Research in the 'Biosystems Control (BioCo)' group aims at sustainable process design and control, applied to biological wastewater treatment and other bioconversion processes. 'Sustainability' is interpreted as meeting the required product or effluent quality while minimizing the use of energy and resources, aiming at reuse and recovery, through compact installations, in an economically viable and socially acceptable way. We do process engineering via physical-based models (mass balances) combined with measurement campaigns at full scale and lab-scale experiments.

For 2023-2024, we offer the following master thesis topics:

* Inschatten van gasvormige emissies uit mestverwerkingsinstallaties (Estimating gaseous emissions from manure treatment)
  David.Ysebaert@UGent.be

* Sustainable recirculating aquaculture systems integrating shrimp with seaweed : monitoring and mass balance analysis
  David.Ysebaert@UGent.be

* Transforming wastewater into valuable resources: New methods for sustainable nitrogen recovery
  Laurence.Strubbe@UGent.be

* How bubbles reflect process behaviour - Control of wastewater treatment basins using off-gas analyses
  Laurence.Strubbe@UGent.be

* CO2 to mitigate carbon impact in industrial wastewater treatment plants
  Eveline.Volcke@UGent.be

* Potential of pure oxygen supply for efficient industrial wastewater treatment
  Eveline.Volcke@UGent.be

(feel free to propose your own topic matching our research scope)

The following master thesis research topics will be carried out in **collaboration with Prof. Di WU (UGent Global Campus) and Prof. Eveline Volcke (Home campus)**. The master student is welcome to carry out a research stay at GUGC, the duration of which will be determined in mutual agreement. **Scholarships** are available for both the **travel costs and the accommodation** at GUGC (deadline for application: 1 March 2023).

This Joint Master thesis research in Global Campus Saline Environmental technoLogy InNovAtion (SELINA) research group and Home Campus Biological system Control (BioCo) research group aims at sustainable process design and control, applied to biological wastewater treatment and resource recovery technology. We do environmental life-science experimental research and process engineering via modeling and machine learning.

* Exploiting sulfur for innovative nitrogen removal from wastewater
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* Efficient and sustainable wastewater treatment with aerobic granular sludge
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* Phosphorus recovery from wastewater
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* AI-powered Membrane-based biotechnology for Greywater Potable Reuse
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More information on these topics is provided below. Do not hesitate to contact us if you are (potentially) interested

Inschatten van gasvormige emissies uit mestverwerkingsinstallaties
Estimating gaseous emissions from manure treatment

Summary

In opdracht van de Vlaamse Milieumaatschappij (VMM, Emissie-Inventaris Lucht) wordt het Emissie Model Agricultuur Vlaanderen (EMAV3.0) ontwikkeld door het Vlaams Instituut voor Landbouw- en Visserijonderzoek (ILVO). Het bestaande EMAV-model incorporeert het emissiestadium 'mestverwerking' wat resulteert in een inschatting van de NH3-, N2O-, NO- en CH4-emissies van Vlaamse mestverwerkingsinstallaties. Het is echter geweten dat de uitwerking van dit emissiestadium zeer rudimentair is en heel wat ruimte laat voor verbetering.
In deze masterproef zal je op basis van beschikbare data en informatie de meest toegepaste mestverwerkingsconfiguraties in kaart brengen. Voor deze configuraties zal je massabalansen opstellen en een inschatting maken van de emissies van NH3, CH4, en N2O. Je kan hierbij rekenen op de ondersteuning van experts van ILVO, VCM (Vlaams Centrum voor mestverwerking), en van je promotor. Jouw taak bestaat erin de bestaande informatie en complementaire expertise samen te brengen. Deze resultaten van dit masterproefwerk zullen rechtstreeks gevoed worden aan de werkgroep rond mestverwerking voor de EMAV-studie.

Dit is jouw kans om mee input te geven aan het beleid rond stikstof- en broeikasgasemissies in Vlaanderen!

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Key words: gasvormige emissies, ammoniak (NH3), methaan (CH4), lachgas (N2O), mestverwerking, mestbewerking

Relevant for: Campus Coupure: Bio-ir – Milieutechnologie, Campus Coupure: Bio-ir – Landbouwkunde

Sustainable recirculating aquaculture systems integrating shrimp with seaweed : monitoring and mass balance analysis

Summary

Recirculating aquaculture systems (RAS) are applied to grow commercially important aquatic organisms such as shrimp and fish in a controlled environment. The RAS reuses most of the water within the system and is considered a sustainable way of doing aquaculture. The advantages of using a RAS entail a low water use, efficient land and energy use, easy harvesting and disease control. To preserve the quality of the water which is reused within the system, RAS also requires a water treatment unit e.g. a trickling filter, moving bed bioreactor (MBBR) etc.
A RAS infrastructure consisting of integrated shrimp and seaweed culture within the R&D facility of ZILT will be utilized for this study.
This master thesis will focus on tackling some of the challenges regarding measurements within this full-scale RAS. More specifically, the high salinity of the water makes it difficult to use sensors to accurately measure e.g. the low ammonia concentration in the water. This ammonia can be toxic for the shrimp at low concentrations, thus tracking these concentrations is crucial for a successful culture. This thesis will investigate whether mass balances and correlations between components in the water can provide accurate estimates of concentrations. Both modelling and data from lab/pilot/full-scale setups will be used to address these challenges. The potential for automation of certain measurements can also be investigated.

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Key words: RAS, aquaculture, modelling, mass balances, sensors, wastewater treatment

Relevant for: Bio-ir - Chemie en bioprocestechnologie, Bio-ir - Milieutechnologie
Could also be taken by incoming exchange students.

Transforming wastewater into valuable resources: New methods for sustainable nitrogen recovery

Summary

While the primary objective of wastewater treatment is to protect the environment and human health, there is a growing need for secondary objectives related to resource recovery. The recovery of valuable products, such as nitrogen, is an area of particular interest due to its potential to create economic value while also promoting environmental sustainability.

Anaerobic digestion produces an ammonium-rich waste stream which is traditionally treated through the well-established DEMON process. However, this process results in the loss of valuable nitrogen into the atmosphere. While physico-chemical processes can recover ammonium in the form of an economic valuable product for agriculture, heat requirements limit the exploration of such technologies. Recent advancements in green technologies, for example hydrogen electrolysis, generating excess heat, enables the potential of nitrogen recovery.

In this thesis, you will investigate the potential of transforming wastewater into a valuable product by the use of two physico-chemical processes and compare them with the traditional DEMON process. You will compare product recovery, chemical and energy use through simulation with available models in Matlab-Simulink and/or Python. Data will be provided or can be obtained through experimental work. The collaboration with the company BESIX Environment ensures practical significance, access to resources and expertise to develop innovative solutions for wastewater recovery.

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Key words: Resource recovery, wastewater treatment, nitrogen, modelling, experimental work, CAPTURE

Relevant for: Campus Coupure: Bio-ir - Chemie en bioprocestechnologie, Campus Coupure: Bio-ir – Milieutechnologie, Campus Coupure: Msc in Environmental Science and Technology

How bubbles reflect process behaviour- Control of wastewater treatment basins using off-gas analyses

Summary

A biological wastewater treatment basin consists of wastewater, purifying bacteria and air bubbles. The air bubbles are essential for providing the purifying bacteria with enough oxygen to consume the waste out of the water. As the air bubbles rise to the top of the basin, they release a gas that contains less oxygen and more carbon dioxide than the air that was originally pumped into the system. This change in gas composition tells something about the ongoing biological processes occurring within the water.

This raises some questions: could the oxygen and/or carbon dioxide concentrations in the gas leaving the reactor be used to determine when the wastewater is clean enough for discharge? Could a wastewater treatment plant be operated automatically without human intervention, even with changing influent composition and flow rates, solely based on off-gas composition? How would this approach compare to existing control loops based on liquid-phase measurements?

In this thesis, a mathematical model of a biological wastewater treatment reactor will be used to address these questions. Through the mathematical model, it is possible to gain insight into the processes that affect the gas phase of a wastewater treatment plant. This insight can be used to propose new operational strategies to optimize the treatment process in a way that is never done before.

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Keywords: Biological wastewater treatment, modelling, simulation, off-gas, control, CAPTURE

Relevant for: Bio-ir - Chemie en bioprocestechnologie, Bio-ir - Milieutechnologie
Could also be taken by incoming exchange students.

CO_2 to mitigate carbon impact in industrial wastewater treatment plants

Summary

Many industrial wastewater treatment plants need to spend resources on adjusting wastewater characteristics such as pH to ensure a good performance of the biological systems that remove the pollutants from the wastewater. pH adjustment is usually done through the addition of chemicals such as sulfuric acid or sodium hydroxide, which supposes a high cost for the treatment plants. One way to reduce the use of chemicals is to increase the buffering capacity or alkalinity from the wastewater. CO_2 injection holds the potential to retain alkalinity, and therefore reduce the use of chemicals for pH control.

In this thesis, you will study how CO_2 supply impacts the buffering capacity of the wastewater, and therefore the use of chemical compounds for pH adjustment. This will be done through modelling and simulation, focusing on an industrial case study. Scenario analysis will be performed to evaluate the impact of replacing the current solution by CO_2 supply for pH adjustment in a full-scale industrial wastewater treatment plant.

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Keywords: Industrial wastewater treatment, modelling, simulation, CO_2, CAPTURE

Relevant for: Campus Coupure: Bio-ir - Chemie en bioprocestechnologie, Campus Coupure: Bio-ir – Milieutechnologie, Campus Coupure: Msc in Environmental Science and Technology

Potential of pure oxygen supply for efficient industrial wastewater treatment

Summary

Aeration is the most critical aspect in aerobic biological wastewater treatment. It is key to ensure a good reactor performance and it is one of the most energy-consuming processes. During aeration, air is supplied to the reactor to provide the purifying bacteria with enough oxygen to remove the pollutants present in the wastewater. However, the oxygen transfer efficiency is usually low, meaning that most of the oxygen in the supplied air leaves the reactor without being effectively used. This strategy is usually enough to treat municipal wastewater, but limits the treatment of industrial wastewaters, since they present higher pollutant concentrations. One option to improve the efficiency of aeration for the treatment of industrial wastewater is the use of pure oxygen. Potential benefits are a better buffering capacity of the wastewater due to the produced CO_2 in solution and a better pH control. In addition, the overall stripping potential of volatile compounds and dissolved gasses is also reduced to a great extent.

The aim of this master thesis is to investigate the potential of pure oxygen supply for the aerobic biological treatment of industrial wastewater, as well as to quantify its benefits on the overall plant performance and operational costs. The research will consist of modelling and simulation work applied to an industrial wastewater treatment plant in which the operators can choose between pure oxygen and air aeration depending on the requirements. The overall benefits throughout the water chain will be evaluated from water treatment to water reuse in the specific industrial case study.

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Keywords: industrial wastewater treatment, pure oxygen, modelling, CAPTURE

Relevant for: Campus Coupure: Bio-ir - Chemie en bioprocestechnologie, Campus Coupure: Bio-ir – Milieutechnologie, Campus Coupure: Msc in Environmental Science and Technology

Exploiting sulfur for innovative nitrogen removal from wastewater

Summary

Biological nitrogen removal during municipal wastewater treatment is crucial for both human health and the environment. Conventional technologies consist of nitrification followed by denitrification on organic carbon, additional amounts of which may need to be dosed. In the meantime, many wastewater treatment installations cope with problems related to sulfide (e.g. odour, corrosion, toxicity).

However, sulfide can be used beneficially via sulfur-based denitrification. It relies on the activity of autotrophic microorganisms that are capable of oxidizing sulfide or elemental sulfur while reducing nitrate and nitrite. This innovative and cost-effective process holds advantages over heterotrophic denitrification in terms of reduced sludge production and lower electron donor costs. A strategy that could even further optimize the process is shortcut nitrification to nitrite (25% lower aeration) coupled to shortcut denitrification of nitrite (40% less electron donor).

This master thesis will evaluate the performance of different sulfur-based denitrification process configurations, through mathematical modelling and simulation. Control strategies will be implemented for process optimization. Overall, this master thesis aims to provide a proof of concept for the proposed sulfur-based denitrification technology.

This research will combine experimental work and data analysis (at GUGC-Korea), with mathematical modelling and simulation (in UGent home campus).

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Key words: Biological wastewater treatment, modelling, simulation, sulfur cycle, CAPTURE

Relevant for: Bio-ir - Chemie en bioprocestechnologie, Bio-ir - Milieutechnologie

Could also be taken by incoming exchange students.

Efficient and sustainable wastewater treatment with aerobic granular sludge

Summary

The aerobic granular sludge technology is a true revolution in the field of wastewater treatment and also offers great potential for resource recovery. It has been widely applied for municipal wastewater treatment, but not yet so much for industrial wastewater treatment). One major knowledge gap is the removal of particulate (not soluble) compounds, which can contribute up to 50% of the total organic content present in the wastewater. This process has a big impact on the overall reactor performance, but it is still not well-understood (e.g., involved mechanisms, effect of operational parameters such as oxygen, pH, temperature).

The aim of this master thesis is to investigate the removal mechanisms and develop smart control strategies for the efficient removal of particulate compounds from wastewater with aerobic granular sludge. This research will mainly consist of experimental work, that can be complemented with mathematical modelling and simulation.

In this thesis, you will gain hands on experience on the operation of lab-scale aerobic granular sludge reactors. Besides, you will collect and analyze data, and evaluate several scenarios through batch tests to study the biological processes and find the best operational conditions for the removal of particulate compounds.

This research will combine experimental work and data analysis (at GUGC-Korea), with mathematical modelling and simulation (in UGent home campus).

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Keywords: Biological wastewater treatment, lab-scale experiments, modelling, particulate compounds, aerobic granular sludge, CAPTURE

Relevant for: Campus Coupure: Bio-ir - Chemie en bioprocestechnologie, Campus Coupure: Bio-ir – Milieutechnologie, Campus Coupure: Msc in Environmental Science and Technology
Could also be taken by incoming exchange students.

Phosphorus recovery from wastewater

Summary

Phosphorus (P) is a vital but scarce resource, which may be depleted in 50~100 years. Phosphorus recovery from wastewater could meet around 15-20% of the total world demand of P resource. Wastewater treatment plants offer multiple locations both on water and sludge line for the recovery of phosphorus. Digested sludge and sludge ash are the two hotspots on sludge line for phosphorus recovery as they have the maximum concentration of phosphorus retained in them i.e., 90% of the total influent P. Due to the presence of heavy metals and persistent organic pollutants in the sludge, direct application of sludge as a phosphorus fertilizer is banned in some countries like Netherlands, Belgium etc., while in other countries, regulations for land application of sludge have become more stringent. Therefore, other pathways such as thermo-chemical methods are used for the extraction of phosphorus from digested sludge and sludge ash.

The aim of the thesis would be to evaluate different techniques for phosphorus recovery from sludge and ash. Unit process models can be developed for testing different scenarios and optimizing the process parameters. Techno-economic comparison can be established between different techniques of phosphorus recovery from sludge line through plant-wide modelling.

This research will combine experimental work and data analysis (at GUGC-Korea), with mathematical modelling and simulation (in UGent home campus).

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Keywords: phosphorus recovery, plant-wide modelling, sludge ash, digested sludge, optimization, CAPTURE

Relevant for: Bio-ir - Chemie en bioprocestechnologie, Bio-ir - Milieutechnologie
Could also be taken by incoming exchange students.

AI-powered Membrane-based biotechnology for Greywater Potable Reuse

Summary

Greywater refers to the wastewater originating from households without any fecal matter from the toilets. The average greywater production in the developed countries ranged from 60–200 L per capita per day. When fully reused, the recycled greywater can represent 50–80% savings in the tap water usage and reduce the reliance on the depleting freshwater resources. One promising technology to treat greywater effectively is Membrane BioReactor (MBR), which combines biological activity from activated sludge and membrane separation to attain an excellent treated water quality. MBR may also reduce the plant footprint to achieve a more economical solution for greywater reuse. On the other hand, artificial intellectual technology (e.g. artificial neutral network, XGboost machine learning model) is powerful tool for MBR operation optimization. We aimed to develop robust mathematical model based soft-sensor for water quality predication and giving feedback for MBR optimization.

In this research project, you will gain hands on experience on the operation of lab-scale membrane bioreactor. Besides, you will collect and analyses data under different operation scenarios, as well as collecting online data and analyzing the data with machine learning model (e.g. XGBoost). This research will combine experimental work and data analysis (at GUGC-Korea), with mathematical modelling and simulation (in UGent home campus).

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Key words: Artificial Intelligence, Machine Learning, Greywater recycle, CAPTURE

Relevant for: Bio-ir - Chemie en bioprocestechnologie, Bio-ir - Milieutechnologie
Could also be taken by incoming exchange students.