Research Group on Biological Treatment and Valorisation of Liquid and Gaseous Effluents

YEARBOOK
2021

Excellence in environmental engineering research
Departament d’Enginyeria Química, Biològica i Ambiental

Carrer de les Sitges
Edifici Q · Campus de la UAB
08193 Bellaterra (Cerdanyola del Vallès)
Barcelona · Spain

genocov@uab.cat ·
www.uab.cat
www.uab.cat/departament/enginyeria-quimica
## CONTENTS

**Presentation**  
4

**Personnel of the research group**  
5

### Main Research Areas

- Treatment and resource recovery of highly-loaded off-gases  
6
- Characterization and biofiltration of odorous effluents  
11
- Industrial wastewater treatment  
13
- Recovery of biopolymers  
15
- Microfluidic lab-on-a-chip platforms and (bio)sensors for process monitoring  
17
- Urban wastewater treatment  
20
- Fundamentals and application of bioelectrochemical systems  
23

### Main Research Cross-topics

- Development of process monitoring tools  
27
- Process Modelling  
28
- Molecular Biology Tools  
29
- Process Automation and Control  
30
- Electrochemical Analyses  
31

### On-going funded projects in 2021  
32

### On-going agreements projects in 2021  
36

### SCI research papers published in 2021  
37

### PhD thesis defended in 2021  
39

### On-going PhD thesis in 2021  
40
GENOCOV stands for **Research Group on Biological Treatment and Valorisation of Liquid and Gas Effluents**. The group is composed by researchers of the Department of Chemical, Biological and Environmental Engineering of the School of Engineering at the Universitat Autònoma de Barcelona. GENOCOV has been recognized by the Catalan University Quality System (AQU) as a reference research group (2009, 2013 and 2017 SGR).

GENOCOV, whose principal investigator is Prof. Javier Lafuente, has been active over the last 25 years in the study of biological processes for the treatment of urban and industrial water and gaseous effluents, with special emphasis on monitoring, modelling and control of complex biological systems, both continuous and discontinuous in the field of Chemical and Environmental Engineering.

The group is highly active in research, including: i) Coordination and participation in several EU projects and other projects funded by the Spanish Government, ii) Publication of more than 100 peer-reviewed publications in international journals during the last 5 years and iii) Important participation in international conferences.

The research group activities are focused on Urban and Industrial Wastewater Treatment, Valorisation of Effluents, and Characterization and Treatment of Gaseous Effluents. Research activities are developed in the following main research areas:

- Treatment and resource recovery of highly-loaded off-gases
- Characterization and biofiltration of odorous effluents
- Industrial wastewater treatment
- Recovery of biopolymers
- Microfluidic lab-on-a-chip platforms and (bio) sensors for process monitoring
- Urban wastewater treatment
- Fundamentals of bioelectrochemical systems
- Scaling-up of bioelectrochemical systems

Visit our website for further details at [www.genocov.com](http://www.genocov.com)
Personnel of the research group

Senior Researchers
Dr. Francisco Javier Lafuente Sancho, Professor
Dr. Juan Antonio Baeza Labat, Professor
Dr. David Gabriel Buguña, Professor
Dr. Mireia Baeza Labat, Associate Professor
Dr. Julián Carrera Muyo, Associate Professor
Dr. Albert Guisasola Canudas, Associate Professor
Dr. Julio Pérez Cañestro, Associate Professor
Dr. María Eugenia Suárez-Ojeda, Associate Professor

Postdoctoral Researchers
Dr. Daniel González
Dr. Chiara Pasqualetti
Dr. Mira Sulonen
Dr. Luis Rafael López de León

PhD Students
David Camilo Cueto
Pia Oyarzúa
Borja Solís
CongCong Zhang
Aina Soler
Marina Serrano
Rafael Valdés
Eric Valdés
Lluc Olmo
Laia López
Xènia Juan Díaz
Franc Paré
Pilar Sánchez
Ana Vázquez
Javier Fuentes
Óscar Guerrero
Manuel Fachal
Xudong Zhou
Alex Gaona

Technicians
Lorena Ferrer
Main research areas

Treatment and resource recovery of gaseous effluents

Biological reactors for waste gases treatment are known to work well for the treatment of large flows of gas containing low concentrations of pollutants. We have been developing a range of processes to expand their capacities to treat gas effluents containing high concentrations of pollutants. If possible, processes developed target the valorisation rather than the simple removal of pollutants.

The main cases under development are:
- Desulfurization of combustion off-gases, particularly removal of SO₂ for elemental S recovery
- Ex-situ biogas upgrading and energy-rich gases desulfurization comprising:
  - Aerobic and anoxic biological removal of H₂S from biogas
  - Biomethanation of biogas and other CO₂-rich effluents
- Composting off-gases containing large loads of NH₃

Leading researchers
David Gabriel Buguña – david.gabriel@uab.cat
Javier Lafuente Sancho – javier.lafuente@uab.cat

2021 topics
1) Modelling study on sulfate reduction using crude glycerol in UASB reactor
2) Evaluation of sulfate reduction in a sequential batch operation: experimental and mathematical modeling
3) Recovering carbon and elemental sulfur from contaminated matrices by exploiting crude glycerol
4) Development of a robust methodology for assessing biomass activity of H₂-consuming microbial cultures
Motivations

Sulfate is an anion, which widely presents in natural environments. However, high concentration of sulfate can be toxic to aquatic life. Under anaerobic conditions, sulfate-reducing bacteria (SRB) can reduce sulfate to hydrogen sulfide, which is poisonous and corrosive. Therefore, many industrial sites generate gases or wastewaters containing sulfate, that require further treatment. As an alternative to costly physical-chemical technologies, environmentally friendly, biological processes arose recently. One way is that sulfate is reduced to sulfide in an anaerobic reactor such as an UASB and subsequently, sulfide is partially oxidized to elemental sulfur in a second bioreactor under microaerobic or anoxic conditions. In this work, a 2.5 L of Upflow Anaerobic Sludge Blanket (UASB) reactor was operated to treat sulfate rich wastewaters using crude glycerol as carbon source. The mechanisms of sulfate reduction using glycerol was set up by activity test (Fig. 1). The stoichiometric equations involved in the mechanism is shown in Fig. 2. Modelling is showing as an efficient tool to test whether the experiment results follow the established mechanism, and calibrate and predict UASB performance.

Challenges

- As shown in Fig. 3, the modelling data established by the mechanism follows the experiment data, but this calibration is specific to this experiment data. It needs to validate from other experiments.
- It requires to get suitable parameters
- It still needs to test whether the kinetics and parameters that get from activity tests and literatures are well fitted to UASB reactor.

Research topics

- Activity tests
- Mathematical calculations
- Modelling including calibration and validation
Evaluation of sulfate reduction in a sequential batch operation: experimental and mathematical modeling

Motivations
Flue gases are large anthropogenic emissions of sulfur dioxide that affect deeply the environment through acid deposition, and as a second-particle pollutant it has an effect in solar radiation and human health. ENSURE project aims at treating flue gases in which the captured sulfur can be treated in a two-step biological process. In this work, the first step of the biological treatment, the sulfate reduction, was studied in a H₂/CO₂-fed gas-lift reactor (GLR) operated in a sequential batch way. Also, a mathematical modelling was proposed to characterize the biological process. The GLR batches lasted 24 hours, where solids sedimentation (outside the reactor) of 1.5 or 2.5 liters were performed as seen in Figure 1; the sedimented sludge (0.5 liters) was returned to the reactor with fresh sulfate-containing mineral medium (MM).

Research topics

Challenges
- To enhance the autotrophic sulfate reduction, maximize the sulfate conversion and characterize the kinetic performance of the sulfate reducing microorganisms in the GLR.

Plant description
The GLR was operated in 7 stages where different sulfate loads were evaluated; as seen in Figure 2, sulfate was accumulated along the batches, and in the last stage where the sulfate load was 920 ± 78 mg S-SO₄²⁻ L⁻¹ d⁻¹, the sulfate removal efficiency was 93 ± 7 %. Meanwhile, the sulfide stripping along the operation was 67 ± 20 % of the total sulfide produced per batch. Additionally, CH₄ was not observed along the process and homo-acetogenic activity took place from batches 15 to 25 as acetate accumulation reached 14 g acetate L⁻¹; this was attributed to a lost in sulfate reducing activity, and therefore, from batches 26 to ongoing, where sulfate reduction activity was recovered, acetate production was not observed, and it was not detected from batch 47.

Finally, a mathematical model was proposed, where a sensitivity analysis showed that the kinetic parameters of the sulfate reducing microorganisms were the most sensitive: the specific maximum growth rate, the active fraction of the volatile suspended solids and the sulfide inhibition constant. The model calibration resulted in the following values for these parameters: 0.52 d⁻¹, 0.11, and 800 mg S²⁻H₂S L⁻¹, respectively.
Recovering carbon and elemental sulfur from contaminated matrices by exploiting crude glycerol

Chiara Pasqualetti, PhD
chiara.pasqualetti@uab.cat

Motivations
The combustion of sulfur containing matter results in SOx formation which causes health impacts, acid deposition in the environment and visibility depletion if released to the atmosphere. The main goal of this research is to exploit the SOx contained in flue gases focusing on the biological reduction sulfate to sulfide using crude glycerol as carbon source. To achieve this goal, different analysis methods are required.

Research topics
- Liquid, gases and solids sampling from UASB reactor.
- UASB recirculation
- Sulfide production feeding SRB with glycerol
- 18S and 16S molecular analysis

Up-flow Anaerobic Sludge Blanket reactor

Challenges
- To optimize the UASB efficiency in order to maximise the sulfide production
- To acquire knowledge on the recirculation approach in order to avoid the glycerol accumulation
- To provide a full and reliable inventory of sulfate, sulfide, TOC both in the UASB influent and effluent
- To acquire knowledge on both bacteria and eukarya presence in the anaerobic sludge

Plant description
The sulfate reduction process was carried out in a 2,5L UASB reactor exploiting the recirculation approach for 90 days, using 1L of an anaerobic sludge and crude glycerol as carbon source. Both physical-chemical procedures and molecular biology techniques were used to get a broad knowledge of the anaerobic process.
In this work, The UASB reactor allowed the reduction of sulfate producing a high sulfide concentration reaching a good reactor efficiency.
Moreover, the Bacteria and Eukarya analyses were performed and both methanogenic and sulfate reducing bacteria were present in the inoculated anaerobic sludge.
This research could be not only technologically and economically feasible, but also beneficial from the environmental point of view.

Figure 1. UASB reactor. The blue arrow indicates the recirculation approach.

Figure 2. UASB performance during the long-term operation.

Figure 3. Bacteria (left) and Eukarya (right) diversity in the inoculated anaerobic sludge.
Development of a robust methodology for assessing biomass activity of H2-consuming microbial cultures

Motivations
Hydrogen Uptake Rate (HUR) tests are a cost-effective tool to characterize the biological activity of hydrogenotrophic cultures and to study the mechanisms, rates, kinetic parameters or growth yields useful for designing and modelling bioreactors. The conventional approach for a typical H2-activity test is to use a batch system as serum bottles with a H2-rich headspace and measuring the headspace pressure to assess H2 consumption. However, direct measurements of the liquid-phase H2 concentration by in-situ H2 probes demonstrated the problems associated with slow H2 transfer in past H2 batch studies, thus leading to H2 thresholds that vary considerably for a single respiratory group such as hydrogenotrophic methanogens.

Research topics
• Development of a methodology for HUR testing under pressure
• Assessing kinetic parameters of H2-trophic methanogenic cultures

Challenges
• Set up a system able to monitor H2 consumption and operate at pressure up to 5 bars under a robust, reproducible manner

Preliminary procedure
A novel experimental methodology was developed to perform Hydrogen Uptake Rate (HUR) tests to assess the influence of selected variables. Gauge pressures in the range 0-5 bars were used to ensure that H2-limiting conditions are not reached.

A 100 mL Miniclave reactor (BuchiGlas, Switzerland) was used (Figure 1). The procedure essentially consist in 1) completely filling and pressurizing the reactor at a selected pressure, 2) bubbling H2 to reach saturation, 3) injecting biomass and 4) monitoring the dissolved H2 concentration along time with a microsensor (Figure 2). This way, the effect of mass transfer limitations in the batch test are overcome. A commercial H2-microsensor from Unisense is used.

Preliminary results indicate that:
- Abiotic tests results were in agreement with Henry law prediction and allowed to determine the hydrogen saturation concentrations under different pressure conditions.
- Biotic tests allowed the determination of the hydrogen uptake rates under different pressure (1 to 4 bars)
- An increasing relation of the substrate utilization rate with the pressure of the HUR test was obtained.

Figure 1. Setup for HUR testing
Figure 2. H2 profiles under different pressure and initial dissolved hydrogen conditions
Main research areas

Characterization of gaseous effluents from industrial sites

Emissions from industrial facilities are a mixture of a large list of simple and complex volatile, organic and inorganic compounds. Many produce a physiological response in the pituitary gland. We measure odour by dynamic olfactometry while the inventory of the compounds of gas samples is assessed by TD-GC/MS.

Also, Green House Gases (GHG) such as methane and nitrous oxide from a range of sources are characterized to either assess the carbon footprint of different processes and to determine operational strategies for emissions reduction and/or treatment. The C-footprint of industrial sites is also assessed as a results of the analysis of the characterization of the emissions performed.

Sampling of point sources, surfaces and volumetric sites is performed with a range of tools including flux chambers, absorption tubes, canisters, Tedlar bags as well as the use of field sensors. Overall we are able to run complete characterization of waste gases from a variety of industrial sites such as composting piles, biofilters, WWTPs, Municipal Solid Waste Treatment Facilities, sewer networks or landfills.

Leading researchers

David Gabriel Buguña – david.gabriel@uab.cat
Daniel González Alé – Daniel.Gonzalez.Ale@uab.cat
Javier Lafuente Sancho – javier.lafuente@uab.cat

2021 topics

1) Determining the biogas recovery efficiency in Catalan controlled landfills
Determining the biogas recovery efficiency in Catalan controlled landfills

Motivations
Landfill gas (LFG) or biogas is generated when organic matter (OM) disposed in landfills decomposes anaerobically. The main components of LFG are CH₄ (55-60% v/v) and CO₂ (40-45% v/v), and it is continuously formed during decades until the majority of OM in wastes is degraded. In controlled landfills, LFG is extracted and collected through perforated wells and piping systems aiming at recovering energy and mitigating the environmental impact due to CH₄ global warming potential. However, there is not a solid knowledge on which is the real efficiency of the biogas recovery systems installed in Catalan landfills -which has been generally determined by theoretical models such as IPCC Waste Model or LandGEM Model-, as fugitive CH₄ emissions are difficult to determine experimentally in such heterogeneous systems. In this sense, the aims of this research are to develop & prove a methodology to experimentally determine the biogas recovery efficiency, which could be used in different controlled landfills in Catalunya with different characteristics, and to check if there are significant deviations from theoretical model’s outputs.

Research topics
- Gas sampling & analysis methodology applied on controlled landfills.
- Characterization & quantification of the emission fluxes found in controlled landfills.
- Modelling to estimate the CH₄ generation & fugitive emissions in controlled landfills.
- Assessment of the biogas recovery efficiency in controlled landfills.

Challenges
- To develop an efficient & robust methodology for the determination of CH₄ & CO₂ emission fluxes in controlled landfills.
- To prove the developed methodology in a real controlled landfill in Catalonia.
- To assess both theoretically (IPCC Waste Model) and experimentally the biogas recovery efficiency in a real controlled landfill in Catalonia.

Brief description of the methodology
A planification of the sampling points over the surface of the landfill must be performed prior to any field measurement, following statistical recommendations as the ones given by the UK Environment Agency. CH₄ & CO₂ emission fluxes are measured directly in field using a flux chamber coupled to specific detectors to register the variation of each compound's concentration inside the chamber along sampling time, which normally lasts about a minute. This process is repeated in all the sampling points distributed over the surface of the landfill to obtain an emission distribution map of the landfill and, subsequently, the global emission fluxes of both compounds. With this information plus the amount of LFG recovered it is possible to determine experimentally the efficiency of the biogas recovery system.

Table 1. IPCC Waste Model estimation for CH₄ emission & recovery efficiency at Orís controlled landfill (avg values 1991 to 2021)

<table>
<thead>
<tr>
<th>CH₄ emitted (Mg·y⁻¹)</th>
<th>1.22</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ recovery efficiency (%)</td>
<td>28.58*</td>
</tr>
</tbody>
</table>

*Average values from 2005 to 2020

Figure 1. Orís controlled landfill

Figure 2. IPCC Model outputs for the CH₄ generation, emission, recovery and recovery efficiency at Orís landfill (avg values 1991 to 2021)
Main research areas

Industrial wastewater treatment

In this line we study different strategies to treat industrial wastewater contaminated with toxic or recalcitrant compounds and nutrients by using advanced biological treatments (granular biomass for example), chemical oxidation processes or combined chemical and biological processes. Despite all the processes available for the treatment of industrial wastewater, it is still a difficult task to select a single treatment option for these wastewaters.

The selection of the most appropriate treatment depends on several challenging factors: the presence of nutrients, the nature and the concentration of the recalcitrant compounds and the transient or continuous presence of these compounds in industrial wastewaters. In addition, the load applied to the treatment plays an important role with regard to the technic, economic and environmental performance of the proposed treatment.

Leading researchers

Julián Carrera Muyo – julian.carrera@uab.cat
María Eugenia Suárez-Ojeda – mariaeugenia.suarez@uab.cat
Julio Pérez Cañestro – julio.perez@uab.cat

2021 topics

1) Study of dissolution and recovering process of cotton in Ionic Liquids
**Motivations**

The textile industry is the second most contaminant industry in the world. The amount of air and water that is polluted needs to be reduced drastically, as well as the consumption and use of new clothes.

Currently, there is a need of changing the current lineal economy into a circular economy. If this action is taken into the textile industry, it will change the way of production that it is currently being used and it will also motivate to recycle the clothes and have them as a source of textile materials.

The objective of the investigation is to find a way to recycle clothes into textile yarns obtaining them with the best possible quality. Nowadays, this process is being studied with ionic liquids and also, their good properties to dissolve cotton.

**Challenges**

Ionic liquids are fluids compound only by ions, working like salts, with a low melting point. They are formed by an anion and a cation. The cation interacts with the oxygen atoms of the cellulose and the anion interacts with de hydrogen of the O-H bonds of the cellulose. These interactions break the hydrogen bonds between the cellulose molecules and create new bonds with the ionic liquid. This way, the cellulose can be dissolved in ionic liquid.

We will study how 3 different ionic liquids (1- Allyl-3- Methylimidazolium Chloride (AMIMCl), 1-Butyl-3- Methylimidazolium Chloride (BMIMCl), 1-Butyl-3- Methylimidazolium Acetate (BMIMAcetate)) perform at different temperatures (80°C, 85°C, 90°C, 95°C and 100°C) with different weight percentages of cotton (2%, 4%, 6%, 8% and 10%) to understand the capacity of each ionic liquid for the recovery of cotton.

Cotton recovery Is achieved by adding water. Then, cotton coagulates and can be recovered. However, the bottleneck of the process is the recovery of ionic liquid. The loss of ionic liquid is the critical point to optimize because of the elevate cost.

**Research Topics**

- Study the behavior of ionic liquids at different temperatures.
- Characterize the cotton-ionic liquid mixtures in different situations.

---

**Figure 1. Cotton-BMIMAcetate mixtures with different %wt of cotton: 2%wt of cotton (a), 4%wt of cotton (b), 6%wt of cotton (c), 8%wt of cotton (d) and 10%wt of cotton (e).**

**Figure 2. Coagulated cotton during the recovering process.**
Main research areas

Recovery of Biopolymers

The new generation of wastewater treatment facilities should include the recovery of resources as added-value products. In this sense, this theme proposes the production of biopolymers (polyhydroxyalkanoates-PHA- or exopolymeric substances-EPS-) in parallel to the biotreatment of wastewater.

PHAs have properties similar to polyethylene and polypropylene and the large number of copolymers available opens the potential of synthesising biopolymers with tailored properties. So far, we are working in the enrichment of mixed populations able to meet two objectives, elimination of pollutants and production of biopolymers. Also, we are working in optimising the recovery process of the biopolymers from the biomass.

Leading researchers

María Eugenia Suárez-Ojeda – mariaeugenia.suarez@uab.cat
Juan Antonio Baeza – juanantonio.baeza@uab.cat
Julián Carrera Muyo – julian.carrera@uab.cat

2021 topics

1) Acidogenic fermentation of high-COD wastewaters to produce VFA streams with a constant composition in a SBR reactor
Acidogenic fermentation of high-COD wastewaters to produce VFA streams with a constant composition in a SBR reactor

Motivations
In recent years, the production of volatile fatty acids (VFAs) by anaerobic fermentation of different carbon sources has gained interest as an alternative to the traditional processes starting from petrochemical resources. VFAs are value-added products for the chemical industry as they are considered building blocks. Moreover, VFAs have also potential applications as renewable feedstocks in several processes, to name a few: polyhydroxyalkanoates (PHA) synthesis, production of electricity in microbial fuel cells (MFCs), production of hydrogen, production of biofuel or as organic matter source for biological nutrient removal.

In our research, our goal is to develop a continuous process to produce VFA-rich streams, which are then converted into PHA in subsequent steps (Figure 1). Recently, PHAs have attracted attention because they are biodegradable and bio-based plastics with good mechanical properties, that would replace the petroleum-based ones. In order to compete economically with conventional plastic production, PHAs must be obtained from VFAs produced from waste in a microbial mixed process. Among different PHA polymers, poly(hydroxybutyrate-co-hydroxyvalerate) (P(HB-co-HV)) has been selected as the one with best mechanical properties. To obtain P(HB-co-HV) in the following stages, the effluent of the acidogenic reactor must be composed mainly by acetic acid and propionic acid.

Challenges
• To learn how to direct the acidogenic fermentation process to obtain the desired profile of VFAs by tunning the operational conditions and by mixing different kinds of substrates
• To acquire knowledge on how to maintain the VFA profile constant despite the seasonality of the wastewaters used
• To understand how to inhibit the methanogenic activity that would avoid the VFAs accumulation
• To keep the operation of the reactor stable and maintain the pH over values that could affect acidogenic activity in spite of VFAs accumulation

Research topics
• Factors impacting VFA production yield
• Factors impacting VFA distribution in the effluent
• Co-digestion of several substrates
Main research areas

Microfluidic lab-on-a-chip platforms and (bio) sensors for process monitoring

A crucial challenge to address in biotechnological processes is the development of automated devices for real-time monitoring of chemicals involved. The ever-increasing demand of remote autonomous field deployable analytical systems has become the driving force behind the different strategies born.

In this scenario, microfluidic lab-on-a-chip platforms excel, offering continuous tracking of chemical agents in an integrated miniaturised fashion outstripping traditional systems. With the recent advance in printing technologies, highly complex microfluidic devices can be fabricated at low-cost in a rapid manner, making microfluidics more accessible to end users.

Leading researchers
Mireia Baeza Labat – mariadelmar.baeza@uab.cat

2021 topics
1) Inkjet/Screen/3D-Printed sensing platforms for biotechnological applications
Printed-electrodes sensing platform for the detection of \( \text{H}_2\text{S} \) and pH

Motivations

Heavy industrialization has produced the accumulation of hazardous chemical compounds, disrupting many of their natural cycles of regulation. This has led to severe consequences in terms of environmental damage and human health issues. With the objective of combating the further spread of hazardous contaminants, several new treatments have been developed for wastewaters. In order to effectively implement them there has also risen the need for new miniaturized, robust, durable and fast sensing platforms. In order to accomplish it, many innovative technologies have been recently developed. Among them, maskless printing outstands as an economic, highly reproducible and capable of mass production method. It can produce small, flexible and conductive devices (Figure 1).

![Image of small, flexible and conductive device](image)

Figure 1. Inkjet printing sensors are small and flexible

Research topics

- Dissolved gases analytical quantification in aqueous and complex matrix samples.
- Characterization and quantification of the contaminants generated in different sewage sludge biological treatment processes.
- Electrochemical and optical sensors improvement.

Challenges

- To increase the sensors repeatability, robustness and lifetime.
- To fully build the platform through an automated process by means of mask-less printing.
- To characterize the response of the sensors according to the reactor’s needs.
- To incorporate the final platform into a bioreactor and effectively monitor its activity.

Sensors descriptions

The platform is composed of an amperometric sensor for the \( \text{HS}^- \) detection and a potentiometric pH sensor (Figure 2). Bisulfide concentration is quantified by applying a potential higher than 0.01 V and measuring the resulting current when the signal stabilizes. By continuous addition of \( \text{HS}^- \) solutions of known concentration the response of the sensor is characterized (Figure 3), allowing the measurement of samples with unknown concentration.

![Graph of current intensity vs. time](image)

Figure 2. \( \text{H}_2\text{S} \) inkjet printing sensor layer by layer schematics

![Graph of current intensity vs. time for \( \text{HS}^- \) concentration](image)

Figure 3. Calibration of the hydrogen sulphide sensor

The pH concentration is quantified by applying a current of 0.00 A and measuring the resulting potential when the signal stabilizes. Calibration of the sensor’s response to analyte activity follows the same procedure as for \( \text{H}_2\text{S} \) sensor.
New composites for environmental and clinical applications

Motivations
Nowadays, due to industrial activities, metals and emerging pollutants can be found in the environment in hazardous concentrations. For that reason, several instrumental techniques such as AAS, ICP, HPLC, GC and spectrophotometry, among others, have been developed for the determination of metals or drugs with enough sensitivity to suit most of the environmental needs. Nevertheless, such techniques require an extensive sample preparation, expensive equipment, specialized technicians to perform those analysis and, due to the equipment used, they are not portable. In order to avoid these issues, alternative methodologies can be used. Good examples are electrochemical techniques, such as voltammetry or impedance spectroscopy. These techniques offer some advantages, like a relatively short time of analysis, low-cost equipment, no specialized personnel are required, the equipment can be portable and can be used to monitor a reactor or some other systems.

Research topics
- Composite electrodes
- Mercury nanoparticles
- Electrochemical techniques

Challenges
- To optimize the conductor material used.
- To optimize the parameters of the electrochemical techniques used.
- To have more information about the mercury nanoparticles.

Metals and emergent pollutants
To improve the detection limits and to increase the sensitivity of the selected electrode to detect Cd²⁺, Pb²⁺ and Cu²⁺ using Square-Wave Anodic Stripping Voltammetry (SWASV), mercury nanoparticles were applied on the surface of the electrode by drop-casting.(Fig.2.a).

In addition, the analysis of the three metals were performed simultaneously and in real samples obtaining positive results (Fig.2.b).

The next step would be to apply these modified electrodes to new analytes such as ibuprofen (Fig.2.c) using electrochemical Impedance Spectroscopy (EIS).

Fig. 2. a) Calibration curves for each metal, b) Standard addition for real samples; c) Calibration curve for ibuprofen
Main research areas

Urban wastewater treatment

Municipal wastewater treatment was the first research line developed at GENOCOV. The first studies were related to the experimental evaluation of configurations for organic matter, nitrogen and phosphorus removal and hence we have twenty years of experience in nitrification, denitrification and Enhanced Biological Phosphorus Removal (EBPR). In addition, we have developed configurations and control systems for achieving stable partial nitrification since 2003.

Current projects are focused in performing a deep redesign of conventional WWTP, transforming these plants into resource recovery hubs with lower energy requirements than conventional processes. Modelling and control techniques are a great expertise of the research group that is widely applied in all of our projects. We are currently studying recovery of biopolymers as polyhydroxyalkanoates, the combination of EBPR with recovery of phosphorus as chemical precipitate (as struvite), EBPR for low COD wastewaters, mainstream implementation of Anammox for nitrogen removal and increasing methane recovery during anaerobic digestion (biogas upgrading).

Leading researchers

Juan Antonio Baeza Labat – juanantonio.baeza@uab.cat
Albert Guisasola Canudas – albert.guisasola@uab.cat
Julián Carrera Muyo – julian.carrera@uab.cat
Julio Pérez Cañestro – julio.perez@uab.cat
María Eugenia Suárez-Ojeda – mariaeugenia.suarez@uab.cat

2021 topics

1) Study of the granulation process start-up in a partial nitritation system
Study of the granulation process start-up in a partial nitritation system

Javier Fuentes Izquierdo, PhD student
Javier.Fuentes@uab.cat

Motivations
Partial nitritation process combined with anammox technology allows an effective and energetically neutral alternative to conventional processes. In order to obtain a successful and stable partial nitritation process, the application of granular biomass reactors has been studied on the grounds that stratified structure, high settleability and higher retention of granular biomass, present operational advantages compared with conventional sludge.

Challenges
- To acquire fundamental knowledge on the granulation process of autotrophic aerobic sludge in a partial nitritation system.
- To establish the design parameters and operational strategy of granular reactors for the optimization of granulation process start-up.
- To evaluate long-term stability of granular biomass during continuous operation.

Plant description and main results
The sludge granulation process has been carried out, under a previously defined operation strategy, in 2 different air-lift reactors, with similar geometrical configurations (Fig.1). In order to develop granular biomass from activated sludge, performing a stable partial nitritation process, the air-lift reactors worked under sequential batch operation (SBR) and shear stress forces by applying certain air flow conditions. Allowing mature granules selection by its settleability properties.

The operation strategy established allows to improve initial ammonium uptake rate, leading to an early partial nitritation process, 8 days (Fig.2). Granular reactor, 60% of the biomass with a diameter size higher than 200 μm, was achieved in 70 days in both reactors (Fig.3). After SBR operation, an optimization of the three-phase-settler design was taken in term in order to improve long-term stability under continuous operation.

To assess the effects of the airlift reactor geometry, the main design parameters will be modified and study by using the modular reactor.

Research topics
- Fundamental basis of granulation process.
- Operational and design parameters of granular reactors.
- Partial nitritation process start-up strategy.

Table 1. Design parameters ratios. V (working volume); A_r (riser cross sectional area); A_d (downcomer cross sectional area); H_r (riser height); D_d (downcomer diameter).

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>R1</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>V (L)</td>
<td>9</td>
<td>6.6</td>
</tr>
<tr>
<td>A_r/A_d</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>H_r/D_d</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 1. (a) partial nitritation airlift reactor configuration 1 (R1); schematic illustration of the modular airlift reactor (R2).

Figure 2. Early partial nitritation process during SBR start-up of both airlift reactors. (a) R1 ; (b) R2.

Figure 3. Particle size distribution over reactor operation time. (a) R1 ; (b) R2.

Congcong Zhang, PhD
congcong.zhang@uab.cat

Student: Congcong Zhang
Supervisors: Juan A. Baeza and Albert Guisasola

Motivations
This study proposes the incorporation of a side-stream sludge fermenter (SSSF) into the current anaerobic/anoxic/aerobic (A2O) configuration to obtain a much more stable C/N/P removal: the side-stream EBPR (S2EBPR) dealing with the low COD of wastewater. In addition, it explores the possibilities to purge from the aerobic, anaerobic and SSSF reactors aiming at implementing P-recovery strategies.

Challenges
- To study the impact on performance of integrating a SSSF reactor in the A2O plant with low COD wastewater
- To evaluate the S2EBPR performance under different purging flows and positions
- To investigate the P-recovery potential of the S2EBPR

Plant description
The initial A2O configuration consisted of three continuous stirred tank reactors for simultaneous C/N/P removal, with anaerobic reactor (R1, 28 L), anoxic reactor (R2, 28 L), aerobic reactor (R3, 90 L) and settler (50 L). The additional SSSF (20 L) was installed when the A2O system reached steady state (Figure 1). The three reactors were monitored on-line with DO, pH and temperature probes connected to multimeters. DO and pH in R3 were kept at 2 mg/L and 7.5. The system was operated at room temperature. SRT was controlled by discarding a certain amount of mixed liquor from R3 or R1 in the A2O system, and R1 or SSSF in the S2EBPR system. The microbial community was analyzed by sequencing.

The operation lasted for 175 days and was divided into two periods (Figure 2): Period I and II. The most significant results are the higher P-removal capacity of the A2O+SSSF configuration compared with that of the A2O under the same limited COD_{inf} condition (350 mg/L), and that full COD and ammonium removal could be maintained in both systems. However, an increased P load to the system is also introduced, which can lead to lower effluent quality.

Research Topics
- Improvement of EBPR stability by integrating SSSF
- Performances of A2O and S2EBPR under different purging conditions

Figure 1. The integration of A2O and SSSF configuration

Figure 2. Phosphorus fate in the system of A2O (Period I) and A2O+SSSF (Period II).
Main research areas

Fundamentals and application of bioelectrochemical systems

Bioelectrochemical systems combine the metabolism of exoelectrogenic bacteria with electrochemistry. This is an emerging field and as such, high efforts in fundamental research are needed in order to optimise these systems at lab scale. The main focus of our group is to valorise industrial wastewater for hydrogen production.

The main research topics studied are:
- Efficient selection and survival of exoelectrogens from anaerobic sludge
- Optimal cell configuration and operation to minimise internal resistance and, thus, the cell efficiency
- Understand, monitor and model the role of fermenters and H2-scavengers

Also, we target systems’ scale-up. The main focus in this research line is to overcome the existing hurdles from lab to real-scale, particularly in the utilisation of real and, thus, complex wastewaters.

Leading researchers
Albert Guisasola Canudas – Albert.Guisasola@uab.cat
Juan Antonio Baeza Labat – JuanAntonio.Baeza@uab.cat
David Gabriel Buguña - David Gabriel@uab.cat

2021 topics
1) Optimization of bioelectrochemical systems in view of its industrial application
2) Future perspectives of bioelectrochemical systems for wastewater treatment and hydrogen production
Optimization of bioelectrochemical systems in view of its industrial application

Pilar. sanchez.pena@uab.cat
Pilar Sánchez Peña
Student: Pilar Sánchez Peña
Supervisors: Dr. David Gabriel, Dr. Albert Guisasola and Dra. Mireia Baeza

Motivations

Nowadays, the search for new technologies that allow providing renewable energy, besides being a little harmful to the environment, is one of the key points. One of them is the bioelectrochemical system.

This novel technology allows the generation or production of electrical energy or value-added compounds, such as hydrogen, depending on the bioelectrochemical system used. In addition, these systems make it possible to use part of the energy stored in wastewater, which is extremely high and is wasted day after day.

But despite all these advantages, they need to be optimized in terms of their design, components and scalability.

Research topics

• Amount of gas diffusion layers in MFCs.
• Techniques to deposit platinum.
• Anodes with different base material and shape.
• Different types of graphene functionalized with platinum to be used in the cathode.
• Catalyst for hydrogen production.

Table 1. Data obtained with the different platinum deposition techniques and different amount of platinum.

<table>
<thead>
<tr>
<th>Technique</th>
<th>mg Pt/cm²</th>
<th>I_max (mA)</th>
<th>mA/mg Pt</th>
<th>H₂ (m³/m³·d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brush Painting</td>
<td>0.50</td>
<td>10.6</td>
<td>1.77</td>
<td>1.98</td>
</tr>
<tr>
<td>Spray</td>
<td>0.50</td>
<td>13.6</td>
<td>2.26</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>0.24</td>
<td>5.7</td>
<td>1.98</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>0.13</td>
<td>3.2</td>
<td>2.05</td>
<td>0.86</td>
</tr>
<tr>
<td>Electrospray</td>
<td>0.50</td>
<td>13.9</td>
<td>2.32</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>0.24</td>
<td>5.8</td>
<td>2.02</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>3.1</td>
<td>1.72</td>
<td>0.82</td>
</tr>
<tr>
<td>Sputtering</td>
<td>0.01</td>
<td>2.1</td>
<td>17.5</td>
<td>0.52</td>
</tr>
<tr>
<td>Doctor Blade</td>
<td>0.50</td>
<td>7.9</td>
<td>1.31</td>
<td>1.55</td>
</tr>
</tbody>
</table>

Challenges

To improve MECs’ behavior to produce more hydrogen with better quality:

• Reducing the amount of platinum in each cathode to optimize cathode performance and avoid wasted platinum.
• Getting a homogeneous ink for cathodes, using different ink deposition: spray, electrospray, sputtering, Dr. Blade and brush painting.
• Designing, printing with the 3D-printer and testing new conductive anodes.
• Creating and testing different combinations of metals used as catalysts.
Future perspectives of bioelectrochemical systems for wastewater treatment and hydrogen production

Oscar Guerrero Sodric
oscar.guerrero@uab.cat

Motivations
Wastewater treatment is nowadays an energy-intensive process (mostly, because of the treatment of the sludge generated and the large quantities of oxygen needed). It is estimated that this process can account for 1-3% of the country's annual energy consumption in developed countries. However, wastewater should be considered a resource rather than a waste. In fact, wastewater contains many different compounds, including several of organic origin, which can range from simple hydrocarbon chains to more complex molecules, which store energy within their chemical bonds.

With this view, bioelectrochemical systems become a promising alternative to consider as it is possible to generate, simultaneously with the purification of wastewater, a certain electrical potential or value-added products, such as hydrogen.

Plant description
The MEC reactor configuration consisted of a 250 L (total working volume of 165 L) stainless steel tank containing 9 separate MEC cell cassettes that function as individual electrolysers. All cells were placed in series within the tank, so water was forced to circulate on both sides of them. Urban wastewater from the primary effluent of the Manresa's treatment plant was used in continuous mode and it was fed from a refrigerated 2000L tank without any conditioning, being refilled every 2 weeks. Furthermore, a recirculation pump was also installed to mix the liquor. Double chamber cassette type cells were used in this work. Carbon fibers were used for the anodes and stainless-steel wool for the cathodes as both materials exhibit a good compromise between price and performance. Electrodes were physically separated by an anionic exchange membrane and hydrogen was collected from each cathodic compartment. Also, for temperature cycles, an external resistance was used to achieve the desired setpoint.

Challenges
- Characterize the effect of different operational parameters in the system performance
- Search for deficiencies in current design
- Scale-up of the reactor to 1000L

Research Topics
- MEC operation
- Process optimization
- Reactor design
- Environmental engineering

![Figure 1: Exploited view of a Microbial Electrolysis Cell](image)

![Figure 2: Current density and gas characterization for different temperatures](image)
Over the years, the GENOCOV group has gained expertise in several transversal topics that are commonly used to gain knowledge in every of the GENOCOV main research lines. Such cross-topics are:

- Development of process monitoring tools
- Process modelling
- Molecular biology tools
- Process instrumentation, control and automation
- Electrochemical analyses

### Wastewater
- Combination of chemical + biological treatment. Bioaugmentation.
- Biofiltration for NH₃ and VOCs removal.

### Off-gases
- Biotrickling filters for H₂S removal.
- Conversion of chemical scrubbers into biofiltration units.
Main cross-topics

Development of process monitoring tools

Monitoring of physic and chemical parameters and biological activity is needed in any process to understand the interaction between microbial cultures and their environment. In addition to common instrumentation in most research labs, the GENOCOV group has developed several monitoring tools in the field of respirometry, titrimetry, flow injection analysis and microsensing.

A range of batch respirometric and titrimetric assays both in aerobic and anoxic conditions are used to assess biological activity of the biomasses from our experimental setups, as well as, from full-scale systems. As example, we have developed well defined tests to assess the activity of nitrifying biomass, the biological phosphorus removal capacities and the desulfurizing activity of biological samples. Often, the tests are combined with modeling tools to assess, in addition to the biological activity, the biological mechanisms as well as kinetic and stoichiometric parameters related to a particular microbial culture. An example of one respirometric assay is in the following figure.

Flow techniques such as Continuous Flow Analysis (CFA) and Flow Injection Analysis (FIA) have been developed in the GENOCOV group over the years for on-line measurement of chemical parameters in our experimental rigs. Some examples are FIA systems for measurement of nitrate, nitrite and sulfide and CFA systems for hydrogen sulfide, ammonia and ammonium. Recently, the GENOCOV group is developing custom-made microsensors for monitoring key species inside biofilms or granular biomass. Most of such monitoring efforts have been developed in collaboration with the Department of Analytical Chemistry at UAB and with the National Center of Microelectronics (CNM-CSIC).
Process modelling
Models are a powerful tool for a wide range of applications such as predict performance, generate hypothesis, plan of new experiments, etc. The GENOCOV group has a long tradition in modelling biological systems in the field of urban and industrial wastewaters and modelling of multiphase reactors for waste gas treatment.

In addition to Activated Sludge Models (ASM), specific models are developed for our reactors, and particularly, in combination with the use of respirometric and titrimetric data to determine kinetic and stoichiometric parameters during the model calibration stage. Several models have also been developed for modelling respirometric assays, packed bed-type reactors such as biofilters and biotrickling filters, granular systems such UASB reactors and GHG emissions as N₂O.

MATLAB is the platform used as standard in the GENOCOV group for most of the modelling efforts. The utilization of MATLAB linked to the mathematical optimization expertise in the group, allows the fitting of complex models using practical and structural identifiability tools as local and global sensitivity analysis, the Fisher Information Matrix, the implementation of optimal experimental design techniques for an upgraded parameter estimation and the optimization of complex systems using benchmarking frameworks.

Figure: Mathematical simulator developed in Matlab to simulate the control of oxygen of a bioreactor
Molecular biology tools
Identification of the microorganisms responsible for doing the work in our systems, as well as to follow-up the evolution of the microbial populations in our reactors are key issues that have been dealt within the GENOCOV group for many years. A range of tools have been used over the years such as cloning and sequencing, DGGE or TRFLP. However, the GENOCOV group has decanted towards the use of the Fluorescence in-situ hybridization (FISH) coupled to Confocal Laser Scanning Microscopy (CLSM) and, more recently, sequencing techniques using the 454-Roche or Illumina MiSeq platforms as part of its day-to-day routine for assessing the microbial species evolution and diversity in our bioreactors. Taxonomic analyses at different levels (species, family, group...) provide in-depth information for further correlation with bioreactor performance. Coupled to pyrosequencing, FISH probes are used for monitoring the evolution of target groups of microorganisms such as ammonium- and nitrite-oxidizing bacteria, anammox, phosphorus and glycogen accumulating microorganisms or sulfide-oxidizing bacteria, as well as other target species as shown in the following figure. In addition, automated methods for fluorescence imaging thresholding and quantification have been developed.

Figure: FISH-CLSM images obtained for bioaugmentation experiment using 5% w/w of p-nitrophenol degraders
Process instrumentation, control and automation

Scale-up of any process developed at lab-scale needs of advanced instrumentation, Control and Automation (ICA) to operate under continuous, variable conditions while performing in a robust, reliable way. The members of GENOCOV have been involved in ICA since 1994, when it was developed a multilayer monitoring and control system of WWTP with PLC for local control, three distributed computers with a SCADA for monitoring and process control, on-line analysers control and a supervisory expert system. Since that work, several on-line monitoring and control systems for different wastewater treatment processes have been designed and implemented as N/D and EBPR or partial nitrification systems based on on-line OUR or ammonium measurements, both in continuous and in sequenced operation.

The biological systems setups in the GENOCOV labs are currently automated using the available Advanced Direct Digital Control (ADD-Control) software developed in the group with NI Labwindows or with a combination of industrial PLCs coupled to NI Labview software for process monitoring and supervisory control. The instrumentation and other automation devices are industrial equipment to easy the scale-up of our developments. Most pilot and lab-scale systems in our labs operate year-round to demonstrate the long-term performance of processes. Coupled to automation, the GENOCOV group has a large experience in developing and assessing the efficiency of control strategies for biological processes. The efforts have been directed towards activated sludge systems control to maximize nutrient removal coupled to minimal energy consumption.

Figure: SMART-Plant SCEPPHAR pilot plant with its monitoring and control system.
Electrochemical analyses
The group has a research line on bioelectrochemical system (BES). These systems are characterized using the advanced microbiological tools described above in addition to many useful techniques develop for characterizing, monitoring and understanding non-biological electrochemical systems. The application of these “conventional” electrochemical techniques is nowadays a hot topic in the recently-developed BES field. The referred electrochemical techniques are current interruption (CI), electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV) or differential pulse voltammetry (DPV). These techniques aim at identifying the BES limitations to improve their performance. Among them, the use of CV to acquire information about the electron transfer interactions between microorganisms and solid anodes EIS is used to understand and quantify the different resistances in a BES in order to upgrade its design.
On-going funded projects in 2021

Project Title: HIPATIA: Towards the implementation of the concept of biorefinery and energy self-sustainability in a urban wastewater treatment plant

Project identification: Call: CTQ2017-82404-R

Funding Body: MINECO (Gobierno de España)

Participants: Albert Guisasola, Juan Antonio Baeza, Maria Eugenia Suárez, Julián Carrera, Julio Pérez

From: 01/01/2018 to 30/06/2021

Principal Investigator: Julio Pérez and Juan Antonio Baeza

Budget: 242,000 €

WWTPs nowadays consume ca. 8-15 kWh/inhabitant/year to remove COD, N and P to accomplish discharge limits. HIPATIA project aims redesigning current municipal WWTPs through:

(i) reducing the energy consumption to bring WWTP to energy neutrality or even to achieve an energy-producing treatment;
(ii) reducing the WWTP carbon footprint through the design of N₂O mitigation strategies;
(iii) introducing the concept of biorefinery through phosphorus recovery (as struvite) and hydrogen production.

For this purpose, HIPATIA proposes the use of anammox in the main water line to achieve nitrogen removal, allowing maximization of the use of organic matter for energy production (biogas and hydrogen). In particular, we propose:

(i) autotrophic nitrogen removal in a two-stage configuration, splitting partial nitritation and the anammox process to optimize each process separately, and to provide stability at low temperatures;
(ii) utilization of a small fraction of the raw wastewater to denitrify the nitrate produced by anammox;
(iii) removal of the organic matter simultaneously to biological phosphorus removal, in order to enhance net energy production (through operation at low sludge retention time);
(iv) a bioelectrochemical system (MEC) able to remove organic matter with a high energy yield through hydrogen production.

The study is conducted at laboratory scale (reactors of tens of liters) treating real wastewater. We focus on developing new configurations and control strategies in view of real application. Specific experiments are conducted for estimating optimal operational conditions to obtain the highest performance.
Emissions of SOx and NOx from flue gases require treatment before release into the atmosphere according to the current legislation. Available physical-chemical treatments used industrially are expensive and generate effluents that require further processing. Developing a comprehensive treatment process for flue gases by economical, robust and environmentally friendly, biological methods is still challenging. However, the multistage bioscrubber concept developed by UAB and UPC groups in a former project (CTQ2015-69802-C2) has been proven as technically feasible for SOx treatment and points out at a reasonable economical viability for a wide range of scenarios.

The proposed process is based on a sequential absorption step for SOx and NOx coupled to a first biological stage catalyzed by sulfate-reducing microorganisms (SRB) for reducing the sulfate/sulfite mixture from the first absorption stage to hydrogen sulfide. A second biological stage catalyzed by sulfide-oxidizing microorganisms (SOB) oxidizes hydrogen sulfide to elemental sulfur for its subsequent recovery.

Despite the concept has been proven feasible, a range of questions arising from previous results are addressed at laboratory scale for further enhancement of the bioscrubber concept. Basically, three key aspects must be improved to consider the concept applicable in practice: i) removal of NOx, which has been shown inefficient with conventional technologies, ii) sulfidogenesis, which must be improved to ensure process stability and to maximize bioreactors capacities, and iii) process monitoring, which needs of further development of analytical techniques to improve current knowledge. NOx removal will be achieved by testing different approaches from enhanced mass transfer bioreactors to new absorption drivers such as ionic liquids. Sulfidogenesis will be improved by further reactor testing and promoting the growth of acetotrophic SRB. Monitoring will be addressed both through the development of microfluidic systems for S and N species and the use of inkjet printing and the development of biofilm-based microelectrodes for volatile fatty acids analysis. Previous aspects will be complemented with the use of modeling techniques and a range of tools such as batch tests and flat plate bioreactors to determine the activity of SRB. Finally, all stages of the proof of concept will be integrated to practically assess the viability of the SOx and NOx removal process with valuable by-products generation.
On-going funded projects in 2021

**Project Title:** RECYCLES: Recovering carbon from contaminated matrices by exploiting the nitrogen and sulphur cycles  
**Project identification Call:** H2020-MSCA-RISE-2019  
**Type of action:** MSCA-Research and Innovation Staff Exchange  
**Project ID:** 872053  
**Funding body:** European Union H2020  
**Participants:** Universitat Autònoma de Barcelona, Università degli Studi di Firenze, Università di Pisa, AERIS Tecnologías Ambientales S.L., Italprogetti Spa, Pontificia Universidad Católica de Valparaíso, Prince of Songkla University, University of Manitoba.  
**From:** 01/01/2020 to 31/12/2023  
**Principal investigator:** David Gabriel Buguña (project coordinator)  
**Total budget:** 1,209,800.00 €

RECYCLES project aims to form an international and intersectoral network of organizations working on a joint research to favor the exploitation and integration of the carbon, nitrogen and sulphur cycles in bioreactors to design optimal treatment trains to recover added-value products out of liquid and gaseous effluents. The strategy will be to combine interdisciplinary approaches to:

- investigate innovative unit processes based on partial nitrification for nitrogen recycle, autotrophic denitrification for biosulphur recovery and multienzyme-based bioreactors for CO2 valorisation.
- apply technologies that are novel in this field such as moving bed bioreactors, membrane biofilm reactors and enzymatic reactors.
- combine biological processes into innovative treatment trains for wastewater treatment and biogas upgrading.

The topic will be addressed from the point of view of circular economy by exploring the potential synergies of carbon, nitrogen and sulphur cycles in wastewater and biogas treatment trains to reduce treatment costs and to increase production of added-value products. From a methodological point of view, the project targets the improvement of existing knowledge of innovative technologies based on immobilized biocatalysts as well as the demonstration of the viability of innovative treatment trains at in-silico, lab- and pilot-scale levels.

The project is interdisciplinary and intersectoral. In fact, the research teams involved include environmental and chemical engineers, biologists and bioinformaticians and mathematical modelers, while the companies are complementary being specialized in reactors design and construction and in bioprocess design and control.

Finally, the involvement of the industry will allow to receive feedbacks on the solutions needed from pilot case studies using real effluents and to effectively translate novel scientific outcomes into suitable technologies.
On-going funded projects in 2021

**Project Title:** NIMBUS!: Non-IMPact BUS: Demonstration of a biological methanation plant for sustainable urban transport

**Project identification Call:** LIFE19 ENV/ES/00019

**Funding Body:** European Comission

**Participants:** Albert Guisasola, Juan Antonio Baeza, David Gabriel, Mireia Baeza and Oscar Guerrero

**From:** 01/09/2020 to 31/08/2023

**Principal investigator at UAB:** Albert Guisasola

**Total budget:** 1,987,494 €

The transport sector demands around 30% of total primary energy consumption in Europe, but only less than 10% of the fuels used for transport are renewable. In this context, the European Union aims to achieve over 30% of energy consumption for transport from renewable sources by 2030. NIMBUS will foster a more sustainable transport through circular economy. To do this, the project will use biomethane, a renewable and unlimited fuel generated from sewage sludge and the surplus of renewable energies, as fuel for one bus in Barcelona.

Nimbus is a European project co-funded by the LIFE Programme that aims to promote circular economy by generating biomethane from sewage sludge and power-to-gas technologies and using it as a sustainable fuel for public transport

**Main outputs**

- Reduction of a public bus carbon footprint by over 85% by using biomethane as fuel
- Increase of almost 70% of the energy obtained from biogas due to the storage of renewables through biological methanation

**Secondary outputs**

- Production of 4 Nm³/h of biomethane through biological biogas methanation that will be used to fuel one public bus, which will run 48,000 km on renewable biofuel
- Reduction of 9% of CO₂ emissions on the bus line where the biomethane fuelled bus will be tested
- Development of a business model for biomethane in the site of Baix Llobregat WWTP

**Project partners**
On-going agreements in 2021

Project Title: Grupo de investigación de calidad. Pla de Recerca de Catalunya.
Call: CIRIT. Generalitat de Catalunya.
Project identification: 2017 SGR 1175
Participants: GENOCOV Research Group
From: April 2017 to April 2022
Principal investigator: Javier Lafuente Sancho

Project Title: CRYSTALCRO: Optimización de la síntesis de nanopartículas de óxidos metálicos.
Funding Body: CRODA IBÉRICA, S.A.
From: 16/04/2020 to 15/04/2022
Principal investigator: Mireia Baeza.
Budget: 124,304 €

Project Title: Asesoría estudio piloto en EDAR Pinedo (Valencia).
Funding Body: Depuración de Aguas del Mediterráneo (DAM)
Participants: Universitat Autònoma de Barcelona (UAB), Depuración de Aguas del Mediterráneo (DAM).
From: 01/06/2020 to 30/05/2021
Principal investigator: Julián Carrera, Julio Pérez-Cañestro.
Budget: 17000 €

Project Title: THYROFAST: Determinació d'hormones tiroidals mitjançant plataformes microfluidiques impreses en 3D basades en nanomaterials híbrids de grafè.
Funding Body: Convocatòria d'Indústria del Coneixement 2019. 2019 LLAV 00027
From: 23/07/2020 to 22/04/2021
Principal investigator: Mireia Baeza
Budget: 20.000 €

Project Title: PRE-NIMBUS: Evaluación de parámetros cinéticos de cultivos hidrogenotróficos.
Funding Body: Cetaqua, Centro Tecnológico del Agua, Fundación Privada (CETAQUA)
From: 01/01/2021 to 30/06/2021
Principal investigator: Albert Guisasola, David Gabriel.
Budget: 10253 €

Project Title: Estudi sobre una proposta de metodologia per a l'avaluació de l'eficiència de la captació de biogàs en dipòsits controlats de Catalunya.
Funding Body: AGÈNCIA DE RESIDUS DE CATALUNYA, Direcció de Planificació Estratègica
From: 17/02/2021 to 31/12/2021
Principal investigator: David Gabriel, Antoni Sánchez.
Budget: 17154 €

2. Blazquez, Enric; Gabriel, David; Baeza, Juan Antonio; Guisasola, Albert; Ledezma, Pablo; Freguia, Stefano. Implementation of a sulfide-air fuel cell coupled to a sulfate-reducing biocathode for elemental sulfur recovery. International journal of environmental research and public health 18(11):-. (2021). Doi: 10.3390/ijerph18115571


10. Lopez, Luis Rafael; Mora, Mabel; Van der Heyden, Caroline; Baeza, Juan Antonio; Volcke, Eveline; Gabriel, David. Model-based analysis of feedback control strategies in aerobic biotrickling filters for biogas desulfurization. Processes 9(2):-. (2021). Doi: 10.3390/pr9020208
11. Montiel-Jarillo, Gabriela; Gea, Teresa; Artola, Adriana; Fuentes, Javier; Carrera, Julian; Suarez-Ojeda, Maria Eugenia. Towards pha production from wastes: the bioconversion potential of different activated sludge and food industry wastes into vfas through acidogenic fermentation. Waste and biomass valorization.: (2021). Doi: 10.1007/s12649-021-01480-4


15. Sanchez-Pena, Pilar; Rodriguez, Jesus; Montes, Raquel; Baeza, Juan Antonio; Gabriel, David; Baeza, Mireia; Guisasola, Albert. Less is more: a comprehensive study on the effects of the number of gas diffusion layers on air-cathode microbial fuel cells. Chemelectrochem 8(17):3416-3426. (2021). Doi: 10.1002/celc.202100908


Visit our website for further details at www.genocov.com
Improvement of voltammetric nanocomposite (bio)sensors based on graphene
Student: Jordi Rodríguez Rodríguez
Supervisors: Maria del Mar Baeza, Francisco Céspedes
Defense date: 27-01-2021

Innovative processes to integrate biological nitrogen and sulphur removal from tannery wastewater
Student: Cecilia Polizzi
Supervisors: David Gabriel (Universitat Autònoma de Barcelona), Giulio Munz (University of Florence) (cotutela)
Defense date: 17-06-2021

Autotrophic Nitrogen Removal For Urban Wastewater Treatment Based On Anammox
Student: Xenia Juan Díaz.
Supervisors: Julián Carrera Muyo, Julio Pérez Cañestro
Defense date: 6-10-2021

Assessment, modelling and mitigation of greenhouse gas emissions from water resource recovery facilities
Student: Borja Solís Duran
Supervisors: Albert Guisasola Canudas, Juan Antonio Baeza Labat
Defense date: 11-10-21

Fate of Hydroxylamine in the Nitrogen Cycle
Student: Aina Soler Jofra
Supervisors: M.C.M. van Loosdrecht (TNW); J.O. Perez Cañestro (Universitat Autònoma de Barcelona)
Defense date: 11-10-21
Mecanismes moleculars de l'eliminació biològica de matèria orgànica / nitrògen en aigües residuals complexes mitjançant sistemes basats en biomassa granular
Student: Pia Oyarzua Alarcon
Supervisor: María Eugenia Suárez-Ojeda

Monitorización y modelización de reactores sulfato reductores
Student: David Camilo Cueto
Supervisors: David Gabriel / Juan Antonio Baeza / María del Mar Baeza

Assessment and analysis of biological activity of sulfate-reducing bacteria
Student: Xudong Zhou
Supervisors: David Gabriel / Xavier Gamisans / Antoni Dorado

Optimization of microbial electrolysis cells in view of its industrial application
Student: Pilar Sánchez
Supervisors: Albert Guisasola / María del Mar Baeza / David Gabriel

Development of microanalyzers for the monitoring of sulfur species in biotechnological processes
Student: Franc Paré Estalella
Supervisors: Mireia Baeza Labat, Gemma Gabriel Buguña

New composites for environmental and clinical applications
Student: Laia López Fernández
Supervisors: Mireia Baeza Labat, Cristina Palet Ballús

Integrating Enhanced Biological Phosphorus Removal in novel WWTP in view of phosphorus recovery
Student: Congcong Zhang
Supervisor: Juan Antonio Baeza / Albert Guisasola

New configurations for Enhanced Biological Phosphorus Removal with low COD wastewaters
Student: Marina Serrano García
Supervisor: Juan Antonio Baeza / Albert Guisasola

Pilot scale implementation of microbial electrolysis cells for hydrogen production from wastewater
Student: Oscar Guerrero Sodric
Supervisor: Juan Antonio Baeza / Albert Guisasola

Study of dissolution and recovering process of cotton in Ionic Liquids
Student: Rafael Valdés
Supervisor: Albert Guisasola / Paqui Blánquez (BIO-REM)
Acidogenic fermentation of high-COD wastewaters to produce VFA streams with a constant composition in a SBR reactor
Student: Ana Vázquez Fernández
Supervisor: María Eugenia Suárez / Julián Carrera Muyo

Study of the granulation process start-up in a partial nitritation system
Student: Javier Fuentes
Supervisor: Julio Pérez Cañestro / Julián Carrera Muyo

Synthesis and characterization of reduced graphene oxide decorated with metal nanoparticles
Student: Jordi Rodríguez Rodríguez
Supervisors: Maria del Mar Baeza

Hydrogenotrophic methanation: characterization of biological activity and performance of membrane biofilm reactor
Student: Manuel Fachal
Supervisors: David Gabriel, Daniel González

Modelling biological processes coupling N and S cycles
Student: Eric Valdés
Supervisors: David Gabriel, Daniel Gonzalez, Giulio Munz

Development of automated 3D microfluidic platforms for target analytes monitoring in recovery process of value metals from discarded mobile phones
Student: David Ricart Fort
Supervisors: Toni Dorado, Maria del Mar Baeza, Conxita Lao