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Content

- Acklowledgents
- Award winners
- Oral presentations abstracts
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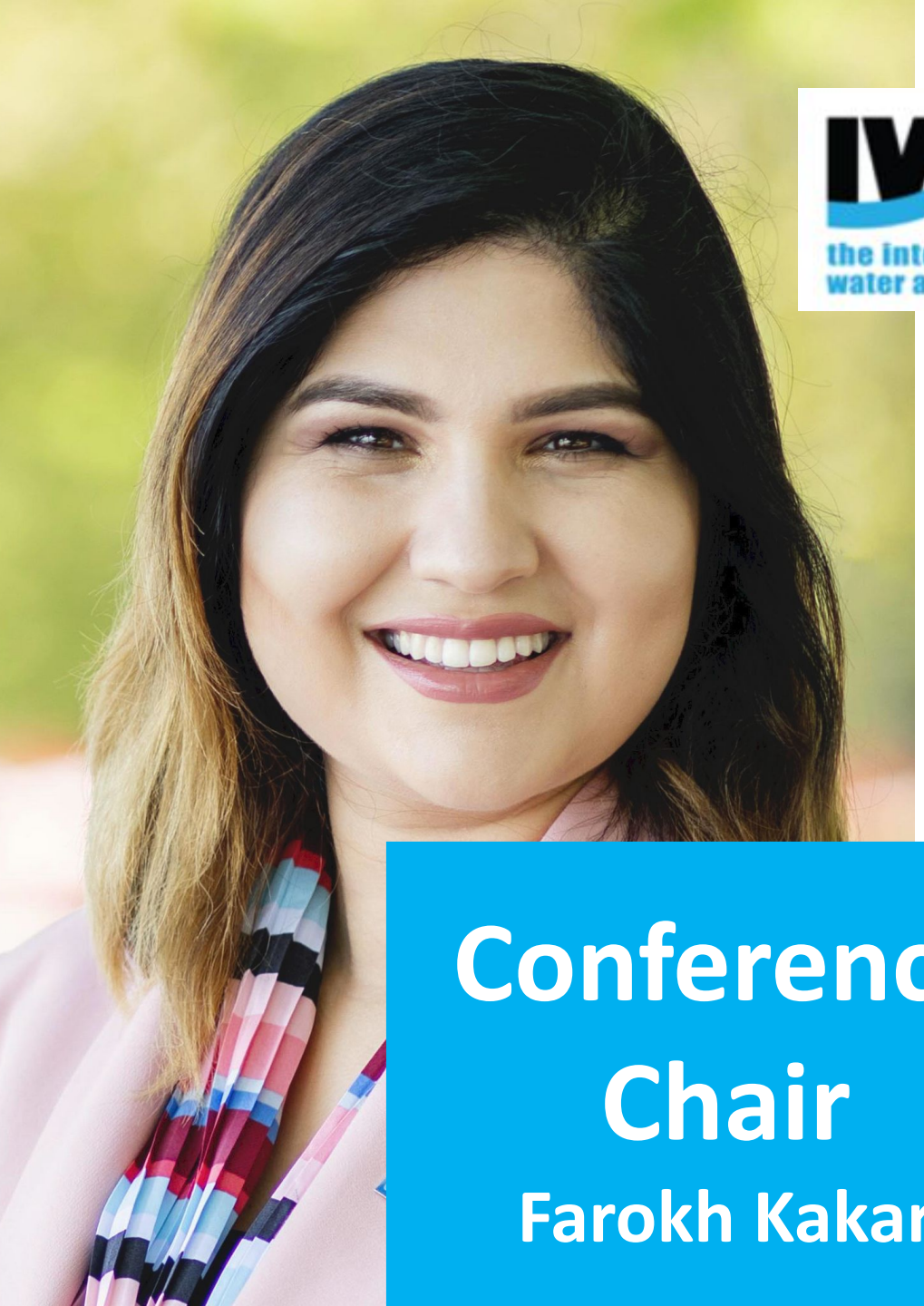

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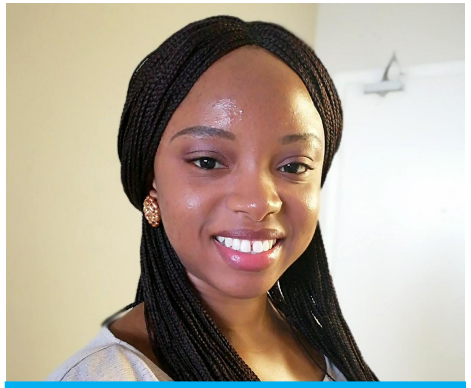

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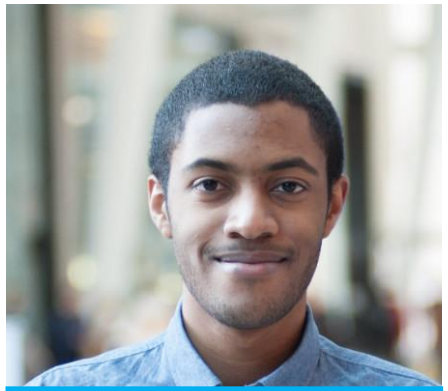

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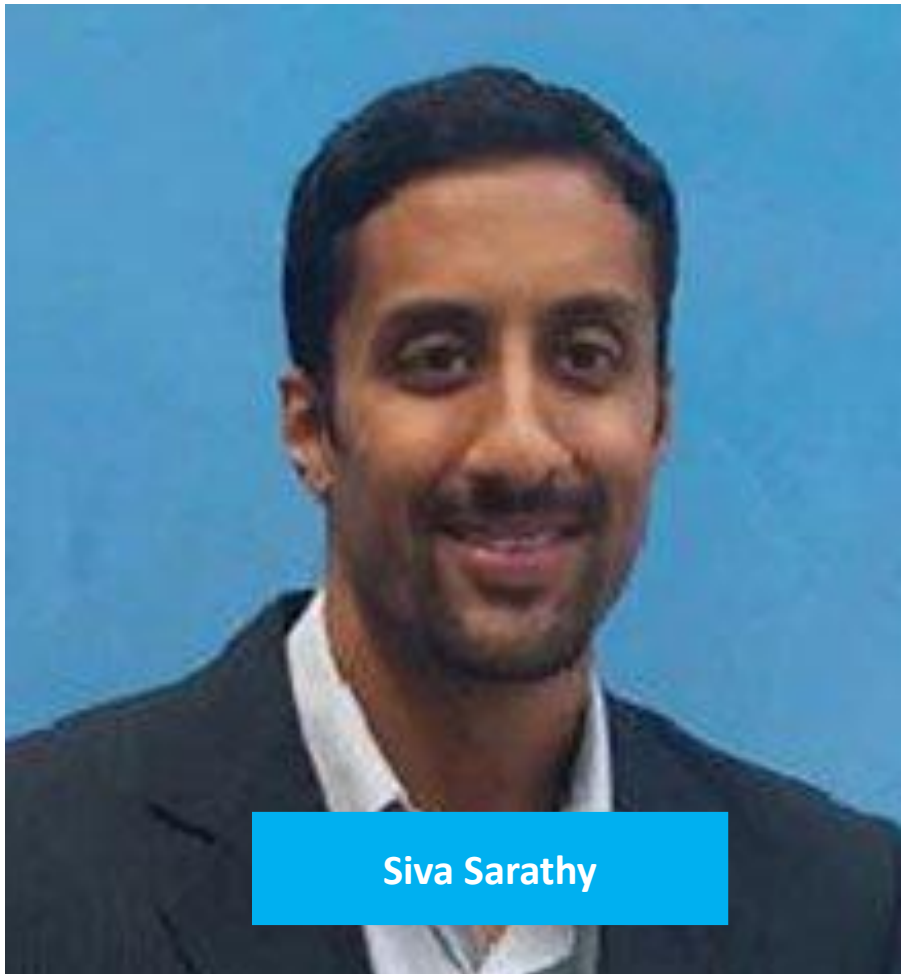

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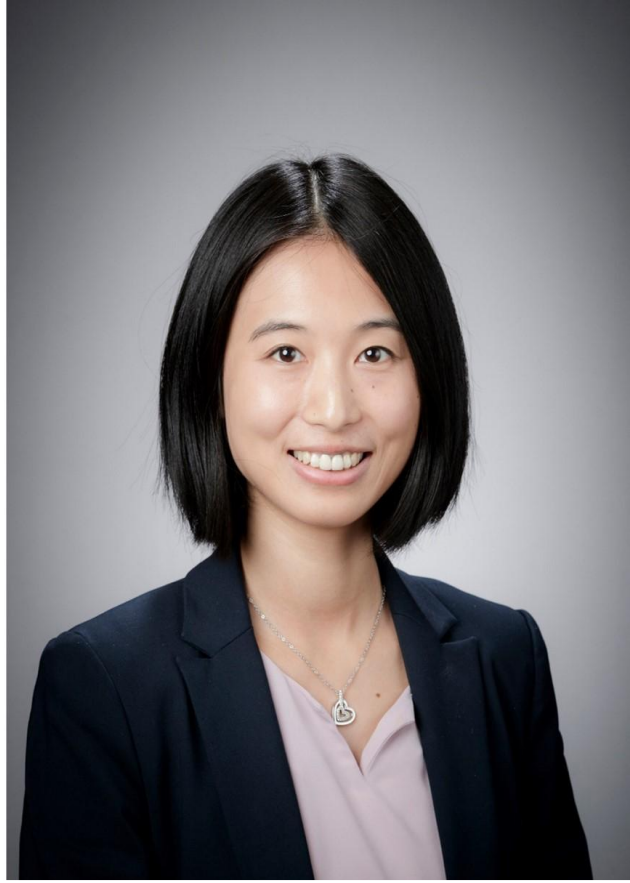


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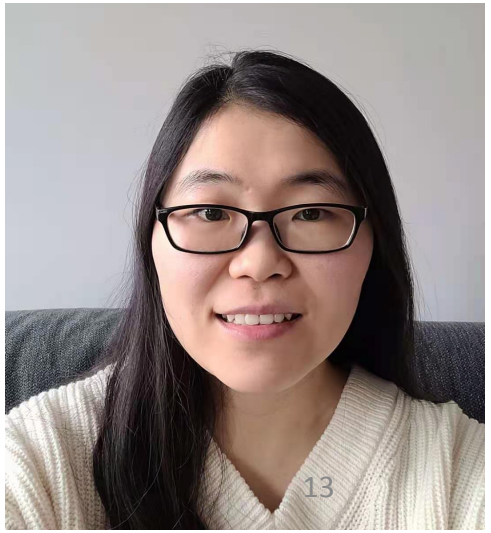
Workshop 1 Speakers







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YWP Canada Awards

YWP Canada award will be given to an individual YWP indicating outstanding contribution to the water sector!

This awardee will be selected based on leadership, contribution, vision and accomplishments throughout her water career. YWPs can be nominated by other parties or self-nominate themselves.

YWP Award - Pratik Kumar!

PhD: Advanced water filtration system for the removal of algal toxins and other water quality parameters from surface water sources

Installed water filters in households in India

Volunteers actively with IWA YWP

Now a professor at Indian Institute of Technology, Jammu

Oral Presentation Award

Oral Presentation Award

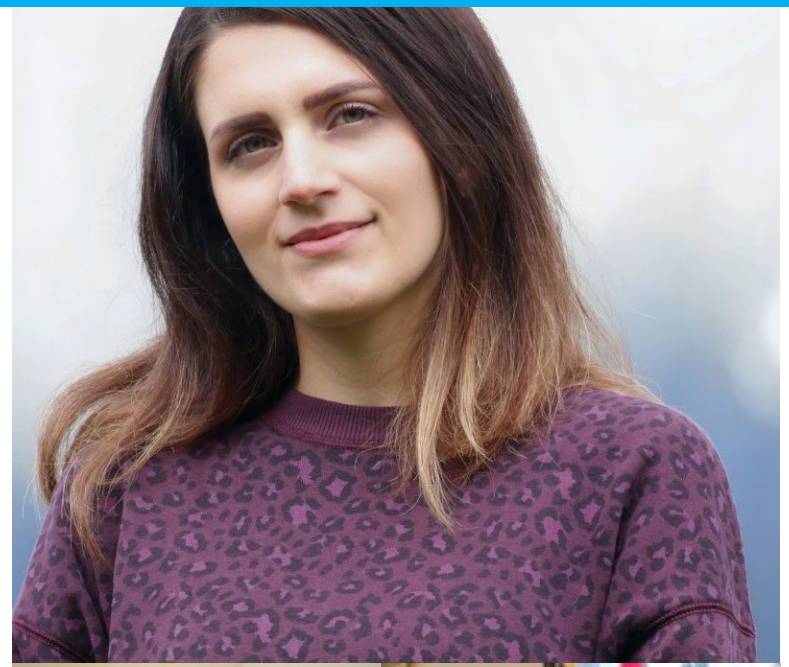
Best Oral Presentation Award

Mahsa Masjoudi - PhD Candidate - UBC - Vacuum-Ultraviolet Advanced Oxidation: How Does Chlorine Affect The Kinetics?

Runner up - 2 winners!

Zanina Illieva, PhD Candidate - Ryerson University - Removal of per- and polyfluoroalkyl substances in sludge processes, Ryerson University

Frances Okoye, PhD Candidate - Ryerson University - Impact Of Vacuum Application During Fermentation Of Primary Sludge, Ryerson University



Poster Presentation Award

Best Poster Award - Gavin Boyd

Undergraduate Researcher McMaster

Influent Forecasting For Wastewater Treatment Plants In North America, McMaster University

Volunteer Awards

IWA YWP Canada
Volunteer of the Year

For contribution to growth and excellence within
IWA YWP Canada

Volunteer of the Year - Gamze Kirim!

Gamze did amazing job for the past year through communication sector.

She has been the reason we have been able to make so many events a success. Communications was by far the most critical part for events success

she's been consistent throughout the year in taking the communications team to a new level.

Gamze is always on top of things!

She was a pleasure to work with on for organizing the conference, and she appeared to be very passionate about it.

Gamze has started, built and led a fantastic team for communications, particularly at the time when we needed digital communications the most: during a pandemic!

Proactive

Oral Presentations

Session (1)

Drinking Water, Basins, and Water Resources

Improving Point-of-use Drinking Water Quality Using Small-scale Membrane Filtration and UV-LED Disinfection

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Introduction

Photovoltaic-powered membrane filtration is a promising solution to the drinking water crisis in remote communities with energy access issues. State-of-the-art filtration systems, such as reverse osmosis (RO) coupled with simple pretreatment already exist in rural communities across South Asia and Sub-Saharan Africa. However, difficulty in regular cleaning and maintenance of storage tanks, piping, and RO membrane elements can compromise the water quality at the point-of-use (PoU). Addition of an in-line UV LED unit at the PoU can mitigate potential downstream recontamination and inactivate microorganisms not filtered by the RO membrane elements. In this work, UV-LED technology was prioritized over traditional UV disinfection methods, as UV-LEDs are an emerging technology and are potentially more suitable for operation in remote conditions due to their low energy requirement and versatility. This design study establishes the requirements for a coupled RO and UV-LED system to operate under off-grid conditions, laying the foundational framework for robust water treatment solutions in low-income communities.

Keywords: RO–UV coupling, Solar-Powered Water Treatment, PoU Water Disinfection

Materials and Methods

To establish the requirements for a coupled RO-UV system, a literature review was conducted to characterize factors influencing the performance of RO and UV technologies in field operation. PV-powered systems, PoU UV disinfection, and RO units operating and interacting within various service environments were researched to identify common failure modes. Based on this information, preliminary design decisions were geared towards maintainability, reliability, and suitability for the service environment. Formulated on these design goals, a RO–UV system was designed by compiling components available on the market and examining their suitability for the design. To comprehend and introduce preventive measures addressing each challenge, the RO–UV system was designed in the context of a primary school community in the Dacope Upazila of Satkhira, Bangladesh, which would serve as an example environment where this system could be of great use.

Design validation was obtained through simulations and calculations to determine if the chosen design would be capable of (a) providing sufficient drinking-quality water and (b) operating year-round despite service environment conditions. Water chemistry related simulations were performed using WAVE from DuPont Water Solutions. Energy demands and ability of the PV sub-system to power the coupled RO–UV system were evaluated using solar irradiance data from the region. Finally, since 90% of schools in Bangladesh retrieve water from tube wells (Tiberghien, 2016) (van Geen et. al., 2003), water flow and pressure calculations were performed after a tube well of 30 meters depth. Following these simulations, components that would minimize required maintenance and training efforts for the community were evaluated.

Results and Discussion

Following preliminary investigation, it was determined that no previous study had focused on coupling RO and UV systems in the context of remote, off-grid operation. Thus, it is of high relevance to pilot a study in which failure modes of such coupled systems are addressed. Detailed analysis indicated the primary challenges associated with coupling RO and UV and providing power via PV panels are: discrepancies in power requirements of all components, the unknown effects of intermittent use on the whole system, e.g., long-term fouling events downstream of the RO membranes and onto the UV reactor, system maintenance, as well as the safe disposal of waste products and consumables. To determine the required capacity of the design, a plausible school size based on an existing school in the area was selected. By choosing a target population of 48-62 students and 10-20 staff members, the nominal goal was to produce 2.9-3.8 m^3 drinking water per day. Data obtained from the National Renewable Energy Laboratory (NREL) elucidated that the region of interest has an average solar irradiance of 288 W/m^2 per day (National Renewable Energy Laboratory, 2020).

The proposed system configuration is shown in **Figure 1**. The UV-LED reactor, capable of delivering a dosage of 40 mJ/cm2, was positioned at the PoU to deal with any downstream recontamination and any possible microorganisms not filtered by the RO membranes. Depending on source water chemistry and a minimum 75% recovery from the RO system, the range of operating pressures would be between 11.3–21.6 bar. Estimating an average working pressure at 14.1 bar, a pump and motor ensemble would have to be able to provide 6.56 m^3/day; amounting to an average load of 191.1–276.9 W for average and maximum pressure settings. Considering all the above requirements and estimating a daily run-time of 9 hours, the energy requirement for the RO– UV system was calculated to be 2.94 kWh/day.

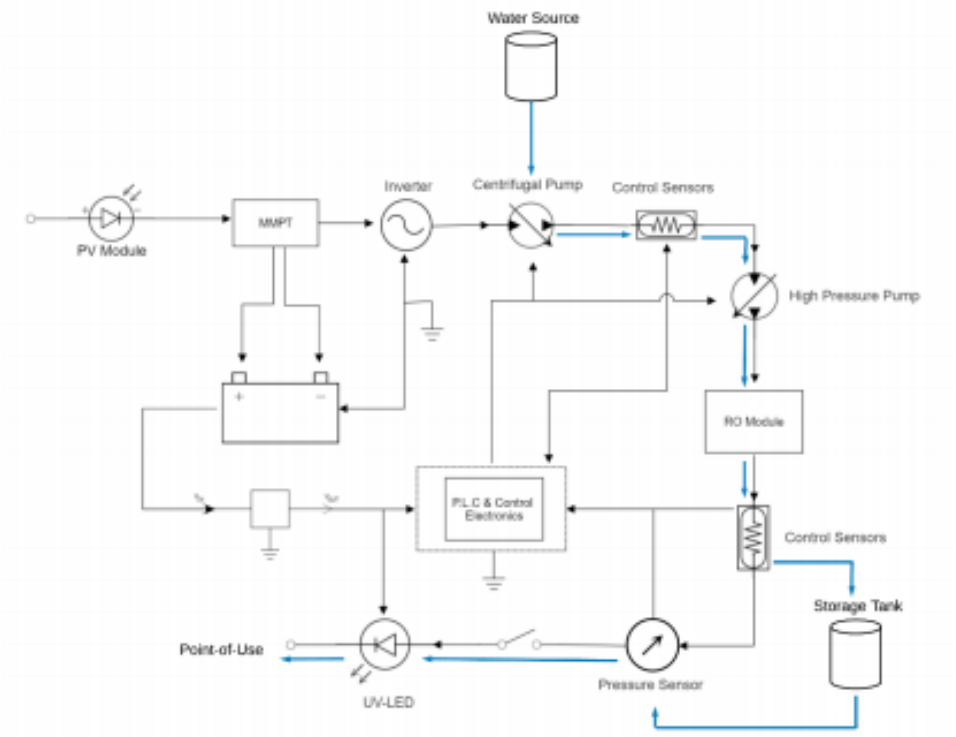

Figure 1: Flow-through diagram of RO–UV electrical and control systems configuration. Two-headed arrows represent feedback loop mechanisms between the controller and systems' sensors for the regulation of pump-motor ensembles, water chemistry monitoring, UV-LED control, and pressure sensors. Blue lines and arrows represent fluid flow between components through which water will pass or be stored on its way to the PoU.

Contributions of the work

Previous studies evaluated the use and performance of UV-LED and RO independently and analyzed the challenges associated with intermittent flow in RO systems or PV-RO matching. This research and preliminary design provide a framework for future work to investigate the suitability and effectiveness of small-scale PoU RO–UV water treatment systems, particularly, within the context of remote community applications. Furthermore, the evaluation of potential failure modes arising from the coupling of both technologies, and their matching to a PV system can further understanding of how to optimize the overall systems' reliability. RO–UV technology has the potential of mitigating long-term maintainability issues for small-scale plants providing drinking water to remote, low-income communities around the globe, thereby, bringing us closer to bridge the access gap and assist to reach the *Sustainable Development Goal 6 – Clean Water and Sanitation for All by 2030*. In the next steps, experimental optimization of.

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Microsystin-LR Degradation by Vacuum UV (VUV): The Effect of Bromide Ions

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Abstract

Microsystin-LR (MCLR) is a toxin that is produced by cyanobacteria, resulting from harmful algal bloom events. Advanced oxidation processes (AOPs), such as UV based treatments, are proven to be effective for the degradation of MCLR. However, halide salts in water sources could have a significant impact on the performance of AOPs. The present work aims to assess the performance of Vacuum UV (VUV) based AOPs for the degradation of MCLR in the presence of bromide ions. Past studies show that bromide ions can be converted to bromine radicals by reacting with hydroxyl radicals. Bromine radicals have the potential to degrade organic compounds. Samples with a concentration of 200 μgL^{-1} of MCLR and different concentrations of bromide ions were irradiated at fluence values ranging from 39.6 to 277.2 $mJcm^{-2}$. Following the irradiation experiments, samples were concentrated using Solid Phase Extraction (SPE) then analyzed with High Performance Liquid Chromatography (HPLC). Increasing the ions concentrations, improved MCLR degradation significantly. The reaction of hydroxyl radicals with bromide ions resulted in bromine radicals which is consistent with those reported in the literature. An additional pathway for the anion radical formation was observed. Bromine radicals can be formed via direct photolysis of bromide ions at 185 nm.These radicals enhanced the degradation of MCLR. Ongoing work is investigation the effects of natural organic matters (NOM), pH, and chloride ions on bromine radicals reaction with MCLR.

Keywords: Advance Oxidation Processes, Bromide ions, Microsystin-LR

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Real-time Computational Imaging of Reverse Osmosis Scaling in mm-scale

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Introduction

Reverse osmosis (RO) is a reliable desalination process where source water is pushed across a semi-permeable membrane, leaving unwanted impurities and minerals behind. Over time, mineral accumulation on the membrane active layer, termed as scaling, degrades its filtration efficacy. The maintainability, lifetime, and overall cost of RO operation largely depend on the degree of membrane scaling and its mitigation techniques. From that perspective, visual tracking of scaling growth can be useful to understand the overall fouling dynamics. Previously, simplified membrane imaging and conventional post-processing identified strong fouling hotspots (Sarker, Ko, and Bilton 2018). However, due to poor image resolution, mechanistic insights of scaling remained mostly qualitative. Herein, a machine learning (ML) clustering algorithm, K-means, was integrated into the image post processing algorithm and compared with the conventional, i.e., binary or multi-level threshold-based, results. The resulting image data revealed more quantitative information from the captured image and further streamlined the study of scaling growth in mm scale. This detailed information would also help to evaluate how mitigation techniques may improve membrane scaling and optimize RO operation.

Keywords: In-situ visualization, scaling kinetics, K-means clustering.

Description of Intervention

In this study, a brackish water RO membrane (DuPont BW30-2540) was scaled for 8 h using lab-prepared $CaSO_4$-saturated feedwater (saturation index 1.32). Scaling experiments were conducted in a bench-scale plate-and-frame RO crossflow module, and the scaling process was monitored using a custom-built in-situ visualization tool. To simulate high water recovery (75%), identical to field-scale units, the reject stream was partially recirculated. Experiments were run at 13.8 bar transmembrane pressure and 20°C temperature. The membrane surface images were captured at 10 min intervals; then, $CaSO_4$ scale distribution and growth were analyzed by classical image processing and using computer vision algorithms (K-means clustering) and compared.

In the classic image processing, the scaling images were histogram equalized, subtracted, and contrast-enhanced to identify CaSO4 scaling hotspots (**Figure 1**). However, during the background segmentation and denoising, some pixels representing newly formed scaling pixels were eliminated. Despite not passing the threshold values to be classified as scaling hotspots, these pixels were still crucial in understanding early-stage scale formation. Hence, alternatively, the K-means++ clustering algorithm in MATLAB was applied on the subtracted images with a goal to extract more information from the original background pixels. Four unsupervised clusters were set up to represent significant, moderate, early-stage scaling and the background based on pixel intensities. Each cluster's number of pixels was then tracked separately and fused with the original image with different colors for each non-zero index, e.g., red, green, blue, and gray for significant, moderate early-stage, and background clusters, respectively.

Results and Discussion

In the conventional processing, scaling pixels connected with each other were filtered from the contrast-enhanced image and represented the large lateral scaling growth locations, i.e., the scaling hotspots (**Figure 1e**). Unlike the conventional processing output, the K-means algorithm segmented the pixels based on their intensity differences and indicated scaling growth in the direction normal to the membrane (**Figure 2a**). Herein, the assumption was that intensity of the pixels in the subtracted image is proportional rough surfaces of the membrane due to scale accumulation. However, a major challenge was to make the default returns from random clustering assignment quantitatively useful after applying the K-means clustering algorithm. So, the number of pixels in each cluster was recorded and tracked over time. Pixels with the highest intensity differences (compared to the reference image) were binned automatically as a significant scaling segment (represented as red), moderate intensity changes were binned as moderate scaling zones (represented as green), minor intensity changes as early-stage scaling (blue), and negligible or zero intensity changes as background (unscaled membrane surface).

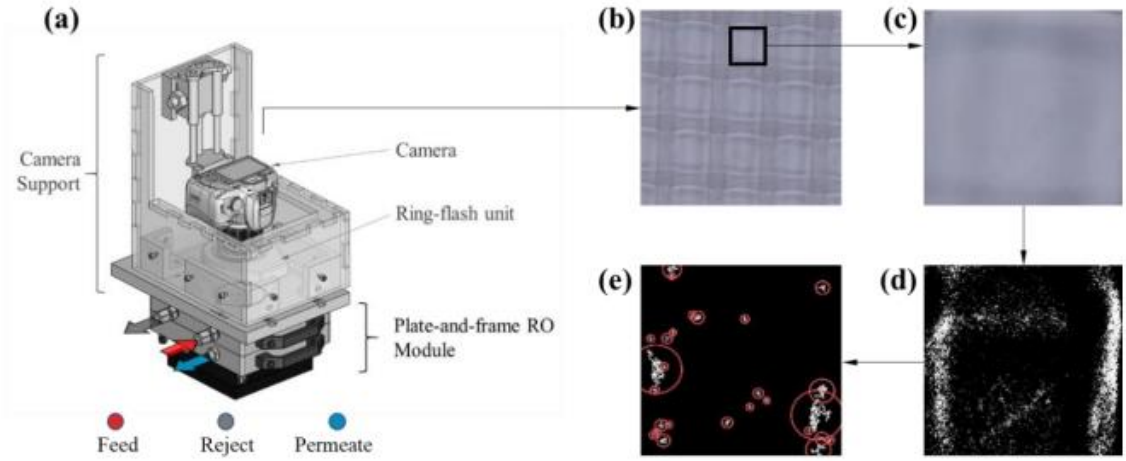

Figure 1. (a) In-situ imaging and classic post-processing of RO scaling; **(b)** a portion of the visualization window after 8 h; **(c)** cropped target section; **(d)** subtracted from the reference image and contrast-enhanced; and **(e)** scaling hotspots encircled in red.

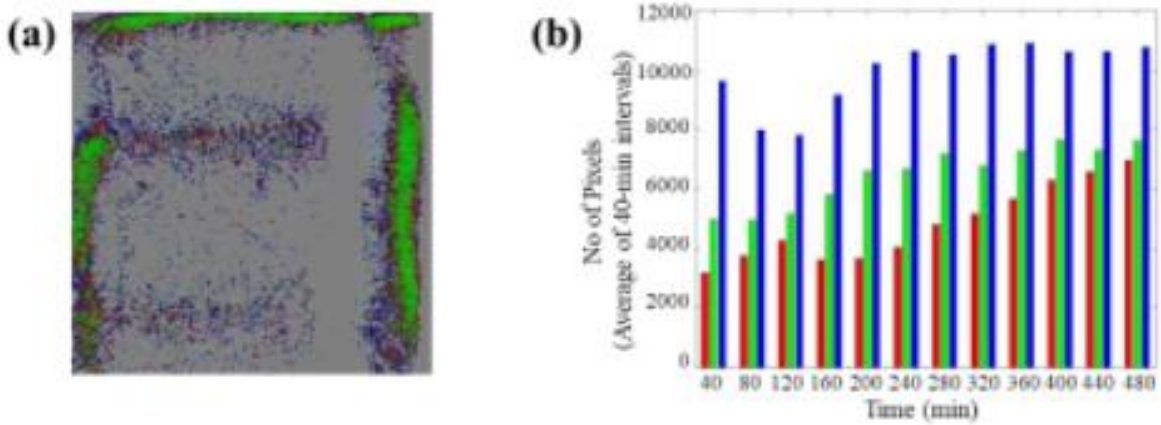

Figure 2. (a) K-means clustering segments – red, green, and blue clusters showing the significant, moderate, low scaling distribution on the RO membrane surface (indicated by gray); **(b)** Number of pixels for each cluster, tabulated every 40 min, indicated a different growth rate for significant and early-stage scaling clusters.

Growth of the identified scaling clusters was also tracked and plotted against time, which concluded an overall steady mineral scaling growth (**Figure 2b**). In the beginning, early-stage scaling dominated the membrane surface coverage. Over time, the generation of new early-stage

scaling sites (as well as moderate scaling sites) remained somewhat constant, especially after the first 3 h of operation (blue and green clusters). However, the number of pixels representing significant scaling zones grew faster (red cluster). This indicated that after nucleation and early-stage depositions, subsequent mineral crystallizations on top of the existing minerals were more favorable compared new nucleation sites on the membrane. Previously, it was shown that surface coverage (due to lateral scaling growth) is correlated with membrane permeability decline (Shmulevsky et al. 2017). Through this work, we were able to get some insights on scaling growth both in lateral and normal directions. Thus, if we assume that membrane surface areas with significant scaling would substantially obstruct water permeation while low and moderate scaling zones may remain permeable due to their loosely packed deposition on the membrane active layer, the current ML post-processing technique may make the connection between surface coverage and permeability decline more accurate.

Contributions of the Work

High quality real-time imaging of RO membrane scaling is difficult, especially with inexpensive DSLR imaging devices. Due to the low-resolution of the image (compared to high-end microscopy) and illumination variance, collecting meaningful quantitative information from these images is also tricky. Thus, for the first time, this work showed that utilizing ML clustering algorithms, e.g., K-means, further information can be extracted from the same macro-scale imaging system. Challenges with meaningful use of default returns from the K-means algorithm was addressed by sorting based on the number of pixels identified in different clusters. The preliminary results were promising and related to the different degrees of scaling, e.g., early-stage, moderate, and significant, and their growth pattern on the membrane surface. This method could be applied to analyze the RO imaging dataset from more controlled experiments and evaluate different approaches to fouling mitigation to optimize RO system operation.

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Impact of Intermittent Operation on Drinking Water Biofilters: A review

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Central Message

Generally, drinking water biofilters are operated continuously without shutdowns, but biofilters at small scale communities or facilities with excess plant capacity are often run intermittently. Periodic/intermittent operations are associated with biofilters being shutdown at regular time intervals, potentially resulting in periods of substrate and oxygen depravation depending on the local conditions. Periodic shutdowns might adversely affect filter performance as the biological activity may be diminished resulting in decreased contaminant removal efficiencies. Longer start up periods may also be experienced for intermittently operated biofilters due to slower developing biofilm. Though some recent studies reported positive effects of cyclical operation in terms of an increased removal efficiency of contaminants. Overall, limited research has been done to determine the impact of periodic operation on drinking water biofilters. In this context, this review identifies knowledge gaps after discussing the impact of the periodic operation on the filter performance, development of biofilm community as well as differences in microbial diversity. Also, the impact of operational parameters on filter performance, will be reviewed. Parameters such as dissolved oxygen, empty bed contact time, backwashing frequency, and filter media status during the resting period (submerged or drained) will be considered.

Keywords: Biological Removal, Biofilm, Operational Parameters

Biological Removal

Benefits of drinking water biofiltration include its ability to adapt to changing conditions within limits, to remove a variety of contaminants, to decrease the formation of disinfection by-products, and to reduce bacterial regrowth within distribution systems (Huck et al., 1998). In comparison to the continuous mode of biofiltration, an intermittent supply of oxygen can result in anoxic conditions. Although the filter would retain significant biomass, this type of operation would apply a selective pressure on the microbial community which may influence the biofilm composition, the biofilm thickness, and the extent of EPS production as well as biological activity and filter performance.

Impact on Biofilm Formation

During the initial stages of biofilm development, a continuous source of substrates is required to develop a fully functioning biofilm. Bacteria in drinking water biofilms derive energy and nutrients from oxidizing dissolved organic compounds. Since the only source of the substrate is in the influent, in case of intermittent operation this supply is not continuous. In that case, it is possible that the Extracellular Polymeric Substances (EPS), which are a major component of the biofilm, are consumed as nutrients during the shutdown. This can affect the physical properties of the biofilm and may lead to the formation of thin biofilms that are better suited for optimal biofiltration performance (Liao et al., 2015).

Impact on Microbial Community

Microbial communities can adapt to changing conditions using one or several mechanisms for example selective enrichment, enzyme regulation or exchange of genetic information. In case of

an intermittent operation where there will be a feast and famine regime of nutrients, microorganisms called copiotrophs may be more likely to be prevalent as they have very fast maximum specific growth rates, they can rapidly take up and use substrates, and they can go into dormant states in a period of famine (Rittmann and McCarty, 2001). Nemani et al. (2018), observed *Burkholderiales* and *Caldilineales*, and the family *Rhodobacteraceae*, being statistically more abundant in cyclically operated biofilters as compared to continuous biofilters. These genera belong to the Proteobacteria family with *Burkholderiales* belonging to Betaproteobacteria which grow under aerobic and anaerobic conditions.

Impact on Biological Activity

Intermittent drinking water biofilter operation can lead to a rapid decline in the dissolved oxygen following filter shutdown, potentially resulting in anoxic conditions that can have a direct impact on ATP levels, i.e., an indicator of viable biomass. Continuously operated biofilters were associated with high levels of viable biomass as measured by ATP, when compared to cyclically operated filters. However, once normalized to biomass, it was shown that cyclically operated filters exhibited higher esterase activity which is used as a surrogate for biological activity (Mckie et al., 2019).

Impact on Filter Performance

In the case of intermittent operation, filter shutdowns may deplete the heterotrophic bacterial biomass affixed to the filter media and degrade the quality of the filtered water. Niquette et al. (1998) observed an increase in the concentrations of nitrite, bromide, DOC, and ammonia, when a biologically active carbon filter was put back into operation after shut-down periods ranging from 6 to 24 hours, whereas McKie et al. (2019) observed an increase in DOC and NDMA precursors removal in cyclically operated filter (8-12 hrs/day). Similarly, Nemani et al. (2018) observed a modest improvement in DOC removal for cyclical operation.

Impact of operational parameters

Shutting -down drinking water biofilters intermittently may promote anaerobic conditions which could lead to reduced biological activity and produce undesirable by-products in the effluent. Niquette et al. (1998) observed that backwashing immediately prior to bringing the filter back on-line eliminated the negative impacts. Hess et al. (2020) showed that intermittent shut-down under submerged conditions did not negatively impact the performance in terms of TOC removal when compared to dry shutdown. Filter media drying might cause a loss of biological activity on the media surface due to bacteria die-off.

Conclusion & Research Needs

Intermittent operation has been shown to have both positive as well as negative impacts on drinking water biofilter performance, thus further research is required to determine the optimal conditions to achieve optimum biofilter performance, especially the role of dissolved oxygen, duration of shutdown, and optimal filter condition during the shutdown period should be considered. Further investigations into identifying the microbial community, understanding the role of EPS and mechanism of formation of biofilm could provide insight into the functioning of drinking water biofilters operated in intermittent mode. This review adds practical knowledge to the intermittent operation of drinking water biofilters as well as identifies areas where further research is required.

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Sustainable Downstream Storage for Coastal Area Water Supply: A Case Study of Brisbane River Estuary and Moreton Bay Australia

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Abstract

Water scarcity has become a serious issue in the coastal area due to rapid economic activities. This study proposes CR as a viable water development solution for Brisbane, Australia coastal areas to fulfill growing water demand. MIKE 21 FM, hydrodynamic module (HD) coupled with the transport module (TR) was used to simulate water quality by analyzing the longitudinal salinity distribution and flushing time. The 2D hydrodynamic model was calibrated and validated for the 2008 and 2011 flow events respectively, by using field observations of flow and salinity data. This study provides the complete salinity distribution and water quality analysis under different flow conditions in the Brisbane River estuary (BRE). Results show that when total river flow into the estuary is greater than 150 m^3 $s{-}1$, then CR could considerably store water during high flow and low salinity time. These results indicate that the optimum value of flows needs to be at least for 302 hours in the estuary to flush the salinity at the estuary mouth and to allow the freshwater inside CR. This study indicates that the common analyses that the estuaries cannot provide freshwater are not correct, instead intermittent fresh water at the estuary mouth can be diverted to CR while carefully regulating the salinity through intake gates. This study is of interest to salinity and flushing management in estuaries and could provide useful information on water management for the coastal community.

Keywords: Water quality, Coastal Reservoir, Numerical Modelling

Combiner Connaissances Scientifiques et Savoirs Hydroécologiques des Populations Pour la Gestion Efficace D'un Risque Hydrométéorologique.

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Abstraite

En Afrique de l'Ouest, plus précisément dans l'ouest du Sénégal, le Plateau de Thiès représente une zone hydroécologique de très grande importance ou les activités humaines dépendent largement de la présence de la ressource en eau. Le bassin de vie du Plateau de Thiès est depuis quelques années confronté à un état hydrologique sévère: l'assèchement de ses cours d'eau, mettant en évidence des conflits et des tensions autour des usages de cette ressource. Pour éviter l'exacerbation des conflits et tensions sur la ressource, il est nécessaire de développer de la connaissance sur l'état hydrologique assec peu ou pas connu. Ceci afin de caractériser cet état et de connaitre les mécanismes qui permettent de suivre son évolution vers des situations critiques. L'objectif de notre étude est de proposer une modélisation graphique de l'assec et des plans de gestion et de prévision de ces situations critiques (pénurie en eau) afin de rendre acceptables ces situations. La solution que nous avons trouvée est de combiner les faibles connaissances scientifiques sur cet état de faibles débits avec les savoirs hydroécologiques des populations vivant sur ce territoire. La participation de la population à l'élaboration des connaissances sur ce risque hydrométéorologique permettra de les sensibiliser, mais aussi de les préparer aux situations de crise en eau futures.

Pour ce faire, il faut connaitre la fréquence d'apparition des assecs à partir des variables de l'offre en eau (précipitations, débits, etc.), de la demande en eau (approvisionnement en eau potable, eau pour l'agriculture, etc.) et de la perception des assecs critiques (perception du risque de pénurie en eau, alerte sur les ressources en eau). Les variables quantitatives de l'offre et de la demande en eau sont traduites en indicateurs statistiques selon une approche fréquentielle. L'approche fréquentielle utilisée permet de définir des seuils critiques dont le dépassement par un ou des indicateurs permet de situer l'état du bassin de vie comme étant normal, critique, surcritique ou supercritique. Les seuils sont définis à partir d'écart type (σ). La définition de seuil permet de proposer une modélisation graphique pour suivre l'évolution de l'assec dans le Plateau de Thiès. Les variables de la dimension sont traduites en indicateurs de sensibilité et de préparation. Une approche qualitative basée sur la collecte de données à partir de questionnaires auprès des populations, d'entrevues auprès des décideurs et de l'organisation d'un cadre proactif de prise de décision, permet d'obtenir les informations sur la sensibilité et la préparation face aux assecs critiques. Les données qualitatives recueillies sont ensuite transformées en données quantitatives et traduites en pourcentage. La solution trouvée pour construire des seuils critiques d'assec pour les variables de la perception est de définir des seuils à partir de valeurs de pourcentage. Une autre modélisation à partir d'une approche qualitative est proposée pour la caractérisation de l'assec et pour suivre son évolution vers des états critiques. En participant aux activités de recherche, les populations participent à l'élaboration des connaissances sur les risques et à l'élaboration de plans de prévision et de gestion des assecs critiques. Cela leur permet d'accepter les réglementations telles que les restrictions d'usage, ce qui participe à réduire les conflits et tensions.

Mots clés: sécheresse, crise en eau, participation.

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Session (2)

Wastewater I: Large Scale

A Comprehensive Floc Model with External Mass Transfer to Simulate Activated Sludge System

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Abstract

In the literature, apparent half-saturation coefficients with a wide range of values have been reported as diffusion effects are typically incorporated into these coefficients (Wu et al., 2017). Since more and more microbial metabolisms and operating environments (i.e. low DO operation) were studied, it is becoming important to accurately and separately describe the effect of mass transfer and intrinsic biokinetics on microbial growth. The addition of external mass transfer mechanisms into a floc model can separate these effects. Constant intrinsic half-saturation coefficients instead of variable apparent half-saturation coefficients are used in floc-based models allowing the model to reflect the impact of floc properties (floc size and density) on mass transfer processes (Wang et al., 2007). In this study, a floc model developed in Sumo© with external mass transfer was presented and a sensitivity analysis was performed to floc-related parameters. Floc size and reduction factor of the diffusion rate were identified as sensitive floc-related parameters in the floc model. With the increase of floc size or the reduce of reduction factor, ammonia oxidation rate was reduced, complete nitrite oxidation was extended, and TIN removal efficiency was increased. Floc size of 1000µm or reduction factor of 0.1 can have a significant impact on system performance. In summary, a floc model with constant intrinsic half-saturation coefficients was presented. More attention should be paid to floc size and reduction factor during calibration. More studies should be conducted to find intrinsic half-saturation coefficients values for each microorganism.

Keywords: Nutrient removal; Simulation; SUMO

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Effect of Thermochemical Pre-Treatment of Thickened Waste Activated Sludge on Solubilization and Anaerobic Digestion

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Abstract

Production of methane from thickened waste activated sludge (TWAS) is often constrained by the poor biodegradability and slow degradation of TWAS. Our earlier study showed that TWAS pre-treatment using free nitrous acid is an environmentally friendly and economically feasible method to increase methane production. To further improve methane production from TWAS, the current study presents a novel thermochemical pre-treatment approach based on a combination of FNA and heat pre-treatment. We assumed that combined FNA and heat pre-treatment can disrupt sludge flocs, organisms' cell membranes, intracellular organic matter, and extracellular polymeric substance (EPS), which increase biodegradability and hydrolysis rate of activate sludge. This could achieve even higher methane production during the anaerobic digestion process compared with FNA-based pre-treatment alone.

TWAS from a full-scale Ashbridges Bay Wastewater Treatment Plant (Toronto, Canada) was treated with FNA alone, heat alone, and combined FNA- heat. The pre-treated TWAS was then subjected to biochemical methane potential (BMP) tests.

This study revealed that the employed thermochemical pre-treatment of waste activated sludge performed better than individual pre-treatment, in all desirable output parameters including increasing methane production as the most important output, increasing in COD solubilization, protein and polysaccharide. Also, the combined FNA-heat pre-treatment is an environmentally and economically attractive strategy for the pre-treatment of TWAS before the anaerobic digestion process, particularly considering that both FNA and heat can be produced as by-products of anaerobic sludge digestion in wastewater treatment plants.

Keywords: Activated sludge, Pre-treatment, Wastewater treatment

Impact of Different Primary Treatments on the Internally Enhanced Biological Nutrient Removal Process

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Abstract

In case of carbon limitation in the influent of wastewater treatment plants, satisfactory performance of the biological nutrient removal (BNR) process rely on supplementing readily biodegradable carbon source. Volatile fatty acids (VFAs) produced during acidogenic fermentation of primary sludge, was shown to be effective to enhance BNR as an internal carbon source. Characteristics of the fermentate is impacted by the composition of organics in the sludge which is correlated to different primary treatment options used in the treatment plant. Comparative studies on the impact of primary treatments on the BNR have rarely been found in the literature. In this study, the application of two primary treatment processes (primary clarification and rotating belt filtration) on the sludge fermentation, and carbon upgrade were compared. Control and enhanced BNRs (with and without supplemental carbon) were fed with either primary or RBF effluent at solids retention time of 10-d. Enhanced BNRs were supplied with sludge fermentation liquid (SFL) fraction of either primary or RBF sludge as carbon source operated at mesophilic temperature and 4-d SRT.

Results showed that combined nutrient removal efficiencies were improved by 65%~73% (TN), and 70%~77% (TP) compared to the control reactors without supplemental carbon. Average effluent nitrogen and phosphorus of both primary effluent and RBF-fed reactors reached to 15 mg N/L, and 0.5 mg P/L. Significant improvements were achieved in readily biodegradable carbon and VFA of the combined influent by addition of SFL. Results showed that regardless of primary treatment option, SFL can significantly enhance BNR in the respective train.

Key words: Enhanced biological nutrient removal, Fermentation, Internal carbon

Removal of per- and Polyfluoroalkyl Substances in Sludge Processes

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made organic compounds used in the manufacturing of a variety of products that people use on a daily basis. With over 4730 identified PFAS in the world, their use is in almost every industry available to mankind (electronics, cosmetics, cleaning, building, apparel, furniture, automotive, oil and gas, health, aerospace, etc). This high production and daily use of PFAS generate high amounts of solid and liquid waste. The solid portion goes to landfills where it contaminates the soil, water and air. The liquid portion goes to wastewater treatment plants but unfortunately the PFAS are not successfully removed during the conventional treatment of wastewater and they will be discharged onto water bodies though the effluent. Moreover, not only are PFAS not removed, but there are studies showing that their concentration actually increases throughout the wastewater treatment train, making wastewater treatment plants a major point source of PFAS to the environment.

This creates a circular problem, where once the PFAS have entered the environment, they are not removed and will accumulate over time. Subsequently, they can end up in the influent waters for drinking water treatment plants. There is evidence that certain PFAS can lead to adverse health problems in humans and animals, such as cell toxicity, growth inhibition, brain and nerves and even cancer.

As wastewater treatment plants are defined as the main source of PFAS pollution into the environment, it is only logical to start there. The general treatment scheme of a wastewater treatment plant includes primary, secondary and in some instances tertiary treatment. In order to understand the fate of different PFAS throughout wastewater treatment plants, our team has performed a statistical analysis on available research papers, analysing influent and effluent PFAS concentrations. Our findings show that from the many PFAS, only 2 main groups are predominantly measured – Perfluorocarboxylic acids and Perfluorosulfonic acids. Further analysis will determine if PFAS within the same group behave in a similar way and if the treatment train (secondary treatment vs secondary + tertiary treatment) has an impact on the total PFAS removal.

Additionally, a literature review on the fate of PFAS molecules during sludge treatment showed contradicting data, where some publications conclude that PFAS can be adsorbed, biotransformed and biodegraded, while other experiments showed unsuccessful results. Based on these results, the researchers will assess the possibility of remediating targeted PFAS compound with conventional aerobic (CAS) and aerobic granular sludge (AGS) in a laboratory setting using synthetic wastewater. The research questions aim 1) to understand mechanisms that these chemicals exhibit during sludge processes, 2) to understand the effect of PFAS on microbial communities, 3) to understand the role of precursors during sludge processes and 4) to assess the performance of CAS and AGS to remove PFAS and compare the data with existing studies. The final goal is to see if GAS can be implemented in wastewater treatment plants to mitigate further PFAS pollution to the environment.

Enhancement of Simultaneous Nitrogen and Phosphorus Removal Using Intermittent Aeration Mechanism

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Problem Statement

Mainly conventional biological nutrient removal (BNR) systems, encounter drawbacks regarding process performance, where the nitrogen removal takes place by pre-denitrification in the fill/anaerobic phase. Therefore, denitrifiers take-up the available readily biodegradable COD, resulting in lower substrate availability for phosphorus accumulating organisms (PAOs), increased microbial competition and higher operational cost. Therefore, stability and reliability of BNR may be problematic due to external disturbance of excessive nitrate loading to anaerobic phase. In addition, aeration as a crucial factor for nutrient removal and odor control, is accompanied with high equipment cost and energy consumption. Therefore, evaluating the stability and reliability of the system by experimenting on effective parameters such as aeration is of importance.

Objective

Intermittently aerating the system in aerobic phase, allows simultaneous nitrification, denitrification (SND) and P-removal with lower aeration rate requirement in a single reactor. Intermittent-aerated SBR reactor, decreases the readily biodegradable chemical oxygen demand (rbCOD) requirement and microorganism competition. In the aeration phase, in high DO levels, ammonium-nitrogen is oxidized to nitrate/nitrite by aerobic nitrifiers. In the following low DO stages, anoxic denitrifiers reduce nitrate/nitrite to N_2 gas. Therefore, minimum nitrogen removal takes place in fill/anaerobic phase, allowing PAOs to store the carbon source as PHA internally. Concurrently, in aeration period, PAOs (DPAOs) utilize the available DO/nitrate to take-up phosphorus from wastewater. However, to achieve the highest prosperity of intermittent aeration and minimum energy requirement, comprehensive investigation on nutrient conversions in sequential anaerobic/aerobic stages to develop a well-operated process is required.

Material and methods

In this study, three sequential batch reactors with constant operational conditions except aeration patterns at 6-hour cycle periods were tested. Synchronous SND and P-removal feasibility evaluation, nutrient profile performance, aerobic kinetics and bacterial structure were conducted. Potential drawbacks and improvement alternatives were inspected and clarified in case of aerobic/anoxic phases and possible occurred processes. In addition, nutrient removal was evaluated by the contribution of the key functional microbial groups through microbial analysis for identification of relative abundance on phylum, class and genus levels.

Results and discussion

Intermittent strategy with 50 minute on/off intervals, decreased PAOs aerobic decay rate, glycogen and Poly-P usage rate leading to long-term storage of EBPR sludge. In case of nitrogen removal, intermittent aeration reported to enhance SND, increase efficiency in organic carbon utilization for denitrification and improve denitrifiers abundance. Yet, as shown in **Table 1**, lower intermittent intervals ($EBPR_{INT-25}$), despite its intermittent aeration, projected a lower removal performance in case of nutrients in comparison to continuous-aerated reactor. At 25-minute on/off intervals, the effluent contained high concentrations of nutrients not reaching the emission

standards. Due to invaded anaerobic conditions and availability of electron acceptors in this stage, processes requiring oxygen, including carbonaceous oxidation, nitrification and P-uptake, occurred. This led to inefficient anaerobic performance of PAOs. Due to high DO concentration, the remaining NO_2-N and NO_3-N from the preceding cycle were not removed by means of denitrification, resulting in an accumulation of nitrate/nitrate in the system.

Conclusion

- Nutrient removal strongly depended on reaction phase configuration representing the importance of aeration pattern.
- For reaching a high N-removal, balancing the aerobic and anoxic duration for complete SND is suggested.
- The primary factors affecting the P-removal performance were known to be insufficient reaction time, variation in DO concentration and carbon source.

	EBPR$_{CONT.}$		**EBPR$_{INT-50}$**		**EBPR$_{INT-25}$**	
	Effluent concentration	Removal efficiency	Effluent concentration	Removal efficiency	Effluent concentration	Removal efficiency
pH	7.51	-	8.27	-	7.86	-
COD (mg/L)	45±10.7	84%±3%	31.2±4.3	91%±1%	33.7±3.3	90%±1%
TN (mg/L)	8.1±0.5	71%±3%	5.4±0.6	81%±4%	14.01±0.3	50%±2%
Orthophosphate (mg/L)	2.55±0.5	83%±3%	1.35±0.3	91%±3%	5.55±1.2	63%±8%
NH_4^+-N (mg/L)	2.1±0.7	93%±2%	1.8±0.5	93%±1%	2.32±0.4	92%±3%
VSS (mg/L)	45±2	-	40±4	-	51±3	-

Session (3)

Wastewater II: Industrial + Small Scale

Impact of Vacuum Application During Fermentation of Primary Sludge

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Central Message

Negative pressure conditions during anaerobic fermentation of primary sludge will enhance solubilisation, promote in situ extraction of volatile fatty acids, and improve the biochemical methane potential of the fermented sludge.

Keywords: Solubilization, Volatile Fatty Acids Extraction, Solid-Liquid Separation

Materials and Methods

Sludge collected from primary clarifier in Ashbridges Bay wastewater treatment facility, a local treatment facility in Toronto, ON, was used as the substrate in this study. The sludge was collected weekly and fully characterised prior to each experimental run. The inoculum for the biochemical methane potential test was the sludge effluent from a continuously mixed digester from the same facility operating with a 20-day retention time (City of Toronto, 2016).

The fermentation equipment setup consisted of a 5L jacketed glass reactor, vacuum pump, hot water circulating unit, distillation column and refrigeration unit. The integration of vacuum conditions to thermophilic fermentation in this study was implemented in two ways; a) vacuum was applied continuously to fresh sludge at varying pressures between 240 mbar and 800 mbar, for a maximum of 72 hours or until thickening of sludge would prevent sampling of the fermentate, and b) vacuum was applied 2 hours daily for 49 days at 250 mbar to fermenting sludge. Samples of the feed, condensate and fermentate were collected with time and analysed for solids content according to APHA methods, COD and VFA concentrations according to HACH methods (APHA, 1998).

Results and Discussion

Applying different vacuum strengths to sludge during thermophilic fermentation caused the sludge to lose moisture to the condensate at different rates which resulted in the tests being terminated at different times. As shown in Figure 1, more moisture was lost over the course of the fermentation period at lower/stronger vacuum pressure. Within 30 hours of operation, the volume of the sludge was reduced by 84% when 240 mbar vacuum was applied. This implies that there is a potential for solid-liquid separation with this technology that will reduce the reactor sizes of following treatment processes and eliminate or reduce the requirement for chemical thickening.

Solubilization of organic matter was enhanced by vacuum application. This was calculated the change in soluble COD mass divided by the initial mass of particulate COD. The change in sCOD mass was determined by adding the mass of sCOD in the fermentate broth to the mass of COD contained in the condensate collected. The 800-mbar trial showed similar results to the control in which no vacuum was applied as after 72 hours 15% and 12% solubilization respectively was observed. Contrarily, the highest solubilization occurred after 48 hours of 400 mbar vacuum application. The solubilization trend for the 300-mbar application fell below the 600-mbar trend but remained above the 240-mbar trial. Enhanced solubilization could be due to the mechanical effect of negative pressure on organic matter that is present in the sludge. This would promote bio-accessibility and could improve fermentation.

Figure 1: Sludge volume reduction at various pressures.

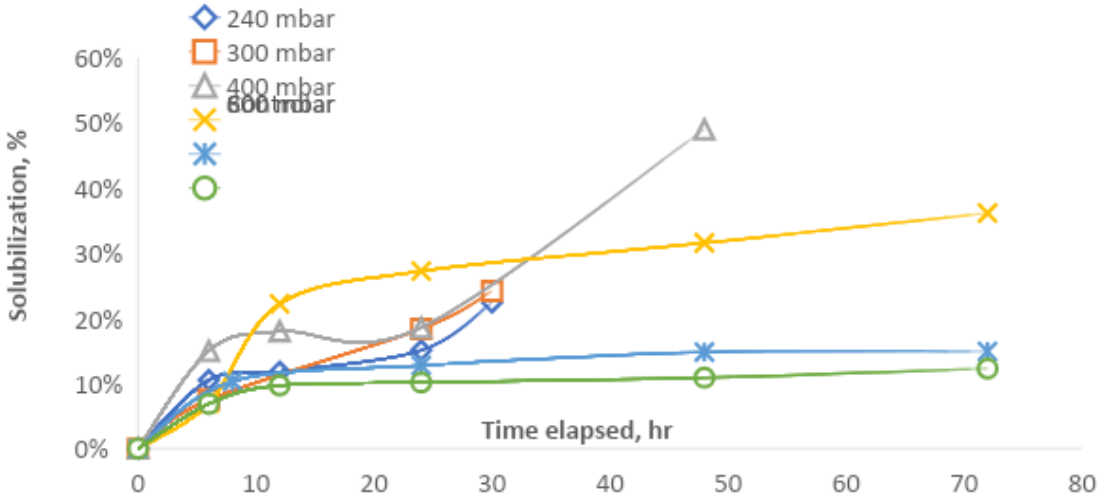

Figure 2: Solubilization trend of sludge for different vacuum levels

The mass of VFA collected in the condensate was calculated in each trial and normalized using the initial TCOD in the sludge prior to commencement of fermentation. The maximum VFA extraction in the condensate was 1% of the total COD in the sludge at the beginning of the experiment when 300 mbar was used for the vacuum. The VFA concentrations collected in the condensate ranged from 51 to 860 mg /L as Acetic acid. These seemed to increase with vacuum strength rather than concentration of VFA in the fermentate, however the maximum concentration was captured when 300 mbar of vacuum was applied. Ammonia concentrations did not rise above 1 mg N/L.

In the second mode of vacuum application to primary sludge, the methane potential of the effluent from the process was evaluated. After 49 days of running a discontinuous fermentation process with sludge in and condensate out. the solids content increased from 3% to 17%. The effluent fermentate and the feed PS were used as substrates for a biochemical methane potential (BMP) test using a food to microorganism ratio of 0.5 g COD of substrate per g VS of inoculum at mesophilic conditions.

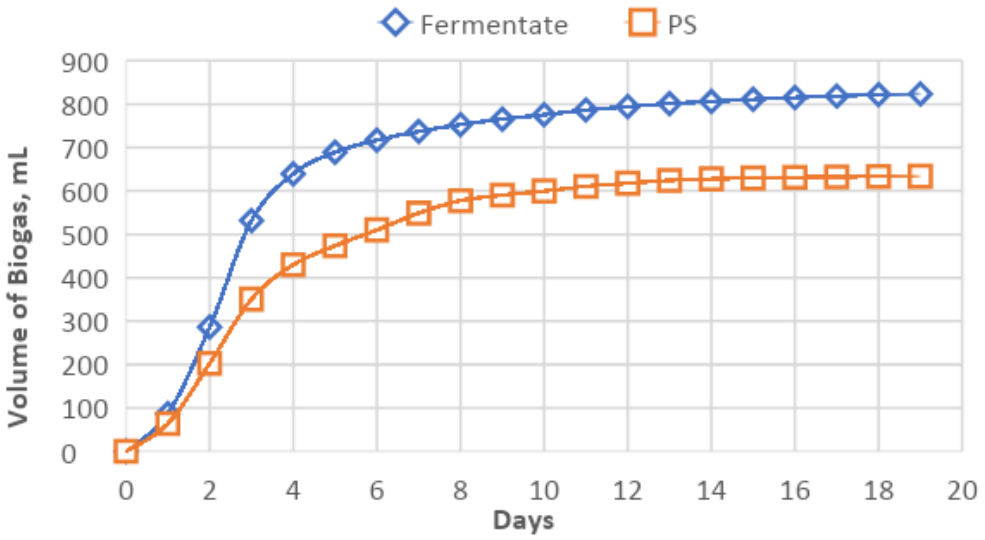

Figure 3: Cumulative biogas production of fermentate and primary sludge

It is expected that the fermentate will have higher biogas production rate than fresh PS initially, however the vacuum treated fermentate also produces 30% more biogas than the fresh PS cumulatively. This confirms that that some organic matter has been made available during the vacuum process that were not available to microorganisms.

Contributions of the work

The study has shown that in situ recovery of VFA remains challenging. However, vacuum application during fermentation makes organic matter available for further biological treatment. While, it is clear that an optimization of vacuum strength and application length is required for economic feasibility, the vacuum technology offers significant thickening potential which combined with other benefits such as the observed increase in methane potential can enhance its attractiveness for use in a wastewater treatment plant.

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Assessment of the Industrial Wastewater Treatment Efficiency Using a Battery of in Vitro Bioassays

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Abstract

Today, oil sands process-affected water (OSPW) is stored in tailing ponds, but efforts are in motion to discharge treated OSPW into regional water bodies. OSPW is a complex mixture that consists of metals, naphthenic acids, and aromatic hydrocarbons, which are associated with acute and sub-chronic toxicity to exposed organisms. Hence prior to its discharge, treated OSPW must be evaluated for its potential to cause ecotoxicological effects in the receiving aquatic environment. A battery of *in vitro* bioassays is an environmental monitoring tool that is gaining traction in water quality assessment due to the potential to detect cell toxicity pathways related to organic chemical pollution (Escher & Leusch, 2012). In this study, we selected a battery of cell-based bioassays to explore the potential impacts of treated OSPW discharge to the following cell toxicity pathways: (1) non-specific toxicity (e.g cytotoxicity), (2) specific toxicity (e.g. immunotoxicity, activation of xenobiotic metabolism endpoints (peroxisome proliferator-activated receptor-gamma and aryl hydrocarbon receptor) and activation of endocrine estrogen receptor), and (3) reactive toxicity (e.g. genotoxicity, mutagenicity and oxidative stress). Current research on method development is underway, including development of sample preparation and extraction methods for the *in vitro* bioassay analysis of the organic fractions of both aqueous and combined aqueous and sorbed phases of water samples. The bioassays will be used to analyze treated and untreated OSPW and compare the toxicity pathways to that of municipal wastewater and suspected OSPW seepage. It is hypothesized that the cell-toxicity pathway signatures stemming from both pollution sources are unique and may be used for future watershed monitoring activities.

Keywords: OSPW cytotoxicity genotoxicity

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Purification of Mine-Impacted Water By Freezing: Laboratory Data Analysis and Mathematical Modeling

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Central message

Current research focuses on the development and optimization of water treatment freezing technology. This innovation holds advantages in northern climates such as Yukon, Canada, since the cold temperatures can be exploited.

Keywords: Cryopurification, Water treatment, Northern climates.

Materials and Methods

Three main interconnected strands make up the current research – the laboratory testing of purification through freezing (cryopurification) of mine-impacted water (Faro Mine, Yukon, Canada), quantitative analysis of laboratory datasets and mathematical modeling of freeze processes (Figure 1). Laboratory experiments were conducted to determine the limits and effectiveness of single-stage freezing and investigate the effect of partial melting on the removal of impurities (zinc and sulphate). The obtained datasets were then quantitatively analyzed using the initial statistical data analysis techniques, statistical methods, and mass balance principles. The datasets were initially assessed to identify inconsistencies in the data and resolve any such issues. This step ensured the later regression methods applied (correlation and multiple regression analyses) can be efficiently used and minimized the risk of incorrect or misleading results. The efficiency of impurities removal by freezing was portrayed and evaluated based on the partition coefficient, K representing the solute concentration ratio in the ice and liquid phases. The coefficient varies between 0 and 1; the lower the K value, the more effective is the cryopurification (Miyawaki & Inakuma, 2021). The quantitative analysis of laboratory datasets was performed using Minitab 17.1.0 and IBM SPSS statistical software packages. Numerical experiments to investigate the effect of initial and boundary conditions on the ice formation process and the process of impurities freeze separation from aqueous solution were performed with computational fluid dynamics software, ANSYS Fluent 2020 R2. The enthalpy-porosity technique was used to model the solidification process. Three major modules were enabled in the simulation – energy (heat transfer), species transport and solidification-melting.

Results and Discussion

The approach combining laboratory testing together with data analysis and mathematical modeling allows to quantitatively describe the variables and simulate physical processes of interest (Figure 1). Using linear regression analysis methods, the empirical models to relate the concentrations of zinc and sulphate as a function of conductivity were developed. The models were used to fulfil the missed values of zinc and sulphate concentrations in the laboratory datasets for each liquid fraction (LF) and melt fraction (MF). The analysis of datasets that include the results of freezing experiments conducted to various ice fraction (IF) and LF proportions among other results revealed that zinc and sulphate concentrations in LF were nonlinear functions of the IF percentage. The concentrations of both zinc and sulphate increased exponentially at 65–75%

ice fractions and higher of the initial testing water mass. The purity of melts to various initial IFs was examined and showed that zinc concentrations decreased with each subsequent melt fraction, indicating an increase in MF purity. Based on these results, the semi-empirical models to quantify zinc and sulphate removal as a function of melt water mass at various IFs were developed. The partition coefficient values were calculated using mass balance principles to evaluate the effectiveness of freeze separation of zinc and sulphate from mine-impacted water. The calculated values of K were equal to 0.353 and 0.382 for zinc and sulphate, respectively.

The outcomes were applied to define the modeling system components, the governing equations describing interactions in the system under consideration and run numerical computational experiments. The influence of initial and boundary conditions corresponding to various ice shapes (produced using laboratory vessels) on the ice formation and the removal of impurities from aqueous solution was numerically investigated.

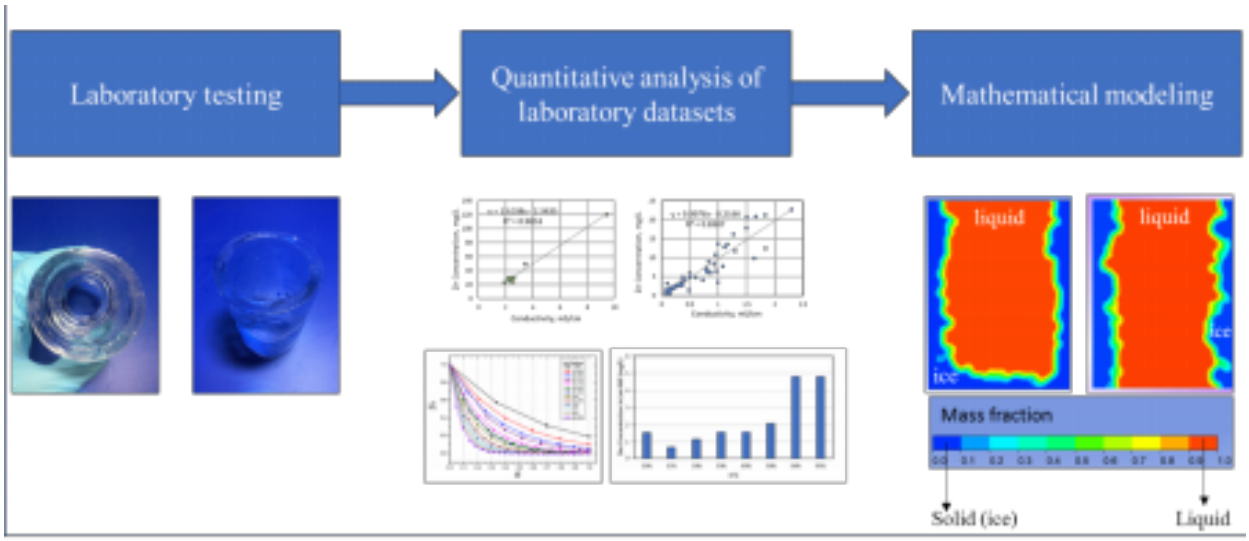

Figure 1: Graphical abstract

Contributions of the work

Cryopurification is a promising, environmentally friendly and energy-efficient water treatment concept (John et al., 2019). Utilizing northern climates' cold temperature conditions, the application of freezing technology could be a viable water treatment solution capable of effectively removing impurities, including toxic heavy metals from water and wastewater. However, to the best of our knowledge, a comprehensive investigation of zinc removal from mine-impacted water using freezing technology has not been reported in the literature. The current research emphasizes the application of cryopurification under the conditions of northern climates to mine-impacted water treatment, decreasing zinc and sulphate concentration under the effluent quality standards. One of the main contributions of current research is the mathematical model that considers the results of laboratory work and describes the processes of ice formation and impurities rejection from the ice to the more concentrated LF. The model allows a user to consider the most important features of the processes under investigation and compute the characteristics describing impurities removal through ice formation. The current research phase results revealed the potential of freezing technology as an approach to effectively remove impurities from mine-impacted water. The future steps within the research project are planned as follows: (i) to continue gathering laboratory data reflecting the impact of various parameters on ice formation and zinc removal using the laboratory setup, (ii) to fulfill a quantitative analysis of new laboratory data, and (iii) to continue the detailed verification of the mathematical model. The findings and knowledge gained from the research project will assist Core Geoscience Services Inc. in advancing freezing technology towards commercialization.

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Salt Recovery from Phragmites Australis, a Phytoremediation Species, After Washing by Electrodialysis

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Abstract

Cement kiln dust (CKD) is a by-product generated during the cement production process that, if landfilled, can result in a significant increase in soil salinity. Soil salinity is a contributor to water salinization, which causes toxicity and nutrient imbalances in plants, imposing a threat to the aquatic environment. Phytoremediation is a biological remediation technique where plants uptake contaminants from soil and store them in their structure. *Phragmites australis* (common reed) was used as a phytoremediation species to remove 65 kg/km2 of chloride from CKD per growing season. Previous work focused on cyclical washing processes to reduce the salt content of the biomass to less than 1 w.t%, from 4%. In this study, washing processes with less particle size reduction are investigated as well as value-added water recovery methods. This research focuses on more industrially relevant washing designs, such as trickle beds and screw feeders. Electrodialysis provides a salt recovery alternative where the wash water is recycled while producing two products. The treatment technique can reduce salinity by 70-80%. The selective recovery of potassium and sodium can also be achieved by choosing the appropriate voltage based on the reduction potential of the elements. This technique would result in the recovery of KOH and HCl. The treated water can also be reused in the washing step. While inherently more expensive than reverse osmosis filtration, electrodialysis would produce higher-value products and offset production from virgin materials elsewhere, leading to enhanced water recovery and circular economy.

Keywords: Phragmites Australis, Phytoremediation, Salt Recovery

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Effect of Temperature and Ore Sample Analysis on Gold Recovery from Refractory Gold Ores by Using Optimized Biooxidation Process in Water-Based Environment

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Abstract

Canada ranks in the top five producing countries for major minerals such as gold. In mining industry, gold is finely disseminated in a sulphide mineral matrix (pyrite and arsenopyrite) which is not recovered with conventional processes such as cyanidation, pyrometallurgy, roasting, pressure oxidation. Harnessing the abilities of some species of prokaryotic microorganisms is profitable to catalyze the oxidative dissolution of sulfide minerals and facilitate the extraction of metals. Here, the microorganisms were collected and inoculated from Acid Mine Drainage of Canada Northern mine site and sequencing analysis was performed to characterize the microorganisms in strain. The ore sample was also prepared from the same mine. Biooxidation of ore sample were performed in three different temperatures (35, 45, and 65℃) with different media (9K and 0.9K). In this research, ORP, pH, bacteria count and concentration of Ferrous, Ferric, sulfite, and sulfate were measured to observe the activity of microorganisms during biooxidation of ore sample. The results indicated that biooxidation occurred in three different temperatures and media indicating the presence of all types of mesophilic, moderate thermophilic and extreme thermophilic acidophil bacteria. Also, this results showed that the amount of pyrite (surrounding the gold particle in ore sample) was destructed efficiently (higher than 90%) by using the biological oxidation of all types of microorganisms in different temperatures and media. During the biooxidation process the value of ORP raised from 350-450 mV to higher than 600 mV for mesophilic bacteria and the pH of solution decreased from 1.9 to below 1. The results also indicated that with the increase of bacteria activity and growth the concentration of ferric ions increased significantly. The results also indicated that the activity of microorganisms were significantly dependent to the pH of solution in which for the values higher than 2 the biooxidation was slowed down and the formation of jarosites were triggered in the water-based environment. Finally, a mathematical model was proposed by using GMDH-based Neural Network to predict the experimental data of biooxidation at different temperature with maximum 10% deviation.

Keywords: Gold recovery, Refractory ore, biooxidation, Correlation, GMDH-based Neural Network

Carbon Nanotube Blended Multifunctional Nanofibrous Membrane via Electrospinning Process for Membrane Bioreactors

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Abstract

In this study, nanofibrous polyvinylidene fluoride (PVDF) membranes incorporated with Carbon Nanotube (CNT) have been prepared via electrospinning process. Then the nanofibrous membrane is integrated with the PVDF open cell foam to produce a multifunctional membrane platform using supercritical carbon dioxide ($ScCO_2$) as high flux and antifouling membranes for membrane bioreactor applications. The effect of CNT and the open cell foam on the membrane morphology, surface hydrophilicity, pure water flux, synthetic wastewater flux and antifouling properties were investigated.

The SEM images showed the macroporous open cell foam for the growth of biofilm to improve the organic removal efficiency of the membranes. Smooth fiber surface at low amount of nanoparticles and the beads or agglomeration of nanoparticles at higher concentration are observed on the SEM images of the nanofibrous membrane. The pure water flux and the synthetic wastewater flux increased with higher CNT loadings and 1.5wt% CNT loadings shows the highest water flux. Membrane hydrophilicity is an important factor on water flux. Experimental results in Figure (ii) indicate that the water contact angle decreased as the CNT loadings increased, which promoted the hydrophilicity of the membrane. Antifouling properties were measured by the filtration of activated sludge. The flux recovery ratio after 10 days of activated sludge filtration showed that the fouling recovery ratio of the samples improved upto 60% after adding CNT in the spinning solution. The activated sludge filtration test was conducted for 10 days and the membranes were again used for the filtration for 10days after cleaning to evaluate the reusability of the membranes in the membrane bioreactor. Figure 1(i) is showing the activated sludge flux of the membranes 10days in 2 cycles. The results showed that 90% of rejection ratio and sCOD removal efficiency of 90% of the membranes.

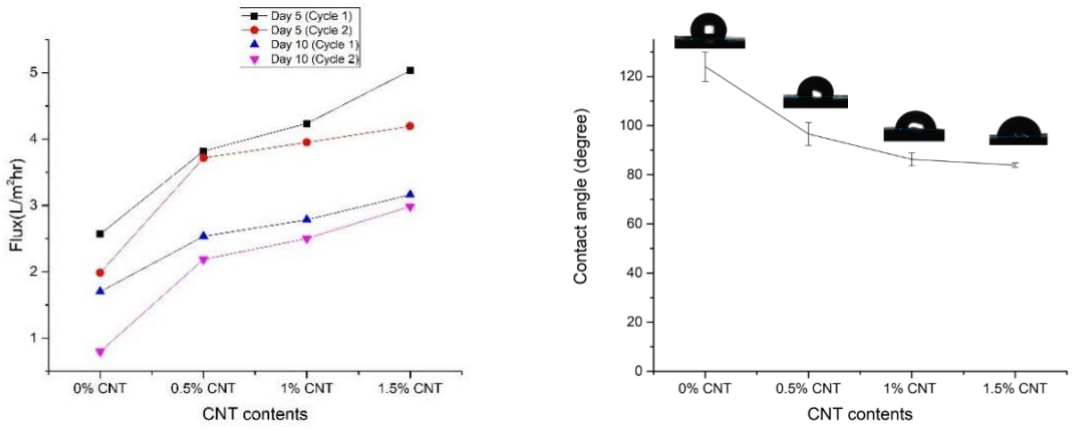

Figure 1: Effect of CNT on (i) activated sludge flux (ii) contact angle.

Session (4)

Resource Recovery

Nutrient Recovery from Wastewater: A Review on the Integrated Technologies of Ammonia Stripping, Adsorption and Struvite Precipitation

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Abstract

The field of wastewater management has seen a transition from "contaminant removal" in wastewater treatment plants (WWTPs) to "nutrient recovery" in so-called water resource recovery facilities (WRRFs) for years. For achieving a higher efficiency and economic benefits, the integration of multiple nutrient recovery technologies (NRTs) is of increased interest. This study provides a comprehensive overview of the integration of ammonia stripping, adsorption and struvite precipitation, three of the most dominant physicochemical NRTs. In their different combinations, a critical comparison of the available research is given from the perspective of process technical description, the current scale of application and potential challenges ahead. The combination of ammonia stripping and struvite precipitation has been applied at full scale, but the end-product collection should be further optimized. Several adsorbents have shown their ability to boost the collection of struvite. However, the adsorption of harmful elements, such as heavy metals and pharmaceuticals, might devalue its end product. Some researchers applied ammonia stripping for the regeneration of adsorbent at pilot scale, but its economic benefit is yet to be proven. The integration of all these three NRTs is a promising perspective in the field of nutrient recovery from wastewater.

Keywords: Macronutrient recovery, Wastewater valorisation, low-releasing fertilizer

Beyond Techno-Economic Feasibility: Life Cycle Assessment of upflow anaerobic sludge blanket (UASB) reactor treating dairy wastewater

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Abstract

Wastewater generated from dairy industries is characterized with high organic matter in the range of 5 g/L COD to 40 g/L COD. Anaerobic digestion process can effectively reduce the organic matter and simultaneously convert it to biogas. Upflow anaerobic sludge blanket (UASB) reactor offers a suitable anaerobic wastewater treatment option for high strength wastewater treatment. While the technical feasibility of UASB reactor is well established in treating industrial wastewater, the environmental sustainability of the treatment system should also be explored. Life cycle assessment (LCA) is an effective tool to estimate the quantitative and overall information on resource consumption and environmental emission associated with a system. A gate to gate LCA was carried out for a UASB reactor treating dairy wastewater using *SimaPro® 9* software. The reinforcement steel and the mild steel plate used for construction of UASB reactor were found to be the major contributors to the potential impacts on the climate change, marine and terrestrial environment, natural resources and human health. However, the replacement of mild steel plates with high density polyethylene can significantly reduce the adverse impacts on human health and climate change.

Keywords: Life cycle assessment; anaerobic digestion, dairy, upflow anaerobic sludge blanket reactor, *SimaPro® 9*

Synergistic Effects of Coupling Ultrasonication to Zero-Valent Iron on Volatile Fatty Acids and Biogas Production

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Abstract

Anaerobic digestion (AD) is considered an essential treatment technology in modern wastewater treatment plants because of its promising performance in converting waste to biogas and fertilizer. It became a greenhouse gas mitigation measure. However, AD is still facing low energy recovery efficiencies which makes of it an aggressive research focus.

In this study, we will present the effects of coupling sonication with nanoscale additive on volatile fatty acids and biogas production from thickened waste activated sludge. Zero-valent iron mainly enhances the methanogenesis phase in AD while ultrasonic pretreatment improves the solubilization of the substrate and hence improves the rate limiting phase that is the hydrolysis, thus, coupling ultrasonication to ZVI improved the hydrolysis of sludge and stimulates increased the biogas production significantly compared to applying them individually as a result of the synergistic effect.

Different ZVI dosages as well as different specific energy inputs by ultrasound both individually and in combination were investigated. On the other hand, the theory behind the synergistic effect of coupling ultrasonication with zero valent iron as additives will be proposed in this presentation.

Keywords: Additive, Ultrasonication, Thickened waste activated sludge (TWAS)

Development of a Generalized Decision-Support Tool for Anaerobic Digestion of Sewage Sludge and Food Residues Using Lab Scale Tests

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Abstract

Anaerobic digestion is a natural process that has been applied for energy production, sludge stabilization and resource recovery at municipal, industrial or farm scale. Even though the technique of biomass degradation is becoming widespread, the techno-economic efficiency can be further improved. In particular, a well-studied start-up of a biogas plant can remarkably increase the economic and environmental value of the entire project. The availability of decision support tools for end-users would be very useful in that regard. The aim of the present work is to generate a decision guideline for the start-up phase of anaerobic digesters based on: critical parameters identified in the literature, experimental results of start-up tests and the application of machine learning techniques. These results will be combined with real logistic and economic data of the Quebec City municipal full-scale biogas plant (currently under construction) in order to develop an optimized start-up protocol. The final tool will consist of a decision guideline specifying important aspects to plan during the start-up of full-scale digesters. The inoculum used to seed a digester is the first important parameter to investigate during the preparation of a start-up protocol. Using a standard substrate with a known methane production potential for that purpose, is found to be an important step toinclude in the preparations of a full-scale digesting systems. Further investigations should concern temperature, mixing scheme, feed and duration of the start-up.

Keywords: Full-scale digesters, Decision support tool, Start-up protocol

Influence of the Applied Voltage and Temperature on the Performance of Bioelectrochemical Anaerobic Digestion of Blackwater

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Central message

The applied voltage is critical for bioelectrochemical anaerobic digestion, whereas it has not been well studied for blackwater. This study investigated how it can influence the system performance at both ambient and mesophilic temperatures.

Keywords: Anaerobic blackwater digestion, Microbial electrolysis cell, Applied voltage

Materials and Methods

Two identical single-chamber microbial electrolysis cell assisted anaerobic digesters (MEC-AD reactors) were fabricated with plexiglass, each with a working volume of 420 mL. Two pairs of stainless-steel frames attached with high-density carbon fibers (2293-A, 24A Carbon Fiber, Fibre Glast Development Corp., Ohio, USA) were used as anode and cathode. An Ag/AgCl reference electrode (MF-2052, Bioanalytical System Inc., Indiana, USA) was inserted into each reactor close to the anode electrode. One DC power supply was connected to each reactor to provide the external voltage. Current in the circuit was recorded by a data acquisition system (Keithley, model 2700/7700, Keithley Instruments Inc., Ohio, USA).

Initially, the reactors were inoculated with anaerobic sludge and the effluent from a lab-scale MEC reactor. After enrichment, the reactors were operated with vacuum toilet blackwater at an organic loading rate (OLR) of 3.0 g COD/L-d. The reactors were operated at 20°C (R1) and 3 °C (R2), respectively. The applied voltages stepwise increased as follows: 0 V (Stage 1), 0.4 V (Stage 2), 0.8 V (Stage 3), 1.2 V (Stage 4), and 1.6 V (Stage 5).

Methane yield was calculated as the ratio of chemical oxygen demand (COD) equivalent of produced methane to total COD input:

$$\text{Methane yield (\%)} = \text{COD}_{\text{methane}} / \text{COD}_{\text{input}} \times 100\%$$

Energy efficiency was calculated based on the net energy income as methane under closed-circuit conditions (electric energy consumption, W_E, was subtracted from total methane energy W_{CH4}) and energy income under the open-circuit condition (W_0 in Stage 1):

$$\text{Change in energy efficiency} = (W_{CH4} - W_E) / W_0 \times 100\%$$

Results and Discussion

The reactors achieved steady-state from Stage 1 to 4. However, when the applied voltage increased to 1.6 V, serious corrosion was observed on the stainless-steel electrode frame, resulting in a system failure with a significant pH increase to about 9.35. Stainless steel electrode corrosion was also observed in some other studies (Peixoto et al., 2019; Song et al., 2011), and the corrosion progress can be faster when applying higher voltages.

Figure 1 shows the methane yield and COD removal efficiency at different stages based on steady-state results. The methane yields of 26.7% and 53.9% were observed without applied voltage in R1 and R2, respectively. For R1, it showed no difference when increasing applied voltage from 0 to 0.4 V. However, a significant increase in methane yield ($p < 0.05$) was observed when applying 0.8 V (31.0%) and 1.2 V (34.8%), as well as a significant increase ($p < 0.05$) in COD removal

from 47% at 0 V to 57.8% at 1.2V, indicating a successful enhancement. For R2, however, no obvious difference in methane yield and COD removal was observed in all stages, probably because the biochemical methane potential (BMP) limit has been reached. Thus, it suggested that the application of bioelectrochemical technology could not further increase the BMP of the blackwater at 37 ℃.

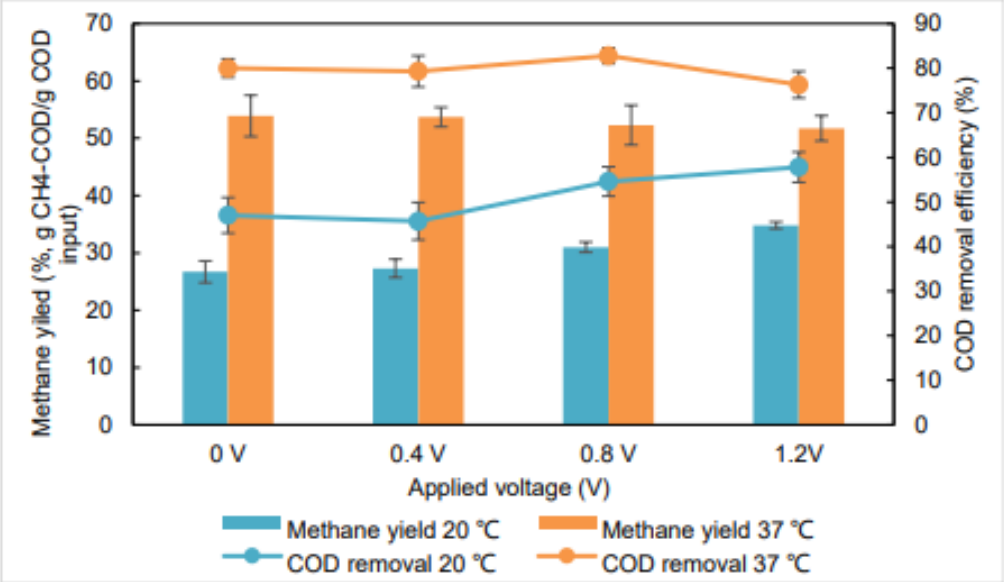

Figure 1. Methane yield and COD removal efficiency of different stages.

Energy efficiency is a critical parameter to consider for system optimization. As shown in Table 1, for R1, the electric energy consumption was completely recovered as biomethane with a significant energy efficiency increase, ranging from 2.2% to 27.3%. However, decreased energy efficiencies were observed in R2. Besides, the heating energy consumed by R2 was also considerable, making MEC-AD reactor operation at 37 ℃ and 3.0 g COD/L-d a less favorable option when considering the energy aspects despite better performance compared to 20 ℃.

Table 1. Energy efficiencies of the MEC-AD reactors at different applied voltages.

		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Applied voltage (V)		0	0.4	0.8	1.2	1.6
Energy Efficiency (%)	20 ℃	100%	102.2%	115.4%	127.3%	-
	37 ℃	100%	99.5%	94.9%	91.9%	-

Contributions of the work

Blackwater contains a high level of organics and nutrients, which is ideal for bioenergy recovery but hard to be treated due to the complex composition. In recent years, bioelectrochemical anaerobic digestion has been demonstrated as an enhanced process for biomethane recovery from various wastes. However, blackwater digestion in MEC-AD systems has barely been studied. Particularly, there is no study that investigated the optimum applied voltage for bioelectrochemical blackwater digestion. In this study, different applied voltages were tested for both ambient and mesophilic temperatures. The results showed applying 1.2 V was optimum at 20 ℃ with the highest methane yield, COD removal, and energy efficiency. No obvious performance improvement was found at 37 ℃, with the decline of energy efficiencies. However, OLR can be increased at 37 ℃ in future studies to challenge the reactor capacity. The results of

this research can guide reactor optimization and engineering practice in the future. Electrode corrosion at 1.6 V was out of our expectation. Inert-coated electrode or other types of electrodes can be used to prevent corrosion in future studies.

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Ultrasonic Pretreatment Effect on Methane and Volatile Fatty Acids Production from Municipal Sludge

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Abstract

The wastewater comprises various industrial and residential effluents carrying biosolids, nutrients, grits, metals, and slurry water. At the same time, as much as 1.3 billion tons of food is wasted annually throughout the globe. Despite the untreated wastewater released to rivers or lakes, unprocessed organic solid waste also acts as environmental pollution, impacting aquatic life and human livelihood. Handling and disposal of these municipal biowaste (sludge) is a big challenge in wastewater treatment management, especially with the highest expense involved in sludge treatment processes throughout the overall treatment process. Pretreatment of the sludge prior to feeding it to the digester aims to improve the process performance. The breakdown of the substrate particles provides more surface area to the bacteria for their biological enzymatic reaction and thus enhance the efficiency of the process and production of biogas.

The main objective of this study was to evaluate the effect of the ultrasound pretreatment of the thickened waste activated sludge (TWAS) on the fermentation and anaerobic digestion processes. In this study, different specific energies (SE) were applied to the TWAS prior to the fermentation and the digestion processes. The results of this study showed that ultrasound pretreatment the highest solubilization of 28% was achieved at SE of 20,000 kJ/kg TS which was corresponding to VSS reduction by 26%. The highest volatile fatty acids concentration after the fermentation process of 2830 mg COD/L was achieved at SE of 3000 kJ/kg TS compared to 14326 mg COD/L for the raw sample. The highest methane yield of 344 mL/g VSS was achieved at SE of 5,000 kJ/kg TS compared to 261 for the raw sample which was corresponding to 32% increase.

Session (5)

Sustainability, Leadership, and Management

Using Data from Community-based Water Monitoring in Nova Scotia

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Abstract

Community-based water monitoring, or CBWM, is an increasingly popular model of data collection in Nova Scotia and elsewhere. In this model, community members are out on the water collecting samples used to better understand water quality. The CBWM model has many advantages: community members are often experts on local water bodies, the sampling process is an opportunity for public education and outreach, communities can identify the sampling parameters most useful to them, and high quality data collection can be less expensive than government-derived data.

Given the promise and rising prominence of CBWM, groups are often approached by governments seeking data for decision making about, for example, whether a body of water is safe for swimming, changes to zoning bylaws, and so on. However, the relationship between the data that is collected and how it is used by various levels of government is unclear.

This report draws on extensive interviews and meetings with CBWM groups and policy makers in Nova Scotia to answer the question, "what happens to CBWM data after it has been collected?". The findings suggest ways to better align data use with data collection, and present a decision-making framework useful for both policy makers and CBWM groups.

We conclude with recommendations for future research on the legal potential and limitations of CBWM data, and a more thoughtful relationship between Western and Indigenous knowledge with respect to water.

Keywords: Citizen science, Decision making, Water data

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Le choix des sites d'implantation des infrastructures vertes de gestion des eaux pluviales: un processus multicritère et multidisciplinaire
Développement d'un outil d'analyse spatiale multicritère pour l'aide à la décision sur les sites d'implantation d'infrastructures vertes de gestion des eaux pluviales: Cas de Trois Rivières, Québec

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Abstrait

L'intégration d'infrastructures vertes (IV) de gestion des eaux pluviales est de plus en plus préconisée dans l'aménagement du territoire urbain face aux pressions climatiques et anthropiques croissantes. La planification des IV doit considérer le contexte biophysique, social et urbain pour maximiser les bénéfices socio-environnementaux offerts aux communautés. L'utilisation d'outils basés sur l'analyse de décision multicritère et les systèmes d'information géographique a le potentiel de minimiser les implantations opportunistes et aléatoires tout en favorisant une approche interdisciplinaire et interactive. L'outil d'analyse spatiale multicritère SSANTO (Spatial Suitability ANalysis TOol, Kuller et al., 2019), développé et testé à Melbourne en Australie, a été adapté à une première municipalité québécoise, la ville de Trois-Rivières, afin de mieux soutenir le processus décisionnel sur l'implantation des IV. SSANTO cartographie le potentiel d'implantation des IV sur un territoire selon une variété de critères et les préférences des décideurs. En consultation avec les parties prenantes concernées de la municipalité, telles que des représentants des citoyens, urbanistes, architectes de paysage et membres de la municipalité du domaine de l'eau, de l'environnement, de la santé et des routes, cette mise à l'épreuve de l'outil visait l'adaptation des critères existants et l'intégration de nouveaux critères afin de refléter le contexte et les priorités locales et faciliter l'utilisation de cet outil par d'autres municipalités québécoises dans le futur. L'obtention de la pondération des critères de l'outil SSANTO par les parties prenantes de la municipalité a permis d'étudier l'influence des préférences des intervenants sur les résultats de l'outil pour la planification des IV sur un territoire, ainsi que la détermination de sous-ensembles de critères permettant d'obtenir une adéquation spatiale représentative des résultats issus d'un ensemble de critères complet. Cet outil a le potentiel d'aider une meilleure planification des IV afin de maximiser leurs bénéfices dans une démarche d'augmentation de la résilience des villes québécoises.

Mots-clés: Planification urbaine, Pratiques de gestion optimale, Gestion des eaux urbaines

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How to Test Water Quality and Influence People: Celebrating Successful Community-Based Monitoring Initiatives in Maritime Canada

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Abstract

The Maritime provinces are home to a vast number of water bodies throughout many watersheds and sub-watersheds. These freshwater lakes, rivers, wetlands, and estuaries play key roles in the variety of ecosystems, cultural norms, and economic activity across PEI, New Brunswick, and Nova Scotia. Due to the quantity and often remote nature of the water bodies, they do not always fall within Provincial water quality monitoring programs. To address this, local citizens have formed organizations and initiatives create volunteer-driven "Community Based Monitoring" (CBM) programs.

A qualitative study was undertaken in 2019 by the Atlantic Water Network (AWN) to identify common attributes or factors among prominent CBM initiatives. Through a series of interviews, the study found reoccurring themes referenced or attributed to program success. The themes most referenced were: a specific issue within the watershed, broad stakeholder inclusion in the program, guidance from a respected institutional partner, involvement from scientific professionals, consistency and clarity in the program, support from the local community, and organizational, and program longevity.

While these themes were prevalent, not every group interviewed had mastered all six within their monitoring program. This leads to the conclusion that each theme is one part of a more complex situational narrative for different organizations and initiatives. However, the commonality of the themes in so many of the cases does indicate a promising finding. Other CBM programs can use the identified themes as a guide to develop or strengthen to their own program to better affect change in local water policy.

Keywords: Citizen science, Water quality, Stakeholder inclusion

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Developing a Watershed Health Monitoring Framework for the City of Calgary

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Abstract

The City of Calgary (CoC) currently monitors watershed health through the use of one indicator: percent of impervious cover. CoC contracted the Southern Alberta Institute of Technology (SAIT) to examine if there is an improved way to represent its watershed health. SAIT conducted a review of both peer-reviewed literature and grey literature from other urban jurisdictions to examine why and how watershed health monitoring approaches are produced and how they have been implemented. The results were then presented and discussed at a workshop of approximately 60 water management experts from other jurisdictions across North America and sectors such as government, academia, and non for profit. The findings from both the literature review and the workshop were compiled to develop a set of steps for a watershed health monitoring framework. These steps are proposed for the CoC to move forward in updating its watershed health monitoring, and it is likely they can also be adopted by other urban jurisdictions looking to review their own approaches.

Keywords: ***U***rban; Watershed health; Monitoring

Session (5)

Water, Health, and Technology

Secondary Treatment of Landfill Leachate by Vertical Treatment Wetlands

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Abstract

In Québec, the most common method for the management of municipal solid waste is its disposal in technical burial sites. One major environmental problem with these landfills is the production of leachate by the percolation of water from precipitation events and humidity from the waste through the landfill. According to la Loi sur la qualité de l'environnement, the environmental law in Québec, the leachate produced, which is contaminated with high concentrations of organic matter, ammonia and inorganic molecules, must be treated prior to its discharge. Treatment of landfill leachate is typically undertaken by physical-chemical (e.g., flocculation) or biological (e.g., activated sludge) processes, with high construction and operation costs. The objective of this study is to evaluate the feasibility of leachate treatment by vertical, subsurface flow treatment wetlands (TWs), planted with willow or *Sporobolus* species. This process consists of a porous, granular substrate (i.e., gravel), planted with vegetation having a high root biomass production capacity and a good tolerance to leachate. Five experimental pilot-scale (450 L) aerated TWs, planted with willows or *Sporobolus*, were operated under summer conditions for a period of 40 days. The TWs demonstrated a 95% ammonia removal and 55% removal of organic matter. The results of this process under winter conditions, which are currently being studied, will also be presented. The results of this study will be used to develop the design and operation criteria for a TW that is economical, environmentally friendly and sustainable for leachate produced by a variety of landfills in Québec and Canada.

Keywords: Phytotechnology, Wastewater treatment, Artificial wetlands

Arsenite Oxidation and Removal by Delayed Fe^{2+} Oxidation in the Presence of Phosphate

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Abstract

Biological arsenite [As(III)] oxidation and removal with groundwater native Fe^{3+}-(hydr)oxide flocs is a promising approach without requiring adsorbents/chemicals (Gude et al., 2018). The delayed/step-wise groundwater native-Fe^{2+} oxidation process was found to be an effective method for As(III) oxidation and removal (Annaduzzaman et al., 2021). However, to optimize this process for application, it is critical to prevent competition of groundwater phosphate (PO_4^{3-}) for arsenate [As(V)] removal. Therefore, this study aimed to investigate delayed Fe^{2+} oxidation towards more efficient As(III) oxidation and removal in PO_4^{3-} containing waters. The research was conducted with 280 µg/L As(III) and 2 mg/L of Fe^{2+}, with an initial pH of 7.0, representing the concentrations in a targeted village in rural Bangladesh. The experiments consisted of aerated single-step and multiple-step jar tests to simulate the delayed Fe^{2+} oxidation through sequential dosing of Fe^{2+}. In this method, 1 mg/L of Fe^{2+} was introduced before and after the sodium hypochlorite oxidation step, as an alternative to biological As(III) oxidation. In the single-step jar test, the As(III) containing system with and without PO_4^{3-} resulted in 20% (C_e=234 µg/L) and 43% (C_e=159 µg/L) As removal respectively, whereas in the multiple-step test, this removal increased to 54% (C_e=129 µg/L) and 94% (C_e=17 µg/L) correspondingly. These results show that delayed Fe^{2+} aeration is beneficial for efficient As removal, either in the presence or absence of PO_4^{3-}. The preference of Fe^{3+}-PO_4^{3-} complexation over As(V) in the first Fe^{2+}-oxidation step and partial PO_4^{3-} removal from the solution before the subsequent oxidation step enhanced overall As removal.

Keywords: Arsenic removal, Delayed aeration, Phosphate, Jar test

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A Genome-Resolved Process Model Mechanistically Captures Resilience to Free Ammonia Exposure in Functionally Degenerate Members of Nitrite-Oxidizing Bacteria

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Abstract

In partial nitritation (PN)/anammox systems, nitrite-oxidizing bacteria (NOB) are out-selected in favor of nitrite accumulation. However, NOB can have high functional degeneracy that makes their out-selection a challenge in mainstream activated sludge systems (Daims et al., 2016). This study examined the stability of mainstream PN promoted by treating to 20% of return activated sludge with 200 mg-N/L free ammonia (FA). An effluent nitrite concentration of 11 mg-N/L was observed by day 34 in the FA-treated reactor. However, it decreased to < 1 mg-N/L by day 64, equivalent to the effluent nitrite concentrations in the control reactor without FA exposure, suggesting an adaptation of NOB to FA exposure. Concomitantly, NOB community shifts were reveled via genome-centric metagenomics, indicating functional degeneracy within the NOB members. Genome annotation indicated that members adapted to FA exposure could use formate as an electron donor as an alternative energy source, and had the potential for reactive oxygen species degradation and trehalose as an osmolyte. These abilities may have provided certain NOB members a growth advantage under FA exposure by enabling growth on cell decay products, or mechanisms to resist FA toxicity. A genome-resolved process model was formulated by linking highly-paralleled respirometry, in-situ reactor nutrient concentrations, and metagenome-assembled genomes in a proof-of-concept. Such integration of biological activity measurements, chemical data, and genomic metabolic potential into the mechanistic process model helped capture process acclimation under a dynamic NOB community composition. Therefore, this genome-resolved process modeling approach could help advance engineering strategies to out-select NOB for energy-efficient nitrogen removal in activated sludge processes.

Keywords: Partial nitritation, Modeling, Metagenomics

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Vacuum-Ultraviolet Advanced Oxidation: How Does Chlorine Affect the Kinetics?

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Abstract

Among the many advanced oxidation processes (AOPs) used in water and wastewater treatment, vacuum ultraviolet (VUV) and ultraviolet (UV)/chlorine offer great potentials for the degradation of recalcitrant contaminants by producing reactive radicals. Although few researchers have recently reported on the high efficacy of the combined VUV/UV/chlorine process, little is known about its kinetics and the role of chlorine and hydroxyl radicals. In this work, the VUV photochemical parameters of free chlorine species were estimated for the first time and VUV/chlorine kinetics were studied in a collimated beam setup using carbamazepine as a model contaminant. While addition of chlorine to the VUV process increased the degradation rate of carbamazepine, very high concentrations of chlorine were shown to produce an inhibitory effect due to its high absorption coefficient. Also, the mechanisms of chlorine and hydroxyl radical reactions were further investigated through competitive kinetic experiments using acetate and acetone as radical scavengers. The results showed that chlorine radicals significantly contribute to carbamazepine degradation. Finally, a kinetic model was developed using MATLAB to verify the proposed mechanisms and predict the concentration profiles of radicals in the VUV/chlorine process. While the research on VUV/chlorine is still at an early stage, the results presented here show the promises of this technology for water treatment and reuse.

Keywords: Photolysis, Chlorine radical, Water treatment and reuse

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Accelerated Development of Anammox Micro-Granular Consortium and Potential Contribution of Hydroxylamine

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Research Background

As a result of the energy-intensiveness of conventional designs, there has been a major shift from nitrification-denitrification system configurations to a new and innovative generation of nitrogen removal processes (Chen et al., 2019). One of the most promising substitutes, initiating an energy-producing treatment system are ANAMMOX-based processes (Reino et al., 2018). Biological nitrogen removal through anaerobic ammonium oxidation (ANAMMOX), leads to significant savings in aeration cost and organic carbon addition requisites, along with less sludge production (Wang et al., 2017. The bacterial community responsible for anaerobic ammonia oxidation is exemplified as extremely slow-growing population, having an approximated doubling time of 10-30 days, leading to low biomass yields (Strous et al., 1998).

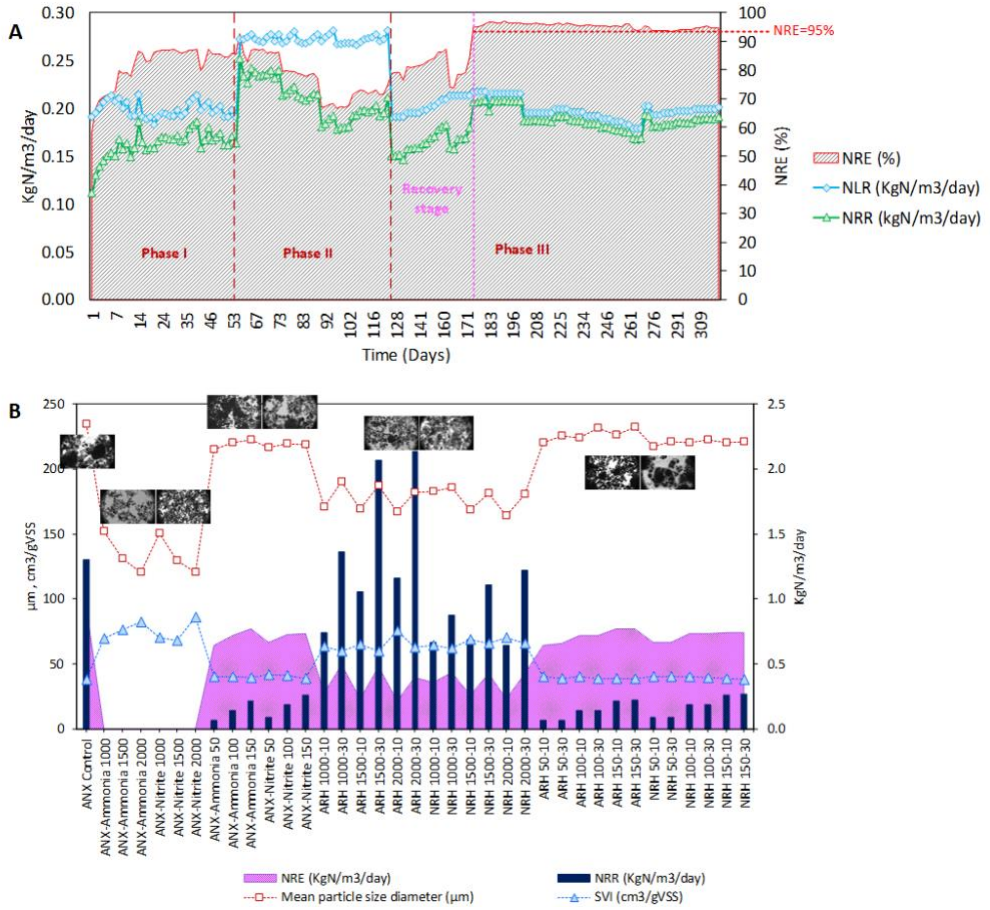

Figure 1: (A)The performance of the reactor with continues operation: Nitrogen load rate (NLR), nitrogen removal rate (NRR), and nitrogen removal efficiency (NRE), (B) Variation of granule size distribution, NRE and NRR in in different hydroxylamine concentrations in batch assay experiments.

Problem Statement

Anammox process long start-up period, continues to be a major issue because of low bacterial growth rates and cellular yields, causing a shortage in providing sufficient amounts of anammox seed and operational limitations worldwide. Development and operation of sidestream anammox processes has augmented since the initial full-scale systems, yet there are several aspects which mandate additional investigation and deliberation by the practitioners, to reach the operating perspective, set for the facility (Izadi et al., 2020). Various approaches are necessary to be studied to accelerate bacterial metabolism, especially in mainstream conditions, to restore the anammox activity and to stimulate the nitrogen removal rate in the system (Liu et al., 2013).

Objectives

This study aims to improve the operational factors for syntrophic micro-granular anammox consortium cultivation in a laboratory scale UASB reactor from sole activated sludge without any bioaugmentation from a previously enriched anammox biomass, to overcome the issues related to seed availability as well as sludge retention and growth in newly started anammox reactors. This research also focuses linking the potential stimulatory effects of hydroxylamine to mainstream application.

Results and Discussions

The reactor, running for approximately one year, reached 95% nitrogen removal, after less than two months in the stabilization phase, with a loading rate of 0.22 KgN /m3/ day (**Figure 1-A**). Settling properties of biomass improved (SVI changed from 81.29 for the initial RAS sludge to 38.33 cm^3. $gVSS^{-1}$), while the SRT of the reactor was 36–72 days. Anammox bacteria abundance increased in process of granule formation and the microbial species present in the sludge changed throughout the three phases. Species identified at the end of process in phase three were more member of anammox or filamentous bacterial groups, than the species of the seeding sludge. This study successfully achieved ideal micro-sized anammox granular sludge to obtain high nitrogen removal efficiency and minimum biomass washouts, as well as prompt anammox enrichment from activated sludge within less than 50 days of operation. Experimentation on two set of batch assays in high-temperature mainstream anammox process conditions indicated that (**Figure 1-B**), addition of 10 and 30 mgN/L of hydroxylamine, increased the NRE from zero to 26.13 and 42.29% in nitrite-inhibited tests.

Conclusions

The result of this study can pave the path towards an improved Anammox start-up and performance in addition to introducing a boosting agent for high-temperature mainstream anammox process implementation.

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POSTAR PRESENTATION

Influent Forecasting for Wastewater Treatment Plants in North America

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Abstract

Autoregressive Integrated Moving Average (ARIMA) which is a time series analysis model, has been proven to be an effective tool to analyze time series and forecast future data points in many different fields of study. However, it has not been widely used to forecast daily wastewater influent flow. The objective of this study is to explore the possibility of utilizing ARIMA for daily influent flow forecasting for wastewater treatment plants (WWTPs). The influent flow data from five stations across North America (ie: Woodward, Niagara, North Davis, and two confidential plants) are used to calibrate and validate ARIMA models. Various statistical good-of-fit measurements are used to evaluate the model's prediction performance. The measurement results show relatively small errors and good fit between observed influent flows and predicted values for all WWTPs, which demonstrates that ARIMA can produce satisfactory daily influent flow forecasts for WWTPs in North America. The developed ARIMA models and their satisfactory prediction results could provide the information of influent flow to help run the WWTPs efficiently, and further support wastewater management planning at various levels within a watershed.

Keywords: ARIMA, time series analysis, wastewater treatment

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The Effect of pH and Hydraulic Retention Time on Volatile Fatty Acids Production from Dark Fermentation of Primary Sludge.

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Keywords: Volatile fatty acids, Primary sludge, Dark fermentation, pH, Hydraulic Retention Time

Introduction

Waste generation and management have been a concern in the modern world. Methods of resource recovery as liquid waste management are preferred over conventional treatment methods. Resource Recovery provides the provision for waste minimization as well as the production of the value-added products. Waste sludge from wastewater treatment plant can be considered as a rich source for volatile fatty acids (VFAs) production. Production of VFAs from Primary Sludge (PS) by acidogenic fermentation (Bengtsson et al., 2008) or dark fermentation (Su et al., 2009) has drawn an extensive research interest nowadays. Considering this potential, the scope of this research has been decided to produce VFAs from PS. VFAs are short-chain fatty acids with six or fewer carbon atoms and can be used in bioplastic and bioenergy production (Lee et al., 2014) as well as in biological nutrient removal (BNR) process that is the removal of nitrogen (N) and phosphorus (P) from wastewater.

Anaerobic Digestion (AD) has acidification step in which VFAs are produced as the intermediate metabolic product such as acetic acid (HAc), propionic acid (HPr), butyric acid (HBu) etc. as short-chain fatty acids with two to six carbon atoms. VFAs production from PS is done through anaerobic biodegradation or dark fermentation process that consists of two sequential steps: hydrolysis and acidogenesis. The first step is hydrolysis or liquefaction where high molecular weight organic compounds, i.e., complex organic polymers of wastewater break down into simple and soluble organic monomers by enzymes of hydrolytic microorganisms. It is characterized by an increase in soluble chemical oxygen demand (SCOD). The next step is acidogenesis or fermentation in the presence of the acidogenic microorganism. The generated SCOD from the hydrolysis step is converted to VFAs in the acidogenesis stage. During this stage, soluble monomers from the first step undergo acidogenesis reaction to produce VFAs such as HAc, HPr, HBu. Both processes are conducted in the anaerobic reactor and involve anaerobic microorganisms (Weiland et al., 2010). The rate of this acidification depends on several factors such as pH, temperature, hydraulic retention time (HRT) and solid retention times (SRT), organic loading rate (OLR), etc. PS and WAS are produced in high volume in a plant with high organic content with total chemical oxygen demand (TCOD) ranging from 14,800 mg l-1 to 52,000 mg l-1 which suggests a high potential for VFAs production (Ji et al., 2010;Wu et al., 2009). VFAs can be used as carbon sources needed during BNR processes. Approximately 1 mg of P can be removed by 7-9 mg of VFAs (Maharaj and Elefsiniotis, 2001). It has been reported that VFAs used to make effluent P levels as low as 0.2-0.3 mg l-1 (Elefsiniotis and Oldham, 1994).

Objective

The primary objective of this study was to evaluate the effect of pH and HRT on the fermentation of the PS to maximize the SCOD and VFAs production. The goal of the project was to maximize the produced VFAs that can be used as a carbon source for the BNR process.

Materials and Methods

The PS that was used in this work was collected from Ashbridge's wastewater treatment plant (ABWWTP). The mean value of TSS and VSS concentration of PS were 36,005 mg l-1 and 28,723 mg l-1, respectively. TCOD and SCOD were 53,386 mg/L and 3016 mgL, respectively. The ratio of mean SCOD/TCOD ratio was 5.6%, and VFAs/SCOD ratio was 42%.

For this purpose, experiments were conducted under both batch and semi-continuous flow regimes. The experiments were first conducted under batch mode at different pH levels from 4.5-11.0. During the batch experiment, samples were collected at 1, 2, and 3 days intervals. After the batch test, semi-continuous fermenters were operated at three pH levels (4.5, 5.5, and 6.5) and under three HRTs of 1, 2, and 3 days. The HRT was kept low until 3 days to ensure VFAs production and inhibit the further step in AD which is methanogenesis that will consume VFAs [8]. The performance of the fermenters was evaluated by monitoring the SCOD and VFAs concentration and yield throughout the process.

Results & Conclusion

Batch fermentation of PS at mesophilic temperature resulted in maximum VFAs production and yield at HRT of 3 days. However, there were no significant differences when the pH changed from 6.5 to 10.0, i.e., there was no significant effect of the pH in the range of 6.5 to 10.0 on the VFAs yields. The HRT significantly impacts the VFAs yield for all pH values except pH 4.5 and 11.0. The VFAs/SCOD ratio was higher for acidic pH compared to alkaline pH.

A further semi-continuos investigation was conducted to evaluate the effect of pH and HRT at the mesophilic temperature. Semi-continuous experiment findings appear to establish that VFAs production increases with an increase of HRT but up to three days and reaches a maximum at pH 6.5. The maximum VFAs concentration of (6,549 ± 414 mg) COD/L, SCOD concentration of (14,600 ± 414 mg) SCOD/L, VFAs yield 290 mg COD /g VSSfeed, SCOD yield 644 mg SCOD/g VSSfeed and degree of solubilization 25% were achieved at pH 6.5 for HRT three days. The high SCOD concentration of 9000 to 14,500 mg/L was achieved at HRT of three days for the three pHs.

Acknowledgements

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Non-Sewered Sanitation Systems Global Greenhouse Gas (GHG) Emissions: Balancing Trade-Offs Amongst Sustainable Development Goals (SDGs)

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Abstract

Sanitation systems are fundamental for human health and sustainable development; however, limited focus has been placed on their contributions to climate mitigation and adaptation. Climate change threatens existing systems, as well as efforts to increase services for over 2 billion people who lack even a basic sanitation service (UNICEF and WHO, 2019; Dickin et al., 2020). At the same time, the sanitation and wastewater sector directly produces emissions associated with the breakdown of organic matter, and treatment processes require large energy inputs (Dickin et al., 2020; Kulak et al., 2017). Currently, there is a conflict between SDG 6, specifically SDG 6.2, and SDG 13 (Dickin et al., 2020; Parkinson et al., 2019). The current Intergovernmental Panel on Climate Change (IPCC) GHG estimation methodology was used as the basis for calculations in this analysis (IPCC, 2019). However, given its limitations, this analysis made provisions for refinement and comparison of the current IPCC model with improved and experimentally verified emission factors (EFs). This analysis has been developed to quantify the impact of eliminating open defecation in addition to highlighting which on-site sanitation technologies are poorer choices from an emissions perspective in achieving this goal. The specific objectives were as follows:

1. Model and compare scenarios for global future GHG emissions that would allow SDG 6.2 to be met in 2030 from household decentralized sanitation infrastructure given differences in demography, urbanization and economic growth as represented by three different Socio-Economic SSPs (i.e. SSP1, SSP2 and SSP3) (Neill et al., 2014).

2. Complete a sensitivity analysis to determine the relative impact each individual on-site sanitation system (e.g. septic tanks, pit latrines, composting toilets, etc.), as they relate to the service level in the sanitation management ladder (i.e. improved, unimproved and no service) defined by the JMP, have on climate change mitigation in the form of GHG emissions.

3. Expand upon the existing IPCC GHG estimation methodology using improved emission factors for each non-sewered sanitation form through augmentation with published measured data sets.

This model aimed to increase the understanding of sanitation and climate change linkages among stakeholders, and more effectively include sanitation in climate action.

Keywords: Sanitation systems; Global Greenhouse Gas (GHG), Climate change

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An Irrigation Scheduling app Based on Evapotranspiration and Effective Rainfall for Bangladeshi Crops

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Abstract

Irrigation management is about determining when and how much water to apply for irrigation. Determining when to apply irrigation depends on the amount of water the crop uses and the total moisture held in the soil. With rising competition for water, irrigation water management activities must be efficient and accessible to all, not just large-scale farms. Precision irrigation optimizes irrigation and minimize water use, while maximizing crop yields, thereby increasing the effective management of water resources. This paper presents a new smart phone app, which uses meteorological and soil data to measure water usage in order to compute a monthly irrigation program for selected crops in Bangladesh. The app calculates the optimal irrigation cycle, that is, the average daily amount of irrigation water in the current month required to maximize crop productivity.

Keywords: Irrigation management, Smart phone app, Bangladesh, Optimal irrigation cycle

Graphitized sand: One solution for all cyanotoxins?

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Abstract

Microcystin-LR (MC-LR) is considered to be one of the most prominent cyanotoxin found in the surface water sources. Their presence in the Drinking Water Treatment Plant (DWTP) was detected at every treatment stages. Chemical treatment processes pose limitation such as insufficient interaction time, toxic by-product formation or the chemical ineffectiveness to most of the cyanotoxins including MC-LR. As a matter, physical process such as sand-based filtration system might provide an economical and sustainable solution. However, sand-based filtration system has been found quite ineffective against the MC-LR. In contrast, the use of graphitized sand (GS1) has shown remarkable results that can be viewed as a possible replacement to the sand media. The adsorption capacity of GS1 was found to be 60 times higher (6 µg- MCLR/g) and at the household level 29 times more economical than the conventional sand media. These results hold promise to further investigate the remarkable adsorption capacity of the GS1 media against other commonly found cyanotoxins such as Anatoxin-a (ANA-a) and Cylindrospermopsin (CYN). In addition, the adsorption kinetics of MC-LR, ANA-a and CYN for GS1 media is studied and the filter bed results are discussed to present a more comprehensive overview of its application with respect to the household as well as DWTP filtration system.

Keywords: Microcystin-LR, Drinking Water Treatment Plant, Sand Filtration

Volatile Fatty Acids Recovery from Different Industrial Wastes

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Abstract

Global climate change has spurred action from many industries towards processes that produce less waste and minimize greenhouse gas (GHG) emissions. On the other hand, the depletion of conventional energy sources (such as fossil fuels) also drives the need for alternative reliable sources of energy. Thus, resource recovery has become a popular term for the capture of valuable products from waste. Interest and research are focused on technologies that can support these waste-to-value initiatives. Fermentation of organic waste has been used in the production of chemicals such as ethanol, hydrogen, and volatile fatty acids (VFAs). This paper examines the potential of industrial wastewater effluents in generating value-added products such as VFAs which can be used in the generation of bioenergy, production of bioplastics, and as a carbon source for biological removal of nutrients from wastewater treatment plants. In this study, a fermentation batch test was performed for four industrial organic waste: (1) bakery processing and kitchen waste (BP+KW) mixture, (2) fat, oil, and grease (FOG), (3) ultrafiltered whey permeate, and (4) powder whey (1:5 slurry). The fermentation experiment was conducted under mesophilic conditions to investigate VFAs production using a food-to-microorganism (F/M) ratio of 1. The liquid parameters were monitored with time daily. The results of this study emphasize the applicability of using industrial waste as a source of VFAs. Among the four wastes that have been used in this study, the whey powder produced the highest VFAs concentration after 3 days of fermentation of about 2900 mg COD/L. The highest soluble chemical oxygen demand (SCOD) of about 12000 mg/L was produced from the powder whey as well. The highest VFAs yield of 305 mg COD/g TCOD added was produced from whey powder followed by 288 mg COD/g TCOD from ultrafiltered whey permeate. The lowest VFAs yield of 118 mg COD/g TCOD for FOG.

Keywords: Resource recovery, Volatile fatty acids (VFA), Fermentation

Biological Denitrification of Wastewater using Volatile Fatty Acids from Industrial Waste

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Abstract

The discharge of nitrate-nitrogen in lakes and rivers can have numerous adverse effects on the environment and human health. One significant adverse environmental impact is eutrophication, which decomposes, leading to dissolved oxygen depletion and death to aquatic creatures. Due to these adverse effects, EPA imposed strict regulations on nitrate-nitrogen levels in discharged wastewater. Biological nutrient removal is one of the most cost-effective and efficient technologies for removing nitrogen and phosphorus from wastewater. Denitrification is part of biological nutrient removal, which involves converting nitrate in wastewater to nitrogen gas with the aid of external carbon sources. Methanol is one of the most commonly used external carbon sources in denitrification in wastewater treatment. This is due to methanol's effectiveness and availability. However, methanol is relatively expensive, and it contributes to the majority of the total operational and maintenance costs of municipal wastewater treatment plants. Several research studies have indicated volatile fatty acids (VFAs)' effectiveness to be an attractive alternative carbon source since they can be produced via acid-phase anaerobic digestion on-site. The main objective of this study is to apply VFAs (generated from the fermentation of four different industrial waste feedstocks) as external carbon sources and investigate their effectiveness on denitrification. The four different industrial waste feedstocks chosen for this experiment were mixed bakery processing and kitchen waste, FOG, Whey permeate in liquid and powdered forms. These four feedstocks were selected due to their high organic and biodegradable content.

The fermentation step was conducted in batch mode for 3 days with a food-to-microorganisms (F/M) ratio of 1. The filtrates obtained from fermentation were then added to waste-activated sludge (WAS) in an anoxic environment with a COD/NO_3-N ratio of 10 to ensure complete denitrification. The initial nitrate-nitrogen concentration in the WAS was set at 20 mg/L, which is the typical in wastewater treatment plants. The experimental analysis deduced that initial nitrate concentration in WAS decreased by 98%, 96%, 97%, and 95% using mixed bakery processing and kitchen waste, FOG, Whey permeates in liquid and powdered forms, respectively. The highest final nitrate-nitrogen concentration was 0.998 mg/L which is lower than EPA's nitrate-nitrogen threshold by 90%. This concludes the effectiveness of the VFAs produced from fermentation as external carbon sources in denitrification.

Keywords: Biological Nutrient Removal, Denitrification, Volatile Fatty acids

Side-Stream Treatment of Anaerobically Digested Sludge Centrate through Selective Enrichment of Nitrifiers in Activated Sludge Sequencing Batch Reactor

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Abstract

Today, anaerobic digestion is vastly becoming a common technology to enhance handling and management of municipal biosolids. With stricter national effluent nutrient limits, side-stream treatment of dewatering waste liquor (centrate) provides a cost-effective method to reduce high concentrations of ammonia generated from anaerobically digested sludge. The objective of this research is to develop a side-stream treatment process based on the selective enrichment of nitrifiers and investigate the nitrification rate for ammonia removal from centrate in a suspended growth activated sludge sequencing batch reactor (AS-SBR). Two identical AS-SBRs with a working volume of 1.5 L were seeded with return activated sludge (RAS) to cultivate and select for nitrifying organisms (ammonia-oxidizing bacteria (AOBs) and nitrite-oxidizing bacteria (NOBs)). Centrate from anaerobically digested sludge from Ashbridges Bay Treatment Plant in Toronto, Ontario with a high ammonia concentration of 600 mg/L was fed to the reactors, which operated at a cycle schedule sequentially: influent filling (30 min), aeration (1290 min), settling (60 min), effluent withdrawal (45 mins), and idle (15 mins). Aeration was provided via air bubble diffusers located at the bottom of the reactor to maintain a dissolved oxygen (DO) concentration > 2 mg/L. Sodium bicarbonate ($NaHCO_3$) was added to one SBR to provide an external inorganic carbon source for nitrifying bacteria and to maintain alkalinity in the bioreactor. The second SBR was operated without any pH control. The reactors were operated at room temperature. Results showed that specific nitrification rates (SNR) were between 1.2 – 2.0 mg N/g VSS.h. In achieving the specific nitrification rate, this research will improve nitrification and reduce high ammonia concentrations in centrate. Further research will focus on transforming enriched nitrifier population to granular biomass in order to promote bioaugmentation of nitrifiers in an aerobic granular sludge sequencing batch reactor (AGS-SBR).

Keywords: Anaerobic digestion, Activated sludge, Batch reactor, Nitrifications