ETE NEXUS

FLUIR + CESAN + UFES

Ricardo Franci Gonçalves
Prof. Titular, D.Ing.
DEA – CT - UFES

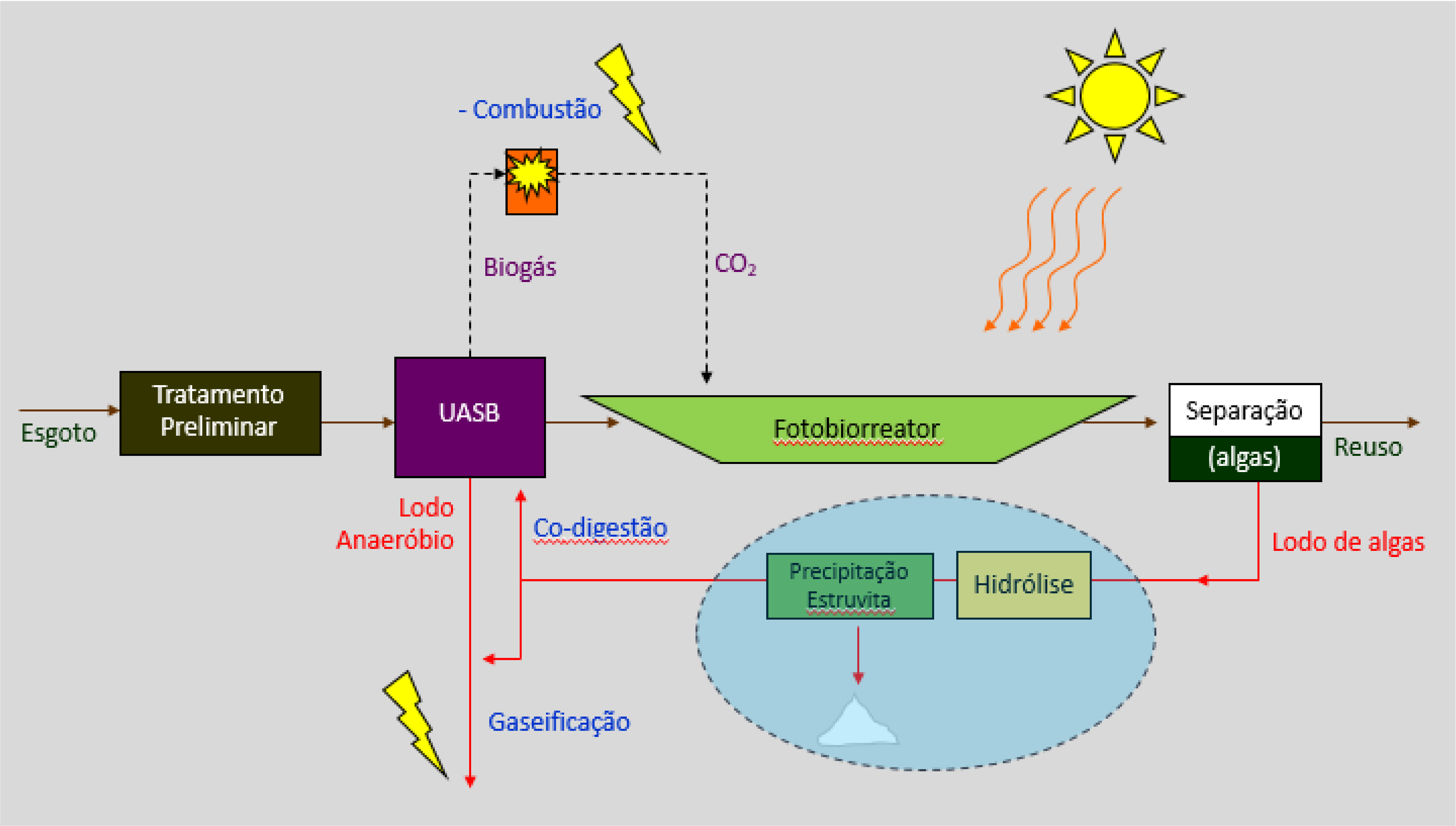


Figura 1: Fluxograma ETE NEXUS.

BREVE HISTÓRICO

1ª configuração → Palestra para diretoria da FINEP no RJ (2007)

2ª configuração → Edital FINEP 2010 → financiamento bi-lateral Brasil + Espanha:

BRASIL: CESAN + UFES e ESPANHA: AQUALIA + UNIV. POLITECNICA DE VALENCIA

3ª configuração → Seleção Pública MCTI FINEP FNDCT 02-2013

CESAN + FLUIR → UFES .... Abril 2018

BREVE HISTÓRICO

1ª configuração → Palestra para diretoria da FINEP no RJ (2007)

2ª configuração → Edital FINEP 2010 → financiamento bilateral Brasil + Espanha:

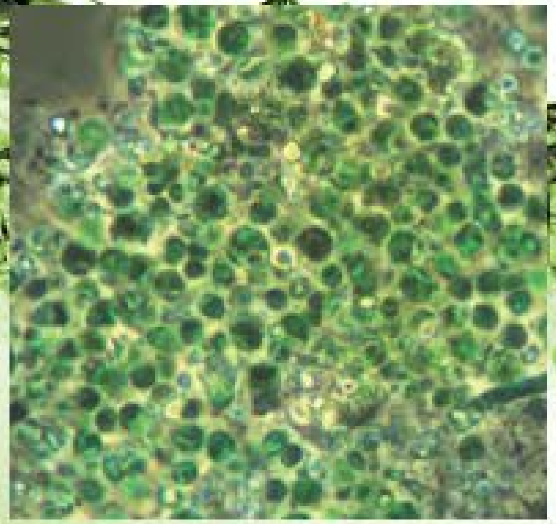
“”

BRASIL: CESAN + UFES e ESPANHA: AQUALIA + UNIV. POLITECNICA DE VALENCIA

3ª configuração → Seleção Pública MCTI FINEP FNDCT 02-2013

CESAN + FLUIR → UFES .... Abril 2018

SEVENTH FRAMEWORK PROGRAMME



Project All-gas

BIOFUELS FROM ALGAE

A MAJOR STEP FORWARD TOWARDS SUSTAINABILITY

PROJECT PARTICIPANTS

- FCC aqualia S.A. (leader)
- BDI Bio Energy International
- Hygear B.V.
- Universidad de Southampton
- Fraunhofer – Gesellschaft
- Volkswagen

DETAILS OF FUNDING

Funding: 7th Framework Programme of the European Union (FP7).

Organism: European Commission (EC).

Project: ENER/FP7/268208

Grant: Subsidy of 57% of budget.

Funding Received

Total Budget in Euro: 7,106,680 €

Aqualia: 4,646,749.91€

ALL-GAS PROJECT

SEVENTH FRAMEWORK PROGRAMME

Biofuels from algae

All-gas

aqualia

Location: EDAR El Torno, Chiclana de la Frontera, Cádiz

Estimated Duration: From the 1st of May 2011 to 9th July 2018

Total Budget in Euro: 11,820,564.14 € **Aqualia:** 8,098,099.82 €

PROJECT LEADER: aqualia (SPAIN)

PROJECT PARTICIPANTS:

· **aqualia** (SPAIN).	Alberto García Martínez jagarciam@fcc.es · Tel.:+34 917036544
· **FEYECON** (NETHERLANDS).	Mark Pages mark@cleanalgae.es · Tel.:+31 (0)294457733
· **BDI BIO ENERGY INTERNATIONAL** (AUSTRIA).	Heike Fruehwirth Heike.Fruehwirth@bdi-bioenergy.com · Tel.:+43 3164009160
· **HYGEAR B.V.** (NETHERLANDS).	Ellart de Wit ellart.de.wit@hygear.nl · Tel.:+31 651118960
· **MTD** (TURKEY).	Mustafa Kemal Öztürk mustafa@turkbiodiesel.com · Tel.:+ 90 5322142565
· **UNIVERSITY OF SOUTHAMPTON** (UNITED KINGDOM).	Charles Banks c.j.banks@soton.ac.uk · Tel.:+ 44 2380594650
· **FRAUNHOFER - GESELLSCHAFT** (GERMANY).	Axel Kraft axel.kraft@umsicht.fraunhofer.de · Tel.:+49 2088598-0

TOTAL EU FUNDS: € 7.1 million.

Project **ENER/FP7/268208**

TOTAL EU FUNDS: € 7.1 million.

Project **ENER/FP7/268208**

7th FRAMEWORK PROGRAMME OF THE EUROPEAN UNION (FP7):

The Seventh Framework Programme (FP7) brings together all of the research community's initiatives under one roof. It plays a crucial role in achieving growth, competitiveness and employment targets. It is complemented by a new 'Program Framework for Competitiveness and Innovation' (CIP), education and training programs and the Structural Funds as well as cohesive support for regional convergence and competitiveness.

SEVENTH FRAMEWORK PROGRAMME

PROGRAM DURATION: 5 YEARS

Phase1.	**Initial prototype phase. Duration 2 years.**
Phase2.	**The second phase is the construction and operation of an algae cultivation facility of 10 hectares. Duration 3 years.**

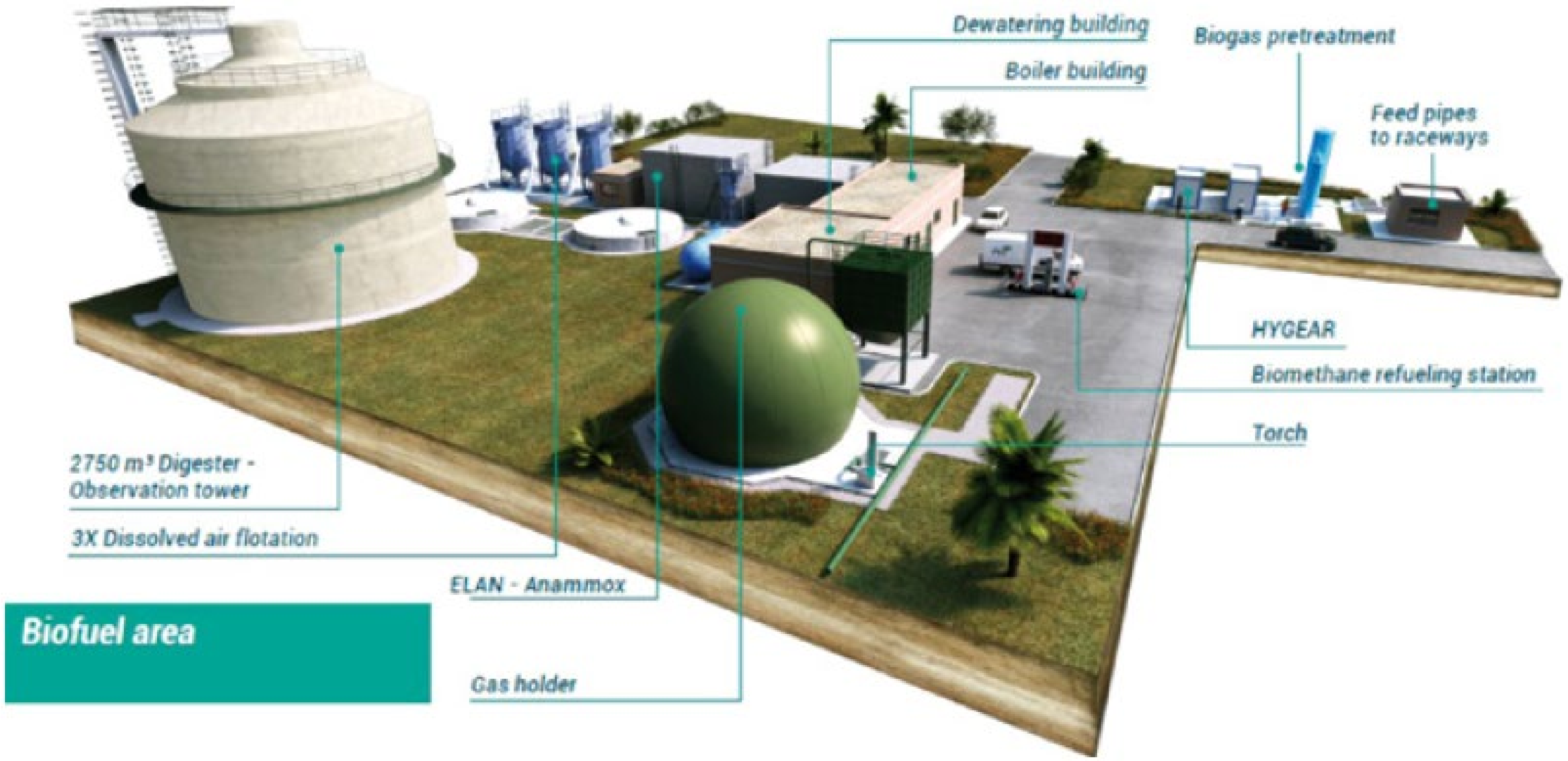
In collaboration with:

chiclana natural

FCC Citizen Services

aqualia

From dream to design to DEMO!



A long road has been covered before we could say “GO DEMO !” This final stage of the All-gas project was started in May 2016, with construction ending in December 2017. During this time, the full process chain at demonstration scale has been implemented, consisting of:

aqualia BDI Fraunhofer HYGEAR UNIVERSITY OF Southampton

Project participants

Aqualia (Spain) as coordinator,
BDI-Bio Energy International (Austria),
Fraunhofer-UMSICHT (Germany),
HyGear (The Netherlands),
University of Southampton (UK).

SEVENTH FRAMEWORK PROGRAMME

- A cultivation area composed by 4 raceways ponds with a surface area of 5 200 m^2 each in which an average of 100 ton/ha-year biomass can be produced.
- A separation and thickening system based on dissolved air flotation (3 units). At this stage the algae broth is concentrated 100 times at very low energy requirement.
- 2 750 m^3 anaerobic digester in which more than 250 L of biogas per kg volatile solid can be produced. Close to 40 cars can be run for 18 000 km each on the biomethane resulting from conversion of the algae biomass.
- A complete biogas to biomethane upgrading plant coupled to a filling station.

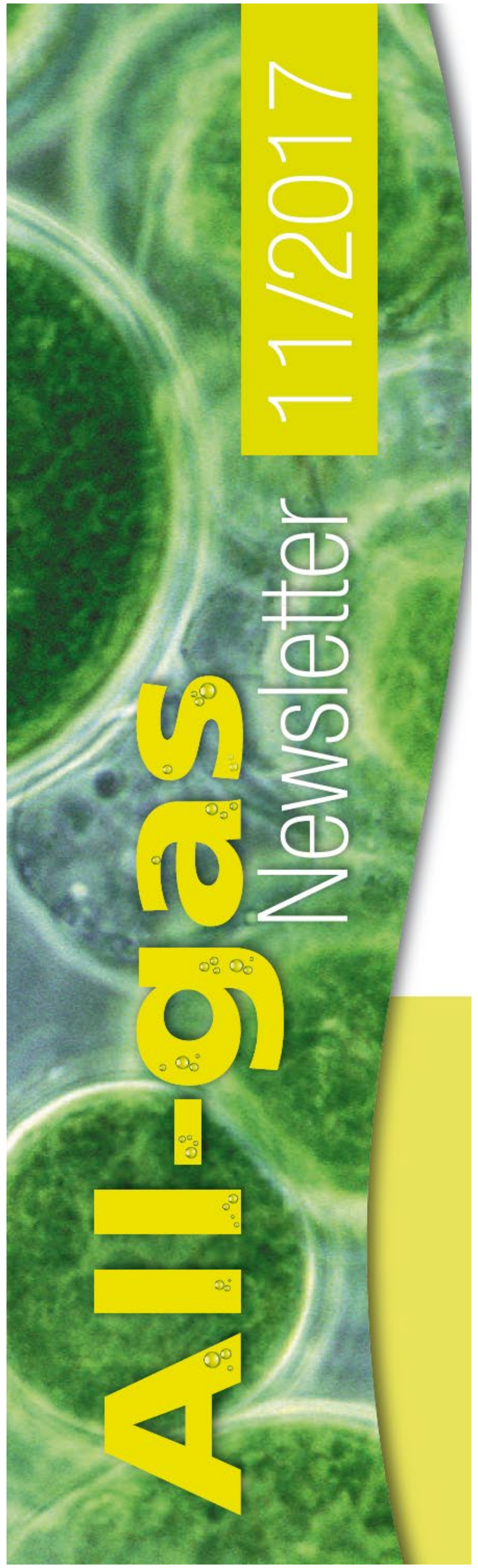
Once all the functional tests of the process units are concluded, large-scale microalgae cultivation and biogas production can start. This last phase of the project demonstrates that all the steps given above satisfy the expectations, and provides an alternative and sustainable response to the reuse of urban waste water, transforming it into a resource for the circular economy.


REMSA
VENTA, ALQUILER Y SERVICIO
954 40 50 21 SEVILLA
All-gas
Industrial scale demonstration of sustainable algae cultures for biofuel production
PARTICIPANT ORGANIZATIONS:
1. aqualia (Leader) aqualia Gestión Integral del Agua S.A.– Spain
2. BDI – BIOENERGY INTERNATIONAL A.G. – Austria
3. HYG – HYGEAR B.V. – The Netherlands
4. SOTON UNIVERSITY OF SOUTHAMPTON – United Kingdom
5. FHG – FRAUNHOFER UMSICHT – Germany
6. VOLKSWAGEN – Germany
ADVISORY BOARD COMPOSED by:
Emilio Molina, University of Almeria (Spain)
John Benemann, MicroBio Engineering, Inc. (USA),
Tryg Lundquist, California Polytechnic University (USA),
Rupert Craggs, NIWA (New Zealand),
and Charles Banks, University of Southampton (UK).
Collaborative Project

Chiclana de la Frontera - Espanha




REMSA
954 40 50 21



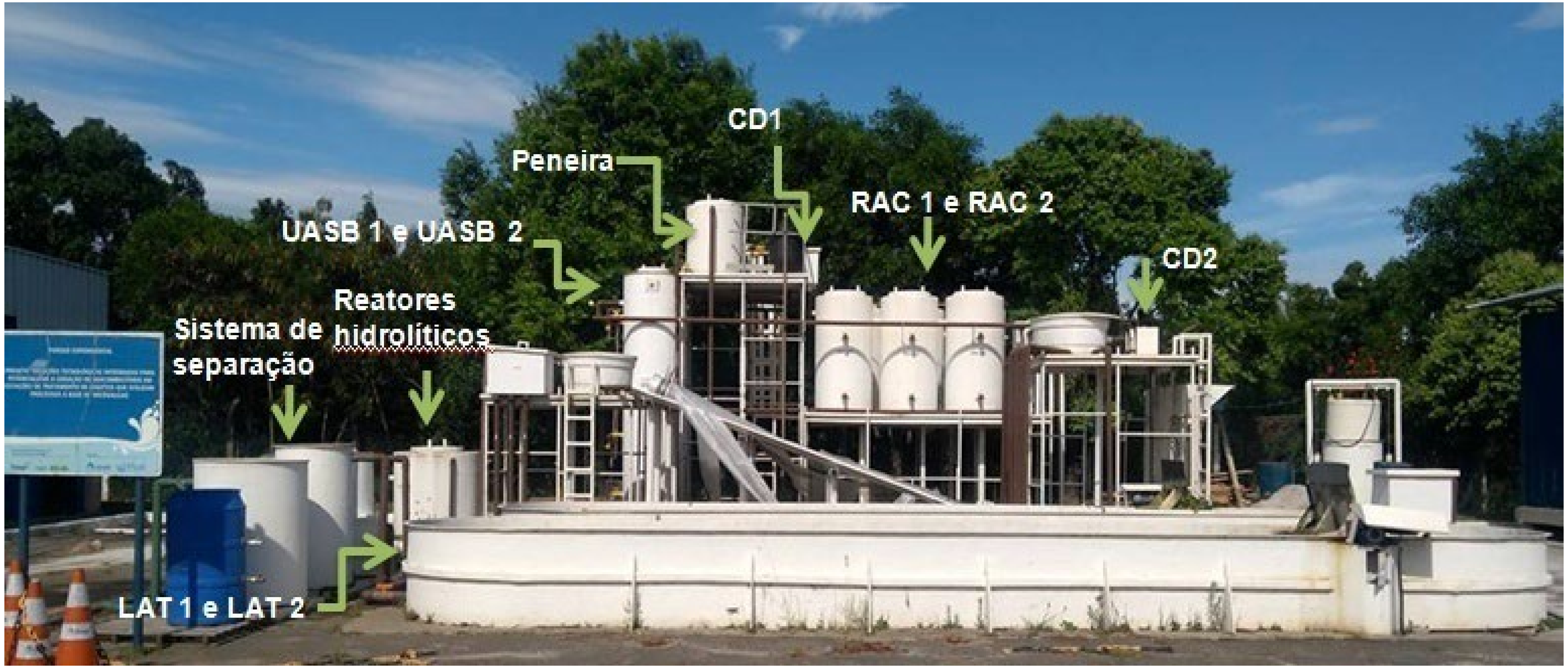
All-gas car reached 30 000 km in one year

Since June 2016 the first All-gas car has almost run around the world using the biogas produced from the microalgae grown in Chiclana and travelling an average of 80 km per day. In December 2016 VW decided to transfer to SEAT, the Spanish company of the VW group, the role of main fleet vehicle provider, which will validate the biomethane quality in long-term tests.

7 years of RTD activities


TRABALHA E CONFIA

Parque experimental de saneamento inteligente
FLUIR + CESAN



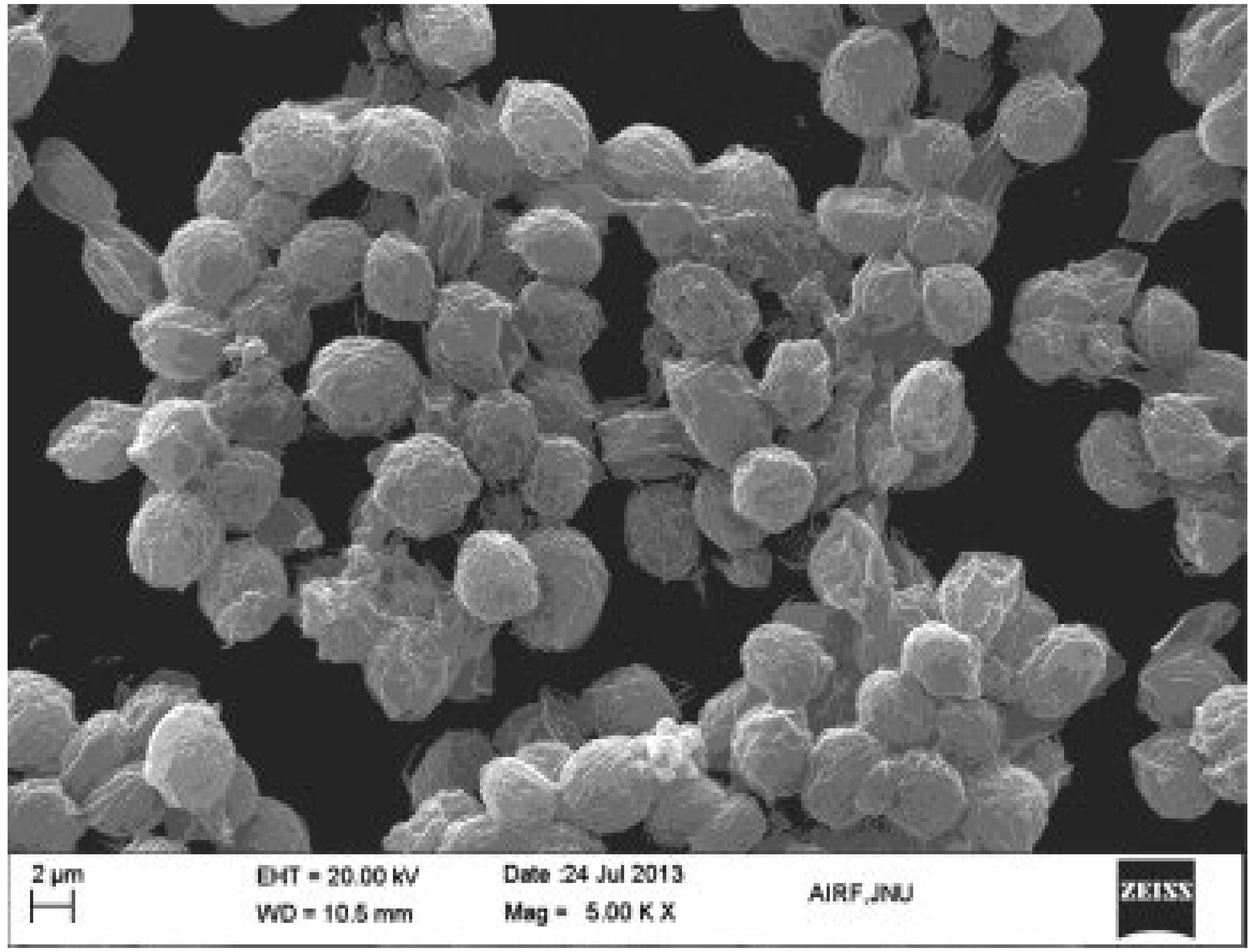
Finep EMPRESA BRASILEIRA DE INOVAÇÃO E PESQUISA
CESAN
Fluir engenharia ambiental
NÚCLEO água Núcleo de Bioengenharia Aplicada ao Saneamento da Ufes


BRUTO
UASB
LAT
LAT
FiLTRAD

Ferreira, 2017
Gavazza, 2017

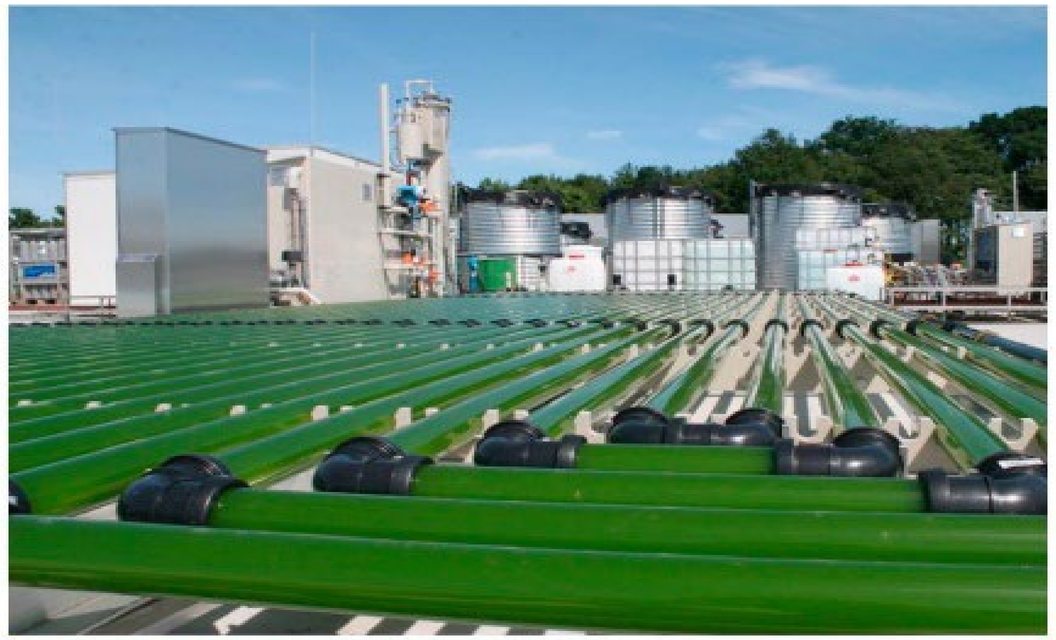
Sistemas cultivo de microalgas em escala piloto

Micrografia eletrônica - *Scenedesmus sp.*



Fonte: Tripathi; Singh; Thakur (2015).

a)

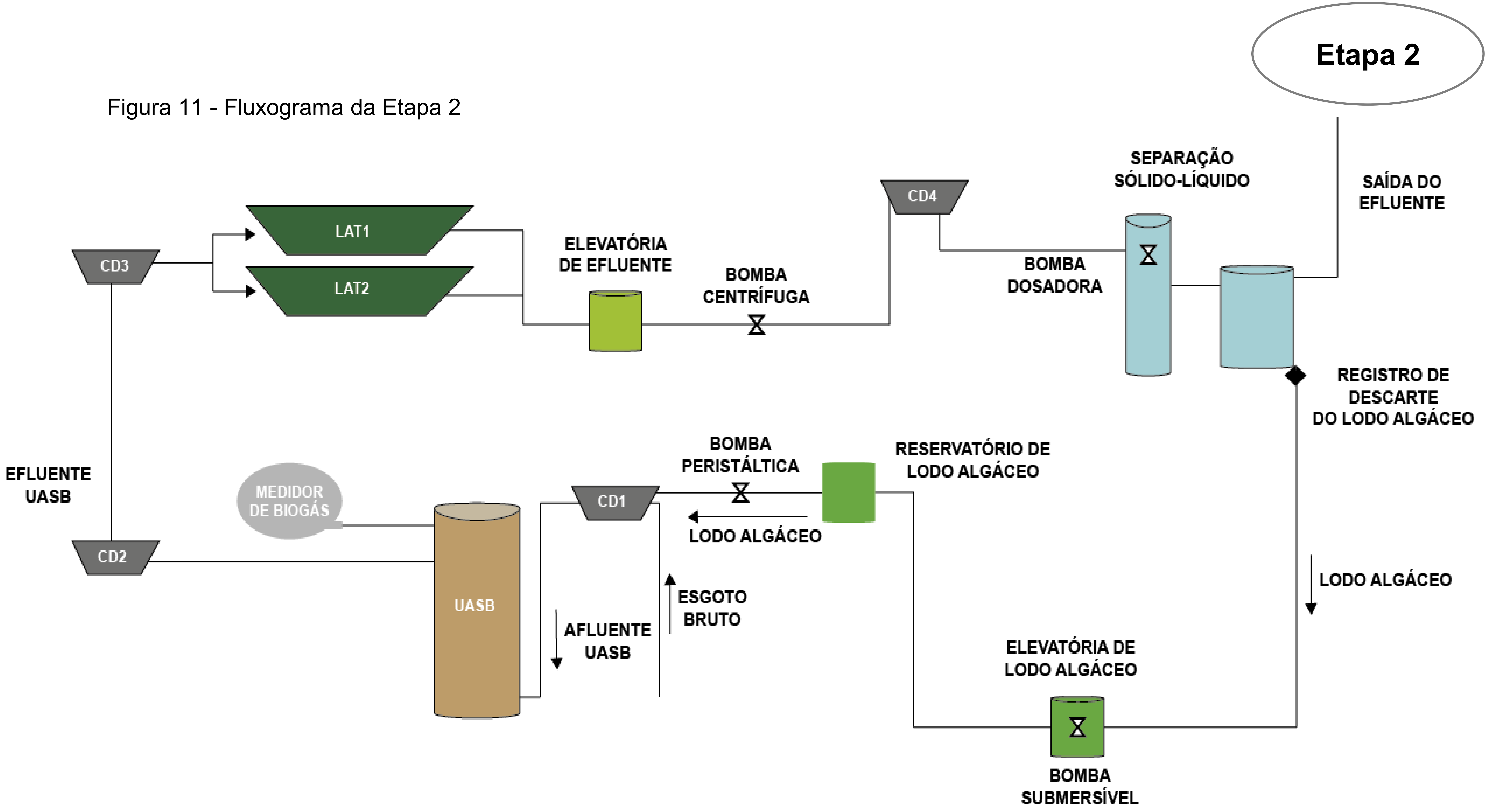


b)

c)

Fonte: Pérez-López et al. (2017).

Figura 11 - Fluxograma da Etapa 2



Etapas da pesquisa

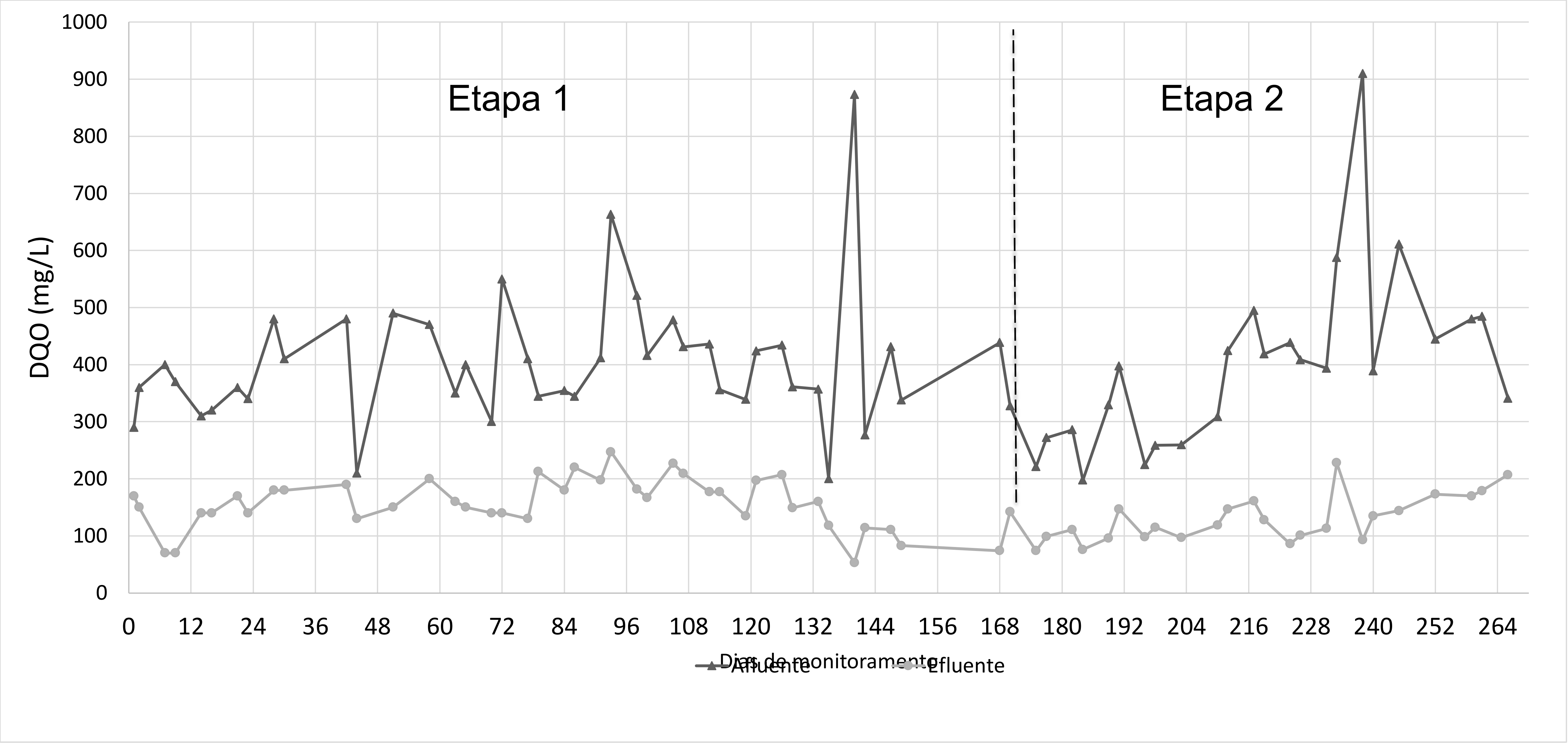
Valores médios dos parâmetros operacionais do UASB durante as etapas avaliadas.

Parâmetro Operacional	Etapa 1	Etapa 2
	Valor médio	
Vazão (L/s)	0,12 ± 0,03	0,11 ± 0,02
TDH (h)	8,8 ± 2,1	9,5 ± 1,6
Velocidade ascensional ($m.h^{-1}$)	0,55 ± 0,1	0,50 ± 0,1
COV ($kgDQO.m^{-3}.d^{-1}$)	1,14 ± 0,3	0,98 ± 0,5
CHV ($m^3.m^{-3}.h^{-1}$)	0,11 ± 0,03	0,10 ± 0,02
Carga biológica ($kgDQO.kgSV.d^{-1}$)	0,11 ± 0,04	0,09 ± 0,03

Remoção de Matéria Orgânica

Análise do efeito da codigestão anaeróbia sobre o tratamento anaeróbio

Figura 19 – Gráficos de monitoramento da DQO total e filtrada do afluente e efluente do UASB.



Eficiência de remoção:

Etapa 1

60%

Etapa 2

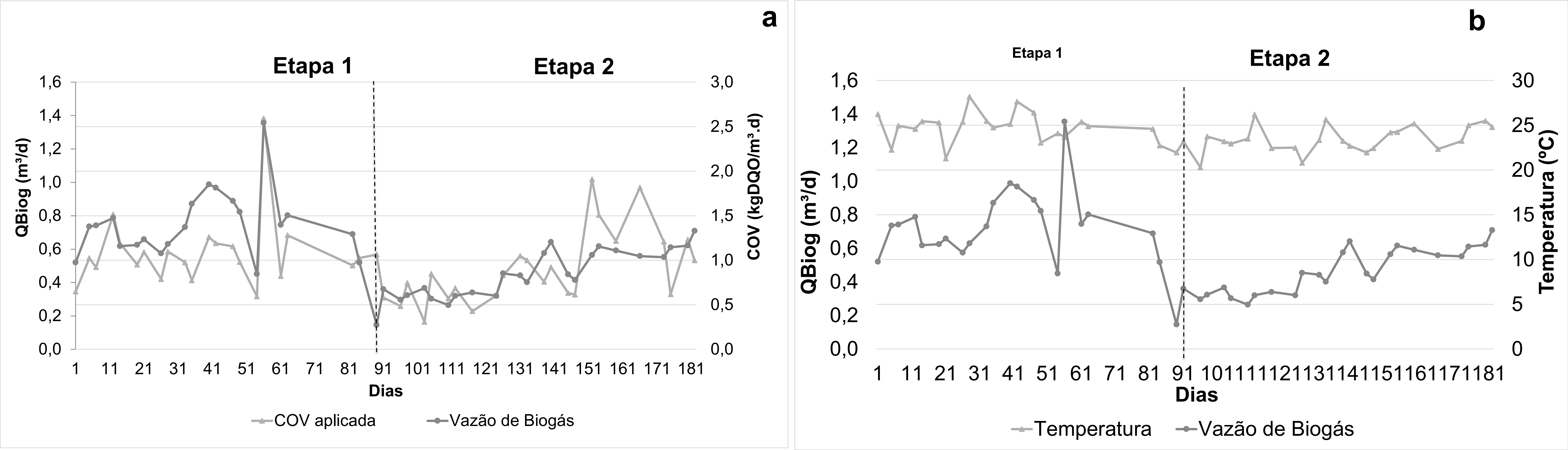
67%

Dentro da faixa citada na literatura

Avaliação do potencial energético do processo de codigestão anaeróbia

Produção de Biogás

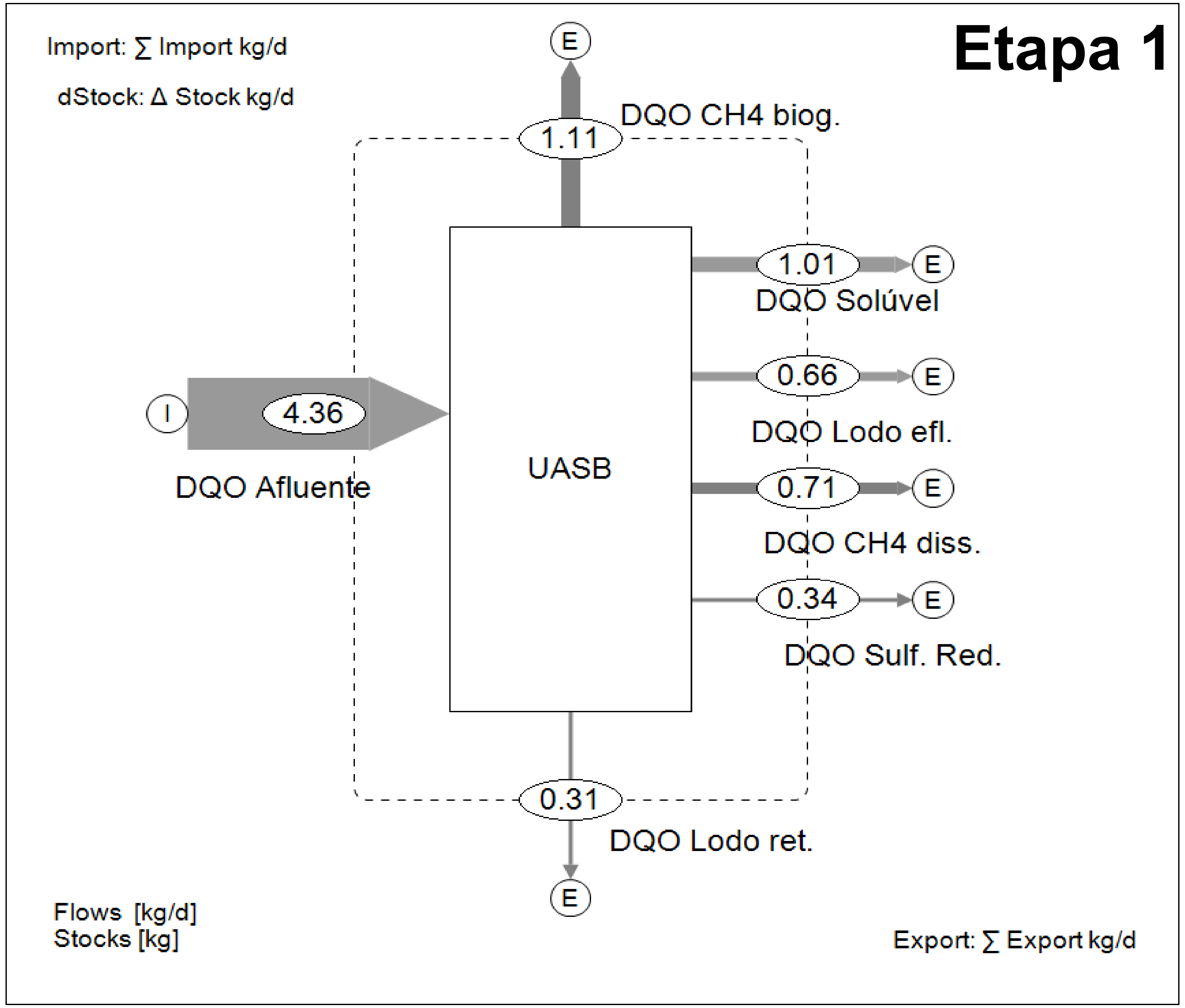
Figura 29 – Vazão de biogás e carga orgânica volumétrica aplicada (COV) (a) e Vazão de biogás e Temperatura (b)

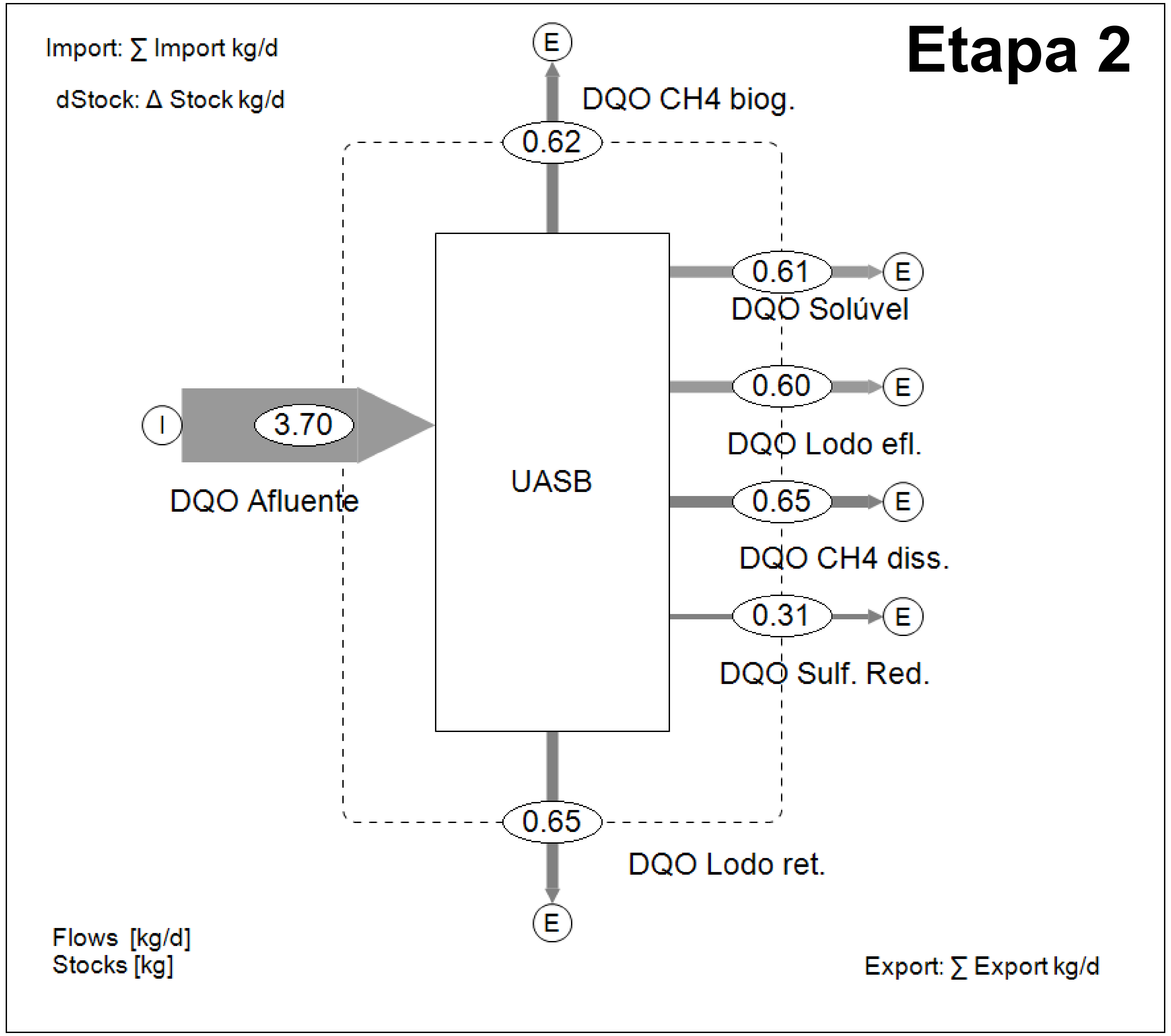


Balanço de massa de DQO

Avaliação do impacto da codigestão no balanço de massa de DQO do UASB

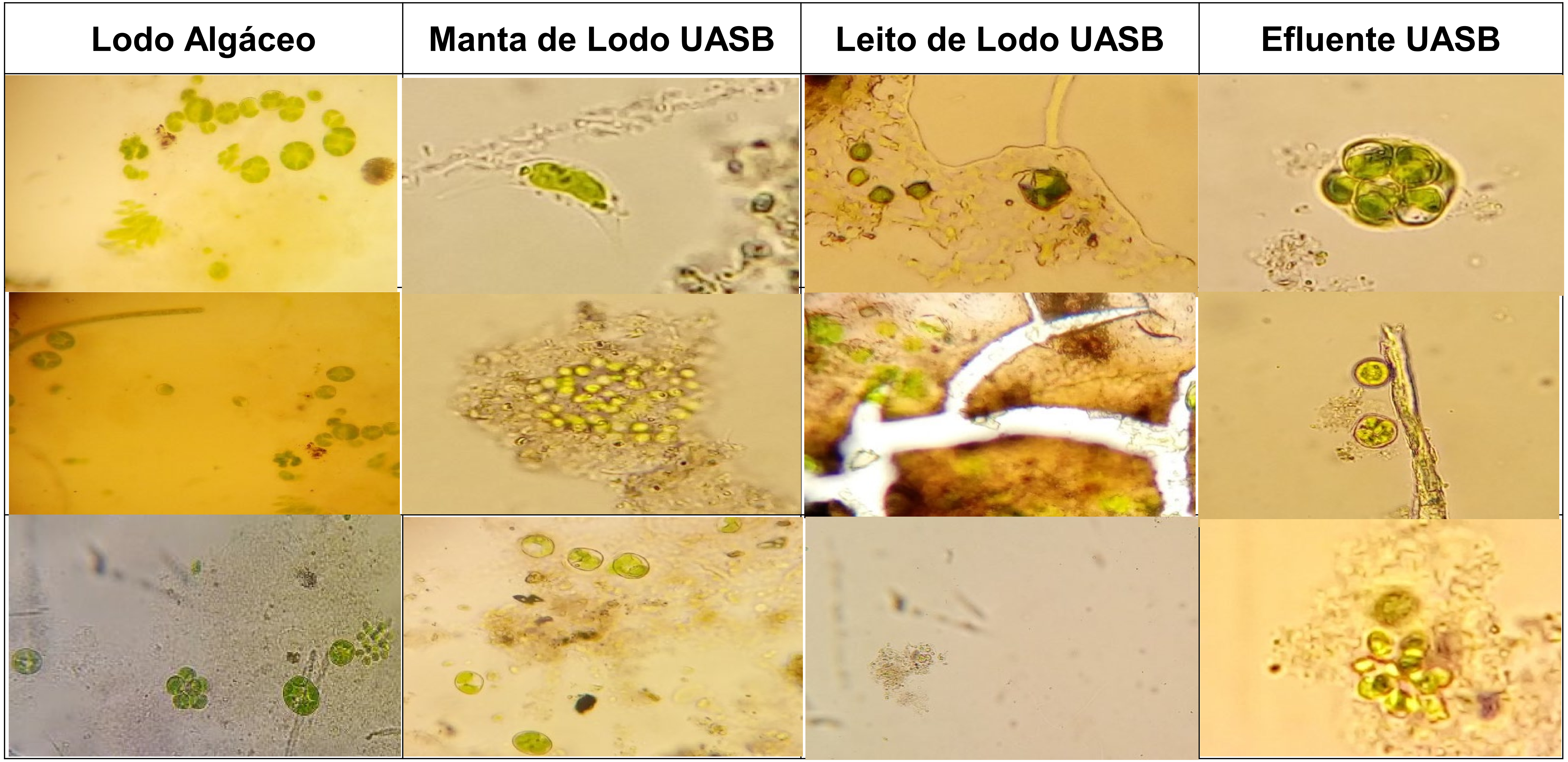
Diagrama de Sankey do balanço de massa de DQO do reator UASB





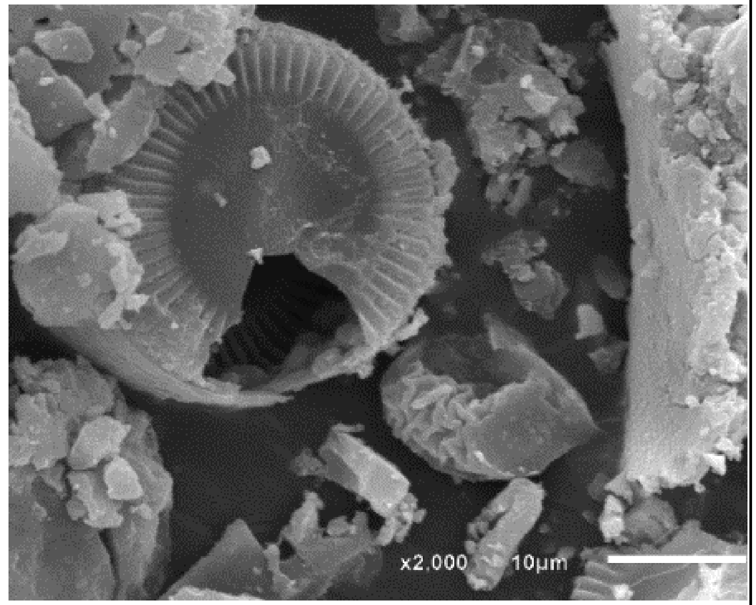
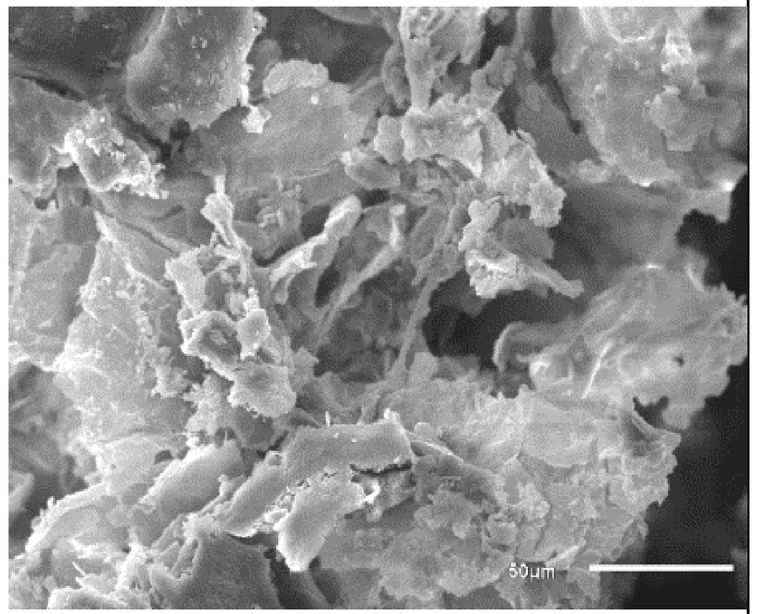
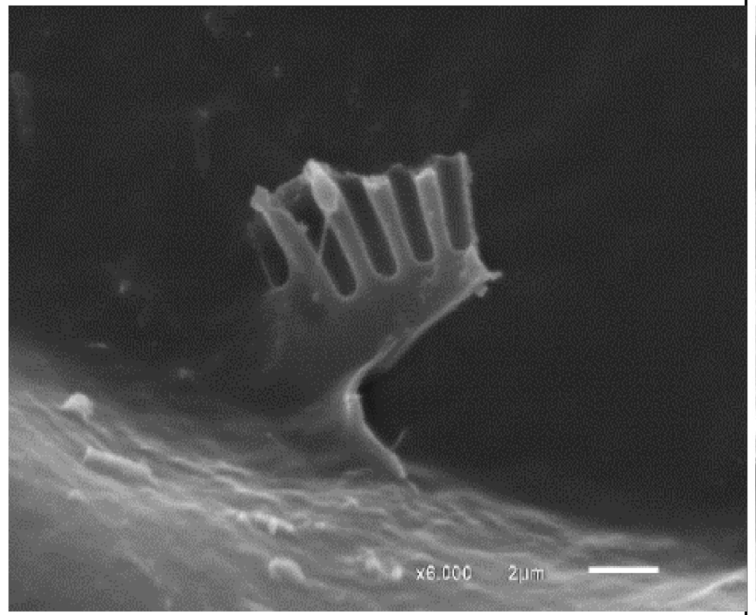
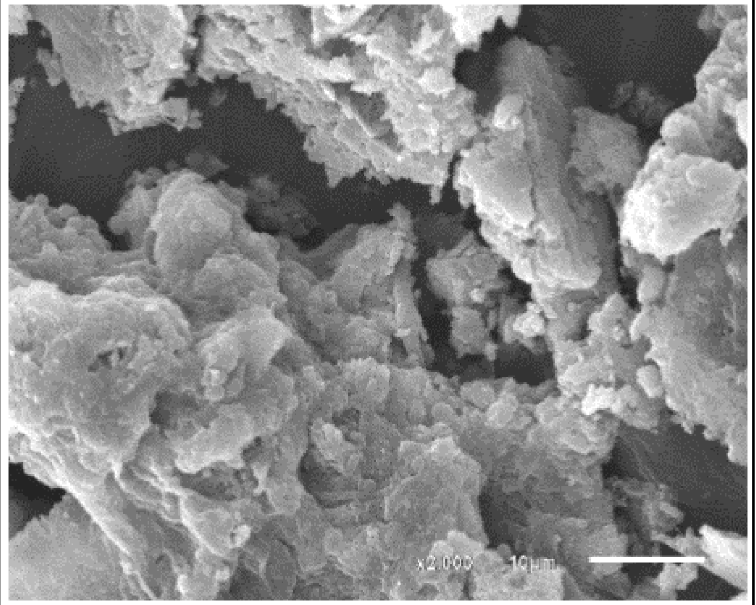
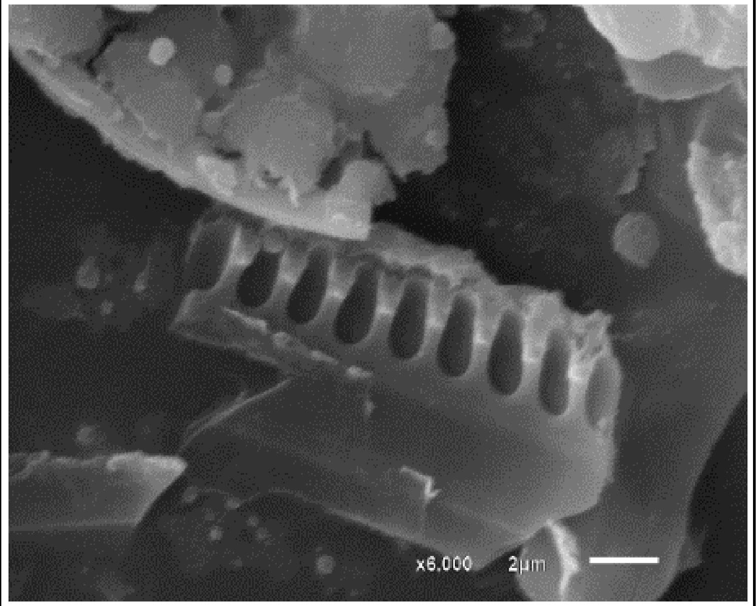
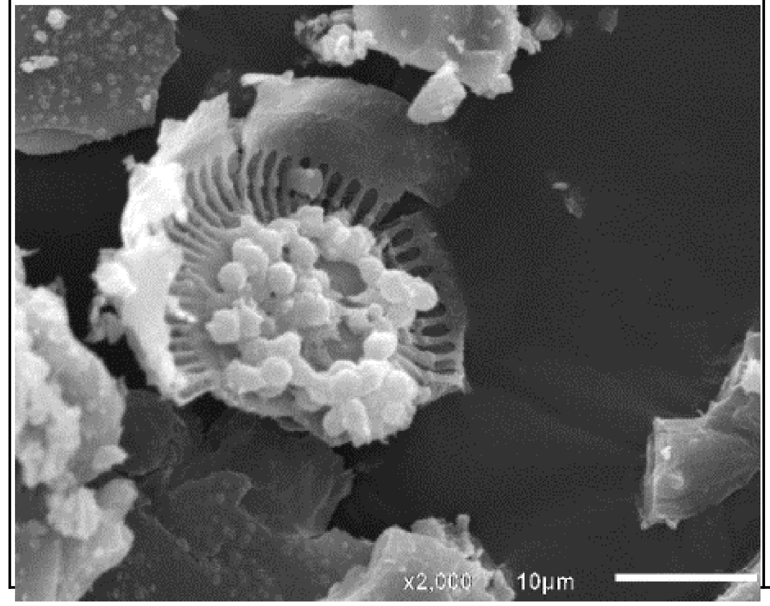
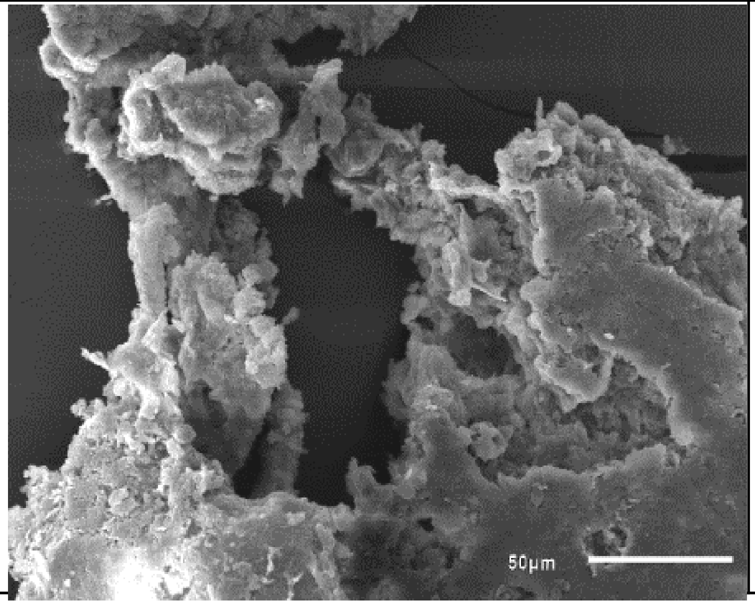
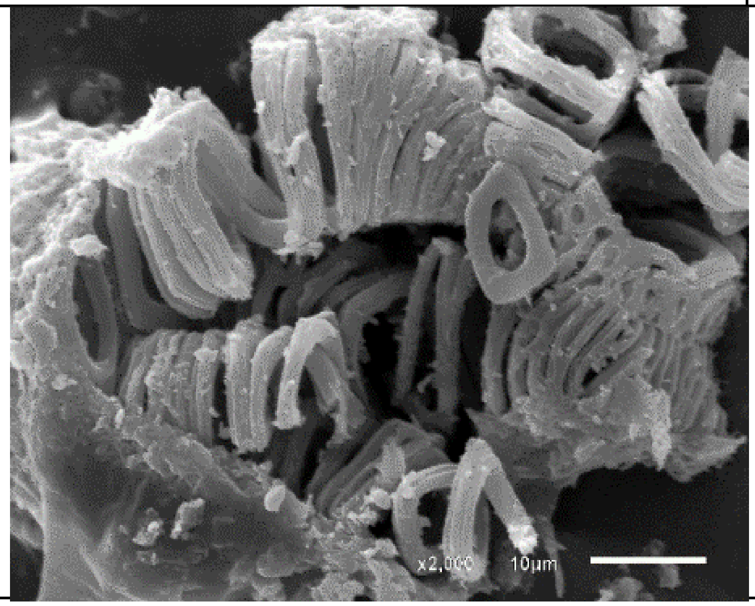
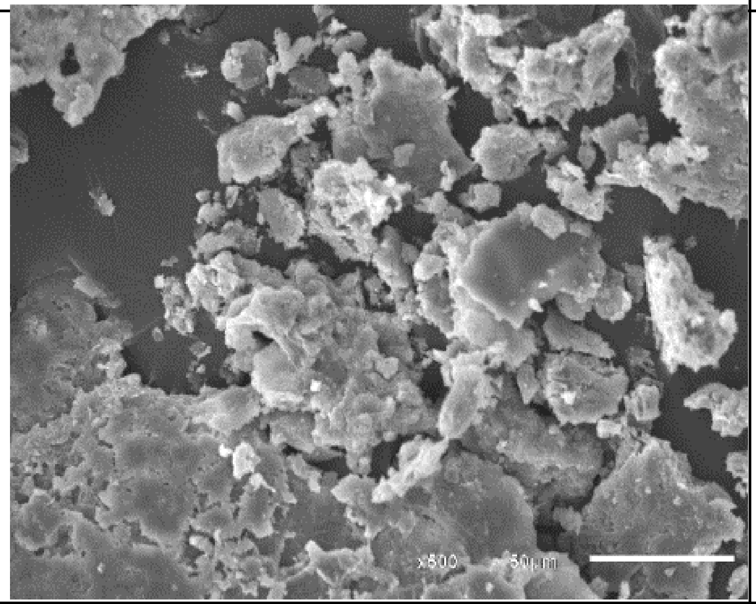
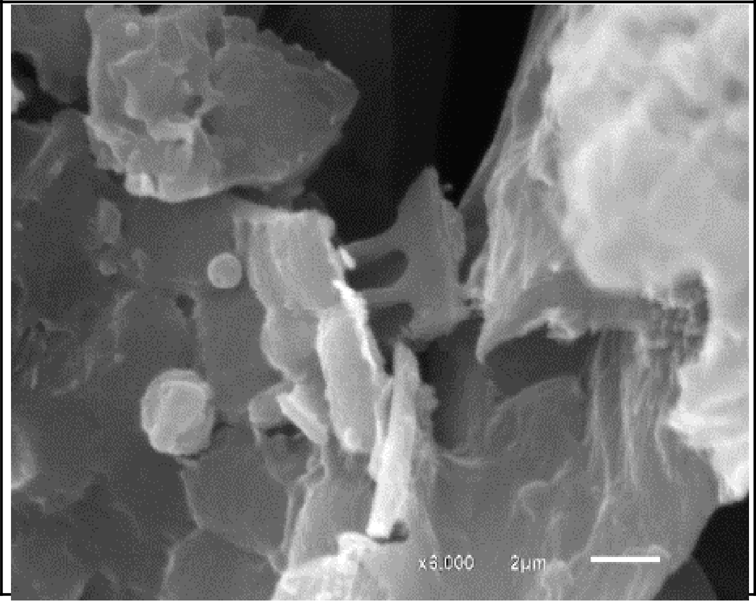
Avaliação das mudanças nas características do lodo do UASB

Figura 26- Imagens de Microscopia óptica



Avaliação das mudanças nas características do lodo do UASB

Figura 27 - Imagens de Microscopia Eletrônica de Varredura (MEV)

Lodo Algáceo	Lodo de Leito antes da codigestão	Lodo de Leito durante a codigestão	Lodo de manta antes da codigestão	Lodo de manta durante a codigestão
				
				

Algal Research 51 (2020) 102049

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Experimental investigation of wastewater microalgae in a pilot-scale downdraft gasifier

Renan Barroso Soares[a,b,c], Márcio Ferreira Martins[c,*], Ricardo Franci Gonçalves[a]

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[b] Federal Institute of Education of Espírito Santo, Avenida Min. Salgado Filho, 1000, Soteco, CEP 29106-010 Vila Velha, Espírito Santo, Brazil
[c] Laboratory of Combustion and Combustible Matter (LCC_m), PPGEM, Federal University of Espírito Santo, Avenida Fernando Ferrari, 514, Goiabeiras, CEP 29075-910 Vitória, Espírito Santo, Brazil

A R T I C L E I N F O

Keywords:
Gasification
Cold gas efficiency
Equivalence ratio
Wastewater treatment plant

A B S T R A C T

Microalgae are potential feedstock for biofuels due to higher heating value and rapid growth rate. It can be cultivated in sewage, avoiding costs associated with clean water and nutrients, making the possibility of energy generation from wastewater treatment plants appealing. Compact microgeneration systems involving biomass gasifiers are already commercialized for small-scale projects and could be adapted for use with microalgae in wastewater. In this study, an experimental investigation of a commercial downdraft gasifier was conducted using microalgae produced in a wastewater treatment plants. The effects of the air-fuel equivalence ratio on syngas composition, higher heating value, and production rates were evaluated. An increasing and then decreasing trend in equivalence ratio with a peak was observed, indicating that the optimum equivalence ratio for the best performance is 0.23. The cold gas efficiency was 87%, higher heating value was 6.2 MJ/Nm^3, and the production rate was 2.8 Nm^3/kg dry biomass. The syngas composition was 11.9% H_2, 19.5% CO, 8.5% C_xH_y, and 9.8% CO_2. The H_2/CO ratio observed in the syngas was 0.61, which is very close to the 0.60 recommended for synthetic fuel production (Fischer-Tropsch gasoline and diesel).

Algal Research 47 (2020) 101864

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/algal

Thermochemical conversion of wastewater microalgae: The effects of coagulants used in the harvest process

Renan Barroso Soares[a,b], Márcio Ferreira Martins[c,*], Ricardo Franci Gonçalves[a]

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[b] Federal Institute of Education of Espírito Santo, Avenida Min. Salgado Filho, 1000, Soteco, CEP 29106-010, Vila Velha, Espírito Santo, Brazil
[c] Laboratory of Combustion and Combustible Matter (LCC), PPGEM, Federal University of Espírito Santo, Avenida Fernando Ferrari, 514, Goiabeiras, CEP 29075-910 Vitória, Espírito Santo, Brazil

A R T I C L E I N F O

Keywords:
Microalgae
Coagulant
Catalytic effect
Thermochemical behavior

A B S T R A C T

Microalgae are a promising alternative energy source for the future due to their high growth rate, cultivation potential in a wastewater environment, and its higher heating value (HHV). However, until nowadays, only the properties for pure species of microalgae that disregard the presence of coagulants used at the harvesting stage are known. In this study, the effects of these coagulants on the thermochemical conversion of wastewater microalgae were evaluated. The results showed a catalytic effect of coagulants. Tannin-based polymer reduced devolatilization temperature peaked at 308 to 274 °C. Although the maximum devolatilization rate occurred in microalgae without coagulants, 4.57%/min at 308 °C, polyquaternium polymer accelerated the total biomass degradation. At a temperature of 892 °C, 14.1% of microalgae remained to be degraded, while in the presence of this polymer, it was only 7.5%. This coagulant presented the best results, such as low cost, high efficiency, a small reduction in HHV, and improvement in the thermochemical behavior of microalgae biomass. The aliphatic amines polymer was the only coagulant that showed chlorine in the ash analysis, preventing its release as acid gases. Therefore, it was suggested as the better coagulant along with the polyquaternium polymer. For inorganic coagulants, the large amount added prevented an in-depth catalytic assessment, and the results portray the effect of coagulant mass incorporated into microalgae more than the catalytic effect. Iron and aluminum coagulants reduced significantly microalgae HHV from 21.58 MJ/kg to 12.91–14.45 MJ/kg.

International Journal of Environmental Science and Technology
https://doi.org/10.1007/s13762-021-03430-y

ORIGINAL PAPER

Mitigation of environmental impacts in warm-weather wastewater treatment plants using the life cycle assessment tool

T. A. Rebello[1] · R. F. Gonçalves[1] · J. L. Calmon[1]

Received: 12 January 2021 / Revised: 28 March 2021 / Accepted: 1 June 2021

Abstract

Literature review provides extensive studies focused on the life cycle assessment of wastewater treatment plants. However, few studies have a mitigation perspective, especially concerning water–energy–nutrient nexus or resource recovery systems for warm-weather countries. In this context, this paper aims to evaluate 10 wastewater treatment plants, based on an upflow anaerobic sludge blanket followed by a high rate aerobic pond. The recovery of biosolids, energy, and water, thermal and alkaline hydrolysis, CO_2 recirculation to supplement carbon, and a membrane system for microalgae harvesting are tested. The paper uses the OpenLCA 1.9 software to evaluate the following categories: global warming potential and global temperature change potential (IPCC 2013); cumulative energy demand (Ecoinvent); acidification, human toxicity, marine and freshwater eutrophication, marine, freshwater and terrestrial ecotoxicity (ReCiPe (H) v.1.13 2008). Input data consist of a background (from Ecoinvent 3.5 and literature) and foreground mix. The work asses the following environmental aspects: energy, chemical materials use, transportation, and emissions. The results indicate that the scenario considering CO_2 recirculation combined with thermal hydrolysis, with higher biosolids and energy production, has the lowest environmental impact for all categories. This result was due to materials manufacture and transportation, and comparative inputs added (natural gas energy, water, and fertilizer). Additionally, transportation variation only affects highly the iron chloride supply scenario. Emissions variation impacted directly on both IPCC categories for all scenarios, due to biogas losses accounted on the upflow anaerobic sludge blanket and anaerobic digester, while energy variation did not affect profoundly any of the scenarios.

ARTIGO ORIGINAL

Avaliação do poder calorífico da biomassa algal obtida por coagulação-floculação

Evaluation of the calorific value of algal biomass obtained by coagulation-flocculation

Data de entrada: 19/08/2018
Data de aprovação: 25/08/2018

Renan Barroso Soares[1*] | Ricardo Franci Gonçalves[1] | Marcio Ferreira Martins[2] | Zudivan Peterli[3]
DOI: https://doi.org/10.36659/dae.2020.030

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Martins MF https://orcid.org/0000-0002-3023-222X
Peterli Z https://orcid.org/0000-0002-8929-0125

Resumo

A produção de microalgas nas Estações de Tratamento de Esgoto (ETE) está deixando de ser vista como um problema e passando a ser vislumbrada como matéria-prima para a obtenção de biocombustível. A biomassa algal apresenta poder calorífico superior (PCS) similar ao da madeira e pode ser usado em processos termoquímicos para a geração de energia. Contudo, essa análise requer mais atenção, uma vez que a literatura normalmente apresenta o PCS para espécies puras de microalgas e sem a presença de coagulantes. Este trabalho analisou a influência de diferentes coagulantes comerciais no PCS da biomassa algal, obtida em lagoas de alta taxa com efluente de reator UASB. Além dos coagulantes inorgânicos tradicionais, polímeros catiônicos também foram avaliados. O coagulante polímero catiônico polydadmac teve o melhor custo-benefício e o PCS deste lodo foi de 21,19MJ/Kg.

Palavras-chave: Microalgas. Esgoto. Coagulação. Floculação. Poder calorífico. Energia.

Algal Research 52 (2020) 102117

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Co-digestion of municipal wastewater and microalgae biomass in an upflow anaerobic sludge blanket reactor

Ricardo Franci Gonçalves[a,*], Tatiana Izato Assis[a], Gabriela Boechat Maciel[a], Raquel Machado Borges[b], Sérvio Tulio Alves Cassini[a]

[a] Department of Environmental Engineering, Technology Centre, Federal University of Espírito Santo, Vitória, Brazil
[b] Department of Sanitary and Environmental Engineering, Federal Institute of Espírito Santo, Vitória, Brazil

A R T I C L E I N F O

Keywords:
Biogas
Co-digestion
Energy
Microalgae biomass
Municipal wastewater
UASB reactor

A B S T R A C T

Upflow anaerobic sludge blanket reactors associated in series with photobioreactors offers an efficient and low cost solution for the wastewater treatment in small communities. However, there is little information about the performance of such anaerobic process fed with microalgae biomass from high rate algal ponds. This study aimed to evaluate the performance of a 3.78 m^3 working volume pilot scale upflow anaerobic sludge blanket reactor during anaerobic co-digestion of municipal wastewater and microalgae biomass from high rate algal ponds (13.7 m^3 each) during 365 days. To establish a basis for comparison, in the first research phase the anaerobic process was fed exclusively with municipal wastewater and, in the second phase, with a mixture of municipal wastewater and microalgae biomass. Similar organic and hydraulic loading rates were provided to the process in both research phases. The results showed a great removal of organic matter (COD) and suspended solids (TSS) in anaerobic process during the first phase (61% COD and 74% TSS) and second phase (63% COD and 74% TSS), the latter in anaerobic co-digestion. No sign of toxicity due to excess of ammoniacal, nitrogen or sulfur compounds was found. However, COD mass balance showed an increase of 54% on COD sludge retained and indicated that most of the microalgae biomass was not converted into methane. It was also observed a significant decrease in biogas production and a washout of microalgae cells to the upflow anaerobic sludge blanket reactor effluent in the second phase. The presence of intact microalgae cells retained in the sludge at all levels of this process also evidenced the incomplete anaerobic digestion of the microalgae biomass. These findings prove that an auxiliary pretreatment of the microalgae biomass is essential to improve its conversion into methane in the upflow anaerobic sludge blanket reactor.

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Autochthonous microalgae cultivation with anaerobic effluent: isolation of strains, survivorship, and characterization of the produced biomass

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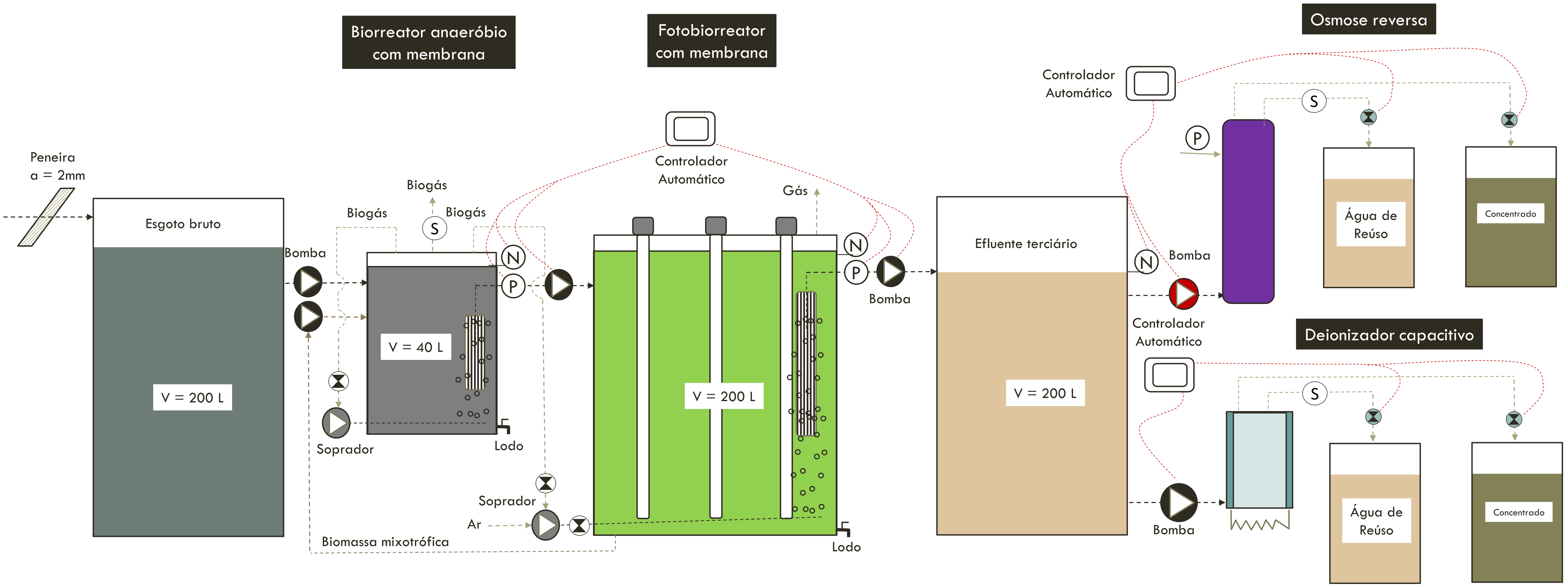
ABSTRACT

Six Chlorophyta strains were isolated from the effluent of an anaerobic reactor treating municipal wastewater and identified as *Desmodesmus* sp. L02, *Chlorococcum* sp. L04, *Coccomyxa* sp. L05, *Chlorella* sp. L06, *Scenedesmus* sp. L08 and *Tetradesmus* sp. L09. The microalgae strains were cultivated in unsterilized wastewater under laboratory conditions to determine their potential to survive under non-sterile conditions. The strains were also cultivated in sterilized wastewater in order to analyze their nutrient removal potential and characterize the produced biomass. Amongst the isolated microalgae, *Chlorella* sp. L06 had the highest survivorship percentage (90%) for ten days of culture, whilst *Desmodesmus* sp. L02 had the lowest, not exceeding 1.8% after 24h of inoculation. The dried biomass of the isolates showed an average of 28.7% of protein, 15.4% of lipids and 14.8% of carbohydrates, with *Chlorococcum* sp. L04 reaching 29.3% of carbohydrates. In terms of nutrients, nitrogen removal varied from 59.2 to 93%, and phosphorus removal ranged from 79.1 to 95.4%, with *Tetradesmus* sp. L09 being the most efficient strain.



Biorreator anaeróbio com membrana
Fotobiorreator com membrana
Osmose reversa
Deionizador capacitivo
Peneira
a = 2mm
Esgoto bruto
V = 200 L
Bomba
Biogás
Biogás
Biogás
S
N
P
V = 40 L
Soprador
Lodo
Controlador Automático
Gás
V = 200 L
Soprador
Ar
Biomassa mixotrófica
Lodo
Bomba
Efluente terciário
V = 200 L
Controlador Automático
Bomba
Controlador Automático
Água de Reúso
Concentrado
Bomba
Água de Reúso
Concentrado

RESULTADOS PRELIMINARES

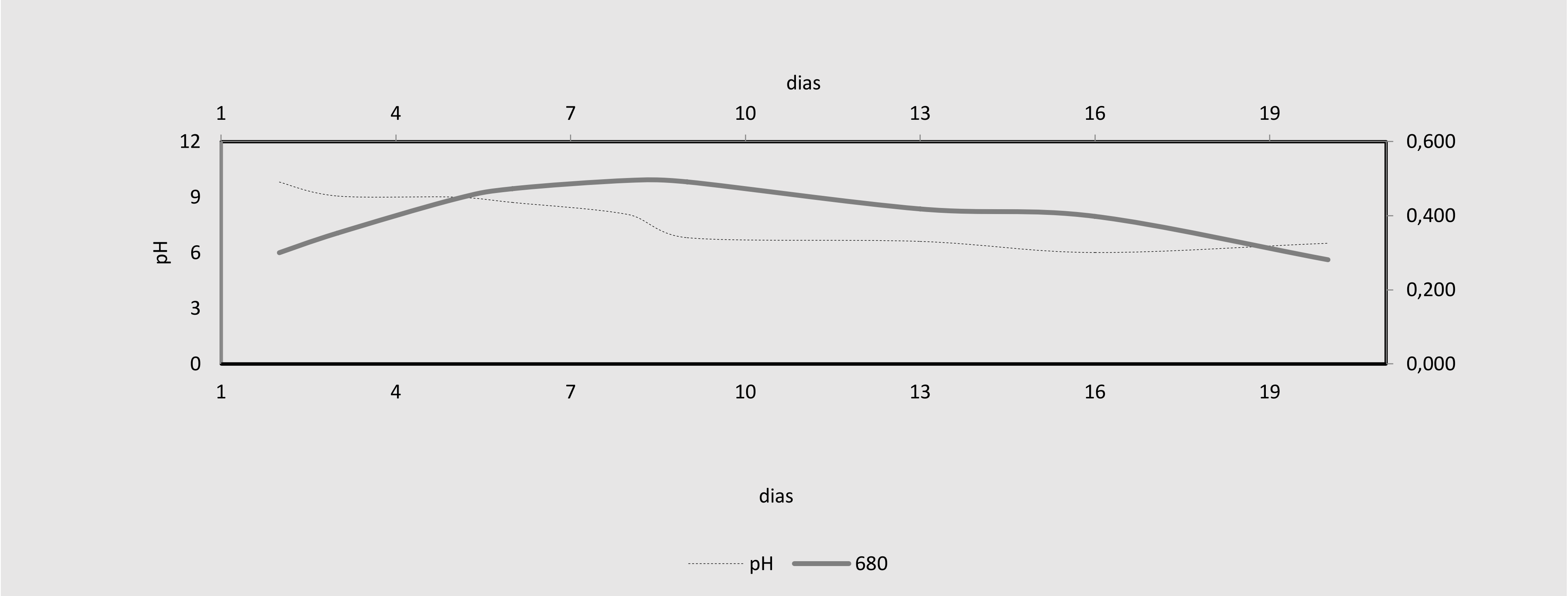
1. Prototipagem:

Tanque cilíndrico comercialmente utilizado como filtro de aquário de água marinha. Este tanque possui volume de 18L e iluminação interna com lâmpadas led de 30 Watts Branco/ 30 Watts Vermelho.

Figura 4: Modelo de tanque cilíndrico utilizado como protótipo
Fonte: Resultados originais da pesquisa

2. Start do Sistema

Construir um protótipo de fotobiorreator em batelada e **analisar** o comportamento da biomassa de microalgas durante um período de tempo.



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