY/month (219.7 kUSD/month) could be saved. If the emission of the barges is reduced by 5 %, this can save 1,289 kCNY/month (197.4 kUSD/month) of environmental cost. The proposed method is handy for analysis under non-standard conditions, such as transport facility disruption and demand increase. It would help in the design a distribution plan from a more comprehensive view, and to provide further direction for reducing the environmental footprint.

Keywords: Downstream Oil Supply Chain (DOSC), GHG reduction, Air pollutants, Performance Analysis.

Design of Geothermal Energy Pile

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Abstract: Sustainable buildings should include energy foundations that exchanges heat energy with the ground. High-rise buildings are often founded on piles because of the large mass of the high-rise building. The article presents the design of an economically efficient geothermal energy pile. Geothermal energy piles are typical geostructures used for heating/cooling buildings. Geothermal energy piles are exposed to cyclical thermal loads and not only to structural loads like conventional piles. These cyclical loads could increase the settlement of piles, especially if they are installed in fine-grained soil. Today, it is necessary to design geotechnical structures in such a way that they are economically efficient and have a low probability of failure. The proposed optimization method is illustrated by applying it to a multi-story building supported by geothermal energy piles. The example presented shows that the load-bearing capacity is fully exploited in the optimal design solution.

Keywords: geothermal energy piles, energy foundations, optimal design, fine-grained soils, high-rise buildings.

References:

1. GSHP Association (2012). Thermal pile design, installation and materials standards, Gr. Source Heat Pump Assoc. Milt. Keynes. 82.
2. Jelušič, P., Žlender, B. (2020). Determining optimal designs for conventional and geothermal energy piles. Renew. Energy, 147, 2633–2642, doi:10.1016/j.renene.2018.08.016.
3. Kravanja, Z., Grossmann, I. E. (1994). New developments and capabilities in prosyn—An automated topology and parameter process synthesizer. Comput. Chem. Eng. 18, 1097–1114, doi:10.1016/S0098-1354(94)85027-5.
4. Žula, T., Kravanja, S. (2018). Optimization of the sustainability profit generated by the production of beams. In Proceedings of the Technologies & Business Models for Circular Economy; Univerzitetna založba Univerze v Mariboru / University of Maribor Press, pp. 159–165.
5. Žula, T., Kravanja, S. (2020). Sustainability Profit Generated by the Optimization of Continuous Beams. In Proceedings of the 2nd International Conference on: Technologies & Business Models for Circular Economy: Conference Proceedings; University of Maribor, University Press, pp. 133–140.

Conceptual Optimisation of Industrial and Urban Symbiosis Networks for Circular Economy

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Introduction: One of the ways of simultaneously minimising the use of fresh resources and pollution reduction in the industrial and urban symbiosis [1], implementing Circular Economy [2]. In the current work, it has been shown that the circularity rate alone is not a sufficient criterion to achieve resource and footprint minimisation. It is also necessary to evaluate the cost and the footprints [3] in a combined way.

Objectives: The current work presents a model optimising industrial-urban symbiosis system by minimising the cost and the footprints [4] against the circularity rate.

Method: The model uses the system material, energy and exergy balances, evaluating Total Annualised Cost (TAC) Greenhouse Gas (GHGFP) and Water Footprints (WFP). The optimisation model has been used with three variants: minimising TAC, maximising GHGFP saving and maximising WFP saving.

Major results: Several curves have been obtained by successive optimisation varying the circularity rate. The TAC curve features a minimum at Total Circularity Index (TCI)=0.465 / TAC=84.5 k€/y. The GHG emission trend is monotonous, which implies that higher circularity rate results in higher GHG footprint savings. The WFP curve has a maximum for TCI=0.353 and WFP saving 827 k(m^3/y). These discrepancies provide information to decision-makers for the approximate cost (≈0.6 €/m^3) of additional reduction of water pollution (by reducing circularity a little) or of the environmental cost of attaining the cost optimum.

Conclusions: The formulated conceptual model allows preliminary evaluation of industrial and urban symbiosis systems and provides useful information to decision-makers and designers of the symbiosis networks. The case study clearly demonstrates the usefulness of the model in evaluating the trade-offs between the considered

process characteristics, showing a 10 % difference between the optimal circularity rates for water footprint minimisation and cost minimisation.

Keywords: resource integration, resource recovery, industrial-urban symbiosis, network optimisation.

Acknowledgements: The funding from the project 'Sustainable Process Integration Laboratory – SPIL funded by EU' CZ Operational Programme Research and Development, Education, Priority1: Strengthening capacity for quality research (Grant No. CZ.02.1.01/0.0/0.0/15_003/000045) under the collaboration agreement with the University of Split has been gratefully acknowledged.

References:

1. M.-L. Tseng, R.R. Tan, A.S.F. Chiu, C.-F. Chien, T.C. Kuo, 2018. Circular economy meets industry 4.0: Can big data drive industrial symbiosis? Resour. Conserv. Recycl. 131, 146–147.
2. K. Hartley, R. van Santen, J. Kirchherr, 2020. Policies for transitioning towards a circular economy: Expectations from the European Union (EU). Res. Cons. Recycl. 155, 104634.
3. B. Holmatov, A.Y. Hoekstra, M.S. Krol, 2019. Land, water and carbon footprints of circular bioenergy production systems. Renewable and Sustainable Energy Reviews 111, 224–235.
4. L. Čuček, J.J. Klemeš, Z. Kravanja. 2012. A Review of Footprint Analysis Tools for Monitoring Impacts on Sustainability, Journal of Cleaner Production, 34, 9-20.

Distribution Company Emission Reduction Design Based on Scheduling Strategy and Route Optimization

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Abstract: At present, research on reducing vehicle emissions is often limited to the optimization of gasoline and engine. For companies with high car usage and regularity, emission reduction optimization from scheduling strategy and route optimization is a direction worth studying. This article is dedicated to improving economic efficiency and reducing environmental impacts for distribution companies.

From the perspective of improving distribution efficiency and optimizing transportation vehicle route planning, coupled with consideration of economic efficiency goals and carbon emissions goals, a general multi-objective mathematical programming model is proposed, and the minimum operational cost that includes loading cost, unloading cost, transport cost, the cost caused by unpunctual distribution, and carbon emission cost are set as objective functions. The delivery plan of the depot (delivery volume during each time interval), the sales plan of the petrol stations (sales volume during each time interval), the path congestion in real time, the spatial distribution, as well as the inventory of the petrol stations and the depot are parameters for the model. The solutions obtained by the model including "when, where to delivery what kind of product, and which road to select." The carbon emission factor and operating cost of each car are also known. Based on discrete representation, the working day is divided into equal time intervals, and the truck distribution process is decomposed into a pair of tasks including driving, standby, rest, loading and unloading. Each truck must execute one task during a single interval, and the currently executing task is closely related to the preceding and subsequent tasks. By accounting for predictive time-varying sales at petrol stations, real-time road congestion and a series of operational constraints, the proposed model produces the optimal truck dispatch, namely, a detailed task assignment for all trucks during each time interval. The model is tested on a real-world case of a replenishment system comprising eight highway petrol stations, one depot, one garage and eight trucks to demonstrate its applicability and accuracy in reducing total operating costs and reducing carbon emissions.

The results show that the optimized model we proposed can shorten the total driving path length of the company's vehicles, reduce engine idle waiting time, and if

calculated annually, 577,357 L diesel consumption, 3,628.3 kg CO2 emissions, 36.085 kg CO emissions, 2.4535 kg Non-methane Hydrocarbon emissions, 2.1647 kg NOX emissions and 0.162498 kg PM particles emissions are reduced compared with the current distribution plan, the emission reduction effect is 1.71%. Besides, it brings economic savings of 1,259,980 CNY/Y to the distribution company, and avoids the situation that some petrol stations cannot get the required oil products due to unpunctual distribution under the current distribution plan. All the petrol stations would receive timely replenishments when their inventories are close to their lower limits.

Keywords: emission reduction, low carbon, route optimization, MILP, discrete representation.

Impacts of COVID-19 on Teaching and Research: Challenges and Opportunities

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Abstract: The COVID-19 pandemics caused worldwide destruction in numerous human activities. The teaching and learning on various levels have not been excluded. Although Universities and other educational institutions have made use of eLearning (in many varied formats) for many years, the recent pandemic that has spread rapidly around the world has forced Universities into adopting new methods of teaching and learning. The recent 4th SPIL (Sustainable process Integration Laboratory) virtual conference in Brno provided a discussion forum for exchanging the information. The issues discussed were: (i) Stepping-up and promoting education and innovation toward sustainable development goals through educational laboratories (ii) A new approach to teaching and learning during COVID-19 restrictions (iii) The potential topics for discussion include: (iv) The pros and cons of online learning (v) The effectiveness of online learning compared to classroom learning (vi) The other challenges during the pandemic period (vii) Tools recommendation In this contribution, the authors attempted to summarise various approaches and methods that have been used to engage learners in their chosen degree programmes, with a focus on the techniques used. Aa advanced blended learning format which has been adopted by the University of Manchester, which makes use of face to face teaching if

safe, but predominantly uses internet-based resources to provide students with their necessary learning, has been discussed. A combination of recorded lectures, problems and solutions, software for applying concepts to larger problems, mini-quizzes, eAssessments, Discussion Boards, and Zoom based activities have been used to provide the learning resources required for the students. Implementing e-learning combined with classroom education in Ukraine technical universities under COVID-19 pandemic restriction has been discussed as well, as well as the methods used by the Faculty of Bussines and Management at the Brno University of Technology.

Keywords: COVID-19 restricted learning and teaching, blended format, challenges and lessons learned, future distant learning.

Acknowledgements: The authors gratefully acknowledge financial support from the EU project Sustainable Process Integration Laboratory – SPIL, funded as project No. CZ.02.1.01/0.0/0.0/15_003/0000456, by Czech Republic Operational Programme Research and Development, Education, Priority 1: Strengthening capacity for quality research under the collaboration agreement with The University of Manchester, UK and National Technical University "Kharkiv Polytechnic Institute", Ukraine.

Circular Economy LCA for Durian Industry in Malaysia

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Abstract: As part of the main objectives stated in the Ministry of Agriculture and Agro-based Industry Outlook: Priority and Strategy 2019 – 2020, agriculture products such as durian should be given great importance as it is a new wealth-generating source for the country. To achieve that objective, the government aims to produce 274,000 and 300,000 metric tonnes of durian for the year 2019 and 2020, respectively. Therefore, the development of durian is expected to increase rapidly with major investments and efforts being conducted to ensure steady positive growth of the industry. However, the exponential growth of the durian industry, if left uncontrolled, will result in major ecological issues such as the exploitation of natural resources, for example land, which eventually leads to widespread deforestation. This major problem is very similar to the previous palm oil industry that experienced a rapid economic boom, which resulted in huge areas of rainforest in Southeast Asia, Latin America and Africa being cleared to allow palm oil plantations to be set up. Besides that, countless issues were brought up during its massive growth, such as human right abuses (e.g. child labor), exacerbation of climate change and loss of habitat for fauna, which eventually raised many concerns and interventions by the European Union (EU) against the palm oil industry. However, the development of durian industry is still in its early stages and thus proper guidelines and policies can be established to ensure the industry is shaped towards a green and lean concept. In response to the problem mentioned, proper expansion of the durian industry should involve the continuous positive growth of the sector in order to generate revenue, along with sustainable development methods aiming to preserve and protect the environment. In overall, well planned activities and development strategies will ensure that the durian industry would thrive for decades as a major source of income for the nation.

The paper will perform a Circular Economy based life cycle analysis (CE-LCA) to assess the environmental impact from each stage of the durian life cycle in order to provide a framework to further optimise the sustainable development of the durian industry. In order to achieve the goal mentioned, several scopes are proposed as follows: 1. To study the added value of durian including the nutritions and bio-chemical values. 2. To suggest debottlenecking solutions by analysing the process via value stream mapping. 3. To optimise logistic operations involving transportation. 4. To design a circular economy system by producing fertiliser and biofuel

Keywords: circular economy, LCA.

A Hierarchical Targeting Method of Hydrogen and Heat Exchange Network Synthesis

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Introduction: Refineries are among the largest consumers of energy and hydrogen. Most of the current studies focus on Heat Integration [1] or the optimisation of H_2 Network [2] in refineries. Heat Integration has been relatively well established. The studies include algorithmic targeting [3] and extensions to locally integrated energy sectors [1] which is based on the Total Site Heat Integration by Klemeš et al. [4]. Hydrogen Integration [2] has been considered mostly on their own, wherein most of the cases Heat Exchange Networks and H_2 Mass Networks coexist separately. This study aims to combine H_2 and Heat Integration in refineries, to minimise resource consumption and emissions further.

Method: The presented paper proposes a hierarchical targeting method for combined H_2 and Heat Integration, following the Onion Model [5]. Firstly, H_2 Pinch targets are obtained. Pinch Analysis was used to analyse a bottleneck of the H_2 Network and diagnose unreasonable H_2 use. They are followed by the identification of the Heat Integration (HI) problem and the HI targeting at two levels – process and site. The Total Site Composite Curves are used to target the HI of a refinery.

Major results: The results show that the H_2 network targeting can guide the optimisation of the H_2 Network, reducing H_2 utility demands and the waste H_2 emissions. The H_2 Pinch concentration of the H_2 network is 89 %. The minimum utility H_2 required for the H_2 Network is 10.95 Nm^3/h. The minimum waste H_2 discharged is 32.13 Nm^3/h. At the Total Site Heat Integration level, the targets show that the maximum reduction can be 86.5 % for hot utilities and 39.8 % for cold utilities.

Conclusions: This study shows an approach to achieve a synergy of targeting H_2 and heat recovery. The unidirectional method, which combines the Onion Model and Pinch Analysis, is simple to use and has the advantages of graphic visualisation. A case study of an oil refinery shows that both resources, H_2 and thermal utilities for a refinery, can save significant amounts, leading to potential environmental and

economic benefits. In future work, the method can be extended to use the Heat Integration targets in a feedback loop, to optimise and tune the H_2 integration.

Keywords: heat integration, hydrogen network, hierarchy design, onion model, minimise resource consumption.

References:

1. Lee, P.Y., Liew, P.Y., Walmsley, T.G., Wan Alwi, S.R., Klemeš, J.J., 2020. Total Site Heat and Power Integration for Locally Integrated Energy Sectors. Energy 204, 117959.
2. Lou Y., Liao Z., Sun J., Jiang B., Wang J., Yang Y., 2019. A novel two-step method to design inter-plant hydrogen network. International Journal of Hydrogen Energy, 44, 5686–5695.
3. Liew P.Y., Wan Alwi S.R., Klemeš J.J., Varbanov P.S., Abdul Manan Z., 2014. Algorithmic targeting for Total Site Heat Integration with variable energy supply/demand. Applied Thermal Engineering, 70, 1073–1083.
4. Klemeš J., Dhole V.R., Raissi K., Perry S.J., Puigjaner L., 1997. Targeting and Design Methodology for Reduction of Fuel, Power and CO_2 on Total Sites. Applied Thermal Engineering, 17(8-10), 993–1003.
5. Linnhoff, B., Townsend, D.W., Boland, D., Hewitt, G.F., Thomas, B.E.A., Guy, A.R., Marsland, R.H., 1994. A user guide on process integration for the efficient use of energy, Revised First Edition. ed. Institution of Chemical Engineers, Rugby, UK.

Substrates' Characterization for Optimization of Carbon-to-Nitrogen Ratio and Moisture Content for Industrial Biowaste Composting

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Abstract: SCR as a putrescible biowaste, poses adverse impacts to the environment such as climate gases emission and waterbody contamination when it is landfilled. As biowaste that contains relatively high protein and trace elements, SCR is gaining popularity as substrates for composting. Composting is a sustainable biowaste treatment technology in the context of volume reduction, bio-stabilization and reducing the burden on landfills. The substrates' characterization for a local large-scale composting project (with SCR as main substrates) shows the current initial mix is in a near optimized condition. The quantities of substrates for a series of scenario with different conditions are determined and optimized with Microsoft Excel Solver. The scenario outcomes serve as part of decision support tool for future planning and improvement of the current composting process, especially in diagnostic of the roles of current substrates, current limitations in composting process and future space design. Compost maturity test with seed germination rate and Solvita® test kit shows the current compost output (open air, 4 months) is in a reasonably active stage of decomposition and needs further management. The research identified that improvisation of aeration with replacement of co-composting materials with higher porosity or installation of active /passive aeration system is the pivotal step for further advancement of the overall composting process and quality of compost output.

Keywords: composting, moisture content, substrates, soybean curd residue.

The Systems Approach to Sustainable Food Production and Higher Share of Locally Produced Food

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Introduction: At the Faculty of Chemistry and Chemical Engineering of the University of Maribor, a new project was launched in November 2020 with the aim of developing optimization approaches for sustainable food production and a larger share of locally produced food. The project is carried out by the Laboratory for Process Systems Engineering and Sustainable Development, which is recognized worldwide for the development and application of an integrated systems approach to the optimization of chemical and biochemical processes, supply chains and networks.

Methods: The food supply chain is an extremely complex system involving large and small producers of plant and animal food, food processing, distribution and consumption, and the collection and processing of discarded food and waste from food production. Making integrated decisions in such a complex and extensive area is a major challenge. Therefore, the project implements a process systems approach to optimize the food supply chain at the level of the Republic of Slovenia. This approach allows for a comprehensive treatment of all entities involved. It takes into account the relationships and synergies between them and generates optimal solutions for the whole system. The food supply chain is a similar system to chemical, biochemical and energy supply chains, which justifies the use of similar approaches. Furthermore, the agri-food chain is an excellent complement to these value chains, as it is a rich source of waste biomass that could be used as a renewable source for the production of secondary raw materials and energy, replacing fossil sources.

Results: The main objective is to create an optimization model that takes into account the entire food supply chain and optimizes arable land, crop types and technologies for their production. The model will take into account the conditions and constraints imposed by the main European and national regulations and directives, such as The European Green Deal, The Farm to Fork Strategy, The EU Biodiversity Strategy until 2030, National Resolution Our Food, Countryside and Natural Resources after 2021, Planned amendments to certain laws on agricultural land policy, etc. It is also important to optimize the management of agricultural waste and to select technologies for its processing into useful products and energy. The model will include economic and environmental assessments. It will take into account uncertainties in agricultural production, such as price fluctuations, variable harvests,

yields per hectare, the relationship between supply and demand, changes in eating habits, etc.

Conclusions: Based on the results of the model, possible solutions for sustainable food production will be proposed, aiming at an appropriate balance between plant- and meat-based food and a greater share of locally produced food. The results of various optimization models will help decision-makers to steer the further development of agricultural policy with much more certainty in order to develop (create) conditions that will allow a higher and more balanced share of high-quality, locally produced food and food products. The project represents a development application of mathematical optimization to the food supply chain with the aim of obtaining useful results for decision making in the Slovenian agricultural policy. The content and objectives of the project are in line with the priority areas "sustainable food production" and "networks for the transition to the circular economy" in Slovenian Smart Specialization Strategy S4.

Keywords: optimization, food supply chain, food security, local food, systems approach.

Acknowledgements: The authors gratefully acknowledge financial support from the Slovenian Research Agency and Ministry of Agriculture, Forestry and Food (Project V2-2009).

Activity of α-amylase from P. ostreatus Grown on Waste Substrates

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Abstract: Forest and agricultural waste can be a major development and ecological opportunity. Therefore, it is reasonable to use biological waste further to produce energy and for the manufacture of certain products with high added value, such as, for example, the cultivation of fungi and, consequently, the production of biocatalysts with high market value. In addition, the use of agriculture waste for Oyster mushroom (P. ostreatus) growth can be integrated to waste management and the development of the bioeconomy. The cultivation of P. ostreatus using waste plant biomass from agriculture (straw, grass, courgettes, cucumbers, peaches, apricots, pears, and peppers) was performed in order to obtain the highest increase in biomass production of the cultivated mushroom and as a potential source of α-amylase, with high catalytic activity. The highest α-amylase activities were achieved when pears or apricots were used as a substrate for P. ostreatus cultivation.

Keywords: P. ostratus, α-amylase, activity, agriculture waste, cultivation.

Value Chain Approach Towards a More Impactful Outcome of Technological Development

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Abstract: Biohydrogen and biomethane have interesting prospects as a clean energy carrier due to their high energy content and environmental-friendly conversions at relatively low energy intensity. Palm oil mill effluent (POME) which occurs in massive abundance in Malaysia as the second-largest producer of palm oil in the world, has created major environmental issues for the oil palm industry in Malaysia due to its highly polluting characteristics. This high strength complex wastewater with high chemical oxygen demands requires bioreactor systems with great stability and efficiency to be successfully treated. The use of a two-stage anaerobic biological process to treat the effluent while generating hydrogen and methane biogases has been proven at pilot scales. In taking the technology to the next level of readiness, a more holistic approach in the study is proposed, involving the value chain steps going from laboratory to end-user. Assessment of the micro and macroeconomics feasibility through life cycle analysis, value chain model, uptake by producers, investors and end-users, and identification of policy drivers for successful implementation are proposed as areas to be addressed. The bioreactor performance in terms of effluent treatment and bio-hythane production in up-flow anaerobic sludge reactor will be examined under various operating conditions, while biogas upgrading and purification using membrane technology will be carried out to obtain higher grade biogas as a future renewable energy resource. Alternative organic effluents such as food waste and the food industry can also be included as part of the bioreactor operation study. Life cycle assessment of biogas production methods and its application in value chain management system will be useful in cost analysis. Additionally, evaluation of market readiness for bio-hythane will be undertaken to address ways in which government policies, fiscal incentives or other stimulus are necessary to attract and further propel the industry players to venture into and further promote bio-hythane as a way to move forward in our commitment towards renewable energy.

Keywords: renewable energy, palm oil mill effluent, bio-hythane.

The Effect of $scCO_2$ Treatment on Protein Concentration and Protease Activity in Graham Flour

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Abstract: The protein content of flour varies depending on the type and brand. Graham flour is a form of whole wheat flour with significantly greater protein values, compared to other types of flour. In this work, the supercritical carbon dioxide (scCO2) was used to inactivate the enzyme activity in graham flour. Enzymatic activity was determined in the extracted supernatant of scCO2 treated graham flour after a specified time using spectrophotometric method. A colorimetric method for the determination of protein in graham flour and activity assay for determination of enzyme protease were described. Additionally, the comparison in protein concentration and protease activity of scCO2 treated graham flour and untreated graham flour was conducted.

Keywords: supercritical carbon dioxide, enzyme inactivation, graham flour, protein, protease.

Biosorption of Heavy Metals from Waste Water by Stabilized Biomass. The Concept of Circular and Green Economy

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Abstract: Proper management of sewage sludge, by-product from sewage treatment plants is a major environmental issue. Wastewater treatment plants (WWTPs) can be an important part of circular sustainability if they are reoriented to treat sludge in order to produce stabilized biomass and its useful reuse.

The main goal of this paper is to develop the reuse of stabilized active sludge in the separation of Cu (II) ions from wastewater. Experimental data obtained from equilibrium biosorption of the system Cu (II) ions – stabilized active sludge were fitted with the adsorption isotherms: Langmuir, Freundlich, Dubinin – Radushkevich and Tempkin using the MATLAB/Curve software package. The pseudo I and II ordered reaction model are used to model the kinetics of the process. The best results for defining the kinetics and equilibrium of adsorption of Cu (II) ions are obtained by applying the pseudo – II order reaction model and the Langmuir – isothermal model.

Keywords: biosorption, copper, stabilized active sludge, kinetics, equilibrium.

References:

1. A.Gupta, A. Garg, Recycling of Sewage Sludge as Adsorbent for the Purification of Wastewater, 5th International Conference on Sustainable Energy and Environmental Sciences, Singapore, 2016.
2. Gherghel, A., Teodosiu, C., De Gisi, S., A review on wastewater sludge valorisation and its challenges in the context of circular economy. J. Clean. Prod. 228, 244e263, 2019.
3. M.C. Collivignarelli, M. Canato, A. Abba, M. C. Miino, Biosolids: What are the different types of reuse?, Journal of Cleaner Production 238 (2019) 117844, 2019.
4. S. Aslan, S. Yildiz, M. Ozturk, Biosorption of Cu^{2+} and Ni^{2+} ions from aqueous solutions using waste dried activated sludge biomass, Polish Journal of Chemical Technology, 20, 3, 20—28, 10.2478/pjct-2018-0034, 2018.
5. Venkata, A. Kumar, N.A. Darwish, N. Hilal, Study of Various Parameters in the Biosorption of Heavy Metals on Activated Sludge, World Applied Sciences Journal 5 (Special Issue for Environment): 32-40, ISSN 1818-4952, 2009.

Use of LCA in the Environmental Declarations of the ZAG EPD Programme

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Abstract: Environmental declarations, issued considering the EN 15804:2012+A2:2019 represent a valuable tool for assessment of the environmental performance of a building. EPDs issued by the ZAG EPD programme states indicators, as set in the mentioned standard. This set, however is not in-line with current Level(s) assessment of buildings. Therefore, it is highly advisable that the indicators, introduced in national systems, based on Level(s) are modified. The background product analysis is done via an LCA analysis, following ISO 14040 and ISO 14044, taking into account requirements of the EN 15804. The ZAG EPD program includes various scopes of the LCA addressed. As a minimum, modules A1-A3, C1-C4 and all parts of module D are addressed. Besides the commercial work often the LCA, targeting the EPD level results are part of the research projects. The rules are therefore the same in both cases, however in research it is difficult to set an appropriate functional unit as well as define the use phase scenarios and to assess the module D correctly. In the present work we are addressing the process of background data preparation, stressing on use of secondary materials and end-of-life scenarios. The results of LCAs for different products vary regarding the impact methods used, explicitly comparing the environmental burdens of residues from industries that are being used as an input material in the assessed system. The calculation is heavily dependent on the classification of the residue, weather it is classified as waste or by-product. Furthermore, by-products could be modelled with two very different methods – with allocation of environmental burdens of the production of the main product to the residue or with system expansion. Burdens that the by-product holds is therefore easily presented as low (in many times even beneficial) when using system expansion or quite large, when using a mass allocation. In the research it is found that the LCA practitioner has to make a series of arbitrary choices that influence the results. In some parameters this influence can be well above 10% which makes comparison of products non-reliable, which is not in line with market requirements and also jeopardizes LCA calculations for buildings.

Keywords: LCA, EPD ZAG Programme.

Textiles Circular Economy Based on Polyethylene from Waste Cotton

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Abstract: Human services require resources from the environment and generate waste; both produce an environmental impact. Almost three quarters of waste textile is landfilled or incinerated and less than 1% is recycled to produce new clothing. The lineal model is not sustainable and circular economy principles must be applied to reduce the pressure on the environment.

Waste textile is a secondary raw material: waste cotton fibres are fermented to ethanol which is used as building block, while polymeric fibres are released and recycled. Diluted ethanol is concentrated by distillation and used to produce polyethylene fibres, which are incorporated again to the woven fabric, closing the cycle.

Nowadays, 70 % of the textile fibres are synthetic and produced from fossil fuels. The mass cycle generated decreases the resources depletion and alleviates human pressure on environment. In this study, the resources retrieved from the environment, liabilities, and the resources lost to the environment, assets, are quantified using exergy balances. Assuming that each kg of waste cotton is able to generate 170 g of synthetic fibres and these polyethylene-derived fibres are recycled 10 times before disposal, then the pressure on the cotton fields to cover the same dressing requirements is almost 3 times lower and the Circular Material Use Rate (CMU) is of 65 %.

The analysis shows that the main liability is the cotton used as raw material and the main asset is the degraded polyethylene fibres that could be further used as coat filling. Finally, waste polyethylene exergy value is similar to the waste cotton from the linear economy. Besides cotton and waste polyethylene, the highest exergy is lost in the ethanol distillation reboiler. Therefore, the focus is placed on decreasing the energy consumption involved in separating ethanol and water.

The results show that a mixture of free fatty acids is as effective as oleic acid as extracting solvent for ethanol from the fermentation broth. However, water solubility in the solvent is also an important parameter that should be further studied. Although further research in this field is required, the study shows that circular economy is suitable to produce textiles without requiring the use of fossil fuels to produce synthetic fibres.

Keywords: exergy balance, bioethanol extraction, waste processing.

Analysis of the Possibilities for Energy Recovery in WWTP

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Abstract: In recent years, there has been increasing talk of improving energy efficiency and the ability to reduce greenhouse gases in wastewater treatment plants. This necessitates exploring the possibilities for reducing energy costs and the possibilities for obtaining energy from wastewater. In the present study, an analysis of the energy consumed at different stages of wastewater treatment in a municipal WWTP in the Republic of Bulgaria is made, and the average monthly consumption of electricity required for the treatment of one cubic meter of wastewater is estimated. Based on the collected and analyzed data, an assessment was made of the possibilities for energy recovery from dry matter from sludge, by combustion and anaerobic digestion. The obtained results allow for the reconstruction of a facility and the use of the hitherto unused energy potential contained in the sludge.

Keywords: energy efficiency, anaerobic wastewater treatment, cost analysis, energy recovery.

Novel Trends in Industrial Design and Management

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Abstract: While Industry 4.0 is still very poorly incorporate in today's production systems, its miss points are evident and have become subject to critique. Meanwhile, facilities with up to date systems are migrating to industry 5.0, that can resolve the problems Industry 4.0 has not, regarding all the predicted future needs. Though Industry 5.0 should present a perfect merge among a complete information circular environment, effectiveness, efficiency, and environmental sustainability, it is subjected to non-correspondence with the actual regulatory systems worldwide.

In this paper, the regulatory problems in the implementation of Industry 5.0 are discussed among the potential solutions. Also, a newly created term "Information circular environment" and it's importance is presented as a new complex system of rules, methodologies, and technologies to accompany the implementation of Industry 5.0.

Keywords: Industry 5.0, International Regulatory Systems, Information circular environment.

Optimisation of Evaporation-Crystallisation System for the Recovery of Sodium Chloride from the Solvay Process Waste Stream

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Abstract: Sodium chloride can be recovered from distiller waste stream ($NaCl$-$CaCl_2$-H_2O) in Solvay process by partial evaporation of water while the remaining concentrated calcium chloride solution can be sold on market or further processed. This work presents the mathematical programming approach for the optimisation of evaporation-crystallisation system for the recovery of NaCl from distiller waste stream. The superstructure proposed includes options for the concentration of waste stream up to saturation point and crystallisation of NaCl with the heat and power integration options enabling energy recovery. A mixed-integer nonlinear programming (MINLP) model is proposed with the objective function to minimise total annualised cost. The optimal design is presented and includes mechanical vapour recompression system with the feed stream preheating options. Main conclusions and further research directions are highlighted.

Keywords: solvay process, distiller waste stream, NaCl recovery, superstructure optimisation, evaporation-crystallisation systems.

Regional Pattern of Energy-Carbon-Water Network of EU and China

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Abstract: A massive amount of production and different kinds of services are shared between different sectors and regions. However, the linkages and key flows of Water-Energy-Carbon Emissions Nexus in the EU and China remain not entirely clear. EU and China have been two of the largest economies as well as water consumers, energy utilisers and carbon emitters. It still under exploration, whether the associated benefits are mutual or not. However, most previous studies were consumption-based assessment, focusing on the individual sectors and fully following the vital intersectoral or interregional supply-chain connections. The optimised strategies for balancing the Water-Energy-Carbon Emissions Nexus in the EU and China should more intensively be considered. A framework for analysing the Water-Energy-Carbon Emissions Nexus has been proposed in this stud to narrow the gaps. It can adequately identify the critical transmission of Water-Energy-Carbon Emissions nexus between different sectors and regions. This study provided a resource analysis approach to identify the synergies in terms of Water-Energy-Carbon Emissions Nexus. It provides decision-making support to be applicable to other regions for better cope with the possible consequences of climate change.

Keywords: energy efficiency, sustainability.

Bioconversion of Fisheries Farm Wastewater for the Production of Algal Biomass of High Value

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Abstract: In recent decades, the inland fisheries industry has increased their production to meet the rising demand for aquatic product consumption. Aquaculture industry's rapid growth has caused severe environmental problems, particularly the treatment of their wastewater [1,2].

Aquaculture effluent is rich in dissolved organic matter, nitrogen compounds (ammonia, nitrite, and nitrate), and phosphorus [1,3]. This effluent can cause toxic algal blooms and deteriorate the natural aquatic environment if wastewater is not treated properly.

However, if the appropriate approach is taken, this waste can be transformed into a sustainable, low-cost culture media for the production of high-value microalgal biomass, which can be upgraded through biorefination.

Algae was recognized as a valuable source of essential nutrients for potential aquaculture systems. Their biomass can contain up to 60% protein, 40% carbohydrates and 20% oils depending on the algal species and their growing conditions [4]. It can also synthesize useful pigments, growth-promoting substances and hormones and secondary metabolites that include natural antioxidants, antimicrobials, anti-inflammatory and immunostimulants to aquatic animals [5,6]. Many species may also synthesize EPA, DHA, and pigments (e.g., carotenoids). Environmentally, microalgal development will allow a significant expansion of global primary photosynthetic production by farming in non-arable soil or along coastal ecosystems, minimizing water demand and recycling nutrients by using seawater and/or wastewater, and transforming atmospheric CO_2 into high-quality feed and animal health products with nutrient-rich renewable feedstocks. This provides the basis for circular aquaculture industry as part of a larger circular bioeconomy [7] and supports several UN Sustainable Development Goals, notably #1-No Poverty, #2-Zero Hunger, #12-Responsible Production and Use and #14-Life Below Water. The incorporation of algal production systems into aquaculture will generate resource-efficient, eco-friendly low-carbon value chains [8] by coproducing bio-based and biodegradable products

(i.e. a bio-refinery approach) [7], while providing nutritious diets and ecosystem services to the aquaculture industry and society at a broader level [9].

In the present work, we study the growth of two strain candidates *Scenedesmus sp*. and *Chlorella sp* in aquaculture wastewater from inland fisheries in Norte de Santander. Results shown that both algae can growth in non-sterile wastewater with a final concentration of biomass of 0.77 and 0.68 g/L for *Scenedesmus sp*. and *Chlorella sp* respectively and up to 51.6% and 53.8% w/w of total protein in both strains. Results also shown that, the application of a solid carbon source such as Na_2CO_3 can effectively increase biomass concentration of up to 1.6 g/L in *Chlorella sp* with a total removal of 99.7% of NO_3 and 89% for PO_4.

Keywords: microalgae, wastewater, aquaculture, bioactive compounds.

References:

1. S. Chen, J. Yu, H. Wang, H. Yu, X. Quan, "A pilot-scale coupling catalytic ozonation–membrane filtration system for recirculating aquaculture wastewater treatment", Desalination. 363:37-43, 2015.
2. Mook W, Chakrabarti M, Aroua M, Khan G, Ali B, Islam M et al. Removal of total ammonia nitrogen (TAN), nitrate and total organic carbon (TOC) from aquaculture wastewater using electrochemical technology: A review. Desalination. 2012; 285:1-13.
3. Gao F, Li C, Yang Z, Zeng G, Feng L, Liu J et al. Continuous microalgae cultivation in aquaculture wastewater by a membrane photobioreactor for biomass production and nutrients removal. Ecological Engineering. 2016; 92:55-61.
4. Draaisma R, Wijffels R, (Ellen) Slegers P, Brentner L, Roy A, Barbosa M. Food commodities from microalgae. Current Opinion in Biotechnology. 2013;24(2):169-177.
5. García-Chavarría, Minerva, and Maurilio Lara-Flores. "The use of carotenoid in aquaculture." Research Journal of Fisheries and Hydrobiology 8.2 (2013): 38-49.
6. Michalak, I. and Chojnacka, K. (2015). Eng. Life Sci. 15, 160–176.
7. Carus, M. and Dammer, L. (2018) The circular bioeconomy – concepts, opportunities, and Algae as production systems of bioactive compounds limitations. Ind. Biotechnol. 14, 83–91.
8. Subhadra, B. (2011) Algal biorefinery-based industry: an approach to address fuel and food insecurity for a carbonsmart world. J. Sci. Food Agric. 91, 2–13.
9. Neori, A. (2011) "Green water" microalgae: the leading sector in world aquaculture. J. Appl. Phycol. 23, 143–149.

Reducing the Environmental Impacts of Melamine Etherified Resin Fibre Production

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Abstract: Due to increasing pressure for environmental protection, the importance of sustainable technologies and products in the chemical industry is growing. Among products that could be produced more sustainably are Melamine Etherified Resin (MER) fibres, which are used for a variety of industrial applications and are mostly produced from non-renewable sources. This paper explores the options for sustainable synthesis routes using renewable sources and waste streams. Three pathways for the MER fibres production process are analyzed: i) the conventional process, in which formalin and hydrogen are produced by methane steam reforming (MSR), and alternative processes in which formalin is produced from ii) captured waste CO2 and iii) from wood-based methanol. The three production pathways are simulated using Aspen HYSYS® (except for wood-based methanol and hydrogen production), and Life Cycle Assessment (LCA) is performed to evaluate the environmental impact of the production of 1 kg of MER fibres. Environmental footprints, potential impacts and environmental prices are analysed using OpenLCA software and various supported databases including Ecoinvent 3.6 and GaBi Professional databases. Results show that the investigated alternative synthesis routes for the production of MER fibres could significantly reduce the environmental impact and are consequently more sustainable.

Keywords: Circular Economy; Green chemicals; Melamine Etherified Resin (MER) Fibres; Process Simulation; Life Cycle Assessment (LCA).

Environmental management system and circular economy

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Abstract: EMAS (Eco Management and Audit Scheme) as environmental management system is a structured system designed to help organisations manage their environmental impacts and improve environmental performance. The European Commission has developed EMAS (Regulation EC No. 1221/2009) for businesses and other organizations to help assess, report, and improve their environmental performance. Their knowledge of resource use and environmental impact enables them to implement measures that optimize the use of their resources in accordance with the principles of the circular economy. Thus, EMAS has an important role to play in "supporting" public and private organizations to unlock the potential of the circular economy and use their resources more efficiently. The EMAS practice proves, if the EMAS system is applied and properly implemented, could stimulate (eco) innovation and real market change.

At EU level, over 3.843 organizations with more than 12.751 locations are registered in the EMAS register, mostly in the field of waste management, specialized construction activities and civil engineering. Both large (22%) and medium (30%), small (29%) and micro-organizations (19%) are included. EMAS in Slovenia is being implemented slowly and to a limited extent. In order to increase the involvement of Slovenian organizations in the EMAS scheme, ZRS Bistra Ptuj participated in the EU project LIFE B.R.A.V.E.R. (2016 – 2019). The main objective was to increase the adoption of "regulatory relief" measures by EMAS registered organizations in the participating countries and regions (i.e., Emilia-Romagna from Italy; Basque Country, Catalonia, Madrid and Andalusia from Spain; and the Czech Republic, Slovenia and Cyprus) with the aim of incentivizing the diffusion of Environmental Management Systems (EMS) certification Schemes. The B.R.A.V.E.R. also sought to demonstrate that "better regulation" measures (regulatory relief & promotional incentives) in the framework of environmental policies is possible only if voluntary schemes like EMAS Registration, ISO 14001 Certification are effectively considered and mentioned in developing new laws and/or amending existing ones. In this sense, the project submitted that those companies applying any of these voluntary certification schemes deserve a series of economic and non-economic benefits such as extensions of the validity of permits/authorizations, reduced reporting and monitoring requirements,

presumption of compliance with environmental legislation or reduced inspections, fiscal relief or reduction of the due financial guarantees, etc.

Concerning the main LIFE B.R.A.V.E.R. result regarding the adoption EMAS regulatory relief in the legislation, 24 measures were adopted (6 measures in Slovenia). Also, 40 simplification proposals were tested in the territories involved, 80 EMAS simplification proposals were drafted, all within a framework of the Guidance Tool for EMAS-based "Regulation & Better Regulatory Relief" which includes 39 EU Recommendations and 40 measures at National/Regional.

Keywords: Environmental management system, EMAS, regulatory relief, circular economy.

Water Environmental Assessment Approach Towards Circular Economy

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Abstract: Post-assessment of environmental impact has been one of the significant fields in sustainability research, as evaluating and benchmarking the environmental performance of human activities provides the foundation for pollution reduction and reuse/recycling of energy and resources. However, environmental impact assessment results are often represented in various units due to the characteristics of the assessed environmental issues. For example, water footprint has been of the widely applied approach to determine the environmental impact of water use and pollution. The existing water footprint assessment methods quantify the environmental impact of water quantity consumption and water pollution with different units, e.g. the volume of water consumption (green and blue water footprint), the volume of water used to dilute the polluted water (grey water footprint), and mass of pollutant equivalent (e.g. kg SO2eq) to quantify the environmental impact of different categories. As a consequence, the water footprint assessment results are challenging to provide practical information for the stakeholders to make breakeven decisions in balancing economic and environmental performances. This study proposed a Quantitative-Qualitative Water Footprint (QQEFP) concept and method, which quantifies the environmental impacts of water use and pollution from an economic perspective. The proposed QQWFP covers the impact of water quantity consumption, and the water quality degradation caused by multiple types of pollutants. Different from the general life cycle costing assessment and conventional water footprint assessment method, the QQWFP is specifically designed based on the or water use characteristics and covers water quantity, water quality, distinguish different water sources and considers the compensation of water return to the local water supply system. Using cost as a quantifying unit (e.g. €/t product), the QQWFP provides essential decision-making oriented information for the stakeholders (especially industries) and facilitates water use performance from the cost-saving perspective. The cost-based QQWFP identifies the potential of improving water use efficiency and pollution reduction and serves as

an active interface between the environmental and economical performance of water use towards the circular economy. Post-assessment of environmental impact has been one of the significant fields in sustainability research, as evaluating and benchmarking the environmental performance of human activities provides the foundation for pollution reduction and reuse/recycling of energy and resources. However, environmental impact assessment results are often represented in various units due to the characteristics of the assessed environmental issues. For example, water footprint has been of the widely applied approach to determine the environmental impact of water use and pollution. The existing water footprint assessment methods quantify the environmental impact of water quantity consumption and water pollution with different units, e.g. the volume of water consumption (green and blue water footprint), the volume of water used to dilute the polluted water (grey water footprint), and mass of pollutant equivalent (e.g. kg SO2eq) to quantify the environmental impact of different categories. As a consequence, the water footprint assessment results are challenging to provide practical information for the stakeholders to make breakeven decisions in balancing economic and environmental performances. This study proposed a Quantitative-Qualitative Water Footprint (QQEFP) concept and method, which quantifies the environmental impacts of water use and pollution from an economic perspective. The proposed QQWFP covers the impact of water quantity consumption, and the water quality degradation caused by multiple types of pollutants. Different from the general life cycle costing assessment and conventional water footprint assessment method, the QQWFP is specifically designed based on the or water use characteristics and covers water quantity, water quality, distinguish different water sources and considers the compensation of water return to the local water supply system. Using cost as a quantifying unit (e.g. €/t product), the QQWFP provides essential decision-making oriented information for the stakeholders (especially industries) and facilitates water use performance from the cost-saving perspective. The cost-based QQWFP identifies the potential of improving water use efficiency and pollution reduction and serves as an active interface between the environmental and economical performance of water use towards the circular economy.

Keywords: Water footprint, cost analysis, water quality, multiple contaminants Change keywords

Acknowledgements: The EU supported project Sustainable Process Integration Laboratory – SPIL funded as project No. CZ.02.1.01/0.0/0.0/15_003/0000456, by Czech Republic Operational Programme Research and Development, Education, Priority 1: Strengthening capacity for quality research under the collaboration agreement with the Universiti Teknologi Malaysia (UTM) based on the SPIL project have been gratefully acknowledged.

A circular economy driving change in the management of plastic waste in hospitals during the COVID-19 pandemic

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Abstract: The problem of health waste management is increasingly attracting attention along with the increase in plastic waste due to the COVID-19 pandemic. Due to health and safety regulations, one of the main obstacles to recycling in the hospital environment is separating general waste from infectious waste. Applying a circular economy model for waste management will not only facilitate the transfer of waste collected from landfills to recycling plants but will also help reduce waste generation. This study highlights the need for targeted collaborative research that utilizes waste management principles and a circular economy concept, taking into account the degree of confusion in the hospital. Although this concept has been used frequently in the industry to reduce waste and energy costs, it is used less frequently in hospitals. This research investigates how the circular economy can serve as a driver for change in health care plastic waste management during the COVID-19 crisis to increase hospital value creation and profitability. A framework to describe the strategy for implementing a circular economy in hospitals that focuses on plastic waste management will be developed in this study. This study can help hospital management to contribute to reducing high levels of carbon dioxide in the environment and reducing landfill space.

Keywords: circular economy; healthcare waste management; hospital; COVID-19; plastic.

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