LIST OF SHORT ABSTRACTS

SESSION 1 - P recovery

Chairman	Mathieu Sperandio (INSA Toulouse)
Co-chairman	Katarzyna Jaszczyszyn (Poznan University of Technology)

A Strategic Approach to Sewage Sludge Disposal and Phosphorus Recovery

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New legal requirements for the recovery of phosphorus from sewage sludge as well as decreasing utilization possibilities and capacities for co-incineration of sewage sludge require a restructuring of sewage sludge management and disposal that includes the establishment of phosphorus recovery. Methodically, defining regional clusters followed by further developing time- and region-specific concepts will contribute significantly to sustainable sewage sludge disposal and phosphorus recovery for an entire federal state.

Extraction behaviour of phosphorus and other components from sewage sludge ash with variation of process settings

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Phosphorus, recovered from sewage sludge ash, can be recycled as fertilizer for agricultural means, which helps completing the eco cycle and offers a sustainable path. This study aims to optimise the initial step of a wet-chemical phosphorus recovery by outlining the importance of temperature, extraction time and the usage of different acids. Our work shows the possibility of a more selective extraction process, while maintaining a high standard of phosphorus extraction.

Recovery of phosphorus from dried sewage sludge and subsequent purification using reactive extraction

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A new PULSE process for recovery of phosphorous from dried sewage sludge has been developed. In the PULSE process, acidic leaching is used to dissolve P from dried sludge. By using dried sludge, the consumption of acid for leaching is reduced and the separation of the solid and liquid fractions even at very low pH is easier as compared to using dewatered sludge. Metals and heavy metals that are co-leached with P are then removed by a reactiveextraction step. P can finally be precipitated as calcium or magnesium phosphate. The cascaded option-tree methodology has been used for evaluation of different process options and to develop the PULSE process. For gaining process understanding and process optimization an equilibrium modelling tool has been developed in MATLAB. In the experimental studies, the e different acids and pH on the leaching of P from dried sludge and different extractants for the subsequent metal removal have been investigated. Based on these lab-scale experiments, a pilot-plant scale demonstrator has been designed and built. Product samples containing calcium phosphate salts with a P_2O_5 concentration of up to 29 % have been produced.

Vivianite Formation Potential Profile in a Full-scale Municipal Wastewater Treatment plant

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Phosphate recovery is vital in circular economy. Wastewater, especially sewage sludge, shows a great potential for recovering phosphate in the form of vivianite. This work focuses on studying the iron, phosphorus, and sulphur interactions at Viikinmäki wastewater treatment plant, Helsinki, Finland with the goal of identifying unit processes with a potential for vivianite formation. Mössbauer spectroscopy and X-ray Diffraction analysis is used to confirm the presence of vivianite in different locations on water and sludge lines. The preliminary results show that ferrous is dominant in samples taken from thickened mixture of raw and excess sludge, and digestor tanks, indicating the potential of vivianite formation in these locations. Also, from the thickened mixture of raw and excess sludge iron analysis, it can be concluded that the iron reduction process is a fast process. This work gives valuable insights on dynamic interrelations of iron, phosphorus, and sulphur in full-scale conditions. These results will support the understanding on vivianite formation.

Phosphate recovery from urine waste streams to be used as a fertilizer

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This work present the recovery of phosphate from urine-containing streams via its selective separation through adsorption and subsequent use as a fertilizer. Mg-Fe layered double hydroxide (LDH) was prepared by co-precipitation at a variable pH 8-10. Mg-Fe LDH shows good stable adsorptiondesorption capacity after 4 cycles. The repetitive reuse of the desorption solution until its complete exhaustion guaranteed the increase of phosphate concentration. The final phosphate solution was used as a renewable source for precipitation of a solid fertilizer product, known as struvite. From the extraction and recovery of phosphate, this work promotes a circular and sustainable closed-loop of nutrients.

Dealing with the obligation to recover phosphorus in the Ruhr region: A case study

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Five water associations cooperate to fulfil the obligation for phosphorus recovery from sewage sludge in Germany's largest metropolitan region and to develop a holistic approach for this purpose. This study examines the situation in this region, focusing on the quality of the sewage sludge and sewage sludge ash. It is not possible to use the current sewage sludge ash as a basic product for fertilizer production, since the limits of the German fertilizer regulation were exceeded, especially for Ni and Pb. This made the decision for a wetchemical phosphorus recovery process with heavy metal removal necessary, which will be built in 2024. As some sludges are less polluted than others, alternative solutions can be considered in the future. For this purpose, a management system will be developed to treat the waste streams according to its quality and to reduce the heavy metal content.

SESSION 2 - Deammonification - anammox

Chairman	Stephanie Klaus (HRSD)
Co-chairman	Małgorzata Komorowska-Kaufman (Poznan University of Technology)

Operation of the full-scale DEMON process with micro-screen versus hydro-cyclone for anammox-retention

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Upgrading the aerobic stage to tertiary treatment at the Domzale-Kamnik WWTP (149000 PE) included also the pre-treatment of sludge water from anaerobic digestors with the deammonification (DEMON®) process. A completely new 400 m3 thermally isolated SBR was built to treat up to 270 m3/day of sludge water (270 kgTN/day), equipped with a hydro-cyclone operated at 8,5 m3/h flow and 1,8 bar pressure. The hydro-cyclone is supposed to be the key piece of equipment in order to sufficiently separate the heavy, slow growing granulated deammonification biomass from the light biomass composed of fast-growing nitrification bacteria and of the rest biomass as waste sludge. Within four years of operation few different operational settings with or without the hydro-cyclone have been tested in order to reach the full process capacity at the requested efficiency level. Finally, the hydro-cyclone has been replaced by a micro-screen. The retained biomass inventory increased rapidly from a typical level of 2 gMLSS/L to more than 5 gMLSS/L containing a major portion of anammox granules as demonstrated by granule-fraction and fish-measurement. High anammox inventory translated in high process-resilience.

Partial Denitrification-Anammox (PdNA) application in mainstream IFAS configuration using raw fermentate as carbon source

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This research examined the feasibility of raw fermentate for mainstream partial denitrification-anammox (PdNA) in a pre-anoxic integrated fixed-film activated sludge (IFAS) process. Nitrate residual was identified as the main factor driving the PdN efficiency, while management of nitrate conversion rates was required to maximize overall PdNA rates. Overall, this study showed PdN efficiencies up to 27% and PdNA rates up to 1.2 ± 0.7 g TIN/m^2/d with further potential for improvements. As a result of both PdNA and full denitrification, this concept showed the potential to save 48-89% methanol and decrease the carbon footprint of water resource recovery facilities (WRRF) by 9-15%.

Robustness and stability of partial denitrification – anammox (PdNA) in deep-bed polishing filters: low temperature and backwashing shear

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Ensuring the success of partial denitrification – anammox (PdNA) in polishing filters relies on AnAOB retention and activity in filters. The study demonstrated the robustness of PdNA filters towards temperature and backwash shear. Although a lower AnAOB activity was observed in the winter compared to the summer, there was still 1.5 times higher AnAOB activity present than required to remove the daily nitrogen load to the filters. In addition, even under extreme shear applied to the filters with air scour and backwashing time, AnAOB were not washed out of the filters, and the filter performed as expected. At the end of the shear experiment, the methanol-based PdNA filter showed higher AnAOB shear resistance than the glycerol-based PdNA filter.

Feasibility of a return-sludge nursery reactor to biostimulate mainstream anammox bacteria

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To overcome limited anammox activity under mainstream conditions (15°C, low nitrogen levels), a return-sludge nursery concept is proposed to biostimulate anammox bacteria with a mainstream niche. The idea is to apply sidestream nitritation, and blend the resulting effluent with mainstream effluent to achieve an intermediate temperature (25°C) and nitrogen concentrations. Four modes of nursery vs. mainstream exposure frequency were tested (0.5-2 days nursery followed by 3.5-12 days mainstream). Results showed that the total nitrogen removal rates increased considerably after nursery treatment (18%-80%). And it also showed that the longer nursery, gave a higher and longer activity boost, yet at the same time requiring a larger nursery reactor. Arrhenius expectations could only explain 25-35% of the activity increase during nursing, pointing at the role of other factors (e.g., the higher nitrogen concentrations). Preliminary 16S analyses showed a relatively stable anammox community, dominated by Ca. Brocadia. This mainstream biostimulation approach showed to boost anammox activity, which can be a promising alternative to sidestream-to-mainstream bioaugmentation.

Enhanced mainstream anammox nitrogen removal by switching main flow with sidestream at extensively long time intervals

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During more than 2 years, single- reactor mainstream wastewater (municipal wastewater at 16.5 °C) treatment was performed by switching wastewater flows after 8 weeks with sidestream (reject water at > 22 °C) to sustain anaerobic ammonium oxidation (anammox) biomass activity benefitting from sidestream, as latter contains anammox bacteria and relatively low organic carbon/N ratio of 1.6/1. Experiments in a 20 L moving bed biofilm reactor (MBBR) and batch- scale were performed to evaluate the optimum concentrations of organic carbon on anammox process to perform the autotrophic nitrogen removal for the biomass enriched on ring- shaped biofilm carriers. Loss of anammox bacterial activity at lower temperatures and higher organic contents needs to be studied to perform mainstream anammox at extended cycles (~8 weeks). Real sidestream wastewater (biogas plant effluent) (≈1200 mg NH_4^+ -N L^{-1}) and synthetic mainstream (municipal wastewater-like source) (≈80 mg NH_4^+-N L^{-1})wastewater were used for reactor feeding. The highest total nitrogen removal rate (TNRR) of 530 g Nm^{-3} d^{-1} (average TNRR 180 (±140) g N m^{-3} d^{-1}) was achieved with

sidestream at a low chemical oxygen demand (COD)/TN ratio of 1.1/1. COD/N ratio of 3.2/1 was maintained for mainstream. The maximum TNRR in a batch test was achieved at the COD concentration of 480 mg $^{L-1}$, showing a TNRR of ≈ 5 mg N g^{-1} TSS h^{-1}. With a highest COD concentration of 2600 mg L^{-1} (TOC/TN=8/1), TNRR decreased similarly in both feeds to 1.6 mg N g^{-1} TSS h^{-1}. Among anammox microorganism's genuses relative abundance, Candidatus Brocadia enrichment in deammonification biofilm reactor was elevated at mainstream feeding (constituting 7.6 % of all bacteria) compared with sidestream feeding (<0.7 % out of all species). Planctomycetes abundance was slightly higher in sidestream compared to mainstream feed (5% and 4%, respectively).

The effect of sulphate on the efficiency of anaerobic ammonia oxidation

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Recently, the growing attention has been paid to the novel sulfate reducing ammonia oxidizing - sulfammox process. The aim of the study is to investigate the effect of increased SO_4^{2-} concentration on anaerobic ammonia oxidation. The laboratory scale system consisted of two sequencing batch reactors (SBRs), termed reference (R1) and experimental (R2). In R1, the initial concentration of SO_4^{2-} was 50 mg/dm^3, while in R2 it was 5 times higher - 250 mg/dm^3. AUR and SAA in R1 was 7.3 mg N/g/h and 15.8 mg N/g VSS/h, and in R2 11.4 mg N/g VSS/h and 26.5 mg N/g VSS/h respectively. SO_4^{2-} is potentially an additional acceptor improving the rate and efficiency of the process, increasing the efficiency of NH_4-N removal.

SESSION 3 - Process intensification

Chairman	Haydee De Clippeleir (DC Water)
Co-chairman	Agnieszka Szuster-Janiaczyk (Poznan University of Technology)

Thermal or thermo-alkaline hydrolysis for waste activated sludge? Comparison of pros and cons for a Berlin WWTP

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This study compares thermal hydrolysis of waste activated sludge at high temperature with low temperature thermo-alkaline hydrolysis. Both processes were characterized with lab and pilot trials for a specific WWTP in Berlin, investigating their effect on biogas yield, dewaterability, sludge liquor return load and formation of soluble refractory COD. Data was generated in lab trials for thermal hydrolysis, and in pilot trials over one year for thermoalkaline hydrolysis. The results show that both processes can increase anaerobic degradation of waste activated sludge and related biogas yield, but show distinct differences in their impact on dewaterability and also formation of refractory COD. The comparison of both processes for the Berlin case study show that the choice for a specific hydrolysis process depends on the specific goals of the WWTP for implementing a pre-treatment process and other important boundary conditions, such as COD effluent targets and sludge disposal pathway.

Combined Pretreatment of Municipal Sludge with Free Nitrous Acid and Ultrasonication

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Anaerobic digestion remains an attractive route for sludge management due to its low cost, sludge reduction, pathogen and odour reduction and the potential to produce high calorific value biogas. However, anaerobic digestion of waste activated sludge (WAS) is a slow, low-yield process due to the limited bioavailability of the organic matter that it contains. WAS often requires a form of pretreatment prior to anaerobic digestion to combat the limitation. Ultrasonication has shown encouraging results in full-scale applications, though it is an energy-intensive process. In this study, free nitrous acid (FNA) is combined with ultrasonication to reduce the energy requirement while increasing digestion efficiency. Varying concentrations of FNA (0.7 to 2.8 mg HNO2-N/L) and ultrasonication (600 to 3000 KJ/kg) were used to pretreat polymer-thickened WAS before batch anaerobic digestion. Organic matter solubilization increased by 26% when 1500 KJ/kg was combined with 2.8 mg HNO2-N/L. At this pretreatment level, the biodegradability of TWAS was enhanced from 37.6 to 50%. The methane produced at this level was also 6% more than if the ultrasonication energy input was doubled without FNA

Specific Methanogenic Activity of AnMBR sludge subjected to limited aeration: an adaptation process

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This study investigated the effect of limited aeration on Specific Methanogenic Activity (SMA) of a lab-scale AnMBR fed with synthetic concentrated domestic wastewater. After achieving stable performance under completely anaerobic conditions, the reactor was intermittently aerated with 80 mLair.d^{-1} in three cycles of four hours per day. The addition of air was done in three steps, each one of around 7 days until the desire aeration was achieved. Sludge from each step was collected and their Specific Methanogenic Activity was compared to the one of fully anaerobic conditions. SMA value of the fully anaerobic sludge with no extra aeration was 0,429 ± 0,005 gCOD.$gVSS^{-1}$.d^{-1}. By the last aeration step inoculum (S3), the SMA increased 7 %. Furthermore, extra aeration of 15, 40, and 60 mLair was added to the collected inoculums. While there was a statistically significant SMA difference between the no extra aerated sludge (A0) and when 15mLair were

added to the completely anaerobic sludge (S0), this difference was negligible for the sludge collected over the AnMBR aeration steps (S2 and S3). Thus, it can be concluded that the aerated sludge adapted to changes of 1 % of Oxygen without affecting its Specific Methanogenic Activity.

Could the treatment capacity of a continuous wastewater treatment plant be increased with aerobic granular sludge?

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This study evaluates the potential of increasing the treatment capacity of a continuously operated wastewater treatment plant for carbon and nitrogen removal by replacing activated sludge by aerobic granular sludge. More specifically, it was investigated to which extent advantages related to better settling characteristics of granular sludge are counteracted by its higher diffusion limitation. The effect of better settling, allowing a higher biomass concentration in the reactor, was found to increase the maximal treatment capacity with 40%. However, this positive effect was almost completely counteracted by diffusion limitation in case the plant operation was left unchanged. The operation of the continuous wastewater treatment plant with aerobic granular sludge could be improved by increasing the aerobic reactor volume, but keeping a lower oxygen set-point to increase the anoxic volume in the granule, allowing simultaneous nitrification-denitrification. This improved reactor operation led to a 20% higher treatment capacity and a 10% lower energy consumption than for a conventional activated sludge system.

Influence of mass transfer characteristics on nitrogen removal in sponge-bed trickling filters

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Efficient nitrogen removal following anaerobic sewage treatment is generally accomplished in mechanically aerated systems, which are energy-intensive compared to naturally ventilated processes, such as sponge-bed trickling filters (SBTFs). Promising configurations have been presented for total nitrogen removal in SBTFs treating anaerobic effluents. Nevertheless, there is a remaining knowledge gap on the main factors influencing process performance. This contribution mechanistically assesses the effect of the key reactor and kinetic parameters controlling nitrogen conversions in SBTFs. The results support that the interplay between the oxygen transfer coefficient, external mass transfer resistance, and biofilm thickness influences the optimum oxygen concentration to sustain AOB activity without compromising anammox growth.

Enhancing clarifier performance and capacity through full-scale implementation of high-rate contact stabilization

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SESSION 4 - Nutrient recovery

Chairman	Anna Mikola (Aalto University)
Co-chairman	Katarzyna Jaszczyszyn (Poznan University of Technology)

Optimization of the pilot-scale NPHarvest process in field tests using digester reject water

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Nitrogen and phosphorus recovery pilot was operated with mesophilic digester reject water at Viikinmäki wastewater treatment plant in Helsinki Finland. A wide range of parameters and settings were investigated to narrow down the optimal operational settings. Results show that high flow rate, pH above 10 and dilute nitric acid produce the best ammonia transfer rate. In addition, reject water pretreatment with starch instead of polyaluminum chloride and polymer was successful. Results show that the NPHarvest process is robust and versatile in operation and that it can be optimized for different purposes in different environments

Nutrient recovery from fermentation wastewater by electrodialysis and process control optimisation

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After fermentation with a wide variety of microorganisms, usually there are still nutrients left in the spent culture broth that have to be treated in conventional wastewater treatment before further discharge. In regard to the blue-green economy and closing the loop in production processes, the nutrients comprising a value fraction of the waste broth can be recovered and reused. This paper evaluates electrodialysis (ED) for the nutrient recovery from waste streams after fermentation processes. In the first part, spent broth is introduced to the diluate compartment of the process unit, whereas deionized water spiked with ions (Na^+, K^+, $NH4^+$, Mg^{2+}, Cl^-, SO_4^{2-}, PO_4^{3-}) to induce initial conductivity of the feed is introduced to the concentrate compartment and maintained throughout runs as a receiving media for the ions removed. A concentration factor of 3.2 was achieved. Removal of all present ions up to 98.5 % could be observed. The second part assessed four ED control approaches: constant current (CC), constant voltage (CV), step-wise current (SW_C) and step-wise voltage (SW_V). The step-wise approach attained the highest product purity, containing the least DOC, and the shortest ED separation time. Total energy consumption and current efficiencies were in a similar range for all experiments

Residual phosphorus supply for methanotrophic cultivation and microbial protein production

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Microbial protein (MP) is a promising alternative protein source with several economic and environmental advantages. Currently, there is a research trend investigating the use of residual sources for the inputs of the production process, so it becomes more circular and efficient. In this study, the residual phosphorus (P) sources struvite and precipitated calcium phosphate (PCP), recovered from wastewater, were evaluated as P sources for the production of MP using methane oxidising bacteria (MOB). The study aims to understand the P requirements of bacteria in order to optimise P dosing in the culture medium. Since phosphate is provided in excess as a buffer, its optimal supply for assimilation will have an impact on pH control. Thus, pH and buffer capacity are also monitored. Both nitrate and ammonium were used as nitrogen sources, as they have different impacts on pH. Additionally, strategies for the dissolution of struvite and PCP were assessed, as were their implications on process design. MOB were capable of growing with both PCP and struvite as a phosphorus source. However, PCP shows lower growth rates and is more difficult to dissolve efficiently. Struvite was thus the best candidate for P recovery via MP from MOB.

Ionic strength characterization of sidestreams in WRRFs: towards nutrient recovery implementation

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Literature data combined with full-scale measurements are used to characterize the ionic composition of the different types of sidestreams in water resource recovery facilities (WRRFs). While their contributions in the ionic strength of sidestreams is not negligible HCO_3^- , Cl^- , Ca^{2+}, K^+ , Mg^{2+}, Na^+ are rarely measured compared to NH_4^+ and $P\text{-}PO_4$. The compilation of data from the literature provides concentration ranges that can be used for model-based sizing or operating purposes when the data is not available elsewhere. Furthermore, in modelling practices, the liquid phase of the thickened or digested sludge is generally considered equal to the sidestreams obtained after thickening or centrifugation. However, the thickening and dewatering unit have an impact on the ionic composition of the sludge. This impact should be regarded when sizing or modelling nutrient recovery processes

(Hyper-)thermophilic anaerobic digestion of concentrated BW for pathogen removal and safe nutrient recovery

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Source separated toilet water contains a high concentration of nutrients, which can be recovered to produce fertilizer products. To safely recover and reuse these nutrients, pathogens present in concentrated black water (BW; toilet fraction of domestic wastewater) should be removed. In this study, results showed that thermophilic (55 °C) and hyperthermophilic (70 °C) conditions increase the removal of (antibiotic-resistant) pathogen indicator organisms, compared to mesophilic conditions. Furthermore, the potential of BW as source for safe nutrient recovery has been demonstrated.

Hydrogen production from urea in decentralised wastewater systems

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This work presents a new process for the recovery of energy from domestic wastewater, based on the adsorption of urea from urine and its subsequent decomposition into hydrogen. Urine diversion toilets and urinals can be used to collect undiluted urine, which represents 80% of the nitrogen produced in households, in the form of urea. Rather than a contaminant to be removed in a wastewater treatment plant, urea is instead considered an energy source based on its high hydrogen content. Herein, urea is recovered from an aqueous solution by adsorption onto commercial activated carbon. Thermal urea desorption and decomposition into ammonia led to the regeneration of the carbon, keeping its adsorption capacity for at least 5 cycles. Finally, when the regeneration+urea decomposition step is carried out in the presence of an ammonia decomposition catalyst, hydrogen is produced to be used as an energy fuel. Energy balances show that this energy recovery system in a city of 160000 inhabitants would lead to a daily hydrogen production of 430 kg, with a net energy production of 2850 kWh/day. In addition, it would cause energy savings of 4600 kWh/day in the wastewater treatment plant, reducing its energy consumption by 35%.

SESSION 5 - Hybrid activated sludge processes

Chairman	Alessandro di Biase (University of Manitoba)
Co-chairman	Małgorzata Komorowska-Kaufman (Poznan University of Technology)

Process intensification with Membrane Aerated Biofilm Reactor enables low-SRT nitrification and improves sludge settleability: a long-term experimental study

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The paper focuses on the impact of MABR technology in process intensification for municipal wastewater treatment. Two identical pilot units have been operated side-by-side at different sludge age values for more than 300 days, one of the two being equipped with MABR modules in the anoxic compartment. Nitrification performances of the MABR line were not affected by the system sludge age, resulting higher than 90% even at the aerobic sludge age of 1.8 days, significantly lower than the washout SRT threshold. Respirometric tests carried out on both biofilm samples and sludge collected from both pilots prove that the enhanced nitrification in the MABR line is due to the combined effect of nitrification activity in the attached-growth (NR of about 2.3 gN-NH4 m-2 d-1) and seeding effect of nitrifying biomass in the bulk sludge, with AUR values in the MABR line significantly higher than in the CAS. Furthermore, the potential impact of MABR on sludge settleability was investigated, through both DSVI30 and particle size distribution (PSD) of sludge samples.

Installation and Start-up of the first MABR drop-in solution in UK in this spot

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Spernal Wastewater Treatment Plant processes wastewater from the surrounding catchment area as well as excess biosolids from satellite plants. A number of considerations including increased biosolid loads coming from the satellite plants, future population growth, and tighter ammonia consents, led Severn Trent to look for solutions that could increase the nitrification capacity of the existing activated sludge plants. Thus, ten OxyMem MABR modules were installed at Severn Trent's Redditch Spernal site, which has become the largest MABR system in the UK. The MABR modules were lowered into the anoxic zone of lane 3 over a two-day period and almost instantaneously boosted the nitrification capacity of the current process. Comparing lane 3, and lanes 1 and 2, without MABR, an additional 43 kgN/d were removed in lane 3, which equals to 2.96 gN/m2d on average. The best performance was observed when the influent NH4-N load to each lane increased to 450 kgN/d on peak. Lanes 1 and 2 struggled to process that, and on that day the effluent ammonia concentration from these two lanes increased to 124 kgN/d, but only to 71 kgN/d in Lane 3. The difference in the effluent was 53 kgN/d, showing a peak nitrification capacity of 3.6gN/m2d.

Monitoring of deammonification process in the pilot-scale hybrid reactor (IFAS) by activity tests

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The purpose of the studies was to examine biomass activity in the IFAS reactor after its fast start-up under conditions of its stable performance and in the course of gradual decrease of temperature. Anammox biomass was set apart from activated sludge and grew generally in biofilm (share of anammox nitrogen removal capacity in biofilm and activated sludge was 97.3% and 2.7%, respectively), whereas ammonium oxidizing bacteria (AOB) were distributed uniformly between activated sludge and biofilm (54.5% and 45.5% of AOB activity'sfraction in biofilm and activated sludge). Although relative abundance of AOBs increased in the

course of the studies despite the temperature in the bioreactor had been gradually decreased the guild of nitrite oxidizers (NOB) was still present and the conditions in the bioreactor were not optimal for its removal from the system.

Optimization of a novel one-stage IFAS-SBR unit for thermally pre-treated sludge reject water treatment

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The anaerobic digestion process, followed by dewatering of sludge, leads to the production of a high strength reject water stream which is usually recirculated to the inlet of the WWTP. This work examined the optimization of a novel, one-stage IFAS-SBR unit that was used for nitrogen removal from thermally pre-treated sludge reject water via the nitritation/denitritation process. The 25.1L reactor which contained both suspended and attached biomass on biocarriers, operated for 275 days reaching a maximum NLR equal to 0.99±0.02 kg N m^{-3} d^{-1} while achieving more than 90% of ammonium nitrogen and total nitrogen removal during the whole operation time. The attached biomass of the biocarriers increased from 34.7 gTSS m^{-2} during 1st period to 233.7 gTSS m^{-2} and 195.8 gTSS m^{-2} during 3rd and 4th period respectively. The biofilm was responsible for a significant increase of the AUR and NUR rates equal to 50% and 15% respectively throughout the operation.

Biological nitrogen removal from landfill leachate with an IFAS-SBR

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Realising the significance of nowadays' challenge for sufficient treatment of highly contaminated landfill leachate streams, the current study focuses on the investigation of biological nitrogen removal (via nitrites) efficiency from landfill leachate using an IFAS-SBR. The proposed technology is reported to be able to achieve higher performance stability compared to the conventional system. The IFAS-SBR reached steady state conditions under a nitrogen loading of 0.4kgN/m^3 -d, while the achieved AUR and NUR values were about 5 and 34gN/gVSS-h, respectively. The experimental results indicated that the proposed technology is a promising alternative for the sufficient treatment of heavily polluted landfill leachate streams.

Influence of surface area loading rate and carrier specific surface area on an aerobic moving bed biofilm reactor treating synthetic sugar industry wastewater

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Three 20 L Aerobic Moving Bed Biofilm Reactors (MBBR) were set up at room temperature and filled to 43.3, 30,0 and 27.1% by volume with BioPorts medias with a specific surface areas of 589, 851 and 942 m^2m^{-3}, respectively. The reactors' performance in organic matter removal from synthetic sugar industry wastewater under different surface area loading rates (SALR; 50, 97, and second set of 50 g-sCOD $m^{-2}d^{-1}$) was examined. The best removal efficiency, 87 ± 0.2% removal of soluble COD (sCOD), was observed at the SALR of 50 g-sCOD $m^{-2}d^{-1}$ for all three reactors. Increasing SALR to 97 g-sCOD $m^{-2}d^{-1}$, however, decreased the efficiency below 80% sCOD removal after 12 days of operation. This was due to excessive biofilm growth on the internal surface of all three media types limiting the mass transfer. 14-22% of sCOD was being removed at the steady-state condition of this stage. Setting SALR to 50 g- sCOD $m^{-2}d^{-1}$ for the second time caused biofilm thickness adjustment and recovery in COD removal after 26 days. Recovered efficiencies were in the range of 67-70% of sCOD removal. It was observed that the MBBR's performance was almost independent of media specific surface area. All reactors including different media types provided almost the same biomass activity, removing 43.8 ± 0.4 g-sCOD $m^{-2}d^{-1}$, at SALR of 50 g-sCOD $m^{-2}d^{-1}$. Therefore, the media with the largest specific surface area (i.e., 942 m^2m^{-3}) was considered the most optimum one providing a specific available surface area with the least filling fraction. Aerobic MBBR has been shown to be capable of treating high-strength wastewater at SLAR as high as 50 g-sCOD $m^{-2}d^{-1}$ (28 g-BOD $m^{-2}d^{-1}$), with potentials of handling intermittent high loads and recoverability after experiencing significant efficiency drop.

SESSION 6 - Modeling, monitoring and control of nutrient removal processes

Chairman	Zhiguo Yuan (University of Queensland)
Co-chairman	Rafał Brodziak (Poznan University of Technology)

Model development for integration of complete ammonia oxidation (comammox) into the two-step nitrification activated sludge systems

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In this study, activated sludge model (ASM) was developed to the two-step nitrification and comammox. For this aim, three possible concepts based on the role of comammox were defined and incorporated into the as part of an extended two-step nitrificationASM1. For model calibration and validation, two series of long-term experiments were carried out at 12°C and 20°C in a SBR. The efficiency of the examined models were compared based on the behaviors of ammonia, nitrite, and nitrate in the studied reactor. The simulation results revealed that comammox could be responsible for the conversion of >20% of the influent ammonia load. Therefore, the role of that in the nitrogen mass balance in activated sludge systems should not be neglected and requires further investigation. Furthermore, the sensitivity and correlation analysis showed that maximum growth rates (μ), oxygen half-saturation (Ko), and decay rates (b) of all nitrifiers and comammox were among the most sensitive factors, and the highest correlation was between maximum growth rates and decay rates in kinetic parameters. The estimated kinetic parameters by the best model were 0.57, 0.2, and 0.15 d^{-1} for maximum growth rates of AOB, NOB, and CMX respectively.

Towards a mechanistic model to simulate microbial selection and wastewater treatment of purple bacteria in open raceway ponds

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Purple phototrophic bacteria (PPB) constitute an appealing group of microbes for resource recovery from wastewater. Anaerobic photobioreactors are standard research practice for achieving high PPB selectivity within the microbial community. Investment costs of these systems are, however, prohibitive for widespread implementation. Raceway reactors might offer a solution, yet current mechanistic models of PPB are not adequate to simulate the process and assess their treatment performance as they only include anaerobic conversions. This study has, therefore, developed a mathematical model that includes photohetero- and -autotrophy, and anaerobic and aerobic chemoheterotrophy of PPB and competing microbes. The model was able to accurately predict changes in the PPB abundance and COD removal rates. Short- and long-term process disturbances were modeled showing a collapse of the PPB community (46% to 1%) at incoming suspended solids concentrations higher than 200 mg L-1. Incoming unfermented organics decreased the PPB abundance around 3-12%, yet only at sludge retention times above 4 d.

Investigation of nitrogen bioconcentration from mainstream wastewater using culture- and bioinformatics-based approaches

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Dilute concentrations of nitrogen in mainstream wastewater are a hurdle for widespread nitrogen recovery. There is not yet a practical means of nitrogen bioconcentration; however, phosphorus bioconcentration is successfully applied in enhanced biological phosphorus removal (EBPR) through phosphorus accumulating organisms (PAOs). Cyanophycin, a nitrogen-based biopolymer, is a promising means to bioconcentrate nitrogen in a mixed culture system analogous to EBPR. Cyanophycin accumulating organisms (CAOs) have not been investigated to date for resource recovery from wastewater. This research investigates the feasibility of nitrogen bioconcentration by CAOs through culturing Acinetobacter baylyi, a heterotroph found in activated sludge, and analyzing metagenomes of wastewater bioprocesses for evidence of the cyanophycin metabolism. A. baylyi cultures successfully produced cyanophycin up to 66% of cell dry weight, suggesting the utility of CAOs for high-rate nitrogen bioconcentration. Marker genes of the cyanophycin metabolism were found in all 23 publicly available metagenome datasets from JGI analyzed in this work, suggesting the feasibility of selecting for CAOs in existing wastewater bioprocesses. Overall, the results of this work are promising for further development of nitrogen bioconcentration by CAOs.

A flexible, ORP-based phenotype activity model for simulating biological phosphorus removal processes

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Modeling the complex mechanisms of conventional and sidestream enhanced biological phosphorus removal (EBPR) usually poses challenges when only a single PAO biomass is used. The latest generation of advanced models, employing PAO-GAO competition using an extended number of biomasses, occasionally combined with metabolic models, proved to be more effective. However, their application comes with increased model complexity and simulation runtimes. This paper presents a new approach of using a single biomass with a flexible phenotype activity model, where the balance between PAOs and GAOs, as well as the fermenting activity of PAOs is controlled by the actual ORP conditions. The built-in temperature-sensitivity of the PAO-GAO competition was tested by sensitivity analyses executed on a set of BNR layouts. The performance of the model was also compared to its two-biomass PAO-GAO predecessor using real-life treatment plant models, including sidestream EBPR processes. The new model was found to have similar prediction quality and being more reliable.

Development of real-time control strategies for the optimisation of nitrogen and phosphorus removal in Intermittently Aerated Sequencing Batch Reactor technology

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Advances in instrumentation, control and automation for use in the wastewater sector have led to increasing interest in the application of advanced control systems to the sector which yield significant benefits in terms of nutrient removal and energy savings. To date, their implementation has been limited due to technical challenges and track record of effective operation particularly in decentralised treatment systems. However, further research is needed to validate the robustness and performance of these treatments systems. The Intermittently Aerated Sequencing Batch Reactor system is a novel technology that offers a level of energy efficient treatment that can improve on conventional SBR systems. This technology, when combined with real time control, offers a solution that can provide advanced levels of treatment, while optimising energy

efficiency. This study analyses the impact of the deployment of advanced control at a decentralised wastewater treatment facility treating wastewater for a population equivalent of up to 200. Based on this case-study, this research analyses the level of efficiency that can be achieved with advanced control strategies and investigates the savings on a larger scale that may be achieved if utilised

Improved nitrogen removal efficiency by implementation of intermittent aeration

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An intermittent aeration system was implemented at selected wastewater treatment plants. In all cases, this system led to a significant reduction in total nitrogen outflow concentrations without the need to incur additional investment costs or increase operating costs. Moreover, the implementation of intermittent aeration has led to significant reduction in energy consumption and decreased cost of external substrate. The results proved that it is possible to utilize intermittent aeration for treatment plants initially designed with permanent aeration of nitrification sections, if the current load is lower than the designed capacity.

SESSION 7 - Recovery of valuable organic products

Chairman	Michele Laureni (TU Delft)
Co-chairman	Karolina Mazurkiewicz (Poznan University of Technology)

Enhanced polyhydroxyalkanoate production in membrane bioreactor system from citrus processing wastewater treatment

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Enrichment of PHA-accumulating bacteria and PHA productivity were studied both in a sequencing batch membrane bioreactor (SBMBR) and a conventional sequencing batch reactor (SBR) using citrus processing wastewater as a feedstock. Both enrichment reactors were operated under organic loading rates (OLRs) ranging between 1-3 kg COD m^{-3} d^{-1} to simulate the seasonal variability of citrus processing wastewater composition. PHA content was higher in the SBMBR (26-39%) than in the SBR (13-38%) under all the OLR investigated. Moreover, a higher PHA productivity was obtained in the SBMBR than in the SBR (0.60-1.90 vs. 0.26-0.37 g PHA L^{-1} h^{-1}), suggesting a better enrichment of the microbial community in the SBMBR. Mass balances performed in the accumulation reactor highlighted a lower propensity to convert the organic matter in extracellular polymeric substances (EPS) in the SBMBR (7-18 vs.13-26%), fact that favoured PHA synthesis (37-62 w%) since competitive reactions involving organic matter metabolization were more limited. Also, results obtained suggested that the lower F/M and a better selection of the microbial community in the SBMBR improved the overall process efficiencies.

Connecting physico-chemical characteristics with gelling properties of alginate like exopolymers recovered from wastewater granular sludge

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Alginate like exopolymers extracted from aerobic granules have shown interesting gelification properties. The composition of those extracts has been proven to be very complex, therefore the need to understand which molecules and mechanisms are responsible for the gelification properties is necessary. A fractionation method coupling anionic exchange chromatography with size exclusion chromatography has been used to separate molecules into fractions according to their global charge and size in order to determine which physico-chemical properties are the most important for their application as functional hydrogels. A miniaturized gelification screening method has been developed to compare the capacity of the collected fractions (corresponding to polymers with diversified charge and size) to gelify in standardized conditions.

Acid whey wastewater valorisation to caproate using reactor microbiome

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Resource recovery from wastewater is possible through fermentation processes by biological conversion using naturally occurring microbial consortia – microbiomes. One of the valuable product is caproate, a medium chain carboxylate formed in chain elongation process. The objective of the work was to effectively recover carbon in the form of caproate from acid whey wastewater. In the research a long term caproate production from acid whey and shaping the reactor microbiome for that purpose was demonstrated. Lactate-rich feed stimulated chain elongation and caproate production while ethanol addition led to short chain carboxylates production. Product inhibition was identified as main process bottleneck for higher caproate productivity and selectivity. The microbial analysis revealed abundance of Coriobacteriaceae and Ruminococcaceae families and Caproiciproducens ssp. was identified as key caproate producer. The results broaden the knowledge on lactate-chain elongation process and provide a novel technology for acid whey valorisation.

Preparing wastewater for resource efficient treatment: pre-filtration combined with carbon source production

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A novel pre-treatment, combining rotating belt filtration (RBF) with acidogenic fermentation of primary sludge for production of volatile fatty acids (VFA) is studied in pilot-scale at a municipal wastewater treatment plant. The aim is to recover carbon in the influent wastewater for biogas production, and at the same time produce sufficient carbon source for biological nutrient removal (BNR). During the first three months of operation, the RBF effluent quality was stable with SS concentrations continuously below 110 mg L^{-1} with average SS and particulate COD reductions of 64% and 73% respectively. Size characterisation showed an efficient removal of particles above 5-10 µm. The VFA species distribution in the fermenters during the first three months of operation was on average 25% acetate, 41% propionate, 17% butyrate, and 15% valerate expressed as COD.

High optically active L-lactate production from co-fermentation of food waste and waste activated sludge: impact of salinity and ammonia

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Recently, food waste and waste activated sludge (WAS) have been bio-valorized to lactic acid, an important industrial intermediate and widely used precursor for biodegradable plastic. However, a racemic mixture of L-lactate and D-lactate was generated in the mixed microbiome from organic waste fermentation. This work introduced two important factors: salinity and ammonia on produce L-lactate and the pilot study for lactate recovery (2 ton/d). We observed that an efficient approach of using salt (10-30 g/L) could increase LA production. And ammonium addition (300 mg of NH_4^+-N/L) can double the yield of LA and increase OA of L-LA by fivefold during repeated batch fermentation of food waste. This coincided with a significant increase in the glycolysis activity and the relative abundance of key lactic acid bacteria (LAB) genera and the ldhL gene associated with L-LA production. Finally, the pilot study was also scaled up (2 ton/d) for the sustainable enrichment of L-lactic acid from waste streams with high optical activity.

Volatile Fatty Acids production by acidogenic fermentation of sucrose in a sequencing-batch reactor under different organic loading rates and C/N ratios

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Volatile Fatty Acids (VFAs) are value-added products that can be produced by fermentation of waste using Microbial Mixed Cultures (MMC). However, more research is needed to understand how to drive the fermentation process to give a specific spectrum of products to be used as building-blocks in other processes. Thus, in this work, the fermentation of a sucrose solution was carried out in a sequencing-batch reactor (SBR) to assess the influence of the volumetric organic loading rate (OLRv), the specific organic loading rate (OLRs) and the Carbon to Nitrogen (C/N) ratio on the degree of acidification (DA) and the composition of resulting effluent, among other parameters. We found that an OLRv of 6 g $COD \cdot L^{-1} \cdot d^{-1}$ lead to high DA (56%) and high butyric acid concentrations (4.4 g $COD \cdot L^{-1} \cdot$), while higher OLRv (11 and 16 g $COD \cdot L^{-1} \cdot d^{-1}$) yielded lower DA and an effluent mainly composed of ethanol and acetic acid. Rising the OLRs (from 2 to 3.6 g COD·g VSS-1·d-1) and the C/N ratio (from 11.7 to 25), resulted in an increase in the concentration of non-identified compounds the effluent. This work contributes to the understanding of the VFA fermentation process by MMC from the different organic matter components.

SESSION 8 - Photoprocesses in wastewater treatment

Chairman	Frank Rogala (Aqualia)
Co-chairman	Tomasz Schiller (Poznan University of Technology)

The photogranulation process: potential for aeration-free and net autotrophic wastewater treatment

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There is an increasing number of studies demonstrating the use of microbial granules that possess the oxygenic function, due to the growth of oxygenic phototrophic microorganisms incorporated, for wastewater treatment. These oxygenic photogranules (OPGs) can potentially treat wastewater without aeration, which currently causes the highest energy demand in wastewater treatment, and enable net autotrophy by fixing carbon and yielding greater chemical energy output than influent wastewater in the form of granular biomass. The photogranulation process may thus open a possibility for next-generation wastewater treatment for both high-income and mid/low-income settings. Studies have shown that OPGs can be produced via multiple methods, including hydrostatic and hydrodynamic batches of activated sludge, which do not involve traditional granulation selection pressures, such as hydrodynamic shear and hydraulic selective biomass washout. This study will introduce the goldilocks zone theory for photogranulation as well as the lessons learned from OPG scaleup efforts treating wastewater conducted at the local wastewater treatment plant. We show potential to achieve the OPG process for municipal wastewater treatment with minimal or reasonable modifications, such as a mix (without aeration) of aeration basin during daytime and nighttime with irradiation.

Photogranules: A game changer in biological wastewater treatment

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Photogranules are spherical biofilms of phototrophic and non-phototrophic organisms that show potential to improve the sustainability of current wastewater treatment systems. They have excellent settling properties and the phototrophic (O_2 producing) and non-phototrophic (CO2 producing) synergy allows to minimize or even exclude external aeration. Aeration-free setups have shown to work well in lab-scale stirred vessels. Yet using mechanical steering as mixing mode at large-scale will be challenging due to the geometry of photobioreactors (high surface area to volume ratios). The best way of mixing in conventional photobioreactors is therefore by aeration in bubble columns or vertical tubular systems.

In this study we compare two mixing modes at pilot-scale: 1) external aeration, and 2) headspace recirculation. The latter was completely closed and O_2 was solely produced via photosynthesis and CO_2 via heterotrophic respiration. The system used were four 30L pilot-scale bubble columns operated in a greenhouse under Dutch summer conditions. Despite varying light and temperature, the closed systems performed equally as the external aerated ones. Our results show headspace recirculation is not limited by O_2 and CO_2 and thus not compromised in performance. This significantly lowers aeration needs and simultaneously contains greenhouse gases.

The role of nutrients limitation and depletion in carbon removal by purple bacteria from industrial wastewater

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Application of fuel synthesis wastewater (FSW) is a by-product of emerging processes of clean synthetic fuel production, extremely rich in organic carbon and of high clarity. In this study we investigate its treatment using purple non-sulfur bacteria (PNSB), a group of organisms gaining attention due to their high yield and various harvested resources, such as biohydrogen, bioplastics, pigments, and biofertilizers. PNSB growth is governed by the presence of ammonia (NH_3) and phosphate (PO_4) in the media, which are typically deficient in industrial water streams like FSW. This study explored PNSB growth over two consecutive stages of nutrients limitation and nutrients depletion. Limitation of both nutrients resulted in higher biomass growth, especially NH3 limitation. However, high PO_4 concentrations resulted in an increase of organics uptake from the media. Depletion of any nutrients resulted in growth rate decline, while the lack of vitamins or trace elements from the medium resulted in inhibition of all activities. Depending on the targeted application of PNSB, nutrients concentrations can be altered accordingly to decouple organic removal and biomass growth.

Photo-biorefinery concept using Purple Phototrophic Bacteria to produce value-added compounds from wastewater

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Effective resource recovery remains as one of the biggest challenges to be addressed nowadays in wastewater management systems. Conventional wastewater treatment concepts still suffer from high energy demand whilst dissipating valuable components to be potentially recovered to produce bio-based products and materials. The rationale of DEEP PURPLE relies on a disruptive and low-cost urban bio-waste streams treatment based on the concept of purple phototrophic bacteria (PPB) photo-biorefinery. The largest photo-bioreactor built so far is located at the wastewater treatment plant Estiviel (Toledo, Spain), and has shown promising results treating domestic wastewater: nitrogen and phosphorus removal (up to 60%), and COD and TSS removal close to 90% in a single- step process, thereby avoiding the dissipation of both carbon and nutrients. Next steps involve: (i) the scale-up of the process to demonstrative plant (TRL 7) and (ii) the demonstration of the feasibility of the simultaneous treatment of domestic wastewater with another organic feedstock, i.e., the liquid stream resulting from the thermal hydrolysis of the organic fraction of municipal solid waste (OFMSW).

SESSION 9 - Water reuse and emerging contaminants in wastewater

Chairman	Tao Guihe (PUB Singapore)
Co-chairman	Agnieszka Szuster-Janiaczyk (Poznan University of Technology)

Water recovery from waste water treatment plants as part of the local water cycle

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Recovering water from waste water is part of a circular economy, saving water resources and energy. The EU Regulation 2020/741 (OJ EU:5.6.2020.177), on the use of reclaimed water regulates the principles of proper water reuse. An important element is the obligation to carry out a risk assessment as the basic tool to ensure the safety of reclaimed water. Józefów is a city with low-rise, mostly residential buildings, without industrial plants. Its new waste water treatment plant achieved very good effectiveness. The effluent is discharged to the Świder River. Reclaimed water can be used for the own purposes of the plant, but also irrigation of urban green areas. An alternative to these applications is the use of water from the municipal drinking water network. Despite the positive aspect of water recovery, questions arise about its impact on the environment and the safety of residents. Hence the need to develop a risk analysis for each application. The preliminary risk analysis showed that the treated waste water has parameters ensuring the safety of its use for local purposes, provided that an additional level of treatment (filtration) is installed. It should be emphasized that the use of reclaimed water contributes to the savings of drinking water resources from groundwater intakes.

Variability of organic matter composition in the artificial infiltration intake of a river water

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The work presents changes in the content of organic matter during the preliminary treatment of surface water in the process of artificial infiltration. The aim of the study is to analyse the changes and effectiveness of organic matter removal from surface water in the investigated infiltration intake. The analysed water quality parameters include: fractions of organic matter determined by LC-OCD, BOD_5, TOC, COD-Mn, UV-254 and other physical chemical water quality parameters. The high efficiency of removing and lowering the following water quality parameters was achieved during the infiltration process: BOD_5, TOC, COD-Mn, UV-254. Biological processes play a significant role in improving the quality of infiltrating water. The results of statistical analysis showed that there are significant correlations between the values of conventional parameters indicating the presence of organic compounds in water and the parameters determined by the LC-OCD method.

Multifunctional biocatalytic systems for removal of estrogens from water solutions

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Over recent years the presence of various organic pollutants, so-called emerging contaminants (ECs), including mainly phenols, bisphenols, dyes, pharmaceutics, and even estrogens in the water bodies and wastewater is rapidly growing. Therefore, there is a need to develop efficient methods and tools for removal of the above-mentioned compounds in an eco-friendly and sustainable manner. Thus the main aims of the presented work was to produce advance biocatalytic systems based on electrospun material and immobilized laccase for efficient treatment of estrogens from water solutions. Within the frame of the study the effect of

various process conditions on removal efficiency of 17β-estradiol (E2) and 17α-ethinylestradiol (EE2) was examined in order to define optimal remediation conditions. It was shown that after 24 h of the enzymatic treatment at pH 5 and temperature 25 °C, total removal of both estrogens was achieved. Further, significant improvement of stability and reusability of immobilized enzymes as compared to their free counterparts was also attained. Obtained data clearly indicate that biocatalytic systems produced might be considered as an effective and promising alternatives for recently used techniques of estrogens removal.

Application of iron-containing sediments derived from drinking water treatment in wastewater treatment plants

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Until recently, technological waters (so-called washings) were treated as a company loss necessary to maintain production continuity. In some facilities, the volume of washings accounted for even 10-15% of water intake. To reduce losses and waste disposal costs the effective methods of thickening, drying and granulating the sediments present in the washings were developed, enabling also the recovery of used water. The separated iron-rich sediments, due to their inorganic nature, were used at various stages of the wastewater treatment process. The results of the research have shown that the iron-rich sediments dosed at the catchment points of the supplied sewage perfectly eliminate odours. Tests carried out at the pilot plant have also shown that iron-rich sediments from the iron removal process dosed into the fermentation chambers binds phosphorus compounds present in the leachate with an efficiency comparable to commercial coagulants, e.g. a coagulant under the trade name PIX. The obtained results allowed us to look at the iron-rich deposits in terms of benefits and not losses.

SESSION 10 - Energy recovery

Chairman	Jörg Krampe (TU Wien)
Co-chairman	Tomasz Schiller (Poznan University of Technology)

Controlling biofilm retention time in an A-stage high rate MBBR reactor for organic carbon redirection

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This study sought to control the biofilm solids retention time in a high-rate moving bed biofilm reactor operated at 17 ± 4 g-bCOD$m^{-2}d^{-1}$. Biofilm solids retention time was controlled by one of two strategies (i.e., 100% and 60% effective biofilm removal) that targeted several nominal biofilm solids retention times (i.e., 8, 6, 4, and 2d) by employing different biocarrier replacement times. The results demonstrated that the suspended solids activity could be reduced by decreasing the nominal biofilm solids retention time. Using the 60% biofilm removal strategy, the actual biofilm solids retention time with a nominal biofilm solids retention time of 2d was 12h. When utilizing the 100% biofilm removal strategy, an actual biofilm solids retention time of less than 3h was achieved with a nominal biofilm solids retention time of 2d. Overall, the biofilm removal strategies favored carbon redirection and maximized the biomass yield at 1.1 ± 0.3 g-TSSg-COD^{-1} removed.

Nutrient and energy recovery from wastewater using microbial fuel cell and potential use as fertiliser for urban agriculture

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This study investigated the potential integration of the microbial fuel cell technology in urban agriculture for circular economy. The results showed that the MFC reactor recovered nutrients such as potassium, phosphorus and nitrogen in the form of liquid (catholyte) in previously empty chamber and simultaneously produced electrical energy (20-40 mW) from wastewater to power LED lights. The electro-filtration functionality of the MFC represents an affordable and effective method of purifying and cleaning wastewater while preserving nutrients needed for agriculture.

Biosolids treatment as source for a demand-driven energy generation

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While increasing the share of highly fluctuating renewable energies like sun and wind, there is an increasing need for flexibilities in order to maintain grid stability. Sewage sludge treatment, as energy consumer and generator as well as provider of energy storage, can provide flexibility. Due to the high energy density, co-substrates can be considered as energy storage if corresponding infrastructure e.g. storage tanks etc. is available at the water resource recovery facility (WRRF). The gas storage represents a further component of flexibility which, in contrast to the substrates, can be provided directly via combined heat and power plants (CHP). Another not unimportant component is the use of the digester as energy storage. Appropriate management can contribute to flexible energy flows. Laboratory, pilot and large scale results show the possibilities and limits for a flexible operation of sewage sludge treatment.

Granular Anaerobic submerged Membrane Bioreactor for energy recovery and domestic wastewater treatment

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G-AnMBR is a hybrid anaerobic biotechnology combining anaerobic digestion by granular sludge and membrane ultrafiltration. G-AnMBR have a great potential to compete conventional aerobic treatment for domestic wastewater treatment (DWWT) at ambient temperature by providing a high- quality effluent with less energy consumption and energy recovery through biogas production. Validation and optimization of the process have still to be done since full-scale implementation for DWWT is not yet achieved. A G-AnMBR and an UASB were operated in parallel during 120 days at 25°C with low-strength synthetic wastewater (HRT = 13 h, OLR = 0.8 $kgCOD.m^{-3}$ $.d^{-1}$). G-AnMBR overcomes the usual long start-up period and biomass washout compared to conventional UASB reactor. The total membrane retention greatly improves effluent quality as well as biogas production. G-AnMBR reaches organic removal rate (up to 93% COD and 98% TOC) as high as conventional activated sludge operated with similar operating conditions.

Co-digesting waste activated sludge with food waste to enhance energy recovery: role of trace elements in process stability

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Municipal waste activated sludge (WAS) is considered as renewable energy source via anaerobic digestion (AD), despite its low organic content and its kinetics of degradation. At the same time, municipal food waste (FW) is also considered a good substrate for AD with higher potential for energy recovery compared to WAS. However, FW digestion is based on a delicate balance that may affect the process stability, leading to digester acidification and thus lowering the amount of methane produced. Conversely, WAS and FW co-digestion (AcoD) is reported as a stable process, and such stability is generally attributed to the alkalinity provided by WAS addition. The results obtained here highlight that the stabilizing effect is not only related to buffering, but it is due to the WAS capacity in avoiding VFA accumulation and fall in pH by overcoming methanogenic activity inhibition. Semi-continuous AD and AcoD tests evidenced that the trace elements contained in WAS play a key role in sustaining the growth and the functioning of methanogenic populations, lowering volatile fatty acids accumulation and enabling high energy yields.

Enhancement of biogas production at a municipal WWTP

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The recent trend of turning wastewater treatment plants (WWTP) into energy self-sufficient resource recovery facilities has led to a constant search for solutions which fit into that concept. One of them is waste activated sludge (WAS) pretreatment as well as Chemically Enhanced Primary Treatment (CEPT). Both methods give the opportunity to increase biogas production and significantly reduce the amount of sludge for final disposal. It has a significant impact on operating costs in municipal wastewater treatment plants (WWTPs). The aim of the work was to develop a sustainable process concept that combines increased biogas production, while minimizing the cost of sludge handling. The process of low-temperature pre-treatment of waste activated sludge (WAS) and CEPT was tested. Based on the laboratory and full scale results, energy gains and savings were calculated and an economic evaluation was carried out.

SESSION 11 - P removal

Chairman	James Barnard (Black & Veatch Inc) & Danielle Davelaar
Co-chairman	Karolina Mazurkiewicz (Poznan University of Technology)

Conversion of the McAlpine Treatment Plant to Biological Phosphorus Removal

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Side-stream enhanced biological phosphorus removal (S2EBPR) was applied at full-scale at the McAlpine plant in Charlotte NC, USA by converting two out of fifteen virtual aerations basins to side-stream fermenters, using ten percent of the RAS combined with gravity thickener overflow. The outcome showed that an anaerobic volume fraction of ten percent of the total volume was sufficient to allow an anaerobic solids retention time (SRT) of 1.5 to 2 days for reducing phosphorus from around 5 mg/L to less than 0.2 mg/L orthophosphates as P.

Contribution of Denitrifying Polyphosphate Organisms to Enhanced Biological Phosphorus Removal and Greenhouse Gas Emissions

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The role and contribution of the denitrifying phosphate accumulating organisms (DPAOs) in enhanced biological phosphorus removal and greenhouse gases emission within wastewater treatment process are newly identified and not-fully understood issues. The aim of the present study was to assess the actual contribution and process rates obtained by the DPAOs in nutrient removal systems and their contribution to N_2O gas emissions. A series of two-phase batch tests (anaerobic/anoxic), complemented by measurements of liquid N_2O, with different carbon sources available during anaerobic phase (glucose/acetate) and electron acceptors (NO_2-N or NO_3-N) in the anoxic phase, were caried out at the temperature of 20 °C. Phosphate release rates (PPR) with acetate were approx. 40 times higher compared to glucose. Similarly, denitrifying activity measured as NUR (nitrate uptake rate) and NiUR (nitrite uptake rate), were 10 and 5 times higher during the tests with acetate compared to glucose, respectively. The activity of DPAOs, were exclusive for the tests with acetate and limitation of the external carbon source availability during anoxic phase. Production of N_2O was strongly related to the available nitrogen (nitrite) and carbon source (acetate). Microbial analyses reflected a significant share of DPAOs(at around 10%) in the total bacterial community of the activated sludge.

Does the integration of a side-stream sludge fermenter reactor really help EBPR?

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One of the major causes of enhanced biological phosphorus removal (EBPR) failure in full-scale wastewater treatment plants (WWTP) is the low COD content of wastewater. External carbon addition not only increases the cost but also the carbon footprint. Side-stream sludge fermenter (SSSF) has been proposed as an alternative to provide additional COD. This study systematically evaluated the incorporation of a SSSF into an anaerobic/anoxic/aerobic (A_2O) configuration (A_2O+SSSF) to obtain P/N/COD removal under a limited influent COD (CODinf) condition. Firstly, the A2O plant was operated with decreasing COD concentrations (from 500 to 300 mgCOD/L) to determine the minimum CODinf requirements to achieve complete P-removal (350 mgCOD/L). Then, a SSSF reactor treated part of the recycled activated sludge (RAS) with hydraulic residence time of 2 d. The A_2O+SSSF configuration improved the amount of P that could be removed biologically (+27%),

but it also had the drawback of increasing the P load to the plant as a result of biomass fermentation with P-release, finally resulting in higher P concentration in the effluent despite of the increased removal capacity.

Analysis of a full-scale Phosphorus solubilisation and extraction process for its recovery in Murcia-Este WWTP

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Phosphorus (P) recovery from wastewaters is considered a requirement for next generation wastewater treatment plants (WWTP) as they are a key element in order to avoid the resource depletion. P-recovery processes have been studied broadly and full-scaled implemented in wastewater treatment plants, however most of these implemented technologies are focused on the recovery from the digested sludge and are limited by uncontrolled P-precipitation during the anaerobic digestion. The sludge line of the Murcia-Este WWTP was modified to obtain a phosphate (PO_4) enriched liquid-stream before the anaerobic digestion. This was achieved in a two-steps process in which the poly-P is solubilised and the PO_4-enriched sludge elutriated over the primary thickening to obtain a liquid-PO4-enriched overflow. The PO_4-P concentration in the recovery stream reached 41.1 ± 8.8 mg L^{-1}, which represents the 18.8 ± 6.9 % of the influent P-load to the WWTP. The process was operated under a fuzzy-logic-based controller which shown a high-performance stability independently of the operating conditions.

Evaluating the effect of FNA on denitrifying PAOs

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The purpose of this study was to examine the effect of FNA on denitrifying PAOs. To this end, a highly PAO-enriched biomass was developed at a lab-scale reactor that demonstrated significant phosphorus removal rates under aerobic and anoxic conditions. During operation, the aerobic PUR averaged at 26 mg P g^{-1} VSS h^{-1}, while the average anoxic PUR was 12 mg P g^{-1} VSS h^{-1}. The results of batch tests highlighted that the anoxic PUR was found to be inhibited by 50% under the FNA concentration of 1.8 µg L^{-1} (75 mg NO_2-N at pH=8) while the greatest inhibition observed was 90% at the FNA concentration of 11.5 µg L^{-1}.

Optimisation of hybrid anion exchange nanotechnology (HAIX-Nano) for phosphorus removal: Towards sustainable resin regeneration

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HAIX-Nano (hybrid anion exchange nanotechnology) is a regenerable adsorptive media able to effectively remove phosphorus in very low concentrations from wastewaters or lakes. In the goal of using less chemicals during the regeneration and making the whole process more affordable, we optimised the technology by changing its core from a strong base anionic resin (SBA-HAIX) to a weak base (WBA-HAIX) one. By doing that, we were able to increase the regeneration efficiency by 55%. Also, by using a higher temperature for desorption we succeeded to increase the regeneration efficiency by another 40% while also increasing the rate of regeneration. These improvements will enable to use weaker concentrations of NaOH and NaCl during regeneration. For this project, two different synthesis procedures were used to make the WBA-HAIX. The two resulting materials were compared to a commercial version of HAIX-Nano. The results of those tests showed a good longevity for the three tested versions of HAIX-Nano.

SESSION 12 - LCA and Carbon Footprint

Chairman	Ewa Zaborowska (Gdansk University of Technology)
Co-chairman	Paulina Szulc (Poznan University of Technology)

Evaluation of the impact of urbanism on source separation system by life cycle assessment

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This study aims to assess the effect of different urban configurations regarding the choice of different source separation scenarios (urine, blackwater, greywater treatment). Six different urban configurations representing the different districts in European cities have been tested. The results demonstrate the enormous influence of urbanism typology on the results of life cycle assessment for source separation systems.

NPHarvest pilot tests with digested black water: life cycle assessment for nutrient recovery

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NPHarvest nutrient recovery pilot was operated with digested black water at RecoLab to gather long term operational data with new wastewater stream and identify hotspots of environmental performance using a life cycle assessment as a tool. The ammonia nitrogen recovery efficiency was approximately 50% and phosphorus recovery 90%. Considerable ammonia evaporation from the pilot was identified. This decreased the ammonia nitrogen recovery efficiency and yielded significant environmental impacts. Study showed that circulating nutrients is feasible but there is a further need for both technical and environmental process development.

Analysing the impact of food waste disposal through the sink via life cycle assessment

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This study analyses the impact of diverting food waste from the solid waste management system to the sewerage system using life cycle assessment. The disposal of food waste through the sewers has a positive effect on fossil fuel resources and human toxicity, non-carcinogenic. However, the traditional waste management system lead to larger savings in climate change, reduced discharge of nutrients to the receiving water bodies and lower water demand.

Carbon footprint evaluation of wastewater treatment plants - proposing a functional unit

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This study aimed at proposing a functional unit (FU) to enable a universal comparison of wastewater treatment plants (WWTPs) in terms of their carbon footprint (CF). Altogether, nine municipal wastewater treatment plants (WWTPs) were analysed, including five located in Poland and four located in Finland. In both countries, direct emissions had the highest contribution (70%) to the total CF followed by energy consumption that contributed to over 30% of indirect emissions. The main difference between indirect emissions were attributed to higher chemical consumption of the Finnish WWTPs. Total pollution equivalent removed (TPE_{rem}) FU proposed in this study enabled a better comparison of WWTPs in terms of their total CF. High correlations of TPE_{rem} with other FUs was observed since TPE_{rem} could balance out the differences in the removal efficiencies of various pollutants. WWTPs could reduce their CF up to 27% by different practices such as selling biofuel, electricity and fertilizers.

Reduction of GHG Emissions for Sludge Water Treatment in Biofilm Systems - A Pilot-Scale Study on N2O Formation and Emission as a Function of Aeration Strategies

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N2O formation, conversion, and emission were investigated in pilot-scale biofilm systems (two gas-tight one-stage deammonification reactors, V = 220 l) using different aeration strategies. First, direct aeration within the reactor and indirect aeration of the recirculation stream were compared. Second, the aeration strategies were adjusted to create oxygenconcentration gradients over the reactor height and over the biofilm width, enabling N2O denitrification in anoxic zones. A digital model was employed to support data interpretation and process identification within the biofilm.With indirect aeration, significantly higher N2O concentrations were measured in the liquid phase compared to operation with direct aeration. However, N2O emissions were only slightly reduced. This is due to aninhibition of the N2O reduction by HNO2resulting from high nitrite concentrations during the start-up phase of the anammox process.After achieving full deammonification (reduction of nitrite concentration, increase of pH), N2O emissions were reduced by 70% (direct aeration) and 77% (indirect aeration).Model results confirm that this emission reduction can be largely attributed to conversionby heterotrophic bacteria; HNO2concentration was below the threshold for N2O accumulation in all biofilm layers. The results confirm the key role of N2O denitrification in reducing N2O emissions. In this context, special attention should be paid to the HNO2concentration, since it has a strong inhibitory effect. Assuming a functioning N2O denitrification, indirect aeration has a potentialbecause a higher N2O concentration in the bulk phase is linked to a reduced N2O diffusion rate from the biofilm or evento a re-transfer of dissolvedN2O into the biofilmin the unaerated phase.Consequently,a higher N2O load that can be denitrified.Lower recirculation flows are related tolower N2O emissions; however, abalance must be found between reduced N2Ostripping and O2supply for NH4conversion.

A Thermodynamic Analysis of Intermediary Metabolic Steps and Nitrous Oxide Production in Ammonium-Oxidizing Bacteria

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The latest understanding of the metabolic pathways for ammonium-oxidizing bacteria (AOB) and thermodynamics electron equivalents modeling (TEEM) were integrated to estimate kinetic and stoichiometric parameters for the AOB's multi-step nitrification and autotrophic denitrification reactions. An energetics analysis for each reaction in the oxidation and reduction pathways resulted in an understanding that NH_2OH oxidation is the most efficient means for the AOB to provide electrons for NH_4^+ monooxygenation, making net energetics favorable for biomass growth when HNO and NO provide electrons for respiration and biomass synthesis. NO reduction to N_2O appears to be thermodynamically favorable, but the need for O_2 in NH_4^+ monooxygenation likely precludes NO reduction to N_2O from becoming a major pathway.

POSTERS

Treatment of galvanic industries wastewater using microfiltration

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In this paper, the possibility of regenerating the post-consumer liquid resulting from the degreasing operation of steel connecting elements intended for galvanic treatment in an integrated process system: sedimentation/microfiltration was discussed. The applied approach allowed for a significant reduction in the content of impurities, which negative impact on the quality of the bath used during the degreasing operation.

Meta-omics exploration of the polymer cyanophycin as a novel pathway for nitrogen recovery in wastewater bioprocesses

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This work explores the feasibility of nitrogen bioconcentration with cyanophycin, a nitrogen-based microbial biopolymer, using bioinformatics tools. We examined the genomic potential for cyanophycin accumulation in over 2600 metagenome-assembled genomes (MAGs) from existing full-scale wastewater bioprocesses and found that over one fourth of the MAGs had at least one marker gene in the cyanophycin metabolic pathway. We also analyzed gene expression levels of the cyanophycin accumulation pathway in Accumulibacter MAGs and found similar expression levels to ppk1, the main marker gene for phosphorus accumulation. Our lays the foundation for a novel route to nitrogen bioconcentration and recovery from wastewater via biological cyanophycin accumulation.

Natural quartz as natural adsorbent material for emerging contaminants (oxytetracycline) removal from water

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Oxytetracycline (OTC) in water and wastewater is considered a very important environmental problem and their elimination is mandatory to ensure the quality and safety of water. The present research aims about the OTC removal from aqueous medium using a natural aluminosilicate as quartz (Q) and other its variant but modified with zinc nanoparticles (ZnNPs). The ZnNPs were synthesized by chemical reduction method and were used to modify the Q surface. The OTC adsorption process as a function of drug concentration was investigated by batch test. The adsorption capacities (qe) of Q and Q/ZnNPs for OTC removal were 177 and 78 mg/g, respectively. In general, the adsorption process using the Q and Q/Zn follows a pseudo-first order kinetic model. The results obtained were indicative that the alternative prepared materials were efficient for advanced water treatment of aqueous media polluted with OTC.

Using Mathematical Modeling to Identify Causes of Souring During Food Waste Anaerobic Co-Digestion

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Anaerobic co-digestion (AcoD) offers an opportunity to treat food waste (FW) using extra capacity of municipal digesters but is susceptible to reactor souring. We develop a novel model to explore the conditions where FW AcoD reactors sour based on varying organic loading, hydraulic retention time (HRT), and feeding mode (continuous vs. semi-batch). The model includes typical biomass present in AcoD, common FW components (carbohydrates, proteins, lipids) and their hydrolysis products, pH and chemical speciation, alkalinity and pH, and select fatty acid inhibitions. With a long enough HRT and especially with continuous feeding, increasing food waste loading improved pH stability, biogas yield, and methanogen accumulation. AcoD operated with semi-continuous feeding was more sensitive to lower HRT than AcoD with continuous feeding. For example, feeding food waste having 200 g/L TCOD required a minimum HRT of 10 days for continuous feeding, but 20 days for 2-days in the semi-continuous mode. The best indicators of the onset of souring were bicarbonate total alkalinity below 1500 mg $CaCO_3$/L and VFA greater than 500 mg/L as acetate. The model and its results will help designers and operators determine and monitor crucial parameters for industrial application of AcoD.

Using Ultra-Small Nanofibers for Fog Harvesting

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Fog harvesting has emerged as a promising method of water collection and is a promising alternative to current technology. Ultra-small nanofibers are large area sheets composed of hydrophobic nanofibers that have enhanced surface wetting properties, making these materials ideal for capturing fog. Using a controlled test environment, the amount of water captured in tests using polypropylene film with nanofibers spaced 4 microns apart was significantly greater than the amount collected using polypropylene film without fibers. Various sizes and arrangements of the film were also tested, with a statistically significant difference in the amount of water collected by smaller strips of fibers when compared to larger strips of fibers.

Interactions between humic acids and emerging contaminants in wastewater

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Pollution of wastewater and surface water by organic compounds is a serious environmental problem. Pharmaceuticals and addictive substances represent a significant group of emerging contaminants that enter a large amount of wastewater and associated ecosystems. Paracetamol and caffeine are widely used compounds and their presence in wastewater indicates the degree of pollution caused by human activity. The removal of these polluting substances from water is difficult and they, therefore, become persistent in the environment. Humic acids are natural organic substances formed by the decomposition of mainly plant residues and are abundant in soil, peat, coal, and some waters. Humic acids can interact physically and chemically with a wide range of organic substances. To determine the kinetics of the interactions between humic acids and selected drugs, we extracted humic acids from lignite. Batch sorption experiments with HPLC measurement of drug concentration and surface plasmon resonance method were used for the determination of kinetic parameters. Both paracetamol and caffeine interacted with extracted humic acids that confirms the ability of humic acids to influence the behaviour of simple organic molecules in wastewater, surface water, or soil.

Sustainable wastewater treatment in an integrated advanced system based on chemical pre-treatment, anammox and polishing wetland

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Reverse Osmosis (RO) technologies present a solution for the water scarcity in many parts of the world where brackish water exists. Antiscalants act as a pre-treatment water additive for the RO plants in order to protect the membranes from scaling. This paper presents field, and experimental lab works to examine the effects of antiscalants on the small and medium scale brackish RO desalination plants under real operation conations. To assess the impact of the different antiscalants, a sample of 50-RO desalination plants has been selected along the Gaza Strip, Palestine. The evaluation process was based on three steps (i) RO plant's operational questionnaire, (ii) water samples collection and chemical water quality analysis and (iii) built a generalised linear model for operational process optimisation based on the antiscalants' type, dilution and dose. According to the optimization model to maximize the pollutants' removal, the results show that in order to reach the maximum salts rejection (98%) the first type of antiscalant (polyphosphates) should be used, at 1 ppm concentration with dilution of 2 litres of antiscalant to 250 litres of water. However, using the second type of antiscalant (phosphonates) with the same dose and concentration would lead to a 92% salts rejection.

Technical solutions for determination of membrane permeability of emerging contaminants in liquid phase using 3D printing

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Pollution of water with emerging contaminants is a worldwide problem. To determine the permeability of membranes to the contaminants in the liquid phase, plastic diffusion cells printed by 3D printing were designed. The device consists of two chambers; the upper chamber is flow-through that ensures a constant concentration of analyte above the membrane, while the lower chamber below the membrane is stationary. The cells made from two different materials (UV-curing resin and PLA fiber) have been tested for both artificial membranes (e.g. polyethersulfone) and natural membranes (plant cuticles) with selected analytes from the group of pesticides (e.g. metazachlor) or pharmaceuticals (e.g. paracetamol). In the case of 3D printing, the dimensions of the cell defining the acceptor volume and active area of the membrane can be easily adapted. It is also possible to attach capillaries to the donor chamber and determine the permeability of substances in a cross-flow arrangement. It is advantageous to use resins instead of PLA fibres to print the cells due to their better waterproof properties. The resulting permeate concentration in the acceptor chamber can be determined by HPLC-MS method, which is highly sensitive even to low analyte concentrations.

SAmpSONS: A software tool for comparative preliminary sustainability assessment of wastewater infrastructure systems

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Experts frequently argue over the potential advantages and disadvantages of conventional versus resource-oriented sanitation (ROS) systems in a rather subjective manner. Their views reflect their favoured system, whilst objective quantitative data supporting claims regarding the benefits and weaknesses of either wastewater management systems are often lacking, in particular when it comes to their respective sustainability performance. The freely available software tool SAmpSONS was developed to simulate and visualize both ROS and conventional wastewater infrastructures in terms of their material and resource flows. As particular emphasis is laid on nutrient recovery potential of ROS systems, SAmpSONS also simulates and evaluates respective effects. In addition, SAmpSONS enables a largely quantitative sustainability assessment based on established methods and covering a range of economic, environmental and social indicators. Thus SAmpSONS supports more efficient and informed discussions, decision-making processes and sanitation system planning.

Membranes' performance assessment for microplastic removal – recovery and recycling perspectives

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Microplastics (MPs), labelled as new emerging contaminants, have been detected ubiquitously worldwide. Although their potential hazard on humans is still unknown, their presence in the food chain and their eco-toxicological effects on marine ecosystems have been widely reported. Finding simple, fast, and low-cost solutions to treat domestic drinking water and avoid further release of MPs into the environment is fundamental. In this study, the behaviour of polyamide nylon 6 and polystyrene, commonly utilised in domestic settings, was investigated in the range of 20-300 µm. Their removal was explored using dead-end microfiltration with three different membranes with the same pore size of 5 µm but with different characteristics. Membranes' performance and mass and particle number removal efficiencies were calculated and used to compare the advantages and disadvantages of each system, aiming to provide a good and competitive solution. The highest performing membrane with higher particle number removal efficiency at comparable mass removal efficiency was cellulose acetate. Finally, the recovery and recycling perspectives are discussed.

Microalgae-based treatment of agricultural wastewaters, feasibility study under suboptimal climatic conditions

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The performances of an outdoor RW fed on both the liquid fraction of a piggery wastewater (PWW) and the liquid fraction of digestate from the anaerobic co-digestion of the solid fraction of the same PWW was tested over 2 years. Process stability and performances were accessed from the collected experimental data. In both cases, nitrification played a central role in the N transformation capacity of the RW, followed by assimilation. At farm level, both solutions were proven effective in the reduction of the N load to be disposed of on agricultural lands, though the first option appears to be more efficient with an applicable load of 9-17 tN ha^{-1} y^{-1}.

Qualitative risk assessment for bio-composite materials production

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Bio-composite materials are increasingly common in various applications such as the automotive industry. Usually, bio-composite materials are made from natural resources recovered from plants. A new type of bio-composite material is made from resources recovered from drinking water treatments (calcite), wastewater treatment (cellulose), and material from surface water management (aquatic plants). However, it is not clear what material quality and health risks humans would be exposed to, both during

the production and their use. Therefore, a framework is required to assess, monitor and control health and quality risks in the bio-composite production process and their use. This paper describes a qualitative risk assessment that represents the first step in the development of such a framework. The objective is to identify key potential hazards and associated risks involved in a specific bio-composite production process. A risk analysis was carried out by using the HAZOP methodology in the hazard identification phase. The associated risks were then mapped by using the qualitative Event Tree Analysis. This paper shows the effectiveness of combining of HAZOP and qualitative ETA methodologies for hazard identification and risk mapping. The results of this analysis provide an overview of the risks involved in the bio-composite production process.

Polyhydroxybutyrate production by a photoheterotrophic mixed culture, ethanol as stress-inducing agent.

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The aim of this work was to study the effect of nutrient limitation, the carbon/nitrogen ratio, ammonium chloride and glutamate (as nitrogen sources) and, ethanol addition on the polyhydroxybutyrate (PHB) production by a photoheterotrophic mixed culture isolated from wastewater enriched in Rhodopseudomonas palustris, a purple non-sulfur bacterium (PNSB). Commonly the limitation of some nutrient in PNSB induces PHB production. However, in this work the limitation of nitrogen, sulphur and phosphorus had a negative effect on PHB production. Another stress factor used to induce PHB production is a high C/N ratio. But, contrary to expectations, PHB production was better at low C/N ratios. Regarding nitrogen sources, sodium glutamate improved PHB production by 40% compared to ammonium chloride. Interestingly, the ethanol addition had a positive effect on PHB production although it was not consumed during the process. Ethanol (present in winery effluents) appears to be a stressor that induces PHB production, and this is the first time it has been reported. The operation under a feast regime, with addition of ethanol as an inducing agent for PHB production, can be a simple process compared to conventional aerobic processes where it is necessary to operate under feast/famine regime.

Shortcut nitrification in wastewater treatment – a technology of benefits

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The idea of shortcut nitrification is to replace full nitrification (i.e. oxidation of ammonia to nitrate) by nitritation (i.e. oxidation of ammonia to nitrite) in a mainstream 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. The aim of this study was to calculate and present the potential operational and economic benefits resulting from an implementation of shortcut nitrification (i.e. nitritation) instead of full nitrification at a real operating WWTP. To make the calculation, simulation analysis was performed by modified ASM2d model. The results show that even up to 28% of current electrical energy demand of WWTP could be saved. Additionally,

boosted biogas production could contribute to 24% increase in energy production by a plant. Finally, the functional safety of a WWTP could be improved by saving up reserve capacity of activated sludge reactor and secondary settling tanks.

Substrate affinity in a complex activated sludge biocenosis

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The value of affinity constant illustrates microorganisms' activity in different substrate availability conditions. Nitrifiers cultivated in mainstream and sidestream processes differ significantly in this matter and can be classified as examples of different survivability strategies (K and r). High affinity is characteristic for bacteria (K-strategists), cultivated in limited availability of substrate i.e. conventional activated sludge (CAS). Low affinity represents bacteria (r-strategists) in the sidestream processes e.g., partial nitritation (PN), where substrate limitation does not occur. Development of advanced wastewater treatment processes, such as mainstream bioaugmentation with nitrifiers cultivated in sidestream reactor, made coexistence of mentioned groups possible. In this study, effect of blending sludge samples originated from main- and sidestream processes on the affinity level was investigated. Two independent tests were performed: i) batch tests where mixtures of CAS and PN sludge were examined using respirometric methods ii) long-term, experiment where impact of CAS seeding intensity on the affinity level of PN sludge was determined. The batch tests results pointed that resultant affinity index is highly correlated with weighted mean of used sludges and similar tendency was confirmed in the continuous test. Such findings pose valuable contribution both for activated sludge models and further development of wastewater treatment technologies.

Transition towards resource recovery from wastewater treatment plants in megacities of developing countries

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In developing countries there is a lack of scientific data to support the development of coherent policies on the recovery of resources from wastewater treatment. This research aims to guide the elaboration of resource recovery projects by providing accurate and up-to-date data of wastewater treatment plants (WWTP) in the Macrometropolis of São Paulo, one of the largest urban settlements in the world. Data from 143 municipal WWTPs were analysed to understand the current situation regarding the implementation of resource recovery actions. Only 26% of the plants perform at least one recovery practice, and the predominant practice of resource recovery is the internal water reuse. Recovery actions are more concentrated in large plants than in medium and small ones. Sludge is disposed of in landfills, except for three facilities that recycle nutrients from sewage sludge composting. Plant size, local legislation, treatment technologies, interest of stakeholders, and other local conditions influence implementation. Finally, the authors propose a tool called a framework with several steps that can help achieve the implementation of resource recovery. Therefore, the results can provide subsidies for planning of resource

recovery in large cities, contributing to the Sustainable Development Goals (mainly SDGs 2, 6, 7 and 11).

Heat recovery from a wastewater treatment process - case study

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The article presents the potential possibilities and methods of heat recovery from the wastewater treatment process. The currently used solutions enabling the acquisition and use of heat in the treatment plant were reviewed. An analysis of the influence of factors influencing the values of the heat pump's energy efficiency coefficient (COP), such as temperature and flow velocity at check points, was performed. Based on the actual measurements of the values of parameters affecting the efficiency of the heat pump, the possible amount of heat to be obtained for the facility was estimated. Additionally, the possibilities of using the obtained heat in order to increase the quality of the wastewater treatment process were indicated on the example of a wastewater treatment plant (WWTP) in West Pomeranian region in Poland.

Life cycle assessment of semi-centralized municipal wastewater treatment facilities – case study from Poznań, Poland

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This paper presents a comparative environmental assessment of two municipal wastewater treatment plants. These two facilities, located in Poznań, Poland, stay in a close cooperation due to combined wastewater stream share possibilities between each plant, covering the treatment of total used water volume exhausted by the city and its surroundings. Moreover, this relation is also based on mutual sludge dewatering line dedicated for the overall digestate volume produced in the city of Poznań. This specific technological situation makes a very interesting study case. The examination of the WWTPs was based on the method defined in ISO 14040. 18 different categories of the environmental impact were analysed via ReCiPe Endpoint and Midpoint (v1.11) in a hierarchical approach. All calculations were conducted on the complex data base from 2019, which complementary describes the chosen facilities. As a result it was found that the general structure of results for both facilities is comparable, but their monthly distribution strongly differs.

Domestic Greywater Recycling: A Review

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Drought has been an increasing problem in several Mediterranean countries, and supply augmentation proved

to be an unsustainable way to meet potable water demand, while greywater recycling, has great potential to reduce potable water demands. The scope of this research was to assess the public perception on domestic greywater reuse and whether they would be interested to invest in greywater recycling. Whilst the majority were willing to invest in a domestic greywater recycling system, the majority stated that they would not spend more than €500 on such a system (including installation and running costs). Using the stipulated budget, different greywater sources were treated with readily available and low-cost water treatment technologies and their effectiveness was examined. The results showed that ozone and UV are both effective disinfection technologies while activated carbon is capable to treat greywater physio-chemically and is particularly effective in the removal of nitrates.

Specific rates of the phosphorus release and uptake process using hydrodynamically disintegrated excess sludge

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There were two objectives asked of this study: 1) analysing the rate of phosphorus release (v_{PRR}) and phosphorus uptake (v_{PUR}) with using excess sludge, after the hydrodynamic disintegration performed at different energy densities ($Ɛ_L$; 70, 140 and 210 kJ/l) as organic carbon source, 2) analysing the impact of the hydrolysis of disintegrated sludge on the vPRR and v_{PUR}. It was found that the hydrodynamic disintegration at different levels of energy density leads to obtaining dissolved organic compounds characterized by various properties as an organic source in the biological phosphorus removal process. The highest rates of vPRR and vPUR among samples with disintegrated sludge used as a source of organic carbon did not occur for the same substrate. The highest v_{PRR} was observed for organic compounds obtained at ƐL=210 kJ/l (2.2-3.4 $mgPO_4^{3-}$-P/gVSS·h). The highest v_{PUR} was recorded for organic compounds obtained at ƐL=70 kJ/l (2.0-4.6 $mgPO_4^{3-}$-P/gVSS·h/gVSS·h). The use of disintegrated sludge additionally subject to hydrolysis as a source of organic carbon always resulted in an increase in v_{PRR} and v_{PUR} in comparison to samples with an addition of disintegrated sludge not subject to the hydrolysis process.

Hydrodynamic disintegration as a method to enhance the methane potential of bio-waste co-substrate

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In order to assess the possibility of increasing the methane potential of the selected bio-waste (remains of fruits (RF) and sugar beet pulp in the form of pellets (SBP_Pellet)) the Biochemical Methane Potential tests (BMP) were performed. Before the BMP tests, the substrates were subject to the process of hydrodynamic disintegration at three levels of energy density: 35, 70, and 140 kJ/l. The results show that the hydrodynamic disintegration of bio-waste allows to increase their methane potential. For both bio-waste (RF and SBP_Pellet), the highest increase in methane potential was recorded for the lowest of the analysed energy densities equal 35 kJ/l. In comparison to the sample not subject to disintegration process, the methane potential increase was 48 and 9.6% for SBP_Pellet and RF respectively. To sum up, hydrodynamic disintegration is a promising method of pre-treatment of biowaste before its use as co-substrates in the

anaerobic digestion process in wastewater treatment plants.

Waste incineration slag for preparing coagulants to pre-treat wastewater for nutrient recovery purposes

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This work proposes and tests a way of harnessing waste incineration slag for nutrient recovery from wastewater. The study presents preliminary results on the use of a range of organic and inorganic acids for minerals extraction form slag. This leachate was used as a coagulant for pre-treating wastewater for nutrient recovery purposes. HNO_3 and $C_2H_2O_4$ were found to be the best solvents, however, only HNO_3 leachate was tested in this study. The resultant coagulant was tested with and without flocculation aid (Superfloc A120). The coagulant dosage applied in this study was based on Al concentration in the leachate. Three concentrations were examined: 20, 25 and 30 mg Al/L. PO_4 removal was in the range of > 65%, while NH3 concentration only dropped by a maximum of ~14%. Interestingly, using the the resultant coagulant alone produced better outcome than combining it with Superfloc A120 (PO4 and NH3 removal of 83.4% and 7.3% vs 75.8% and 14.1%). Further investigation into the optimisation of both leaching and coagulation processes is required to make this technique economically feasible.

Occurrence of Comammox bacteria in moving bed technology reactors

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The astonishing identification of complete ammonia oxidizing bacteria (Comammox), fundamentally overturned the traditional recognition of nitrification process. Until recently, the key to achieving partial nitrification was to inhibit the activity or completely eliminate NOB from the system while maximizing the activity of AOB. In this study impact of aeration strategy and organic loading on the presence of Comammox Bacteria in a N/D system in moving bed technology reactors was tested. In order to achieve this aim, Ammonia Utilisation Rate Test and qPCR was carried. The research was conducted for biomass collected from the laboratory models of SBR operating in two technological variants: pure moving bed technology - MBSBBR and hybrid technology – IFAS-MBSBBR. It was documented that the analyzed indices influenced the presence of Comammox bacteria depending on the form in which the biomass develops into moving bed reactors.

Intelligent tools for managing the water network in the face of deepening drought.

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The Poznań Water System (PSW) consists of 3 key water intakes and water treatment stations: Mosina, Poznań and Gruszczyn, as well as 14 local ones in the area of neighboring municipalities, 2 complexes of

retention reservoirs with a capacity of 50 and 30 thousand m3 m^3, 2 network pumping stations and a system of mains and distribution cables with a total length of over 2000 km. The entire infrastructure is used to provide access to safe water for over 800000 inhabitants.

We also learned how important it is to maintain health security in the ongoing pandemic that we have constant access to clean water. It would not be possible to maintain hygiene without constant access to clean water from the tap. Thinking about future generations and in response to climate change, we introduce practical solutions in the field of optimization of technological processes. The paper presents the methods implemented in Aquanet S.A. that are used in practice to eliminate and reduce the risks associated with disrupting water supplies. The implementation of monitoring systems for key processes in the water distribution system makes it possible to increase the speed of response to emergencies by minimizing m3 of irretrievably lost treated water.

The study on water purification process in the STP separators

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The article presents a comparison of two types fat separators: standard STP-1 and modified STP-1ZM in water purification process. The tests were performed for various pollutants. It has been shown that the efficiency is high and comparable in both constructions. The STP-1ZM separator shows a little bit greater efficiency for the heavy fraction. The difficulties in cleaning the tank resulting from the use of a baffle were also analysed.

Resource recovery at the ‘Płaszów’ municipal wastewater treatment plant

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New solutions in water and wastewater technology that, on one hand, would minimize the waste production while on the other hand search for effective ways of waste disposal are the biggest challenges of the modern water and wastewater management. In 2015, the European Commission, in its communication "Closing the loop - the European Union action plan for the circular economy" recommended that all Member States switch from a linear economy model to a circular economy model. In the water and wastewater sector, the shift towards a circular economy model includes introduction of more rational methods of management of both water and waste generated during water use as well as wastewater and sludge treatment. The paper presents the balance of waste generated during the wastewater treatment process at the Kraków-Płaszów municipal wastewater treatment plant (WWTP). The authors discus the solutions already employed at the facility and suggest some other methods for waste handling, following the concept of a circular economy.

Water Safety Plan – the Kraków-Raba WTP case study

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The article describes a procedure developed to manage a water supply risk at the Kraków – Raba Water Treatment Plant (WTP). (Materials of Kraków Water JSC. Gierek-Ożóg A., Żaba T., 2021). Risks and hazardous events that may have an impact on security of the water supply system have been identified. The risk assessment was analyzed using as the example water quality deterioration due to eutrophication processes at the surface intake of the Krakow- Raba WTP. The reservoir is the main source of potable water for the Krakow agglomeration. (Materials of Krakow Water JSC) Two factors were assessed in the analysis: atmospheric and anthropogenic conditions (expansion of the sewage infrastructure in the Raba catchment). The first factor was classified as a medium risk category, while the second as a low chance category (Materials of Krakow Water JSC). Some support measures were identified and a strategy protecting against water pollution was developed. (Materials of Krakow Water JSC)

Slaughterhouse sewage hydrolysis

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The main objective of the research was to check how the presence of sewage in the retention tank affects the impact of temperature and chemical hydrolysis on the methane potential of sewage. The temperature of 22°C showed to be more suitable for effective hydrolysis of the organic suspension than temperatures of 35°C and 55°C because at the same time it limits the further fermentation phases responsible for the loss of dissolved COD. Chemical hydrolysis carried out at 22°C with NaOH (increasing the pH to 9) turned out to be much more effective than the acidic hydrolysis carried out with the use of HCl (lowering the pH to 5). Hydrolysis with NaOH increases the methane potential of the retained wastewater much more effectively than that of fresh sewage. The registered methane potential of fresh and retained sewage after hydrolysis with NaOH reached the values of 994 and 473 Nml/g VS, respectively.

The use of nitric acid to shorten the nitrification process in the treatment of activated sludge municipal wastewater

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The aim of the study is to create an innovative Technology that will allow to achieve mainstream shortcut nitrification/denitrification via nitrite at municipal wastewater treatment plants (WWTPs). This will be achieved, among other things, by inhibiting nitrite-oxidizing bacteria (NOB) by nitric acid (FNA) in a separate reactor (selector). Nitrous acid for mainstream augmentation will be produced in a sidestream shortcut nitrification reactor treating reject water from sludge dewatering For this reason, preliminary tests are presented on the influence of FNA on the activity of ammonium oxidizing bacteria (AOB) and

nitrite oxidizing bacteria.

Optimization of nitrogen removal as one of the key aspects of wastewater treatment plant as an energy producer

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The key aspect of the Tychy-Urbanowice wastewater treatment plant is its energy optimization, including maximizing renewable energy production and improving energy efficiency. Energy optimization of the plant is also important in the context of the plant as an energy producer. However, such activities also require optimization of the sewage part by, among other things, treating water from sewage sludge. For this reason, it was decided to develop a solution for nitrogen removal in a two-stage partial nitrification/anammox process. The paper presents the results of research on the development of a two-stage partial nitrification/anammox system on a semi-technical scale.

Surface water or treated wastewater – what should be used in the power industry?

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The research results confirmed that the reuse of treated municipal wastewater in industry should be a commonly used solution in times of increasingly frequent water stress. The strengthening of requirements regarding the quality of wastewater discharged to the receiver allows for its direct reuse for different non-consumption purposes, especially in industry with chemical water treatment plant.

Variability of microbiological parameters and chlorophyll a in the artificial infiltration intake of river water

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The work presents changes in the microbiological parameters and chlorophyll a value as well as selected chemical parameters during the preliminary treatment of surface water in the process of artificial infiltration at the Dębina intake in Poznań. The paper presents the characteristics water quality parameters of a selected infiltration pond during its full cycle of operation in the period. The research was conducted at field research installation, consisting of three piezometers drilled along the infiltration water flow path from the pond to the S-48 well. The quality of the infiltration water was enhanced in terms of the microbiological contamination and organic compounds were decreased. The total suspended solids and phytoplankton measured by chlorophyll a concentration were eliminated. The infiltration intake, even in suboptimal conditions (winter, the first phase of the pond operation), ensures high treatment effects in terms of microbiological (algae and bacteria) and organics removal. Research has shown that indicator organisms, such as Escherichia coli and enterococci, were effectively removed during infiltration. Mesophilic and psychrophilic bacteria were removed to a high extent. The microbial activity measured by the number of colony forming micoorganisms declines along the pond-well path.

Study of low-thermal pre-treatment efficiency of waste activated sludge in technological scale

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The objective of this work was to investigate the effect of a temperature (45°C, 50°C) and time (0-24 h) of low-thermal pre-treatment (LT-PT) of secondary sewage sludge on further biogas production during anaerobic digestion (AD). In this study, sewage sludge pre-treatment was performer in technological scale, in wastewater treatment plant (WWTP) serving rural community (Qav.=720 m3 /d; PE=5500). Effects of LT-PT were evaluated mainly by increase of volatile fatty acids (VFAs), chemical oxygen demand (COD) and biogas production (biochemical methane potential, BMP) values. According to the obtained results, LT-PT sewage sludge showed better degree of solubilisation (increase of VFAs and COD concentrations) and higher biogas production during AD if compared with untreated sludge. The highest value of methane production was observed after disintegration performer by 24 hours in temperature 50°C.

AOB and NOB activity control with free ammonia and free nitrous acid under elevated temperature: preliminary studies

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The inhibitory effect of free ammonia (FA) and free nitrous acid (FNA) on the nitrification process and AOB-NOB activity was investigated in a batch test experiments under elevated temperature 30 °C. The experimental results showed that the increase of FA from 0.58 mg-N/L to 17.2 mg-N/L could supress activity of NOB and ensure nitrite accumulation rate up to 4.3 mg N/(g MLVSS·h) at pH=8.3. For the experiments with the presence of mutual FNA and FA, the activity of NOB was less affected under this condition than the absence of FNA; however, AUR found a slightly increasing trend from 2.05 to 3.87 mg NH4-N /(g MLVSS·h). Thus, these inhibitory influences indicated a much stronger effect of FA on NOB activity than of AOB, supporting that such scenarios can be successfully applied to the wastewater treatment plants to inhibit the activity of NOB and promote shortcut in nitrogen removal processes under elevated temperatures

Simultaneous nutrient removal in sequencing batch reactors

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The aim of the study divided into three series was to compare wastewater treatment effectiveness in three types of reactors: sequencing batch reactor (S1-SBR), moving-bed sequencing batch biofilm reactor (S2-

MBSBBR) and integrated fixed-film activated sludge–moving-bed sequencing batch biofilm reactor (S3-IFAS). The comparison of these three technologies was based on the following assumptions: the reactor's active volume was 28 L; composition of synthetic wastewater was the same for all series; 8-hour cycle of reactor's work, with the same sequence and duration of its consecutive phases and the dissolved oxygen concentration in the aerobic phases was maintained at a level of 3.0 mg O2/L. It was found that in all series high and comparable efficiency of the organic compound removal (93.9 – 95.1%) was achieved. In series S1-SBR and S3-IFAS highly effective nitrification (96.5 – 97.6%) and biological phosphorus removal process (98.9 – 99.3%) was observed, whereas in S2-MBSBBR these processes averaged 90.1% and 51.5%, respectively. Depending on the form of biomass responsible for wastewater treatment, different efficiency of total nitrogen removal process was achieved - averaged 86.3%, 84.8% and 91.6%, respectively for S1-SBR, S2-MBSBBR and S3-IFAS. Monitoring tests also revealed that hybrid system (S3-IFAS) favoured simultaneous nitrification/denitrification and denitrifying phosphorus removal process.

Regulation of microbial contamination under starch production by microalgae using domestic treated wastewater

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The potential feasibility of real treated wastewater for starch production by Chlorella-related microalgae was investigated by evaluating the effect of microbial contamination in real treated wastewater and disinfection of treated wastewater by chlorination. The use of real wastewater showed the higher microalgae/carbohydrate productivity than simulated wastewaters. Additionally, biological contamination originating from the treated wastewater showed inhibition on microalgal growth, demonstrating the necessity for contamination control (e.g. chlorination) during starch production using domestic treated wastewater as the growth medium. Then, three chlorination concentrations were compared, and chlorination at 2.0 mg Cl/L for 15 min was the most effective to maintain a high proportion of microalgae/carbohydrate concentration (19.3 mg/L). The findings of this study provide direction for the application of real treated wastewater and scale-up of microalgae biomass and intracellular starch production.

On the road to a resilient water future: degradation micro pollutants in WWTP effluent by ozonation

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Water scarcity can intensify due to climate chance and with most forms of economic development but, many of its causes can be predicted, avoided or mitigated. All the uses of water are connected in the water cycle and shortening the water cycle will help reaching a resilient water future. The indirect reuse of treated wastewater might be an important possibility. But the presence of micro pollutants and emerging compounds in the wastewater treatment plant (wwtp) effluent are a limiting factor for the indirect reuse.

A theoretical study on all the wwtp's in the Netherlands showed a limited number of plants with a significant effect on the environment. The treated water of these plants is emitted into vulnerable ecosystems or in indirect sources for drinking water. The wwtp of Wervershoof is such a plant. This wwtp is emitting its effluent into the surface water of the Yssel Lake, which is mainly fed by the river Rhine. This surface water is the main source for the drinking water

of North-Holland, produced by PWN Water Supply Company North-Holland (PWN). The water in the Yssel Lake currently contains traces of micro pollutants, including traces of pharmaceuticals. The micro pollutants in the wwtp effluent can contribute to the concentrations found in the Yssel Lake. The Dutch water authority Hoogheemraadschap Hollands Noorderkwartier (HHNK) is responsible the treatment plant of Wervershoof. PWN, PWNT and HHNK are working closely together on the topic of removal of micro pollutants, applying the knowledge on drinking water production to waste water treatment. We will be removing micro pollutants from effluent of the wwtp, using ozonation at a 700 m3/hr scale. The possibilities for reuse of this treated water will be explored in the future. Together we will work towards a more resilient water future.