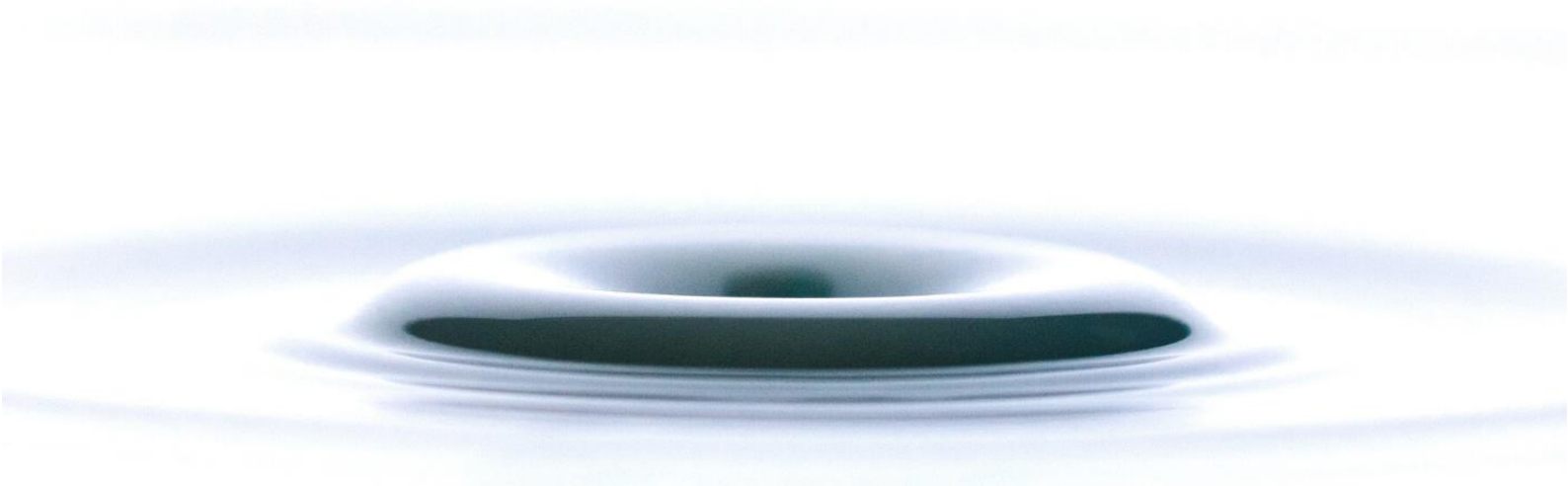
Mineral and Energy Economy Research Institute
Polish Academy of Sciences

MonGOS
International Conference 2022

Water and Sewage in the Circular Economy Model

ABSTRACT BOOK

2022



NAWA POLISH NATIONAL AGENCY FOR ACADEMIC EXCHANGE

MonGOS

International Conference 2022

Water and Sewage in the Circular Economy Model

30 June – 1 July 2022

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Mineral and Energy Economy Research Institute
Polish Academy of Sciences
Division of Biogenic Raw Materials

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ISBN 978-83964171-7-6

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Main organiser of the MonGOS IC2022

Division of Biogenic Raw Materials conducts research in the field of environmental management and engineering as well as biotechnology. The special interest is dedicated to the Circular Economy (CE) model and the Green Deal Strategies in food, water and raw materials sectors. The main research areas include:

- development of recommendations (road maps) for sustainable and circular management of biogenic resources,
- recovery of raw materials from waste, including phosphorus from waste generated in the water and sewage sector (fertilizers from waste),
- water in a circular economy and water footprint,
- evaluation of technological, legal, environmental and social aspects of the management of resources, including biogenic raw materials,
- optimization of resources use at the local, regional, national and international levels.
- strategies to protect waters against contamination with biogenic resources from anthropogenic sources and define directions for counteracting eutrophication,
- analysis of new materials (including nanomaterials) used in the treatment of municipal and industrial wastewater and soil.

Division of Biogenic Raw Materials participates in international projects (Horizon 2020, Horizon Europe, EIT Raw Materials, National Agency of Academic Exchange - NAWA, Visegrad Fund and others) related to the management of phosphorus raw materials and the development of recommendations (roadmaps) for the management of raw materials in the context of implementing the assumptions of sustainable development (SD), circular economy and the European Green Deal in the water and sewage, fertilizer and agri-food sectors.

TABLE OF CONTENTS

Sustainable and circular methods for pollutants removal from wastewater

Clean water environment

Poster session

Introduction

Dear Reader,

I am very happy that the MonGOS International Conference: Water and Sewage in the Circular Economy Model, took place physically in Cracow (Poland) on 30 June and 1 July 2022. The purpose of the MonGOS International Conference was to present a summary of the project MonGOS - Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions, that was dedicated to the development of a framework for monitoring the transformation towards CE in the water and sewage sector.

It is my great pleasure to share the Book of abstracts, that contains all presentations that have been included in the conference programme. In nine sessions of the MonGOS International Conference, Practitioners and Theoreticians presented works related to the implementation of CE in the sector, in two key areas: sustainable management of primary resources (water, raw materials, energy) and, circular management of secondary resources (waste generated in the sector, including sewage, sewage sludge, and other waste).

There was also panel discussion of the Managers of water and sewage companies, presenting barriers and opportunities (legal, organizational, technical, economic) for those facilities in the transition to the CE model.

In summary, during this 2-days conference, 200 Participants had a chance to see almost 80 fantastic oral and poster presentations. This event turned out to be an important place to exchange knowledge and good practices between Participants representing different sides of water and sewage sector - science, business and administration.

The MonGOS International Conference was organised by the Division of Biogenic Raw Materials of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences. We had a great opportunity to organise this event in a one of the most important place on the map of Cracow - Water Treatment Plant Bielany (built in 1901), that is an ideal example of reusing production halls for educational and popularization purpose. I would like to thank the Cracow Water Utilities for hosting our conference in this beautiful place, as well as all project partners, conference partners, units that provided honorary and media patronage, and any other organisations and people that support our event.

I would like to thank for all Participation for being a part of this CE transition in the water and sewage sector. There is no other way now – we have to turn to the Circular Economy.

Prof. Marzena Smol
MonGOS IC2022 Chair

MonGOS International Conference
Water and Sewage in the Circular Economy Model

30 June – 1 July 2022
Water Treatment Plant Bielany Krakow Waterworks
Cracow, Poland

MonGOS

International Conference 2022

Water and Sewage in the Circular Economy Model

30 July 2022

Plenary session

Marzena Smol

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Introduction of the MonGOS project

Project MonGOS "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" is dedicated to development of the Circular Economy (CE) monitoring framework in water and sewage sector. The project was realized by consortium of 8 partners. The Mineral and Energy Economy Research Institute, Polish Academy of Sciences coordinated the MonGOS project. The consortium included 5 strategic partners (Katholieke Universiteit Leuven, Belgium; Lappeenranta-Lahti University of Technology, Finland; Kaunas University of Technology, Lithuania; Tallinn University of Technology, Estonia; University of Latvia, Latvia) and 2 supporting partners (Gdansk Water Foundation, Poland; eRBeKa Foundation, Poland).

Background of the project idea was the problem of monitoring of the CE implementation in water and sewage sector. This sector faces many challenges arising from the CE policy in the European Union (EU). Water and sewage sector is an important element of building CE as wastes such as sewage and sewage sludge are valuable sources of selected raw materials (e.g. Phosphorus) and energy. To measure the progress of the transformation towards CE, in 2018 the European Commission (EC) proposed a set of 10 CE indicators, however, there was limited relationship with the water and wastewater management. Therefore, the main goal of the project MonGOS was to develop a monitoring framework that takes into account comprehensive indicators for CE, on the basis of which it is possible to determine the level of transformation towards CE in the water and sewage sector. Strategic goals of the project included:

- identification and assessment of the potential for transformation towards CE in the water and sewage sector,
- exchange of good practices and transfer of knowledge between leading scientific institutions in Europe in the field of water and sewage management,
- developing a framework for monitoring the transformation towards CE in the water and sewage sector,
- developing and implementing a plan for the dissemination of international research results.

The project was realised in 2020-2022 thanks to support the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.

Keywords: *circular economy; indicators; monitoring; water; wastewater*

Acknowledgments: *The study was developed under the project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" (MonGOS), which is financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.*

Piotr Ziętara

Cracow Waterworks, Poland

Circular economy in Cracow Water Utility

The presentation contained the examples of good practices of the Circular Economy (CE) implementation in the Cracow Water Utility. The inventory of CE actions, as water and wastewater treatment, resources recovery (including phosphorus recovery), water reuse, educations campaigns dedicated to different groups of stakeholders, were presented by the President of the Cracow Water Utility – Mr. Piotr Ziętara.

The main massage was the necessity of the CE implementation in water and sewage sector and taking of leading role of biggest water companies, as the Cracow Water Utility in the transition to the CE model in Poland and abroad.

Keywords: *circular economy; wastewater treatment plant; water treatment plant*

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Recovery of nitrogen in water and wastewater sector

Nitrogen (N) is commonly removed from wastewater via biological nitrification-denitrification, but this combined process consumes a lot of energy. Ammonia recovery offers potential energy savings, as long as it can be achieved with lower energy consumption than industrial production (Haber-Bosch process). A variety of biological, chemical and physical technologies (>50) have been developed for ammonia recovery, but in general they are still in the infant stage. One of the most promising technique is a hydrophobic gas-permeable membrane due to a high N recovery efficiency (>90%) and relatively low energy demand (approx. 1 kWh/kg N). The majority of the techniques (>40%), including the gas-permeable membranes, produce a fertilizer in the form of ammonium sulphate ($(NH_4)_2SO_4$), either in solution or crystalline form. $(NH_4)_2SO_4$ makes up a very small portion of the overall profile of fertilizers (approx. 4%), but it has some advantageous properties (i.e., it contributes S and increases acidity in the soil). Moreover, its market value is much higher than struvite (> 520 USD/ton vs. < 90 USD/ton).

Keywords: *circular economy; fertilizer; N recovery; nutrients; wastewater treatment*

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Water reclamation practice according to EU regulation 2020/741 - case study

Józefów is a residential city near Warsaw, with numerous green areas and forests, without industry. The operator of the urban waste water treatment plant - Hydrosfera wants to provide reclaimed water for irrigation of the surrounding green areas. There is a golf course nearby, as well as city lawns and parks. Water can also be used to wash streets. Water recovered from waste water will be stored in the retention reservoir and made available to recipients.

Hydrosfera tests the quality of reclaimed water to check seasonality related to micropollutants. Laboratory tests cover a broad spectrum of microbiological contaminants. The value of microbial parameters reaches maximums that are not satisfactorily leveled by the wastewater treatment plant.

The results of microbiological and physicochemical analyzes of the reclaimed water quality indicate that to meet the requirements of the water reuse quality (2020/741), it is necessary to add another treatment step. The reclaimed water class should be the highest permitted by the regulation (class A). Even if the watered plants will not be grown for food, the risk of human contact with the reclaimed water should be reduced. The barrier to microbiological parameters is the most important. Research results show that the disinfection process is sometimes insufficient, so prior filtration is necessary.

The risk analysis carried out on the basis of the guidelines from the Regulation indicates favorable conditions for the development of water recovery from urban waste water in Józefów.

Keywords: *water reclamation; EU regulation; wastewater treatment plant*

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Energy implications of wastewater management

Wastewater management is an essential social service, allowing the society to function well, aiding in daily lives and key activities – such as business operations and healthcare. Wastewater itself often contains chemical and thermal energy. On the other hand, it needs treatment for pollutant removal, to enable its release to the environment or supply it for reuse in human activities.

The operation of a wastewater management network requires energy in the form of heating, cooling and power. The streams in the network often need heating or cooling. The various pollutants carried by them can be inorganic or organic. In the latter case, the pollutant itself can be a source of chemical energy. These cases are examples of direct energy use or retrieval potentials in wastewater management. In addition, such processes have indirect implications if the recovery and reuse of secondary mineral resources are accounted for. For instance, metals and phosphorus or nitrogen compounds can be recovered from wastewater streams and then reused in the industry as secondary raw materials.

Wastewater streams managed in a water network can be modelled following the generalised mapping of industrial and urban symbiosis networks (Gai et al., 2021). Their management can be represented as a set of paths for recycling the waste materials, competing with the supply of analogous streams originating from natural resources, as well as adding clean water sinks and ultimate waste disposal sinks.

Each such path is associated with its deficit or excess of energy for carrying out the processing and transportation operations. For instance, wastewater streams containing sludge can be incinerated, and the energy excess can be supplied to energy sinks. On the other hand, other streams would need only treatment and cannot offer energy valorisation, presenting net energy sinks to the network. Further, the paths are characterised by their demand for additional material resources and released footprints.

The arrangement and performance optimisation of the flows and exchange of materials in the symbiosis networks form the basis for the network design and planning. This incorporates the mass balances and the constraints on the footprints related to the flowrates of the consumed resources and the constraints on the released footprints.

This presentation reviews the direct and indirect energy implications of wastewater management networks, discussing the problem of minimising the supply of additional energy and the GHG Footprint in water management networks. The discussion will account for:

— energy supply and GHG Footprint used for the paths of recycling and final waste disposal

— embodied energy and GHG Footprint of the products and streams originating from primary resources,
— use of renewable solar energy and the valorisation of wastewater heat for residential and urban energy needs

Keywords: *wastewater; wastewater management; energy*

Acknowledgement: *This research is funded from the RESHeat project that has received funding from the European Union HORIZON 2020 research and innovation programme under Grant agreement No 956255".*

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International Conference 2022

Water and Sewage in the Circular Economy Model

30 July 2022

Circular economy in water and sewage companies

Panellists

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Bartosz Łuszczek
Wodociągi Miasta Krakowa (Kraków Water), Poland

Przemysław Chrobot
MPWiK S.A. we Wrocławiu, Poland

Beata Wiśniewska
Wodociągi Białostockie, Poland

Jarosław Hermaszewski
ZWiK Sława, Poland

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Circular economy in the facilities of water and sewage companies

Water and sewage companies in Poland have been developing cost-effective forms of using energy from waste generated in sewage treatment plants - sewage sludge for years. These facilities, usually equipped with methane sludge digestion systems, preceded by various disintegration processes, generate significant amounts of biogas, which is mostly used in the production of electricity and heat in gas engines. The heat obtained from the electricity generation process is usually sufficient to meet 100% of the energy needs of the sewage treatment plant. Electricity produced from own sewage sludge allows to cover approx. 40 - 50% of the entire sewage treatment plant's demand. However, the potential of the existing installations allows for the production of electricity in an amount exceeding the needs of the treatment plant itself, it is also possible to supply energy to other facilities of water and sewage companies, such as water intakes, water treatment stations, hydrophore stations, and sewage pumping stations.

Keywords: *sludge; sewage sludge; wastewater treatment plant*

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International Conference 2022

Water and Sewage in the Circular Economy Model

30 July 2022

Wastewater treatment and resource recovery

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Circular economy based on Polish-Norwegian R&D projects

The aim of SNIT project (Shortcut nitrification in activated sludge process treating domestic wastewater - key technology for low-carbon and clean wastewater treatment) is to create an innovative technology that will allow achieving mainstream shortcut nitrification/denitrification via nitrite at municipal wastewater treatment plants (WWTPs). Achieving this objective will significantly reduce oxygen and organic carbon demand for nitrogen removal process, improve effluent quality and increase digester gas production. This technology also includes a development of separate reactor for sludge disintegration with nitrous acid to aim easy biodegradable organic carbon for denitrification process improvement, which is usually limited by organic carbon available in raw wastewater. Disintegration of fish sludge by use of nitrous acid will be tested. Fish sludge can be considered as a co-substrate for sewage sludge anaerobic digestion.

The subject of the DIGEST-PLAST project is methane fermentation of the organic fraction of municipal waste (OFMSW). Additionally, the project focuses on biodegradable bioplastics which recently commonly introduced will undoubtedly have an impact on the properties of the feed directed to digesters, and thus on the efficiency of biogas production, digestate quality and its susceptibility to composting, especially in terms of the presence of so-called microplastics. DIGEST-PLAST project investigates possibilities of the organic fraction of municipal and industrial waste utilization for renewable energy (biogas) production.

Keywords: *circular economy; projects; municipal waste; fermentation*

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Unconventional waste water treatment plant- recovery possibilities in small and medium sized facilities

The aim of this study was to test the improved processes of waste water treatment in medium-sized wastewater treatment plants - Bionor Sludge Strategy - in order to achieve valuable products - biomass and energy. In this case the goal is to predict the environmental burden of the aerobic treatment technology in question and potential environmental benefits concerning replacement of common commercial fertilization and soil amendment products.

Wastewater treatment plants can become bio-factories that generate energy and recover nutrients and biomass. Local conditions in the case of smaller installations will also directly affect their operation and the possibilities and directions of recovery. For analysed Bionor Sludge Technology, produced biomass is a key feature of the technology and have several options for utilisation. The LCA analysis confirmed the high value of obtained biomass production and utilization, when comparing different possible concepts of sewage sludge management. In this case the high potential environmental benefits concerning replacement of common commercial fertilization and soil amendment production was recognized.

It was found that generated biomass is a key feature of the technology and have several options for utilization. The most beneficial scenario for investigated WWTP is biomass as both fertilizer and soil amendment.

Keywords: *bionor sludge; sewage sludge treatment; biosolids; LCA; recovery*

Acknowledgments: *The research has been funded by project no SKN/SP/496788/2021 financed by the Minister of Education and Science from the state budget under the program "Student research clubs create innovation" and internal project BS/PB-400/301/22.*

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Hybrid, Natural Material Based Sorbents for Removal of Pollutants from Wastewaters

Sorbents are materials that can bind organic and/or inorganic substances, for example, oil hydrocarbons or heavy metals as a result of absorption and/or adsorption processes. There is a growing interest in application of natural materials as sorbents, however, to achieve desired selectivity, needed sorption capacity, often there is a need to modify properties of natural material – to obtain sorbent combining carrier and modifier properties. The present work investigates possibilities to modify low-cost natural materials (clay, peat, straws and other materials) to obtain sorbents for removal of metal ions, metalloids (arsenic, antimony and tellurium) as well as phosphorus from wastewaters. As modifiers iron oxohydroxides, oxihydroxyapatite were used as well as chemical modification of the carrier material were done. The results were obtained using batch tests, and the sorption kinetics was studied as well as sorption thermodynamics as a function of initial sorbate concentration, pH and temperature. The optimal pH interval for the sorption of each studied element could be established The impact of temperature on the sorption capacity was tested. The sorption capacity increased with increase in temperature for all of the studied sorbents. The calculated thermodynamic parameters suggest that the sorption process is of a spontaneous nature and endothermic. Furthermore, the biodegradation potential of studied biomaterial sorbents is undeniable, and they also have other notable advantages, such as low cost and availability.

Keywords: *wastewaters; biosorbents; pollutants; mechanism*

Acknowledgments: *Authors acknowledge MonGOS project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions", financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme. Web-page: mon-gos.eu.*

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Sustainable macronutrient recovery options from the municipal wastewater

In recent years, a gradual increase in the awareness of the need to close the nitrogen and phosphorus cycles has been observed. Despite numerous macronutrient recovery processes from waste streams in the form of so-called waste-derived fertilizers have been developed, only a few of them have been fully commercialized.

Since the new Fertilising Products Regulation ((EU) 2019/1009) is expected to uniformize marketing opportunities for both raw-material and waste-derived fertilisers, this study reviews the existing macronutrient recovery processes from municipal wastewater in terms of recovery, energetic and economic efficiencies, and the market readiness for the products reuse.

For all stakeholders involved, the most important is product safety, thus its uncomplicated and trusted composition. The "manufacturers'" (i.e. WWTP operators') driving force are reduction of the nutrients amount in the effluent, GHGs emission and possible financial benefits. Both, the final users and suppliers, underline the importance of the ease of storage, transportation and handling fertilisers, pointing the preference of crystals form. Farmers admit the nutrient content is not as much important as the rate of their release and the fertiliser price.

The review recognized the lack of sufficient financial and energetic analyzes of available recovery technologies. However, a low cost-to-benefit ratio was identified for integrating struvite precipitation from anaerobic digestion liquors with absorbance of the remaining ammonia to sulfuric acid via gas-permeable membranes. The technology ensures solving operational problems of the WWTPs, i.e., pipes clogging and NH3 emissions, while offering two crystal-type fertilisers, including a slow release struvite ($MgNH_4PO_4$) and ammonium sulfate ($(NH_4)_2SO_4$).

Keywords: *circular economy; waste-derived fertilisers; market readiness; integrated recovery processes; efficiency*

Acknowledgments: *The research leading to these results has received funding from the Norway Grants 2014-2021 via the National Centre for Research and Development under the grant number NOR/SGS/INPORR/0074/2020-00.*

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Integrated system for the treatment of sewage and water sludge at the Kraków-Płaszów WWTP

The article presents the developed sequence of processes for the simultaneous treatment of two groups of sludge formed during the operation of urban infrastructure: sludge from water treatment plant and sewage sludge. The main aim of the process was the modified anaerobic stabilization of wastes with synergistic biogas recovery (improvement of the city's energy balance). The innovative feature of the project involves an unique and not used on a large-scale process of common fermentation of sewage sludge as well as sludge after water treatment. The sludge with a reduced content of organic compounds was subjected to autothermal combustion under controlled conditions in a fluidized bed furnace. The final product was ash, used as a valuable component of cement composites used in the construction of road infrastructure. As a result of the application of the proposed technology, the profits for the company were determined: increase in biogas production (10%), heat recovery and obtaining components for the production of construction materials (obtaining concrete of good quality - detailed indicators are included in the publication). The developed technology is one of the first, practical solutions of a waste-free sewage treatment plant in line with the current assumptions of a circular economy in the water and sewage sector of the municipal economy.

Keywords: *synergistic sludge disposal; municipal water-sewage system*

Acknowledgments: *The project was supported by the European Union Funds, The National Centre for Research and Development, Poland, POIR.04.01.02-00-0032/17.*

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Fundamental principles and approaches of waste/ water management in sustainable urban development

The concept of sustainable urban development as a broad conceptual framework moves towards achieving economic growth, social and cultural growth, and environmental protection. Today, sustainable urban development focuses on metropolitan areas to study and recognize the environmental status and bottlenecks. Among those, environmental deterioration, nutrient deficiency of the agricultural lands, and waste (water) management require the utmost attention. A few key parameters for successful implementation of waste management are proper waste collection, storage, and treatment.

In this research to analyze the waste increment production and reduce the recycling policies in the metropolitan city of Shiraz-Iran, multi-criteria decision-making methods such as the Promethee, scalogram, Morris method, as well as network analysis process (AHP) were used to weigh various criteria. For analysis, eleven districts of Shiraz were compared and ranked. The results of the study based on the Promethee method showed that in terms of the health and environmental index, districts 9 & 6 ranked highest, scoring 68.95 and 67.26, respectively. Also, according to the Scalo gram method, regions one and eight are in the first place with 55 and 49 points. These results indicate how the regions are well developed in the center of Shiraz City w.t.t environmental protection criteria.

In conclusion, apart from public awareness, governmental involvement to develop sustainable waste management are the key solution to sustainable waste management. Other significant constraints are the lack of up-to-date information and resources and the lack of leadership that necessitates in development of Public-private partnerships to overcome waste management challenges in the cities.

Keywords: *waste (water) treatment; urban planning; sustainable development*

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International Conference 2022

Water and Sewage in the Circular Economy Model

30 July 2022

Monitoring of the circular economy implementation in the water and sewage sector – indicators and measures

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Monitoring framework for the circular economy implementation in the water and sewage sector

Achieving a climate-neutral circular economy CE) requires the full mobilization of companies operating in the water and sewage sector. This sector is an important element in building the CE, because on the one hand it uses primary resources - water, and on the other hand, it has a great potential for the circular management of waste, such as sewage and sewage sludge, which are a valuable source of nutrients - in the CE model, there are they turn into resources.

An important element of the CE transition is ability to measure the level of progress toward the CE model in different context, as regional, local, unit or sectoral level. In the project entitled "Monitoring of water and wastewater management in the context of implementing the assumptions of the circular economy" (acronym: MonGOS), comprehensive CE indicators were proposed as a part of developed CE monitoring framework in the water and sewage management sector. The proposed indicators in six areas of developed CE framework: rethinking, reduction (minimization), removal, reuse, recycling, recovery, will be of great importance for the strategic planning of the development of organizations using water resources in their activities, not only in the field of the CE, but also in the area of supporting innovation, education, employment and the development of industry and services.

Keywords: *circular economy; indicators; monitoring; water; wastewater*

Acknowledgments: *The study was developed under the project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" (MonGOS), which is financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.*

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Indicators for resource recovery monitoring in the wastewater sector

The transformation towards circular economy is ongoing in almost all economic sectors in the European Union member states. Water and sewage management is considered to have one of the highest potentials to rapidly increase the transformation progress by implementing circular and sustainable solutions in water and sewage-related infrastructure. Resource recovery is one of the leading goals of the circular economy in sewage management. Therefore, to enable efficient monitoring of the circular transition dedicated indicators are necessary. The study carried out under the MonGOS project was aimed to review the existing indicators for measuring circular economy implementation and propose key recommendations to improve the resource recovery monitoring framework in sewage management. Within the identified indicators, most of them were focused on technical aspects of resource recovery such as nutrient removal efficiency, sewage sludge processing methods and environmental aspects as the pollutant share in the sewage sludge or its ashes. Additionally, more wide-scope indicators were included in the study such as the wastewater service coverage and the production of bio-based fertilizers and hydrochar from sewage sludge. Moreover, based on the reviewed indicators a new circularity indicator for a wastewater treatment plant was proposed that highlights the opportunities and future challenges in circular transition in the sewage management.

Keywords: *indicators; resource recovery; sewage; wastewater; nutrients; circular economy*

Acknowledgments: *The study was developed under the project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" (MonGOS), which is financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.*

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The role of wastewater treatment plants in phosphorus circularity in Lithuania

Various human activities interfere into the natural flows of phosphorus (P). Wastewater collection and treatment in wastewater treatment plants (WWTPs) is one of such activities, which results in P being diverted from one media into another, and which has a potential to contribute to P circularity. The aim of the study was to assess the flows of P through the WWTPs in order to find out how much the WWTPs contribute to the circularity of P flows, what are the shortcomings, and to evaluate the possibilities for further improvements.

WWTPs contribute significantly to reducing water pollution with P and preventing eutrophication; however, point sources account for about 13% of the P load from Lithuania to the Baltic Sea. Unfortunately, in recent years there have been cases where the permissible P concentrations in the effluent have been exceeded. P recovery technologies to recover fertilizer from supernatant liquor or sludge ash have not been implemented in Lithuania, but the widespread use of sludge in agriculture and composting allows up to a third of P to be returned to the economic cycle.

Keywords: *phosphorus; wastewater treatment plants; circularity*

Acknowledgments: *The study was developed under the project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" (MonGOS), which is financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.*

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Circular economy indicators and measures in water and wastewater sector – case study

The objective of this study was to create the list of circular economy indicators that could be used for monitoring the implementation of circular economy principles in the Municipal Water Supply and Sewerage Company in Warsaw, a joint stock company. The applied methodology for the analytical and conceptual work included a detailed analysis of statutory activities implemented in this type of enterprises and a review of the benchmarking indicators and the enterprise's documentation for the identification of indicators that could be used in the system of monitoring of water and wastewater enterprises in terms of their transformation towards circular economy. Particular attention was paid to measures undertaken in the aforementioned sector related to minimising the use of primary resources (particularly water), renewable energy production, waste management, and possibilities of resource recovery. The possibility of the analysis of implementation of an information-educational strategy aimed at increasing social awareness in the scope of pro-CE activities was also considered, as well as expanding the skills of staff in the CE area. The proposed monitoring system includes 29 indicators divided into the following six groups: Resources Used, Resources Recovery, - Energy, Emissions, Waste, Other (economic and social indicators).

Keywords: *circular economy indicators; water and wastewater enterprises; environmental indicators; economic indicators; social indicators*

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Comparative analysis of selected benchmarking indicators in the context of resource efficiency of water utilities

For effective project management aimed at changing the economy to a more resource-efficient one, it is necessary to develop evaluation methods. The aim of the assessment should be to check if the performed tasks resulted in the intended effects. Water utilities collect large amounts of data for the purpose of strategic infrastructure management. Based on this data, Key Performance Indicators (KPIs) are calculated. KPIs are used to evaluate the activities of enterprises and to define management goals. Such indicators are generally assessed using internal or external benchmarking.

The main thesis of this paper is that the benchmarking indicators can be used as an effective tool to support the circular economy. The paper presents selected benchmarking projects and indicates which indicators can be used to assess the resource efficiency of enterprises. The indicators and data sets collected under the benchmarking project of the Polish Waterworks Chamber of Commerce, and available in the open report on the ECB benchmarking will be discussed. The advantages and disadvantages of currently used indicators (especially related to monitoring of losses and energy consumption) will be presented. The needs for changing the currently used and introducing new indicators will be shown. The possibility of using the benchmarking data will be assessed in the context of sustainable investments and EU requirements for financing projects from public funds. This will help to assess the potential of Polish entities to implement projects aimed for the circular economy.

Keywords: *benchmarking; KPI; water loss; energy efficiency*

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Social indicators in water and sewage sector

The Circular Economy (CE) is an economic model based on more sustainable resource management. In the context of the water and wastewater sector, the transformation towards CE includes more rational ways of managing water (as a primary raw material) and waste generated in water use and wastewater treatment processes.

The paper presents the identification of social indicators applicable to the measurement of the transformation towards CE in the water and sewage sector. The indicators were divided into 4 groups: people and water resources, research and education, households and devices, safety and quality, to which the relevant indicators were assigned. The statistics concerning the research and education group were characterized and presented, such as:

- implementation of projects related to sustainable water and sewage management,
- fields of study related to a circular economy,
- implementation of projects related to students' education in the circular economy topic.

The presented examples of social indicators can contribute to education and building public awareness of the importance of CE. The motivation to undertake this study was the identification of the current needs for a comprehensive inventory containing social indicators that can describe the actual transition to CE in the water and wastewater sector.

Keywords: *indicators; social indicators; water; sewage; circular economy*

Acknowledgments: *The study was developed under the project "Monitoring of water and sewage management in the context of the implementation of the circular economy assumptions" (MonGOS), which is financed by the Polish National Agency for Academic Exchange (NAWA) under the International Academic Partnerships Programme.*

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International Conference 2022

Water and Sewage in the Circular Economy Model

30 July 2022

Sustainable and circular technology in the water and sewage sector

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Water supply for the scout camp according to the principles of sustainable development

Zaopatrzenie w wodę obozu harcerskiego zgodnie z zasadami zrównoważonego rozwoju

There are more than 120.000 scouts in Poland, and most of them go camping every year. Some of the camps are located in forests without sanitation facilities. Therefore, the guides organizing the camps must prepare sanitation systems even if they do not have experience in this. Normally, they decide to use easier but often less environmentally friendly solutions, e.g. drinking water from plastic bottles. Polish Scouts are members of a movement that also works for global sustainability. The United Nations, an intergovernmental organization, in 2015 developed the Sustainable Development Goals plan. Achieving these 17 goals and, associated with them, 169 targets means that humans develop in a sustainable way. Sustainable development can meet the needs of current generations without limiting the possibilities of future generations. This is a global issue, but acting locally is also important, and Polish scouts should be concerned. They can reduce their negative impact on the environment, for example, by removing plastic bottles during their camps and using inferior quality water to wash.

In this publication, the authors, based on the example of a summer scout camp in Nowa Brda on Lake Babinko, will present how to provide water to 50 people in a water-balanced manner. They will show that in this type of event, ecological solutions can be chosen for the preparation of water.

Keywords: *drinking water; sustainability; scout camp; sanitation systems; Sustainable Development Goals*

Acknowledgments: *The research was financed by the Ministry of Science and Higher Education, Research Subsidy of the Poznan University of Technology 2022 entitled: "Improving methods, devices, and systems of environmental engineering for sustainable development" (5200 201/0713/0010/SBAD/0958).*

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Membrane separation processes in water and wastewater treatment

Procesy separacji membranowej w oczyszczaniu wody i ścieków

Inconveniences and changing approaches to traditional natural water and wastewater treatment and water re-use are creating opportunities for new separation techniques, among which membrane methods have the greatest advantages and capabilities and are now being considered as alternative processes.

In water and wastewater treatment, mainly pressure-driven membrane techniques are used, i.e. reverse osmosis, nanofiltration, ultra- and microfiltration, but other processes such as forward osmosis, electrodialysis, membrane distillation and liquid membranes are also considered. The choice of the appropriate membrane process depends on the size range of the contaminants and admixtures present and removed, The selection of a suitable membrane process depends on the range of sizes of contaminants and admixtures present and removed. Membrane techniques can be used to remove contaminants from water and wastewater as stand-alone processes, or in combination with complementary unit processes to form integrated/hybrid systems. There is an unending list of membrane technology applications in water and wastewater treatment.

Reverse osmosis retains monovalent ions and most low molecular weight organic compounds and is used for desalination of water and removal of organic and inorganic micropollutants from water and wastewater. Similar applications have forward osmosis and membrane distillation processes. Nanofiltration membranes retain colloids, a range of low molecular weight organic compounds, and divalent ions; therefore, they can be used for water softening and removal of micropollutants. Ultrafiltration and microfiltration provide a barrier to dispersed substances and microorganisms and are therefore used for water disinfection and turbidity removal.

The use of reverse osmosis, nanofiltration in the treatment of water and wastewater containing inorganic and organic micropollutants allows more or less selective removal. Disinfection by-products, residues of pharmaceuticals and personal care products and endocrine active compounds are very important. The latter include, in particular, polycyclic aromatic hydrocarbons, surfactants, pesticides, phthalates, alkylphenols, polychlorinated biphenyls, hormones, synthetic pharmaceuticals, and other substances discharged into the environment. The use of microfiltration and ultrafiltration in the removal of micropollutants is possible in systems integrated with coagulation, adsorption, complexation and biological reactions.

Keywords: *membrane techniques; water treatment; wastewater treatment; hybrid processes*

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Road map of the transformation of MPWiK in the capital city Warsaw S.A. towards a circular economy

Mapa drogowa transformacji MPWiK w m.st. Warszawie S.A. w kierunku gospodarki o obiegu zamkniętym

The model of the circular economy (CE) assumes the creation of a closed loop of processes, where the generated waste is used as raw materials in other production stages. Municipal Water Supply and Sewerage Company in Warsaw Joint Stock Company is a public utility company striving to ensure that its operations have the least possible impact on the natural environment. For this reason, it implements projects aimed at transformation towards a circular economy. The presented topic includes an analysis of the activities which fulfil the CE model - undertaken and planned to be implemented in the company in the upcoming years. Due to the fact that only a holistic approach can ensure full benefits from this new economy model, it is needed to take 3 types of action: economic, socio-economic and environmental. It is crucial to promote solutions that reduce the consumption of raw materials, electricity and amount of generated waste, such as: process optimization, implementation of new technologies, recycling and recovery and green energy production. The activities that increase social awareness, both among residents and city administrators are recommended as well. Last, but not least important, is the day-to-day operation of the company, which should be based on reduction of used consumables, proper use of equipment and full digitization. The combination of these factors and activities must be properly managed and monitored to maximise the effect of implementation.

Keywords: *CE model; holistic approach; sustainable development; green energy; process optimization*

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Rainwater, greywater, wastewater in circular urban water management on the example of the CWC project

Deszczówka, szara woda, ścieki w cyrkularnej gospodarce wodnej w mieście na przykładzie projektu CWC

Fresh water is a finite resource and its availability is threatened by overexploitation, pollution and changing climate. On the one hand, heavy rains, on the other, prolonged droughts - excess and scarcity of water are two extreme threats to cities resulting from a climate change. The linear model of urban water usage does not work. In the circular model, we can think about water in the city in microcycles, for each microcycle we can consider where to get water from, how to use it, where to discharge it and whether on the discharge path we can re-circulate it, so that the water circulates in the system as long as it is possible before we get rid of it. According to the concept of circular economy, rainwater, greywater and treated wastewater are not seen as waste but as resources that can be used to reduce the consumption and demand for drinking water. The CWC project (City Water Circles: Urban Cooperation Models for enhancing water efficiency and reuse in Central European functional urban areas with an integrated circular economy approach) financed by the European Regional Development Fund under the Interreg Central Europe Programme the five pilot investments been implemented which showed water urban management tools in accordance with the principles of circular economy.

Keywords: *rainwater; greywater; wastewater; circular urban water usage*

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Urban aquaponic farms supplied with rainwater as a way to implement the idea of circular economy in the water and sewage sector

Miejskie farmy akwaponiczne zaopatrywane w wody opadowe sposobem na realizację idei GOZ w sektorze wodno-ściekowym

The ongoing climate change and its effects, as well as the uncertain geopolitical situation or the COVID 19 pandemic, make it necessary to take action at various levels to ensure the safety of city residents. At the same time, such activities should meet the requirements of sustainable development and circular economy, so as not to further aggravate the climate crisis. Particular needs arise especially in the sector of providing food to the citizens. Aquaponic farms seem to be the solution to these needs.

The article presents urban aquaponic farms fed by rainwater as solutions implementing the ideas of circular economy together with a discussion on the challenges and opportunities, as well as threats and limitations in the development of such facilities in the cities of the future.

As part of the introduction to the work, the definition of aquaponics, the division of aquaponic crops and their basic characteristics are presented. Particular attention was paid to discussing the features that meet the requirements of the circular economy.. The perspectives for the development of such solutions are presented, taking into account both the possibilities and threats that may occur in this respect in the cities of the future in the era of climate change. The paper also presents a SWOT analysis of the development of urban aquaponic farms fed with rainwater.

Conclusions formulated on the basis of the conducted analysis indicate the directions of further activities in the field of development of urban aquaponic farms. They relate to the technical, economic and sociological spheres.

Keywords: *aquaponic; rainwater; stormwater; circular economy; food*

Acknowledgments: *The article was written as part of the USAGE project. The project USAGE no. NOR/IdeaLab/USAGE/0004/2020-00 has received funding from Norway Grants 2014 – 2021 and the state budget of Poland via the National Centre for Research and Development within "Applied Research" Programme.*

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Disinfection of treated wastewater

Dezynfekcja oczyszczonych ścieków

One of the key tasks that the modern world has to face is to ensure that all residents have an effective and uninterrupted distribution of water. The dangers of microbial contamination of waters do not apply only to drinking water, directly distributed to humans. The reuse of water, e.g. for irrigation of crops in agriculture, also requires that a certain criteria of microbiological quality are ensured. That is why, in order to protect human health, it is very important to diagnose possible risks as early as possible and then carry out the necessary processes, and apply the best techniques to guarantee the proper quality of the water used. Sewage disinfection processes seem to be an inseparable element of their proper treatment. Different methods of implementation (from physico-chemical processes to the latest technological achievements) have one common goal: to ensure the recovery of water, enabling its repeat safe use. Therefore, in addition to effective disinfection of wastewater, it is really important to detect hazards quickly and in a timely manner.

The presentation focuses on presenting the risks and prospects for the future of reusing reclaimed water from wastewater. Attention was drawn to the change in the law being in force in the EU and the consequences of this were discussed. The techniques used so far for the disinfection of sewage were indicated, with a clear emphasis on new, constantly developing technologies. The current methodologies for assessing the microbiological quality of wastewater were presented and techniques that offer a real opportunity to improve and shorten the time of implementation of this assessment in the future, were briefly discussed.

Keywords: *disinfection of sewage; assessment and microbiological quality of sewage; reuse of water*

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International Conference 2022

Water and Sewage in the Circular Economy Model

1 June 2022

Plenary session

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Ash2Phos – Recovery of clean calcium phosphate from sludge ash

EasyMining has developed a process for phosphorus recovery from sludge ash named Ash2Phos. The process is based on wet chemical processing of mono-incinerated sludge ash. Phosphorus is recovered in form of clean calcium phosphate. Several options exist for using the calcium phosphate as it is, e.g. as feed additive or fertilizer, or converting the calcium phosphate into water soluble fertilizer. After successful pilot trails, work is ongoing on the engineering and permit of the first full-scale plants in Germany and Sweden.

Phosphate rock is the primary raw material for phosphate production, but unfortunately mineable phosphate rock is a limited non-renewable resource. Large amounts of phosphorus end up in manures and in urban waste, mainly in sewage sludge and slaughterhouse waste.

Today EU are countries re-circulating phosphorus by distributing 48% of the sludge back to farmland. The positive aspect is that phosphorus is re-circulated, but it is not problem free. Sewage sludge can still contain viruses, heavy metals, and other substances that can be harmful to human health. Currently 27% of the sewage sludge is landfilled or used in other ways that rarely recover any phosphorus. 25% of the sludge is incinerated and the ash is mainly landfilled.

The Ash2Phos process contributes to the goal of a circular and sustainable society by recovering phosphorus, but also aluminium and iron, from ash of incinerated sewage sludge (SSA). Phosphorus recovery from SSA will be mandatory in Switzerland beginning in 2026 and in 2029 in Germany with other European countries to already discussing similar obligations.

Keywords: *phosphorus recovery; sludge ash; fertilizer; feed phosphate; sewage*

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5 innovative technologies for circular economy

At Isle Utilities we scout the global markets for the innovative technologies for our clients. In this presentation Luiza will showcase five most exciting examples of technologies that meet the principles of circular economy, i.e. design out waste and pollution; keep products and materials in use, and regenerate natural systems. It is possible for instance to transform FOG (Fat, Oil and Grease) into biodiesel, extract heat from wastewater, convert wet biowaste into solid biochar (biocoal), split ammonia to produce hydrogen and nitrogen and capture carbon dioxide to stabilise a wide variety of materials, e.g. new fertiliser products. The presentation will cover key aspects of the technologies and their benefits to society.

Keywords: *innovative technologies; circular economy; wastewater*

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Raw materials recovery in water and sewage sector – current trends and future perspectives in the circular economy model

193 nations have agreed on ambitious sustainable development goals in Paris in September 2015 – to be achieved by 2030. Yet in regard to resource extraction, pollution, nutrient losses and access to sanitation the global community is not anywhere close to achievement. Also, wastewater treatment plants (WWTP) are relevant energy consumers, estimated to consume between 1% and 3% of the global energy output. Consequently, research efforts are underway globally to reduce the energy consumption of wastewater treatment – mainly caused by the aerobic activated sludge treatment by aeration responsible for more than 50% of the WWTP's energy consumption. Other and currently more promising strategies are untapping the intrinsic energy content of wastewater and converting it to gas, heat and power as well as recovering and recycling minerals and nutrients. To achieve the climate protection and sustainability goals, the global community needs to decouple material wellbeing (economic growth) of humans from resource use. Decoupling economic growth from CO2 emissions has proven to be achievable by various EU member states in the period between 1990 and 2018. Municipal wastewater treatment plants can make relevant contributions.

The MonGOS conference presentation showcases current trends in regard to treated wastewater reuse for irrigation, energy recovery and nutrient recovery from wastewater which in selected European countries is enforced by legislation. Topics to be covered include using large heat pumps to provide district heating and cooling, and energy recovery from sludge through anaerobic digestion and/or incineration. Future options for energy recovery in the water sector will be presented. Also, examples are given for recovered products for use in agriculture and as chemical building blocks. Benefits and trade-offs of the different processes and products will be discussed. Eventually, the presentation will turn to perspectives and deal with the question if – municipal and private - treatment plants should become first movers in energy and nutrient recovery from wastewater and sludge. Successful models show that by using available, mature technologies, a sewage plant can become an energy provider instead of an energy consumer. This raises the question, if revenues from energy supplies to industries and high income residents in future could sustain operations of wastewater treatment plants in low income countries and thus mobilising financial resources so urgently needed.

From attending the presentation, participants will

- be able to identify potential opportunities for energy recovery from water and sludge including,
- resources for district heating, district cooling and renewable energy carriers (biogas and power),

— be in a position to initiate energy and nutrient recovery projects, including finding resources for relevant information and support,
— be able to identify future opportunities and challenges for minerals and nutrient recovery in the water sector including an overall understanding of the different pathways, technologies and products including related benefits and challenges.

Keywords: *raw materials; recovery; water, sewage, circular economy*

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Algal biomass utilization towards circular economy

The Circular Economy addresses the benefits to the environment, economy and society. The concept of Circular Economy is linked to the Sustainable Development Goals by reducing consumption and achieving savings of raw materials, water and energy. Reducing greenhouse gases emissions, producing biofuels, food, bioplastics, cosmetics, pharmaceuticals and feed for animals, as well as water and wastewater treatment are possible to realize by utilization of algal biomass taking into account European Green Deal. We discuss the possibilities of reducing the CO_2 emissions due to the CO_2 capture by photosynthesizing algae. Besides reducing the greenhouse effect and contributing to the decrease of the amounts of harmful substances in the air, attention has been paid to the possibility of using algae for wastewater treatment. A review of the potential ways of algal biomass utilization has already been done. Algae can be used to produce biofuels (biogas, biohydrogen), wastewater and water treatment, fertilizer industry, cosmetics, pharmaceuticals, dietary supplements, and feed for farm animals.

Keywords: *algae; biofuels; biomass; CO_2 capture; wastewater*

Acknowledgments: *This scientific work was supported by the statute subvention of the Czestochowa University of Technology.*

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Smart Agriculture Challenges to Reduce Environmental Footprint Related to Fertilisers Overuse

Agriculture worldwide is one of the most spread-out activities, which is crucial for the humankind population and the environment, and it deserves increasing attention. According to statistical data, 26% of global emissions are from food, among which agriculture contributes approximately 40%. Cropland has gobbled up over 1,000,000 km^2 of Earth's surface, and agriculture accounts for 70 % of all freshwater withdrawals globally.
Behind the need for smart agriculture are:

- emphasis on Enhancing Efficiency and minimising waste from the overuse of fertilisers (phosphorus is one of the key issues),
- the need for Water Conservation,
- Preventing Climate Change, e.g. climate-smart agriculture, greenhouse gas (GHG) emission reduction,
- fundamentally reducing the waste production and optimising the waste treatment chains toward the Circular Economy,
- smart agriculture mitigates food security challenges by increasing productivity and enhancing resilience (e.g. drought, pests, disease).

The development of smart and also precise agriculture, including the use of the Internet of Things (IoT) and Artificial Intelligence of Things (AIoT), mainly through smart sensors, big data, blockchain and robotisation/artificial intelligence, has been accelerated. Smart agriculture's total addressable market has grown from USD 13.7 billion (109) in 2015 to 26.8 billion by 2020, with a compound annual growth rate (CAGR) of 14.3% and robust escalating growth being expected to come. However, it is not only increasing investment. In some cases, it has been idealised as a very green and environmentally friendly solution possible to salvage the planet from deterioration of the living conditions and the environment. This contribution is raising some potential positive and negative issues, including the burdening footprint of IoT, AIoT, and blockchain solutions, and attempting to make some forecasts for the future development, pointing out issues which should be considered as well.

Keywords: *smart agriculture; reduced environmental footprints; fertilisers overuse; preventing climate change; reducing the waste production; water and energy*

Acknowledgments: *Visegrad Fund Project: Phos4V – Visegrad Group (V4 – Czech Republic, Hungary, Poland and Slovakia) to build a P management strategy in V4 to secure enough P for food production.*

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Thermal use of sewage sludge in accordance with the assumptions of circular economy

Sewage sludge is considered as a biomass due to its biodegradability. Legal conditions in the European Union prohibit sewage sludge storage. Therefore, there is a need to develop thermal methods for sewage sludge treatment. The most common way to date has been combustion. However, this process has a lot of disadvantages associated primarily with environmental harmfulness and the immediate need to use the heat produced. Pyrolysis and gasification are considered the most promising methods of sludge management. They have many advantages over combustion. However, it is difficult to tell which method is more likely to be widely used. Therefore, the paper presents a comparison of the solar pyrolysis process and gasification in the fixed bed of municipal sewage sludge. The analysis of the process parameters and combustible properties of the gaseous fuels obtained was analysed.

Keywords: *circular economy; sewage sludge; sewage sludge treatment methods*

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International Conference 2022

Water and Sewage in the Circular Economy Model

1 June 2022

Sustainable and circular methods for pollutants removal from wastewater

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Review on the sonochemical degradation of selected organic micropollutants from water

Recently, the ultrasonication process was found to be an interesting alternative for the removal of many harmful substances which enter the aquatic environment daily. It was proved by many authors that due to urbanization and population increase more and more organic micropollutants are identifying in water. These groups of substances attract the attention of many researchers because they could be harmful to humans even in low doses. The organic micropollutants include among others pharmaceutical and personal care products (PPCPs), polycyclic aromatic hydrocarbons (PAHs), pesticides, hormones, flame retardants, detergents, and medicines. Thereby, this work presents a review of the literature on the degradation of selected microorganic pollutants including bisphenol A, carbamazepine, triclosan, ethinyloestradiol and pyrene by ultrasonication process from various water matrices. Moreover, in the study effect of ultrasound combined with other advanced oxidation, processes were analyzed. In this work, the use of diverse sonocatalysts and sonosensitizers in micropollutants elimination was also summarized. Although ultrasound technology is known for many years, its mechanism of micropollutants removal from water and impact of the operational parameters on the process efficiency was not completely explained and tested, thus its influence is included in this review.

Keywords: *ultrasound; sonication; water treatment; advanced oxidation processes; micropollutants*

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An evaluation of physical, chemical and biological adsorbents for remediation of heavy metals and synthetic dyes from aqueous solution

Severe environmental problems have been encountered worldwide due to generation of wastewater polluted by heavy metals and synthetic dyes based on them. As a part of their treatment technology, adsorption is one of the most trusted and applied technology. Variety of adsorbents are covered in the chapter along with their performance evaluation. Biochar is a porous carbon rich product prepared from pyrolysis process of different biomass. Due to multifarious property, the use of biochar as an adsorbent for the removal of pollutants elicited increasing. This article throws insights on influencing factors and mechanism of physical adsorption by biochar on such emerging pollutants like heavy metals and synthetic dyes in wastewater. Recent application of biochar as an adsorbent in constructed wetland system is also discussed. Additionally, numerous chemical adsorbents like molecular sieves, zeolite, metal oxides etc. have also been proven to be efficient in removal of such pollutants. And in terms of biological adsorbents, the bacteria, fungi and algae could be utilized to remove different pollutants from aqueous environment. The white rot fungi have vast application in sorption and degradation of heavy metals and complex structure containing synthetic dyes. The pH, temperature, initial heavy metal or dye concentration, amount of fungus has huge impact on the biosorption capacity of white rot fungi. The adsorption kinetics and adsorption isotherm model like Langmuir and Freundlich Isotherm Model is also discussed in this manifesto which can be beneficial to study the mechanism of pollutant removal by adsorbent.

Keywords: *biochar; white rot fungi; heavy metals; synthetic dye; adsorbent*

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Effect of pyrolysis temperature on the organic pollutants content of sewage sludge derived char

Pyrolysis is one of the sewage sludge treatment methods in which sludge char (biochar type material) is produced. Sludge char can be used in agriculture as a soil improver (to improve water retention, permeability, or aeration) and as a medium-to-long-term source of phosphorus and nitrogen. Despite these valuable properties, the application of sludge char on soil has several limitations in terms of potential pollutant content and legislation. Pyrolysis is not suitable for sewage sludge with high heavy metal content, as a significant proportion remains in the resulting char, and organic pollutants have been a lingering problem because it was unknown whether they are removed during the pyrolysis process. Based on this deficiency, the STRUBIAS report (data source for Regulation (EU) 2019/1009) opposes the use of sewage sludge as a raw material for pyrolysis due to its potential organic pollutants content. However, this shortcoming has been refuted by our research. We aimed to determine sufficient temperature for the removal of frequently occurring organic pollutants in the sludge. The results show that substances such as PFASs, PCBs, PAHs, pharmaceuticals, endocrine disruptors, or hormones are sufficiently removed at a temperature higher than 600 °C, confirmed both on the laboratory and application scales. Such sludge chars, formed at temperatures above 600 °C from the sludge with low heavy metal content, no longer pose a risk to the environment compared to sludge. Properly operated pyrolysis units are part of the sewage sludge treatment chain, especially in areas with smaller sludge production.

Keywords: *sludge char; pyrolysis; carbonisation; organic pollutants; sewage sludge; sludge treatment*

Acknowledgments: *This work was supported by the Ministry of Agriculture of the Czech Republic – project QK21020022), Czech Academy of Sciences AV 21 – Sustainable energy, and Specific university research – grant No. A1_FTOP_2022_001 and No. A2_FTOP_2022_003.*

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Monitoring of AOB/NOB competition in the context of the implementation of modelling for N_2O prediction in short-cut nitrification systems

Management and methods of monitoring wastewater in the context of AOB/NOB competition in short-cut nitrification process and the successful implementation of mechanistic modelling, especially for N_2O prediction in real WWTPs are still need to be evaluated according to the EU - GHG regulations and circular economy assumptions. A high calibration complexity of those models resulted from the fact that N_2O is only an intermediate in the nitrogen transformation chain, but an unsatisfactory goodness-of-fit of the predictions was also reported (Mampaey et al., 2019). In this study, a hybrid mathematical method proposed by Mehrani et al., 2022 was used to determine the interaction among different operating factors along with N_2O emission and nitrification rates according to a conventional models and machine learning model for prediction of N_2O production in a nitrifying SBR. In parallel, NOB activity could be also limited under optimal conditions to make the process more cost-effective and energy-saving. Regarding this, under lab-scale environment, DO=0.7 mg/l was detected as optimal value for inhibiting NOB activity and enhancing AOB activity. For this aim, first of all, biological processes were simulated using a validated two-step ASM (mechanistic model) for expanding the series of grab samples of nitrogen species and biomass components into an extensive data set, similar to the recorded liquid N_2O sensor. In the next step, the ML algorithm was used to predict the liquid N_2O concentration. The importance of developing mathematical modelling methods have gained significant attention in order to better understand the possibility of minimizing GHG in WWTPs.

Keywords: *N_2O emission; ammonium /nitrite oxidizing bacteria (AOB/NOB); minimizing GHG; ASM; circular economy model*

Acknowledgments: *This work was financially supported by the National Science Centre as a result of the research project no.2017/26/D/ST8/00967.*

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Mathematic model for calculation the impacts of decentralised wastewater systems on groundwater quality

Within the framework of the Project “Implementation of River Basin Management Plans of Latvia towards good surface water status” (LIFE GOODWATER IP, Project number: LIFE 18 IPE/LV/000014) a logical risk modelling tool has been developed for identification and characterisation of the potential impacts of decentralised wastewater systems, as well as identifying the risks of environmental pollution using the "traffic light principle". Based on the results of the analysis, the tool provides general recommendations and lists possible actions to prevent/reduce the impact of the risks.

The aim of the logical risk modelling tool is to provide an instrument for policy planning decision makers and representatives of the municipal wastewater sector for informative overview of the current and potential environmental pollution and public health risks, in support of selection of the most appropriate and environmentally friendly decentralised water treatment technologies in a given area, modelling the development/escalation of the situation with regard to pollution risks, identification of areas where connection to centralised sewerage networks is recommended and/or indication of the need to establish such networks in a specific region, identification of areas where in-depth geological research is required, determination of potential drinking water pollution risks, and highlighting the importance and the impact of the tourism flow and seasonality factor on decentralised sewage systems.

The tool is designed in 2 levels, based on the GIS system. The first level is based on basic or mandatory input data on the impact of the parameters characterising the decentralised sewage system on the environment/groundwater and surface waterbodies. The second level envisages in-depth environmental impact research, analysing background data in addition to basic data: terrain characteristics, dominant soil classes, drainage systems network, data on the hydrogeology of the territory and the structure of vegetation. The performance of the model has been validated for the village of Engure, located on the shores of the Gulf of Riga.

Keywords: *decentralised wastewater systems; mathematic model; environmental impact*

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The reducing potable water consumption in building as part of the circular economy model – perspectives of implementation

The progressing climate changes, the emerging drought and the prospect of problems with access to water mean that measures are taken to implement the circular economy, also in the water and sewage sector. The solutions used in the various stages of the circular economy model are being developed. Various kinds of innovations are introduced.

The aim of the study was to present possible directions of activities in the field of water use in buildings in order to reduce water consumption, and increase the water efficiency use, together with a discussion of various practices used, with particular emphasis on innovative solutions.

As part of the introduction, a circular economy model for the water and sewage sector was presented, and a classification of the methods used to minimize water consumption was proposed. The perspectives for reducing potable water consumption were discussed in terms of the existing opportunities, as well as threats, barriers and limitations. The SWOT analysis of implementing reduction of potable water consumption in the cities was presented. The challenges for engineers, constructors and consumers as well as the opportunities for the development of this phase of the water life cycle were also considered. As a complementary supplement to the topic, activities facilitating the introduction innovative water management in buildings were also discussed.

The conclusions summarize the current status and prospects for water management in buildings. On the basis of the analysis, suggested directions of activities for the future cities in terms of technical, technological, social and economic were indicated.

Keywords: *water consumption; circular economy; 5Rs, water efficiency; sustainable use of water*

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Removal of micropollutants from the wastewater stream using an integrated biological approach

Industrial activities are responsible for producing huge amounts of highly polluted effluents that may contain various organic and inorganic pollutants depending on the type and scale of the industrial process (Rekhate & Srivastava, 2020). Most conventional wastewater treatment technologies are not capable of dealing with recalcitrant and non-biodegradable organic compounds in the content of the released effluents. Hence, there has been a concern regarding the possible ecotoxicological and health impacts of such toxic compounds in the receiving environments. Among various types of pollutants present in the composition of (waste)waters, contaminants of emerging concern (CECs) are increasing in concentrations in the water bodies, requiring specific attention, especially in the upcoming years. Pharmaceuticals and personal care products (PPCPs), pesticides, endocrine-disrupting compounds (EDCs), as well as artificial sweeteners (ASWs), flame retardants (FRs) in the aquatic environments are considered the main types of the CECs (Salimi et al., 2017). These pollutants are listed on the EU's first "watch list" reported under water framework directive (Barbosa et al., 2016).

The current wastewater treatment systems are not fully designed and adopted to treat low concentration micropollutants. A wide range of technologies is being investigated to reduce such micropollutants efficiently. Although conventional biological treatments could reduce the contaminants partially from the system, they were still not able to entirely eliminate the CEC's, and still, the presence of the contaminants even in low levels is considerable. Therefore, further progressive investigations are required to implement membrane biological reactors (MBR to treat different trace elements).

Keywords: *anaerobic digestion; micropollutants; microbial communities; biodegradation*

Acknowledgments: *The author acknowledges the Department of Chemical Engineering, KU Leuven University for providing the lab facilities and financial support.*

MonGOS

International Conference 2022

Water and Sewage in the Circular Economy Model

1 June 2022

Clean water environment

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Use of sewage sludge for the production of fertilizers - analysis of the risk of microplastic re-emission into the environment

Wykorzystanie osadów ściekowych do produkcji nawozów – analiza ryzyka reemisji mikroplastiku do środowiska

Plastics dominate the world material market. From year to year, there is an intensive increase in their quantity, which has a negative impact on the environment. The biggest threat from mass production is microplastic. By definition, these are pieces of plastic smaller than 5 mm. Depending on the source, there are primary and secondary microplastics. Due to its ubiquity, ability to adsorb pollutants, high emission potential and sizes below 10 µm, microplastic is a serious problem for ecosystems and can have a significant impact on human and animal health. Scientific reports show that sewage sludge can accumulate significant amounts of microplastics. The fertilizers produced from them are a source of re-emission to microplastics into the environment. The study decided to analyze the content of plastic micro-fragments instabilized sewage sludge and fertilizers produced from them. The samples were subjected to the extraction of microplastics by means of density separation and elimination of organic fractions using oxidizing methods. The identification was then performed using a FTIR microscope. Larger fractions were analyzed using the ATR FTIR overlay. Research has shown a significant amount of plastics of various sizes, shapes and colours. The produced fertilizers are a source of microplastics re-emission into the environment.

Keywords: *microplastic; environmental pollution; fertilizers; circulation economy; sewage sludge*

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Toxicity of TEQ of supernatants after fermentation of sewage sludge

Toksyczność TEQ cieczy nadosadowych po fermentacji osadów ściekowych

The paper presents the results of the assessment of the toxicity of supernatants separated from the fermented sewage sludges. The sewage sludges were incubated at 37°C. The research was conducted in three variants. The control sample consisted of municipal sludge inoculated with fermented sewage sludge. The tested samples were, on the other hand, municipal sludge along with the inoculum, into which the coke sludge was introduced in the amount of 5% and 15% v/v. Based on the concentrations of PAHs in supernatants, the toxicity level of PAHs was determined by using the TEQ (Toxic Equivalency) index that was calculated by using the so-called TEF equivalent toxicity factors. In the supernatants separated from the control sludge, the initial total mean concentration of PAHs was 2.03 µg/L. After the fermentation process, the mean total concentration of 16 PAHs was greater than the initial one over 6 times (12.84 µg·L). The initial mean total concentration of 16 PAHs in municipal sludge with coke oven sludges in the amount of 5 and 15% was 4.01 and 8.85 µg/L, respectively, while after the process it increased to 20.12 and 49.85 µg/L, respectively. In the supernatants obtained from the control sludge, an almost 7-fold increase in the total average TEQ value was recorded (from 0.19 to 1.29). In the supernatants of municipal sludge mixtures with 5% and 15% addition of coke sludge, the total average value of TEQ 16WWA increased, respectively, almost 4 times (from 0.41 to 1.51) and more than 3 times (from 1.15 to 3.63). Due to the increased toxicity of over-sludge supernatants, their recirculation may adversely affect the effectiveness of biological wastewater treatment.

Keywords: *TEQ, supernatants; PAHs; fermentation process*

Acknowledgments: *The study was funded by the scientific subvention of Czestochowa University of Technology and Cardinal Stefan Wyszynski University in Warsaw.*

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Wetlands: ecology and prospects for modern use

Bagniste tereny: ekologia a nowoczesne perspektywy wykorzystania

Today, while considering possible ways of developing regions and Ukraine, and especially rural areas, such unique landscape elements that are part of the hydrosphere as wetlands are undeservedly ignored. Today, while considering possible ways of developing regions and Ukraine, and especially rural areas, such unique landscape elements that are part of the hydrosphere as wetlands are undeservedly ignored. In this regard, the potential for entrepreneurship in the villages is very limited, which entails a significant reduction in the number of ways to create competitive advantages for rural areas. Wetlands make up about 2% of the total area of Ukraine, which is equal to almost one million hectares. The presence of a swamp in the territory is very often considered as a negative factor, this is due to a number of reasons: high humidity, poor or non-existent roads, and so on. Therefore, for a long time the idea of the harmfulness of swamps dominated, while the beneficial features of the swamp were ignored. History remembers the great defensive value of swamps, when the presence of this element of the landscape and people who knew the passage to islands with solid soil saved the lives of entire communities and villages during aggressive wars and attacks, such cases are described in many chronicles. The swamp fauna is rich and varied, the swamps of Ukraine provide shelter for 39 species of mammals, 176 species of birds, 11 species of amphibians and 7 species of reptiles. Wetlands are rich in valuable berries and forest plants. And other marsh plants (almost all) are also used. Hydromelioration is one of the ways to drain wet areas, but it has a significant drawback, since it changes the general hydrological regime and has already caused great damage to many areas. The potential of wetlands, including tourism, is used to a very small extent, which is inappropriate, especially considering the great popularity of traditional medicine. More attention should be paid to the collection and use of wild marsh plants.

Keywords: *swamp; ecology; tourism potential; rural area*

Acknowledgments: *I express my gratitude to the organizers of the conference for such a necessary and relevant event.*

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Pharmaceuticals in the WWTP in Żory (Poland) in the aspect of different seasons

Farmaceutyki w oczyszczalni ścieków w Żorach w aspekcie różnych pór roku

The issue of the presence of pharmaceuticals in wastewater and their fate during treatment is still poorly understood. Concentrations of pharmaceutical compounds in municipal sewage were determined at various levels. The obtained values depended on environmental conditions such as the type and amount of wastewater, technological solutions of the treatment plant or temperature. An important issue is the lifestyle of the inhabitants of the city where the sewage treatment plant is located.

In order to learn about the fate of pharmaceuticals during wastewater treatment in a medium-sized city, the content of 51 pharmaceuticals in raw and treated wastewater at the municipal wastewater treatment plant in Żory (Poland) was examined. Average daily samples collected for six days in the summer and six days in the autumn were analysed. SPE extraction and Waters Acquity UPLC system (Waters) coupled to a Xevo TQD Triple Quadrupole Mass Spectrometer (Waters, Manchester, UK), were used for the analysis.

The conducted research has shown that the concentration of pharmaceuticals is reduced during the wastewater treatment process. Nearly 100% reduction was observed for several compounds (e.g. pyrazinamide, isoniazid, nalidixic acid). The concentration of almost all tested pharmaceuticals decreased, and the level of their reduction often depended on the season of the year during which the research was conducted. The distribution of pharmaceuticals in the sewage treatment plant in the autumn season was less intense than in the summer season.

Keywords: *pharmaceuticals; micropollutants; sewage; wastewater treatment plant*

Acknowledgments: *Research supported by the Polish National Agency for Academic Exchange in the Bekker programme (no. PPN/BEK/2020/1/00243/). Research was partially supported by Research Subsidy AGH 16.16.210.476. Research supported under the Implementation Doctorate in the program of the Ministry of Science and Higher Education.*

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Marl and travertine and their thermal modifications as reactive materials for phosphorus removal from wastewater

Margiel i trawertyn oraz ich modyfikacje termiczne jako reaktywne materiały do usuwania fosforu ze ścieków

Phosphorus as a component of agricultural fertilizers is the main factor causing the eutrophication process, which necessitates its effective removal from sewage. Currently used wastewater treatment methods, based on the biological binding of phosphorus or its chemical precipitation, require high investment and operating costs, with its incomplete reduction at the same time. Modern technologies of wastewater treatment from phosphorus compounds are based on the use of reactive materials that bind phosphorus in adsorption and precipitation processes, while enabling its recovery in subsequent stages. Such an approach is consistent with the assumptions of the circular economy, especially taking into account the non-renewable resources of phosphorus and its importance in food production, which place it in the group of strategic raw materials. The paper presents new reactive materials, marl and travertine with their thermal modifications and for comparison, the commercialized material Polonite® in terms of phosphorus binding from wastewater. The research included the analysis of the phosphorus sorption process under static conditions, as well as the influence of the dose of materials, pH of the initial solutions and temperature on the efficiency of phosphorus reduction and sorption capacity. The thermal treatment of marl at 1000°C and travertine at 700°C significantly improved their sorption capacity and increased stability under various process conditions, compared to their natural forms, which show a decreasing efficiency in phosphorus binding with a decrease in the process operating temperature.

Keywords: *wastewater treatment; phosphorus sorption; circular economy; ecotechnology*

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International Conference 2022

Water and Sewage in the Circular Economy Model

1 June 2022

Poster session

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Oxidation of aqueous bisphenols A and S by pulsed corona discharge: impacts of process control parameters and oxidation products identification

Widespread usage of bisphenol A (BPA) and its potential replacement bisphenol S (BPS) has led to their presence in natural waterbodies. The experimental research into degradation of both aqueous pollutants by application of gas-phase pulsed corona discharge (PCD) was undertaken with variation of process control parameters, pulse repetition frequency, gas-liquid contact surface and addition of surfactant OH-radical scavenger sodium dodecyl sulphate (SDS). Although the contact surface variation had only a moderate impact on bisphenols degradation, its effect was stronger in total organic carbon removal. The addition of SDS showed a moderately negative impact on energy efficiency at all studied conditions. The obtained results showed energy efficiency surpassing the closest competitors, ozonation and other electric discharge processes. The detected major oxidation intermediates were mainly formed through hydroxylation and cracking of benzene rings, followed by further degradation into short chained aliphatic acids. The oxidation end-products were quantified as acetate, formate and oxalate. The obtained results showed PCD as a promising method in treatment of waters containing bisphenol's.

Keywords: *pulsed corona discharge; surfactant radical scavenger; AOPs; bisphenol's; gas-liquid interface*

Acknowledgments: *This work was supported by the Institutional Development Program of Tallinn University of Technology for 2016-2022, project 2014-2020.4.01.16-0032 from EU Regional Development Fund.*

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Oxidation of aqueous dexamethasone solution by gas-phased pulsed corona discharge

Steroidal and nonsteroidal anti-inflammatory drugs are some of the most frequently detected pharmaceuticals in water treatment plants and waterbodies worldwide. This is due to their massive consumption and incomplete removal during wastewater treatment process. Dexamethasone (DXM) is most widely used corticosteroid, which in aquatic environment can pose a threat to both human health as well as aquatic environment and animals. Experimental study was conducted for DXM oxidation with gas-phase pulsed corona discharge (PCD) varied in pulse repetition frequency, pH, DXM initial concentration and additions of surfactant sodium dodecyl sulphate (SDS) and tert-buthyl alcohol (TBA). The experimental study included also ozonation compared to PCD in energy efficiency. The advantageous energy efficiency of PCD was observed in wide spans of pH and DXM initial concentrations surpassing ozonation by about 2.4 times. Identified transformation by- and end-products (fluoride and acetate), as well as the impact of radical scavengers, point to the prevalent radical oxidation of DXM. Somewhat increased toxicity observed on the course of PCD-treatment of high DXM concentrations presents a subject for further studies.

Keywords: *dexamethasone; ozone; plasma; wastewater treatment; hydroxyl radicals*

Acknowledgments: *This research was funded by the Institutional Development Program of Tallinn University of Technology for 2016-2022, project 2014-2020.4.01.16-0032 from EU Regional Development Fund.*

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Persulfate Contribution to photolytic and pulsed corona discharge oxidation of metformin and tramadol in water

Metformin (MTF) and tramadol (TMD) are typical medicines commonly found in the environment. MTF is the common drug used in the type 2 diabetes treatment. TMD is an opioid analgesic to treat moderate to severe acute or chronic pain. Both of them pose a threat to the aquatic life at environmentally relevant concentrations.

This study aimed investigation of degradation and mineralization of MTF and TMD in water in UV photolytic oxidation and pulsed corona discharge (PCD) combined with extrinsic persulfate (PS) as UV/PS and PCD/PS systems. The effect of PS dose variation on the oxidation rate and efficiency was assessed. The UV/PS system showed considerable effect in MTF and TMD removal, enhancing mineralization up to 60% at maximum PS dose, thus providing the highest cost efficiency. As for the PCD/PS oxidation, the synergy was noticed for MTF, moderately increasing the oxidation rate at somewhat increased expense. The PS addition to PCD treatment, however, demonstrated no effect on TMD oxidation. The highest energy efficiency in MTF and TMD degradation was showed by non-assisted PCD treatment at energy efficiencies of 5.6 and 13 g $kW^{-1}h^{-1}$, respectively, confirming its practical applicability. The effective mineralization of the target compounds in UV/PS makes it promising for use in advanced water purification.

Keywords: *advanced oxidation; pharmaceuticals; photolysis; peroxydisulfate; plasma*

Acknowledgments: *This work was supported by the Institutional Development Program of Tallinn University of Technology for 2016-2022, project 2014-2020.4.01.16-0032 from EU Regional Development Fund.*

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Recirculation of backwash water in the water treatment plant for the needs of the combined heat and power plant

The power industry is one of the most water-consuming industries, therefore water management in this sector of the economy is a very important element of sustainable development. The analysis of the management of water streams at the surface water treatment plant (WTP) with decarbonization and ion exchange for water softening and demineralization was done. The main emphasis was placed on the effect of recycling of water used for the WTP's own purposes on the quantity of intaken water and the quality of treated water. The article shows that water savings should also be sought at WTP in combined heat and power plants. Accurate distribution of used technological water streams and determination of their quality allows for the appropriate indication of the points of their return to the main technological line without additional treatment or only with the use of basic technological processes, e.g. sedimentation. In the analyzed WTP, the quality of the backwash water returned after treatment was in terms of parameters, i.e. conductivity, hardness, alkalinity, CODKMnO4 and iron concentration, better than the quality of raw surface water. The reduction in the amount of water abstracted due to recycling of water treatment plant technological waters was about 8.3% (approximately 130 000 m3/year).

Keywords: *backwash water; reuse; water savings; industrial water treatment plant*

Acknowledgments: *The research was financed by the Ministry of Science and Higher Education, Research Subsidy of the Poznan University of Technology 2022 entitled: "Improving methods, devices and systems of environmental engineering for sustainable development" (5200 201/0713/0010/SBAD/0958).*

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Evaluation of ion exchange material applicational efficiency prediction method for non-tested water conditions

Driven by a necessity for streamlining the evaluation process of alternative ion-exchange materials in real-life dishwasher applications, the author devised a method for fast derivative approximation of strong cation exchange resins' operating capacity in varying conditions. The method, shown in the poster, consists of an extrapolation method using MDS data for target approximation material, a single condition operational capacity comparison data for approximated material and a reference material, and the target application operational capacity of the reference material.

The benefit of the method can be seen in need of multiple alternative materials evaluation for multiple applications – a single point comparison dataset of N resins, in case of M applications can reduce the amount of operational test by (N-1)(M-1)+1 runs.

The study shown in the poster evaluates the accuracy of the devised predictive method relative to the chemical evaluation of target resin operational capacity measured by the standardized EDTA titrimetric method based on processed water.

The approximation performance deviates on average by 0,8% from chemical testing of operational ionic capacity, which proves the method applicable for the described purpose. Furthermore an additional benefit can be considered, as predictive method could be seen as a prospective laboratory test control method.

Keywords: *ion-exchange resin; water softening efficiency; design process optimization; ion-exchange resin operational capacity*

Acknowledgments: *This research was supported by the Ministry of Science and Higher Education, Republic of Po-land within the "Doktorat wdrożeniowy" program, 4th edition. The laboratory equipment and materials were co-financed by Polish National Centre of Research and Development (grant n. POIR.01.01.01-00-1408/20).*

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Possibilities of industrial water reuse in urban area: case of Warsaw, Poland

Problem of water scarcity has been known in hot and arid climates for years now. In many regions with limited access to water, various solutions reducing freshwater uptake were successfully implemented. Recently, due to the climate change, coupled with intensive industrialization, water scarcity became a challenge, that countries located in colder climates will also have to face, with Poland being one of them. Continuously expanding polish urban areas, require large amounts of water for construction and manufacturing purposes. Poland's capital city – Warsaw, with two big power plants, surrounded by factories and manufactures, produce around 500000 m3/d of treated wastewater, almost entirely discharged back into rivers, dismissing its water reuse potential. In this paper, water reclamation systems in Warsaw's urban area were proposed, targeting industrial reuse. Effluent quality and volumes for different WWTPs were shown. According to each analysed WWTP location in Warsaw, neighbouring industrial sites suitable for water reuse implementation were suggested. Methods of tertiary treatment allowing to obtain required water quality for a specific use were defined, focusing on removal of suspended solids, water turbidity and hardness. Current regulations for water reuse applicable in Poland were discussed, together with suggested changes allowing easier transition onto new solutions. Other uses for recycled water in Warsaw were also briefly discussed, showing a broad spectrum of possibilities. Proposed water reclamation systems in urban area would be a good contribution to European Union's circular economy practices, bringing Warsaw closer to meet expectations of #6 SDG "clean water and sanitation for all".

Keywords: *water reuse; process water; tertiary treatment*

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Anaerobic co-digestion of waste activated sludge and distillery residue from sugar beet molasses – an example of industrial symbiosis

The sewage sludge management is still one of the basic problems of wastewater treatment plants (WWTP) and most challenging environmental and logistic issues in the country. One method of sewage sludge treatment and disposal is anaerobic digestion (AD) process, resulting in the production of biogas used for co-generation of electricity and heat, which causes that sludge is perceiving not only as a waste, but also as source of renewable energy. Poland is one of the largest producers of beet sugar and alcohol from sugar beet molasses in EU. Distillery residue (DR) obtained as a by-product of the alcohol production process from sugar beet molasses is characterized by a high methane yield, which was confirmed by own results. It was assumed that DR can successfully be applied as a co-substrate in AD process of municipal sewage sludge, and can therefore contribute to an increase in energy production from renewable sources. Moreover co-digestion might providing energy self-sufficiency at WWTP or even resulting in surplus energy production.

Results obtained in the biochemical methane potential tests show that the application of DR as a co-substrate in the AD of waste activated sludge (WAS) allowed for a 78.2% increase in the amount of generated methane as compared to mono-fermentation of WAS. Taking into consideration reports from Polish distilleries that suggested a lack of interest in using DR for fodder, and the limited possibility of distributing it over a land surface, co-digestion of this two wastes (DR and WAS) might be an example of industrial symbiosis.

Keywords: *anaerobic digestion; co-digestion; distillery residue; industrial symbiosis; waste activated sludge*

Acknowledgments: *The study was implemented in the scope of a research project entitled "Development of a technology for preparation substrates used in methane co-fermentation by disintegration methods" (DEZMETAN) (No.: POIR.04.01.02-00-0022/17), financed in the scope of Measure 4.1 of the Operational Programme Smart Growth 2014-2020 co-financed from the resources of the European Regional Development Fund.*

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Barriers and opportunities of wastewater reuse – Polish experience

Due to worldwide water shortage and constantly deteriorating quality of surface waters there is a need of searching new opportunities of water reuse. Wastewater produced in technological processes is a constantly available source of water that can be included in closed water circuits limiting the consumption of fresh water. It is also possible to reuse domestic wastewater (e.g. for flushing toilets) or for irrigation of grasslands after prior cleaning. Unfortunately, the survey conducted as a part of the project "SMART-WaterDomain: Framework for organizational decision-making process in water reuse for smart cities" showed that there is a serious social resistance to introducing such solutions. Identified barriers include the legal, psychological and economic sectors. Respondents representing the industrial sector indicate that the costs of modernization of installations are too high to ensure closed circuits of technological waters. That is the reason why in Poland only 34.4% of industrial plants are equipped with closed circuits, reusing for production goals less than 4.5% of water. According to the collected data, thanks to water recycling installations, industrial plants manage to save from 40 m3 to even 15000 m3 of water per year. The main mental barrier concerns the safety of water obtained from sewage for the use for communal purposes. Therefore, the greatest challenge of scientists fighting for the protection of water resources is to change habits at the level of the entire society.

Keywords: *wastewater reuse; closed circuits; opportunities of sewage reuse; water shortage*

Acknowledgments: *The authors acknowledge the support of the Project Organisational Decision-Making in Water Reuse for Smart Cities (SMART- WaterDomain), funded by The National Centre for Research and Development and supported by the EIG-Concert Japan.*

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Qualitative analysis of greywater from a public utility building

The reuse of greywater as an alternative source of water in a building is not subject to any specific regulations. There are provisions relating to greywater, clearly indicating the need for a new approach to their use, however, there are no basic legal regulations and quality requirements in this regard. The aim of this study was to assess the quality of greywater generated and stored in a existing public utility building. The building was designed and built on the basis of the latest available technologies and in accordance with the principles of sustainable construction. Greywater is collected in a separate wastewater pipework and reused for flushing toilets. The maximum amount of greywater is 10 m3/d. The use of greywater as well as the use of modern fittings allows to reduce water consumption by 60%. In the study, the quality assessment was based on the values of physicochemical and microbiological parameters of greywater. Greywater is characterized by high qualitative variability. The temperature of the greywater was about 20-35°C. The content of organic substances determined in the greywater samples is in the range of 20-300 mg / l, COD 100-600 mgO2 / l, TN 5-17 mg N / l. The paper will also include the determination of microbiological indicator parameters, i.e. the total number of microorganisms at 36/22ºC, the number of coliforms and Escherichia coli and the total number of enterococci. The knowledge of loads and concentrations of physicochemical and microbiological parameters is fundamental for select the type of treatment technology and ensure sanitary safety.

Keywords: *greywater quality; water reuse; greywater recycling*

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Phosphorus removal from wastewaters using phyllosilicate-based innovative materials impacting on resource recovery and circular economy

Phosphorus (P) is a crucial element for life, but the natural P cycle has been perturbed to such an extent that humanity faces two dovetailing problems: (I) the dwindling supply of phosphate rock as a resource, (II) the overabundance of phosphate in water systems leading to eutrophication. Recovery of P from wastewaters has been gaining more attention lately. In the European Union, the regulation on municipal wastewater treatment (Directive 91/271/EEC) does not state any limits for permissible P concentration in the effluent from wastewater treatment plants (WWTPs) operating in small agglomerations with less than 2000 p.e. Furthermore, as of now commonly used methods still cannot reduce the P concentration to an ultra-low level (<0.1 mg P/L). The objective of this research is to develop an affordable technology that recovers P from wastewater in small and medium size municipal and industrial WWTPs that enables the use of it directly as a fertilizer in agriculture. In the preliminary experiments, the synthesis of sorbent/coagulant materials based on srebrodolskite or clay minerals was performed. The sorption capacity of developed materials against phosphate ions in batch experiments and untreated wastewater samples was determined. The results indicated that the synthesized mineral-based materials can also compete with the chemical coagulant PIX 115 used in WWTPs and can reduce the amount of phosphates up to 30 times. Continuing the research, it is planned to develop an environmentally friendly and cost-effective phosphorus recovery technology suitable for small and medium-sized WWTPs without the construction of additional infrastructure.

Keywords: *natural sorbents; modification; phosphorus removal; wastewater treatment*

Acknowledgments: *This research is funded by Fundamental and applied research projects of the Latvian Council of Science "Unused Latvia's natural mineral resources for the development of innovative composite materials for phosphorus recovery from small municipal and industrial wastewater treatment plants to implement the principles of circular economy (CircleP", No. lzp-2021/1-0090.*

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Humic fertilizers in agriculture

Soil fertility is one of the most important functions of this medium. It is responsible not only for the water and nutrients storage but also for the preservation of micro and macro biotic life in the environment. The components that play an important role in soil fertility are humic acids. They constitute a diverse group of chain organic compounds of irregular form and chemical composition. In many cases, the presence of humic acids in soil is treated as an indicator of soil with high agricultural potential, which is often associated with the brown or even black color of soil particles. Therefore, when a given environment shows a deficiency or lack of the discussed component, it may be considered as an area of lower agricultural utility. This problem may relate to heavily exploited land or areas exposed to the negative influence of weather conditions. The aim of this article is to indicate the methods of remediation of the soil environment, taking into account the external application of humic acids and the stimulation of their synthesis. The given issue will be discussed in the context of remediation methods and fertilization techniques that can be used in normal agricultural practice.

Keywords: *humic acids; soil; fertilizers; natural agriculture; soil fertility*

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Comparison of the efficiency of TiO_2-P25 and ZnO in solar-driven photocatalytic removal of sulfonamides from the aquatic environment

Titanium dioxide (TiO_2) is one of the most widely used photocatalysts for the removal of organic pollutants, including antibiotics, from the environmental matrix. Zinc oxide (ZnO) has been recently found a promising alternative to TiO_2 for environmental purposes. However, there is still a lack of studies dealing with their effectivity in more complex matrices. The goal of the study was to compare the efficiency of TiO_2-P25 and ZnO in the removal of selected sulfonamides (SAs): sulfadiazine (SD), sulfamethazine (SMZ), and sulfamethoxazole (SMX) from the aquatic environment.

After 90 min of the photolysis degradation of target SAs did not exceed 42%, 50%, and 38% in distilled water (DW), river water (RW), and municipal wastewater effluent (MWWE), respectively. The complete removal of SAs from DW was observed after 20 min in TiO_2-P25-based photocatalysis and after 30 min in the ZnO-based photocatalysis. In the case of more complex matrices, the removal efficiency of SAs did not exceed 48% (RW) and 38% (MWWE) after 90 min of the TiO_2-P25-based photocatalysis. The ZnO-based photocatalysis was a more efficient process. The removal efficiency of SAs was up to 89% and 75% in RW and MWWE, respectively. The degradation of target SAs increased with doubling the photocatalysts dose up to 61% and 98% in RW, and up to 81% and 99% in MWWE for TiO_2-P25 and ZnO respectively.

Due to the lower cost of ZnO than TiO_2-P25 and high removal of microcontaminants from the environmental matrices, ZnO is a promising alternative photocatalyst to TiO_2-P25 for photocatalysis processes.

Keywords: *photocatalysis; sulphonamides; titanium dioxide; water purification; zinc oxide*

Acknowledgments: *The research was supported by the Ministry of Education and Science (Poland) (Project 08/070/BK_22/0012).*

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Quasi-technical installations for treatment of domestic wastewater in closed technological loops as an effective protection of water resources in rural areas without access to sewage networks

The innovative installations presented by ITP - PIB GCB in Tylicz uses equipment and technological objects configured in a highly efficient wastewater treatment line, starting from the classic sanitary technique in the form of multi-chamber septic tanks (unit volume 800 dm^3/person).

Other devices are special sprinkled filter beds filed with LECA granules (with an area of 4.0 m^2) and innovative, shallow soil-grass filter beds in the form of grass strips located on slopes with an area of 15 m^2/person.

Final purification take place undergroud in separated soil and plant areas and ponds, as well as in additional filters filled with reactive mineral materials to remove phosphate and fecal bacteria.

Devices for hygienization and sludge disposal (in situ) were also applied. The scientific and utilitarian goal of the project is the implementation of highly - efficient bio-agro-technical devices in individual wastewater management in rural areas, enabling the full treatment of domestic wastewater in rural farms, with final closure of the circulation loop of water and matter recovered from wastewater within the habitat. Discharge of wastewater to surface water bodies is excluded. A three-year study showed a very high quality of all- year (summer-winter) treatment. The average level of nitrification was 91.8% and 90.2%, respectively. Total nitrogen reduction: 85.9% and 81.4%. Reduction of BOD5 indexes: 96.7% and 99.1% and COD: 96.2 and 96.6%. The efficiency of phosphate and total suspended solids removal was: 62.5% and 72.6%, 94.4% and 93.0%, respectively.

The installation meets the requirements of national regulations and meets the criteria of circular wastewater economy at the level of a single farm in the effective protection of local water resources.

Keywords: *rural areas; quasi-technical wastewater treatment plants; circular wastewater economy; soil and plant environment*

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Reducing microplastic pollution from a circular economy perspective

The growing production of plastics contributes to the increasing environmental pollution with microplastics. These are small pieces of plastic with the largest dimension ranging from 1 µm to 5 mm. One of the most important sources of microplastics in the aquatic environment are microfibers derived from synthetic textiles. Others include, for example, tyres or personal care products containing plastic microbeads. In addition, microplastics can also result from the degradation of larger plastic waste. The abundance of these micropollutants in the water varies over a wide range of concentrations, reaching up to several thousand pieces per litre. The presence of microplastics in aquatic ecosystems is associated with a potential threat to living organisms, including humans. Therefore, solving the problem of their release into the environment is an essential issue, which has been undertaken by the European Commission as part of the European Green Deal. The aim of this initiative is, inter alia, developing measures to increase the capture of microplastics (mainly from tyres and textiles) at all important stages of the lifecycle of products. Focusing on preventive options early in the lifecycle of tyres and textiles is seen to be the most cost-effective strategy to reduce this pollution. However, from a policy perspective, a comprehensive approach to this issue is crucial, including measures to control microplastic emissions during use and to improve end-of-life processing. Taking this into account, the implementation of appropriate steps in the field of circular economy can reduce the increasing trend in the pollution of the water environment with small plastic particles, which is the main topic of this paper.

Keywords: *microplastics; microplastic pollution; microplastics in the aquatic environment; circular economy*

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Treatment of brackish wastewater using pressure membrane techniques

The term brackish wastewater is applied not only to mine waters but also to industrial wastewater containing high concentrations of organic and mineral compounds like the one produced from the food and the oil and gas industries. The fractionation of brackish wastewater and the appropriate treatment of each individual waste streams constitute proper industrial wastewater neutralization and are fully compatible with circular economy assumptions.

One of the significant problems in Poland is mine water, which is collected in reservoirs of liquid substances and then discharged into natural water resources like rivers.

The present research studied the fractionation of brackish wastewater along with the use of a multi-stage membrane system consisting of the following processes: microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF). MF and UF membranes are characterized by pore size or cut-of, while NF and RO membranes are characterized by cut-of, and $MgSO_4$ & NaCl retention. During the experimental work, a polymer MF membrane manufactured from polyethersulfone (PES) with a pore size of 0.1 μm, a polymer UF membrane with PES with a cut of 5000 Da, and a polymer NF membrane with polyamide-TFC with a cut of 300 Da were used.

The integrated membrane system achieved a high removal efficiency of organic compounds (TOC) that have reached about 99.71% and also a 97.79% removal efficiency of Inorganic compounds (IC). Finally, there were three obtained waste streams with significantly different properties and thus being an easier medium for management. The last stream contained the highest salinity of 3846 mg/L.

Keywords: *brackish wastewater; separation; MF; UF; NF*

Acknowledgments: *This work was supported by Ministry of Science and Higher Education Republic of Poland within statutory funds, 2021-2022.*

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Treatment of sidestream dewatering liquids via nitritation/anammox in moving bed biofilm reactor

The process of anaerobic digestion (AD) is currently commonly applied in wastewater treatment plants (WWTP) as a method of energy recovery. AD is applied to sewage sludge constituting waste biomass resulting from wastewater treatment processes. In recent years, one of the fastest developing circular economy trends in WWTP has been the intensification of the AD process through among others the process of codigestion of sewage sludge with organic waste, or an increase in the availability of the substrate with the application of the disintegration process. Such measures on the one hand allow for an increase in the amount of produced biogas, and on the other hand cause an increase in the amount of digested sludge. As a result of its dewatering, considerable amounts of dewatering liquid are obtained, characterised by exceptionally high concentration of ammonium nitrogen resulting from protein biodegradation. Limiting the load of ammonium nitrogen introduced to the main technological line involves treatment of dewatering liquids in a side technological line by means of deammonification combining processes of partial nitritation and anammox (PN/A).

The objective of the study was the analysis of the course and efficiency of deammonification applied in the moving bed reactor (MBSBBR). The reactor operated in a system of two 12-hour cycles per day. Each complete cycle consisted of dosing wastewater (simulating dewatering liquid), phases with continuous aeration, sedimentation, and decantation. Dissolved oxygen was kept at a concentration of 1.5mgO2/L. The temperature was 30◦C. The influent concentration of nitrogen was 600mgNH4-N/L. The efficiency of nitrogen removal reached 83.3±2.0%, and nitrogen concentration in treated wastewater 111.9±15.2mg N/L.

Keywords: *deammonification; MBSBBR; anammox; biofilm reactor*

Acknowledgments: *The study was conducted as part of the research project titled "Identification, characteristics and modeling of the COMAMMOX process - a new link in the nitrogen cycle in wastewater treatment systems" (UMO-2017/27/B/NZ9/01039), financed on behalf of "OPUS14" competition by the National Science Centre (Poland).*

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Specificity of wastewater from Motor Rest Areas

Motor Rest Areas are places that are used to maintain and protect the motorway. They are intended only for its users in order to provide travellers with the opportunity to meet their physiological needs. The most popular solution on MRAs is collecting sewage into septic tanks, which are emptied periodically. Wastewater from MRAs has a high content of ammonium nitrogen and is problematic due to the variability of the hydraulic load. It often happens that wastewater systems are not efficient and do not ensure the correct wastewater treatment process. The research was carried out on 3 MRAs facilities. Wastewater samples were collected for physicochemical tests from the primary settling chamber. Wastewater from MRAs did not show the typical composition of domestic wastewater. Wastewater was alkaline, and their high content in urine sewage causes a high concentration of ammonium nitrogen (336.00-593.20 mgN-NH4·dm-3). Such a high concentration inhibits the nitrification process in wastewater. Only one sample of sewage showed a COD/BOD5 ratio lower than 1.8, which indicates a low content of matter not susceptible to biodegradation. The obtained results show the difficulties occurring during wastewater treatment. They indicate the lack of a sufficient amount of nutrients for the activated sludge microorganisms, which significantly affects the treatment systems used for MRAs. The composition of wastewater from MRAs is considered problematic, therefore the technology of treating such wastewater should be appropriately selected, taking into account its different type, and control of the method of treatment of wastewater generated on MRAs.

Keywords: *Motorway Rest Areas; wastewater with specify physicochemical composition; ammonium nitrogen*

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Methods of prevention of waste formation in the process of chitosan derivatives preparation

Chemical reactions usually generate a lot of waste, especially in organic chemistry. It is not only connected with the use of different organic solvents in the synthesis procedure, but mostly with isolation and purification processes, where often water is used.

Modification of chitosan requires heating of reaction mixture in the temperature of boiling point of the solvent used. This can be realised with conventional heating or with the use of microwave radiation, which enables a significant reduction of reaction time. Moreover, this process is mostly carried out in closed system, where reflux condenser is used. Such systems are cooled with the use of running water generating a lot of waste. For the isolation and purification processes water is also used for product precipitation and elimination of unreacted substrates.

The main objective of this study was a development of chitosan derivatives synthesis method with the use of microwave radiation, as well as closed cooling system and regeneration of solvents. Such procedure enabled to great reduction of reaction time, eliminated the need of running water application and formation of toxic waste due to utilization of green solvents.

Keywords: *waste formation; chitosan derivatives; chemical modification; microwave radiation*

Acknowledgments: *This research was supported financially by The National Centre for Research and Development, grant number LIDER/42/0149/L-9/17/NCBR/2018.*

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State of the art in recovery technologies of nutrients, cellulose and polyhydroxyalkanoates in wastewater treatment plants

The paper presents the critical review of recovery methods of various elements and compounds from wastewater. Wastewater as an element of circular economy is discussed. The paper presents technical parameters and description of the most promising recovery processes of ammonium, phosphate and potassium recovery. Also other promising technologies such as cellulose or polyhydroxyalkanoates are described. Technical descriptions of the methods are supported by analysis of the economic costs and other barriers of the application of the methods at industrial scale. Some reducing costs strategies and solutions are also discussed. Future prospects, challenges and developments in the field are also presented.

Keywords: *struvite; potassium recovery; cellulose; polyhydroxyalkanoates*

Acknowledgments: *The scientific research was funded by the statute subvention of Czestochowa University of Technology, Faculty of Infrastructure and Environment.*

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Assessment of the migration degree of selected chemical components from filter waste

As part of the research, an assessment of the possible reuse of filter waste from the bathing water treatment cycle was performed: the diatomaceous earth-powdered coal mixture and washings. The selected physicochemical parameters of the water extract from solid waste were analyzed (assessment of the leaching degree), and the phytotoxicity of the soil with the addition of waste was assessed. The physicochemical and ecotoxicological quality of washings collected after the rising filter was also assessed. The washings were mixed with water matrices - tap water and rainwater, to assess the possibility of their use in vegetation irrigation (volume fraction of washings up to 75%). The entirety of the results was a comprehensive assessment of the possibility of using waste products from swimming pool facilities.

The washings from the rinsing of the pressure filter beds contain residues of aluminum coagulants. One of the possibilities of using the washings is their use with rainwater, which minimizes the toxic effect of aluminum on plants. For the analyzed concentrations of washings, plant growth inhibition was observed along with an increase in their content in rainwater. The evaluation of the ratio of the dry and fresh mass of assimilation organs also showed different sensitivity of the studied plant species. In turn, the addition of filter waste to a low extent increases plant biomass growth. Both the washings and the mixture of diatomaceous earth and activated carbon can be reused in plant cultivation.

Keywords: *swimming pool; ecotoxicology; circular economy; closed circuit; leaching*

Acknowledgments: *Presenting research was funded from grants for young scientists statutory fund of The Faculty of Environmental and Power Engineering.*

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Closed water circuits in industry and services based on the example of Polish experiences

Clean water intended for human consumption becomes a scarce commodity due to water shortages. Of great importance for the availability of water resources is also its quality, which is constantly deteriorating due to human activity. It is possible to reduce water consumption, especially in the industrial and service sectors, by introducing closed cycles of technological water or generated wastewater. According to the survey data collected under the project Organisational Decision-Making in Water Reuse for Smart Cities (SMART- WaterDomain), it is possible to save up to 15,000 m3 of water by using closed circuits. However, in Poland, only about 30% of industrial and service plants decide to reuse wastewater and technological waters. The example of a large mountain hotel shows that the use of gray water to flush toilets and water after the second and third wash cycles for prewash allows a water recovery of 40%. It allows you to reduce the costs associated with the purchase of tap water by about 25%. In the sugar industry, it is possible to save up to 98% of water with the use of a water recovery installation, mainly in cooling water circuits. Despite the benefits of introducing closed water circuits, the vast majority of industrial plants use systems for its recovery in the amount of less than 10%. Increasing water and wastewater reuse in the future can make a significant contribution to global reduction of water shortages.

Keywords: *water shortages; closed water circuits; wastewater reuse*

Acknowledgments: *The authors acknowledge the support of the Project Organisational Decision-Making in Water Reuse for Smart Cities (SMART- WaterDomain), funded by The National Centre for Research and Development and supported by the EIG-Concert Japan.*

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Opportunities of water recycling in industry - selected examples

In this paper an overview of solutions for water and sewage management in selected industrial plants is presented. The use of industrial wastewater focuses on a serial or circular model of a plant's water and wastewater management. Moreover, in some cases it is possible to simultaneously recover valuable ingredients and water for their further use. The most popular solution in industrial plants, used for a long time, but not always called the circular economy, are the following activities: closing water circuits, including cooling water, serial use of technological waters, use of treated wastewater for technological purposes, use of treated wastewater for hydro-transport of raw materials or waste, use of rainwater for industrial purposes. The aim of the work was overviewing the applied solutions for treatment of industrial wastewater and use of treated wastewater in the aspect of circular economy. Possibilities of recycling water in the industry are as follows: use of water recovered from wastewater to supplement water and steam cycles in the power plant, use of treated wastewater for hydro-transport of raw materials and waste, use of a biologically treated waste water stream (BAT requirements) for coke cooling, use of biologically treated wastewater for washing and cooling of waste gases, the use of water recovered from sewage in construction for the preparation and production of building materials, use of treated wastewater from the food industry in agriculture.

Keywords: *treatment technologies; industrial wastewater; water recovery; circular economy*

Acknowledgments: *The study was funded by the scientific subvention of Czestochowa University of Technology.*

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Computer Simulation as a Tool for Implementing the Circular Economy Solutions in Water Management

Water management, as one of the strategic economy sector of any country, embraces the system of a large number of natural water bodies and technical infrastructure objects, intended for water resources use and protection and requiring a rationally operating management system. The need to move from a prevailing linear strategy to a circular one is driven to a significant extent by water crisis and the depletion of mineral and energy resources. The urban wastewater treatment plants (WWTPs) can be an important part of circular sustainability due to integration of energy production, resource recovery and clean water production.

Wastewater and sewage sludge can be reused to boost the scarce resources and to optimize the future investments in water and wastewater sector.

The transformation of WWTPs have to be based on holistic approach assuming political, economic, environmental and social aspects, but the optimal recovery technology is a prerequisite for the implementation of CE solutions. Water-and-resource efficient technologies and the Reduce, Replace and Reuse (3Rs) approach should be adopted in the initial stage of planning and designing of WWTPs.

The simulation models can be efficient instrument for establishing the optimal way of WWTPs designing and modernization towards circular operation & managing model in order to maximize their recovery potential.

The aim of this paper is to analyze the existing simulation models, their possibilities of forecasting the recovery potential from wastewater and sewage sludge, illustrated by selected examples.

Keywords: *wastewater reuse; WWTP simulation models; resource recovery*

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Quantity and quality identification of odorous gases emitted from high temperature processing of animal by-products category 3

Fetors out of industrial production is a long term problem of environmental enginery that gathers more and more society's attention. Epidemiological data shows that odors present in inhaled air cause not only disturbing discomfort but also can contribute to the development of respiratory, digestive and nervous system diseases. The value of odors emission has also became one of the key factors deciding of social and economic attractiveness of the area to choose for a place to live, invest money or local tourism development. One of industrial sectors characterized by high nuisance is high temperature processing of animal by-products category 3, including drying processes of bone-meat tissue.

Basic components of odorous waste gases generated during termical manufacturing animal material category 3 are ammonium, sulphur compounds and volatile organic compounds. Unfortunately, there is poor literature data of volatile organic compounds emission from high temperature processing of animal by-products category 3, including drying processes of bone-meat tissue. Scientists mainly focus on odors emission out of wastewater treatment plants, incineration plants, farms or chemical industry. That lack of knowledge significantly impedes the development of successful technological solutions of purifying waste process gases coming out of mentioned industrial area. Therefore, in this work, the attention has been focused on analyzing in quality and quantity of odors emission out of indicated previously industrial processes.

Keywords: *high temperature animal fat production; odorous gases; biofiltration*

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Waste management on the example of Municipal Sewage Treatment Plant Krakow-Płaszów - content of the sand traps

Wastewater is subjected to mechanical-biological technological processes in which wastes are a side effect. These wastes can include the contents of sand traps. Removal of sand at the stage of mechanical treatment has a very important function - during this process mineral impurities are eliminated, which have a negative impact on pumps and other equipment. Also, this process prevents accumulation of sand in tanks (e.g. in separate digesters and reactors). According to the Regulation of the Minister of Climate of 2 January 2020 on waste catalog [Journal of Laws 2020, item 10] sand from grit chambers is classified as waste with code 19 08 02. It is worth emphasizing that this raw material is a material of great potential and its reuse brings many financial and environmental benefits.

The Kraków-Płaszów sewage treatment plant will receive 68.5 million m3 of sewage in 2021. As part of the investment, the company replaced sand separators with more efficient ones. Thanks to this investment and the use of highly efficient equipment, it was possible to optimise their operation, which had an impact on minimising the amount of waste produced and its odour nuisance. In 2019, 4,265 Mg of sand was generated. The annual operation of the new separators resulted in a reduction of sand to 3,054 Mg (2020), which is about 28% less than the previous year. Moreover, after optimization of equipment operation, significant improvement of sand quality was observed (laboratory tests confirmed effectiveness of organic compounds reduction to less than 3% of dry mass).

The use of high-efficiency equipment gives the opportunity to lift the status of waste to a product that can be reused. Currently, tests are being conducted to verify compliance with the requirements for obtaining an administrative decision on removing the waste code. This activity perfectly fits into the assumptions of a circular economy, where waste is treated as secondary raw materials and remains in circulation as long as possible.

Keywords: *wastewater treatment plant; technological waste; grit chamber contents; mechanical wastewater treatment processes*

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Polyvinyl alcohol hydrogel beads for biological water treatment and micropollutants removal

Due to growing concerns about water quality in the world, not only conventional but also innovative methods are used for wastewater treatment. Today, attention is being paid to advanced water treatment technologies, able to remove impurities from wastewater faster, more efficiently, and without major infrastructure changes. Micro-pollutants, such as pharmaceuticals, phenols, phthalates, etc., which are found in wastewater are of concern to engineers and the public because they could cause long-term adverse effects on the aquatic environment, even at low concentrations.

Polyvinyl alcohol (PVA) hydrogel beads are a biological carrier with a 3-4 mm diameter and a very porous structure (pore size ≈ 20 μm). Cultures of microorganisms that decompose contaminants in wastewater are immobilized inside the macropores of the beads. The network of macropores in beads, which extends through each granule, ensures a constant supply of oxygen and nutrients to the bacteria inside the hydrogel beads. It helps create a highly resistant and efficient biological wastewater treatment system. PVA hydrogel beads not only increase the efficiency of the biological wastewater treatment system but also have excellent sorption properties in removing pharmaceuticals and residues of other micro-contaminants from the wastewater.

This research aims to clarify the synthesis mechanism of PVA hydrogel beads and evaluate feasibility of their application in wastewater treatment. PVA hydrogel beads were successfully synthesized using a cross-linking method. The study confirmed the efficiency of the PVA hydrogel beads as the sorption agent. The experimentally tested removal efficiency of tetracycline using PVA hydrogel beads is 74.0 % (± 0.16). The highest efficiency was observed in removing methylene blue, with the concentration of which in the solution reduced by 97.9 % (± 0.33).

Keywords: *polyvinyl alcohol; hydrogel beads; micropollutants; biological wastewater treatment*

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Soil bioremediation with immobilized microorganisms as a green technology

The research study on total petroleum hydrocarbons (TPH) bioremediation was conducted in field study. The area requiring remediation and heavily contaminated with TPH, was the site of the former locomotive refueling station in Poland. In previous years, the removal of free petroleum product from the groundwater table by selective pumping was undertaken and remediation wells made for this purpose have been made. From the beginning of the research on the water-soil environment (year 2000), strong contamination with petroleum substances was found in places exceeding 10,000 mg / kg d.w. in the soil and 100-3,000 mg /dm3 in water (total hydrocarbons) and a layer of free petroleum products floating on the surface of groundwater in places exceeding 1 m in thickness. The thickness of the contaminated layer was determined at 3.5-4 m in the place of the highest concentration of pollutants. Remediation works related to the application of microspheres into remediation wells with immobilized autochthonic microorganisms have been undertaken. After 2 years of monitoring the bioremediation process, significant decreases of pollutants concentration were noted.

Soil bioremediation process using autochthonic immobilized microorganisms can be effective process, which provides low rate of water and chemical substances consumption. The application of complex biopreparations with a controlled release can replace the use of chemicals that oxidize organic pollutants, which significantly disturb the soil microbiome and require the consumption of large amounts of water.

Keywords: *bioremediation; soil; total petroleum hydrocarbons; hybrid methods*

Acknowledgments: *The research has been funded by BS/PB-400/301/22. The research was based on the results of TANGO1/266740/NCBR/2015 project.*

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Spent coffee grounds utilization as high value-added products in the context of the implementation of the circular economy assumptions

Spent coffee grounds (SCG) are the solid residue resulting from coffee brewing, either domestically or at an industrial level in the production of soluble coffee. As the global coffee consumption increases steadily every year, the production of SCG has also increased rapidly worldwide, providing great potential for resource recovery and recycling. There are some approaches recently reported such as extraction, co-digestion, compost, conversion into biochar or biodiesel production and reusing for construction or water treatment. However, the community of SCG researchers is relatively small and isolated without timely information interchange. Therefore this review summarizes current knowledge on the output, management, characterization, treatment and different methods for resource recovery and recycling of spent coffee grounds in an attempt to promote understanding of SCG. The review also discusses future perspectives with respect to integrating and utilizing information resources for the reuse of the main coffee industry residues from environmental and economical viewpoints in the context of the implementation of the circular economy assumptions.

Keywords: *spent coffee grounds; circular economy; water treatment; recycling; resource recovery*

Acknowledgments: *This work was partly financially supported by Ministry of Science and Higher Education in Poland, within the statutory research of particular scientific units and by Shanghai international collaboration project (17230741000).*

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Microplastics detection in treated sewage sludge

The study used municipal sewage sludge (treated with thermo- chemical method and untreated) with the addition of different plastic polymers (PVC, PE and PDS) in various concentrations. The sludge was treated in order to obtain an organic-mineral fertilizer. This study was aimed also to study if the treatment method is applicable for microplastics removal from sewage sludge. The basic preparation of the samples for the test consisted in the oxidation of the organic material in a modified Fenton reaction. The test material was stained with two dyes: Rose Bengal and Nile Red. Each stained sample was subjected to microscopic observations and counting. Due to the visibility of the microplastic under the microscope under ultraviolet light, the method of spectrophotometry was also used. During the research, it was observed that the increase in temperature generated during the processing of sewage sludge reduces the polymers structures and reduces the concentration of microplastics. The presence of an oxidizing substance in the form of PDS in the tested samples also contributed to the reduction of the microplastic amount.

During the tests, the presence of microplastics was observed in each of the samples, including those without admixtures of polymers. This means that the applied thermal-chemical sludge treatment process does not remove completely microplastic present in sewage sludge, but changes its size and shape. Moreover, the method of spectrophotometric analysis of microplastics can be an easy and quick way to measure the concentration of microplastics and to detect it, due to the repeated peaks in certain range of wave length.

Keywords: *microplastics; sewage sludge treatment; biosolids*

Acknowledgments: *The research has been funded by project no SKN/SP/496788/2021 financed by the Minister of Education and Science from the state budget under the program "Student research clubs create innovation"andinternal project BS/PB-400/301/22.*

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Monitoring and analysis of disinfection by-products in swimming pool water treatment circuits

The sequence of processes and reliable operation in a pool water treatment system must ensure an environment that is safe for the health of swimmers and pool staff. This is extremely important in the context of the treatment of swimming pool water in a closed circuit, where the concentration of certain pollutants can occur, especially those present in dissolved form. The monitoring of disinfection by-products (DBP) was carried out for water samples from 9 pools. Pool water disinfection was carried out in two stages (UV irradiation and sodium hypochlorite solution dosing). In swimming pool waters, combined chlorine, total trihalogenomethanes (THM), and chloroform are considered indicators of DBP. These DBPs, which are highly toxic, difficult to biodegrade, mutagenic, and cause skin irritation and asthmatic symptoms in bathers, must be under constant control. As part of the presented work, the content of combined chlorine (monochloramine + dichloramine + trichloramine) and the sum of trihalogenomethanes (trichloromethane + bromodichloromethane + dibromochloromethane + tribromomethane) were analysed. Relationships between these DBPs and the indicator parameters of pool water quality were determined. Concentrations of combined chlorine ranged from 0.05 mg Cl2/L to 1.13 mg Cl2/L. Total THM concentrations ranged from 0.013 mg/L to 0.053 mg/L. The content of the DBP depended on the type of pool and related parameters, i.e. the water retention time in the pool basin and the basin load (persons per m3). The factors influencing the content of combined chlorine and THM were water temperature, permanganate index, total organic carbon and absorbance. An increase in the values of these indices also resulted in an increase in the content of the DBP tested.

Keywords: *monitoring; swimming pool water; disinfection by-products; water treatment circuits*

Acknowledgments: *This work was funded by the Ministry of Science and Higher Education of the Republic of Poland within statutory funds.*

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Washing up the soil contaminated with arsenic with a solution obtained from sewage sludge

Arsenic (As) is the second, after lead, pollutant most often identified in soils, but due to its toxicity it is considered the most dangerous. Permanent removal can be ensured by one of the remediation methods based on soil washing. The quality of the washed soil depends on the washing agent used. To establish effective remediation with the simultaneous enrichment of soil with nutrients washing agents from organic waste are being sought. Sewage sludge is a source of organic matter, when dissolved, can complex metal ions due to the presence of functional groups.

The aim of the research was to determine the suitability of dissolved organic matter obtained from sewage sludge, for removing As from contaminated soil. The soil washing was carried out under static conditions with the use of soil from the former arsenic ore processing areas. The process included determination of the optimal concentration and pH of washing agent, determination of the optimal time of washing, physical and chemical analysis of the soil before and after the washing process.

It has been shown that to remove As from soil, washing agents from sewage sludge should be used at a concentration of 7 g/dm^3, pH 3.0, washing time 30 h. The use of washing agents extracted from sewage sludge reduces the total concentration of As in the soil (efficiency: 73%) and improves the fertilization value of the treated soil by increasing the concentration of nitrogen and phosphorus.

Keywords: *remediation; soil washing; sewage sludge; dissolved organic matter; arsenic*

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Business opportunities in water and wastewater sector

The circular economy (CE) is the regenerative system where the value of resources is maintained as long as possible in the economy and the production of waste is minimized. Sustainable and circular water management is one of the main tasks for the water and wastewater sector for which water has economic value. Therefore there is strong need to further implementation of the business opportunities in this sector to maximize the use of water potential, as well as accelerate the transformation process towards the CE model. Paper presents inventory of examples of good practices (business opportunities) in water and wastewater sector, that have been divided into six action areas for businesses and countries transforming from linear to the CE model: Regenerate, Share, Optimise, Loop, Virtualise, and Exchange. There are several possibilities to implement CE in analysed sector, including recovery of renewable energy and nutrients from waste generated in water and wastewater treatment plants, providing water supply systems in cities and rural areas, optimisation of the amount of energy, minerals, and chemicals use in operation of water systems, water reuse for agricultural and industrial purpose, digitisation of device controllers in water treatment stations and wastewater treatment plants, or replacing industrial devices with more energy-saving ones. Implementation of the proposed solutions should contribute to create the balance between economic, social and environmental aspects, that is a base for sustainability. Therefore, an economic feasibility assessments of proposed projects should takes into account also social, environmental and resource availability. The current economic systems, including water sector, put emphasis on the CE matters, due to they can create a series of business and economic opportunities, next to environmental and social benefits.

Keywords: *circular economy (CE); water; wastewater; business; Circular Business Models*

Acknowledgments: *This research was funded by the project "wodoGOZowanie" (no. MFEOG.07.03.03-50-0114/21-00) co-financed by EEA Financial Mechanism 2014-2021 under the program: "Environment, Energy and Climate Change" (Norway Grants) and subsidy of the Division of Biogenic Raw Materials at the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences.*

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Removal of phosphates from aqueous solutions using modified chitosan hydrogel beads

In the 21st century, more and more attention is paid to the eutrophication process occurring in surface waters. This process is caused by the increasing concentration of biogenic substances, mainly nitrogen and phosphorus compounds, and its effect is the multiplication of algae, deterioration of oxygen conditions in the reservoir and finally reduction of the biological diversity of the aquatic environment. The amount of phosphorus reaching water reservoirs is particularly related to human activity, mainly food production. Removal measures have been taken to counteract the accumulation of phosphorus compounds in surface waters and bottom sediments. One of the methods of removing impurities is physicochemical methods, which include the sorption technique. The paper presents a method of sorption removal of phosphates based on the use of chitosan hydrogel modified with cerium (IV) ions. After synthesis, the sorbent was characterized by determining the sorption equilibrium, the kinetics of the sorption process, and its structure was examined using scanning electron microscopy (SEM). Studies have shown that the modified hydrogel shows a high degree of phosphorus removal, reaching as much as 96.9%, thus reducing the phosphorus content in water, characterized by a pH of 7, from 0.894 ± 0.032 mg/L to 0.027 ± 0.004 mg/L P- PO4. The use of a hydrogel modified with cerium (IV) ions makes it possible to reduce the amount of phosphorus below the concentration of 0.05 mg/L, at which the intensification of the water eutrophication process is observed.

Keywords: *sorption; chitosan modification; phosphorus removal; eutrophication phenomenon*

Acknowledgments: *The research was financed by the Rector of the Silesian University of Technology as part of the Project Based Learning of the "Excellence Initiative - Research University" programme.*

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Social acceptance of the use of waste from the water and sewage sector - the perspective of farmers in the Małopolskie voivodship

Social acceptance for bio-based fertilizers (BBFs) have a significant impact on the profitability of their production from waste materials, e.g. agricultural waste or sewage sludge. Farmers, as the main users of fertilizers, are the most important stakeholder group. Their opinion therefore may turn out to be crucial for introducing to the market and popularization fertilising products made of organic waste. Therefore, it is extremely important to understand farmers' preferences in terms of the properties and characteristics of BBFs. This will make it possible to meet the users' needs , define production parameters and make recommendations for the optimization the use of waste-based fertilizers in agriculture. The paper presents some of the results of a survey conducted among Polish farmers, as part of the Lex4Bio project. The presented part of the results was obtained from farmers from the Małopolskie voivodship. Collected information concerns the use of bio-based fertilisers, properties assessment and farmers' willingness to pay for these products.

Keywords: *bio-based fertilisers; farmers attitude; survey; nutrient recycling*

Acknowledgments: *The survey of farmers' attitudes, currently conducted in Poland, is part of the Lex4Bio project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818309 (LEX4BIO).*

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Circular management of waste from water and sewage sector in V4 countries

A circular economy (CE) is a model of socio-economic development focused on the rational use of resources (from primary and secondary sources) and reducing the negative impact of products and processes on the environment along the entire value chain. The aim of this approach is to close the flows of materials and energy circulating in the economy, which will contribute to its improvement. The process of transformation towards CE requires the use of sustainable resource and waste management practices in the entire economy, and thus also in the water and sewage management sector. Practices regarding water supply and sewage disposal as well as rainwater management have changed over the years, depending on the existing needs of the society and the stage of development of the world economy, including the economy of the V4 countries.

The paper presents the assumptions regarding the transformation towards the CE model in the water and sewage management sector. Examples of good practices for the implementation of CE in enterprises from the water and sewage management sector were also indicated, which enable sustainable recovery of water, energy and raw materials in the Visegrad countries.

Keywords: *circular management; waste; sewage sector; V4 countries*

Acknowledgments: *The study was developed under the project: „ PhosV4 – „How to stay alive in V4? Phosphorus Friends Club builds V4's resilience", no. 22110364 (2021-2023), which is financed by Visegrad Fund.*

Organisers of the MonGOS IC2022

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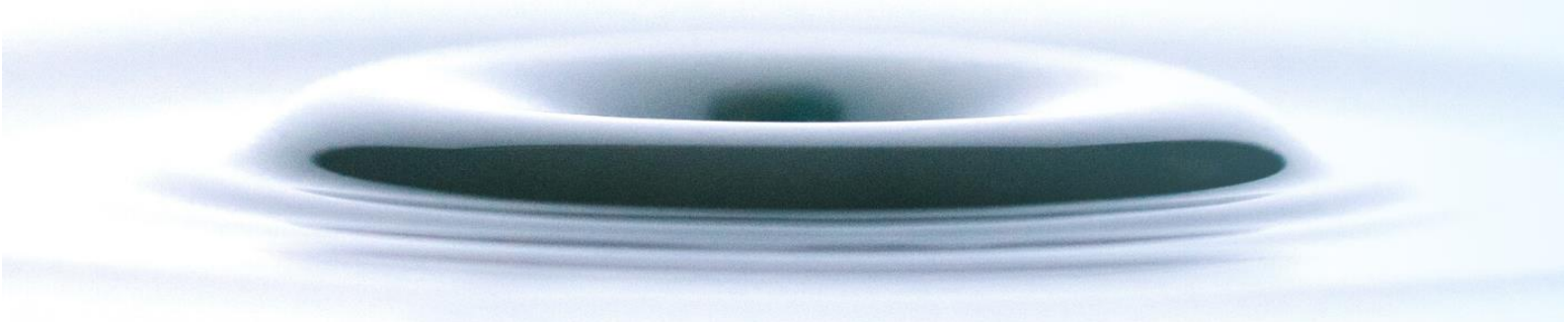

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ISBN 978-83964171-7-6