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II Ciclo de 20 MasterClass

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MasterClass 20

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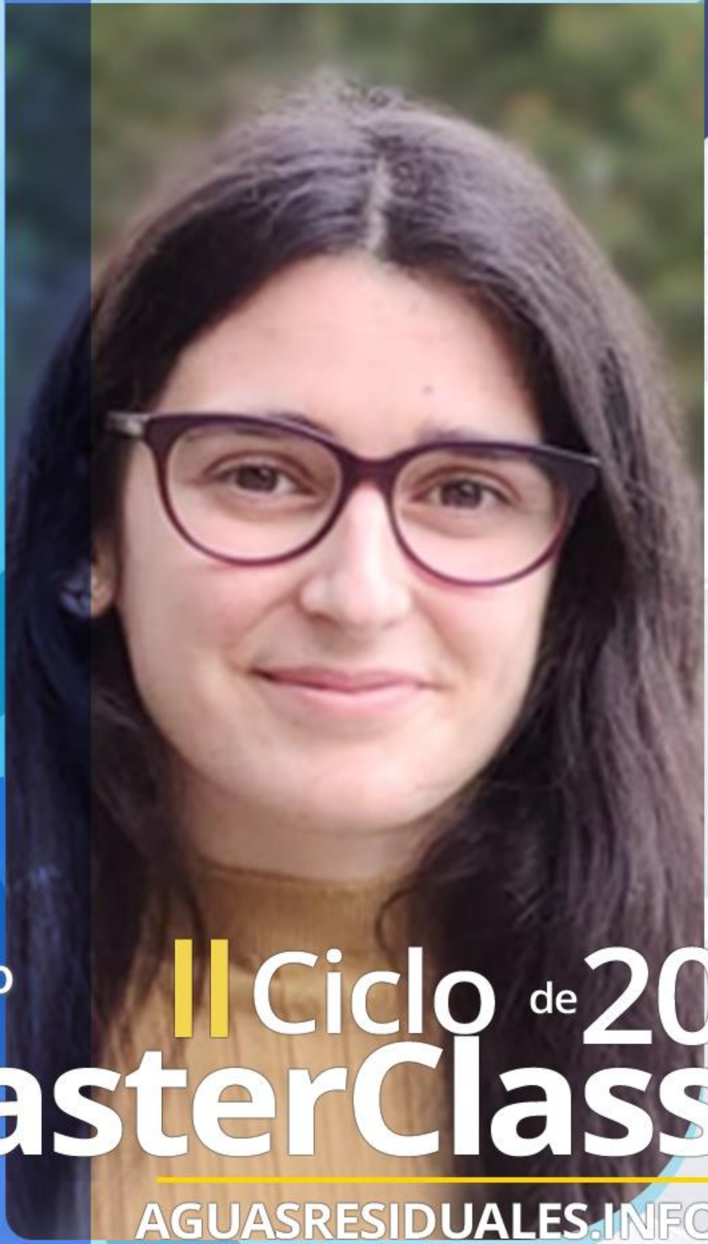
“Uso de fango aeróbico granular para el tratamiento de las aguas residuales industriales agroalimentarias”

Patrocinada por:

TORO
WASTEWATER EQUIPMENT INDUSTRIES®



Aurora Rosa

Doctoranda FPU en el programa de doctorado de Ingeniería Civil de la Universidad de Granada en el Departamento de Microbiología

Grado en Biología y Máster en Investigación y Avances en Microbiología en la UGR

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Índice

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Fango aeróbico granular

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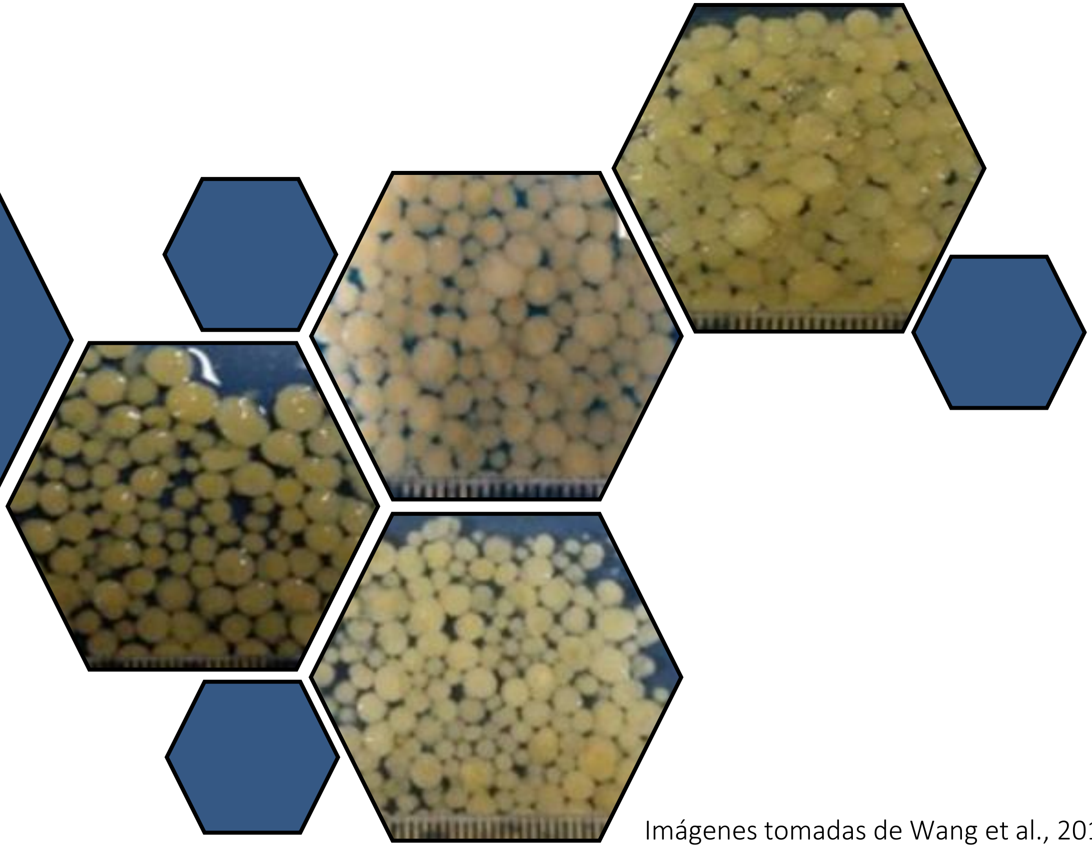
Fango aeróbico granular

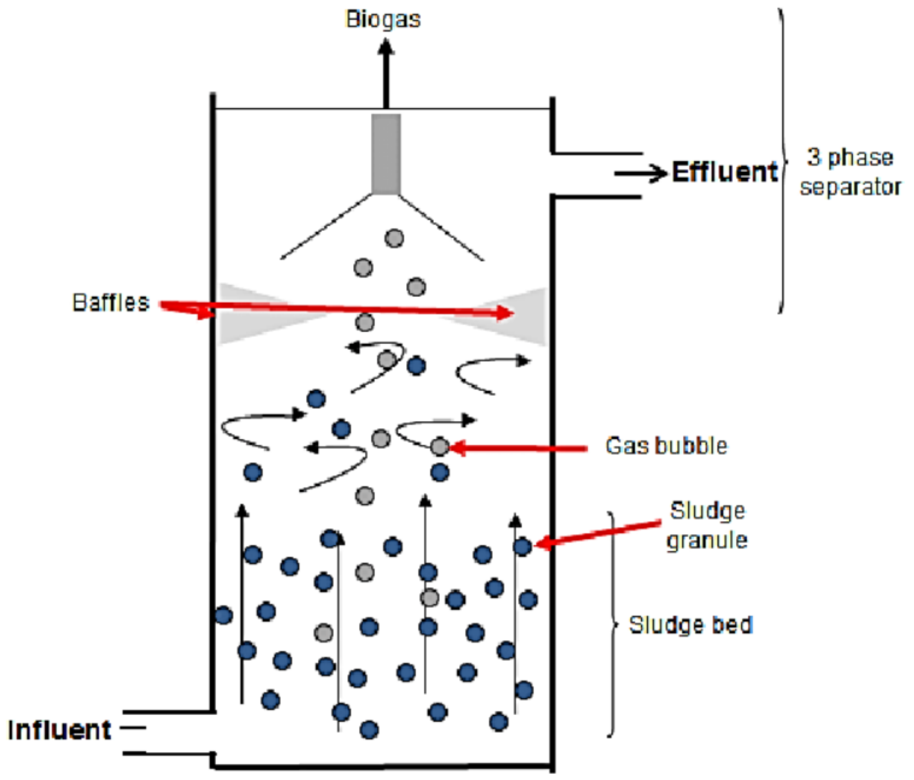
¿Qué es?



Imágenes tomadas de Wang et al., 2018

Fango granular

Lettinga et al., 1980



https://www.netsolwater.com/what-is-meant-by-the-uasb-reactor-its-working-and-quality-of-treated-water-using-a-uasb-reactor.php?blog=30

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Fango granular

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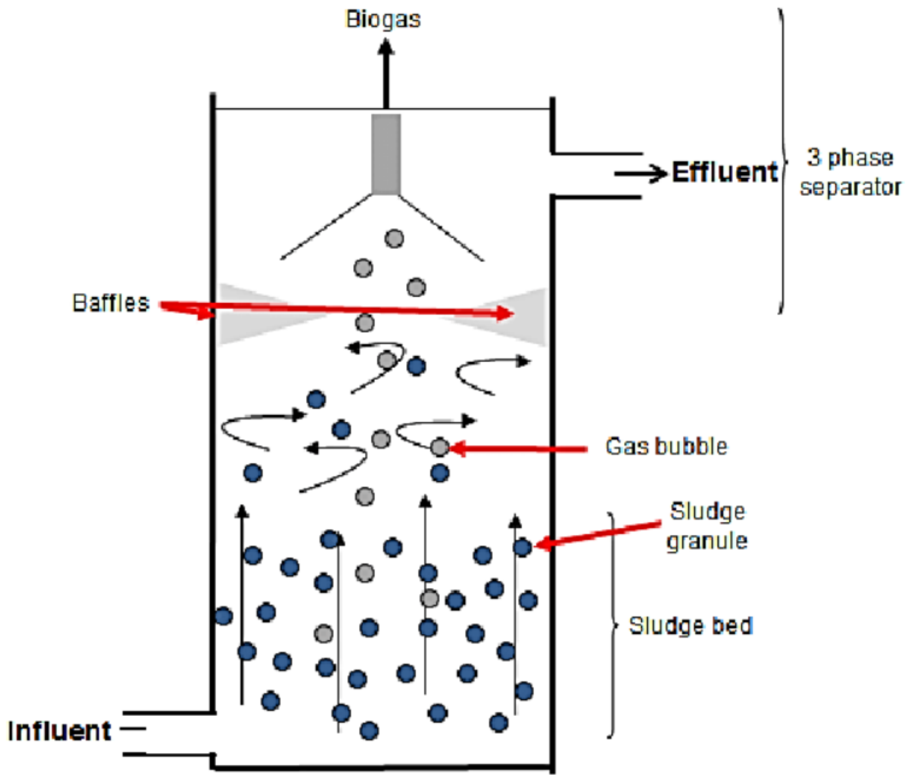
Lettinga et al., 1980

Beneficiado por

Bajo TRH

Alta carga orgánica

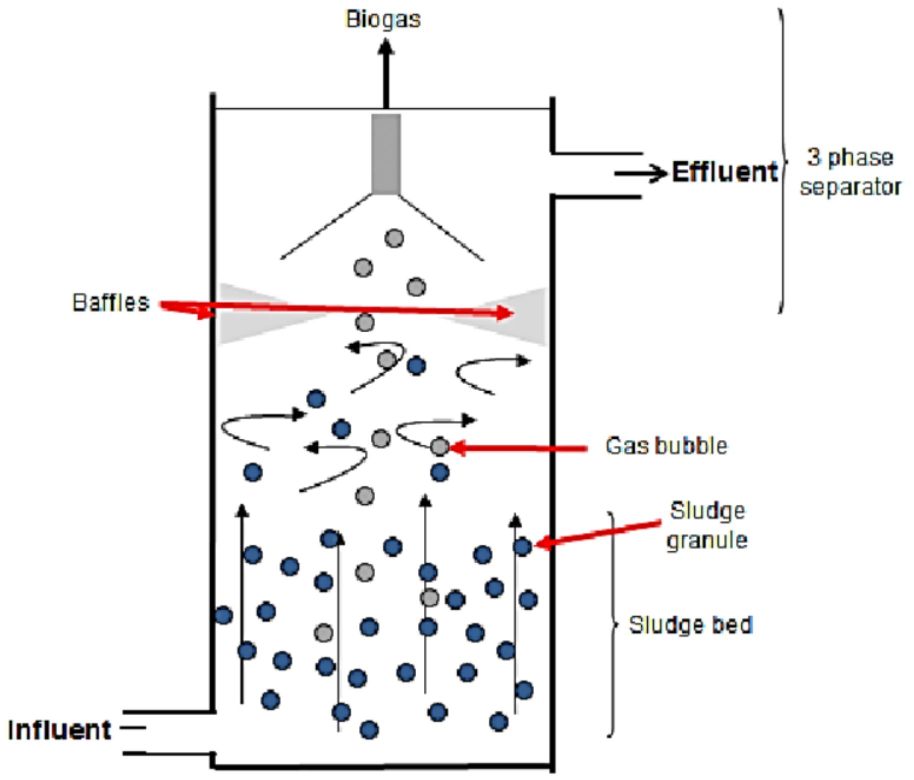


https://www.netsolwater.com/what-is-meant-by-the-uasb-reactor-its-working-and-quality-of-treated-water-using-a-uasb-reactor.php?blog=30

Fango granular

Lettinga et al., 1980

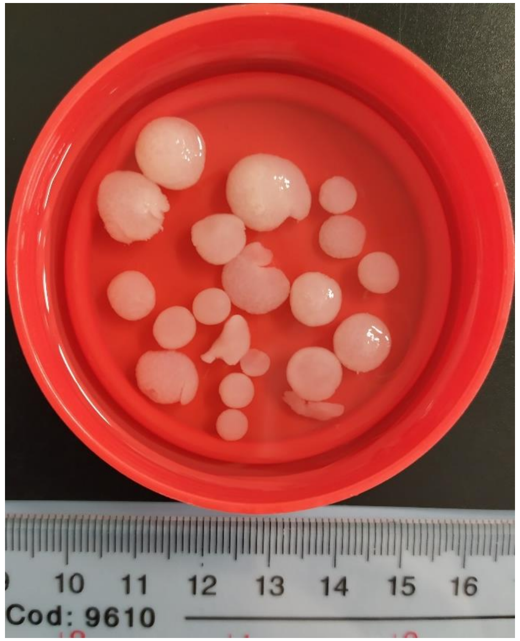
Beneficiado por	Formación
Bajo TRH	Movimiento
Alta carga orgánica	Sustancias poliméricas extracelulares

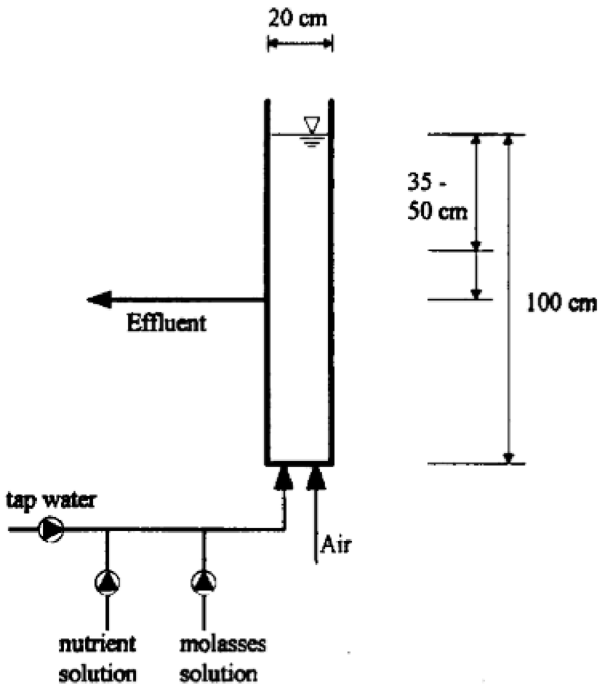


https://www.netsolwater.com/what-is-meant-by-the-uasb-reactor-its-working-and-quality-of-treated-water-using-a-uasb-reactor.php?blog=30

Fango aeróbico granular

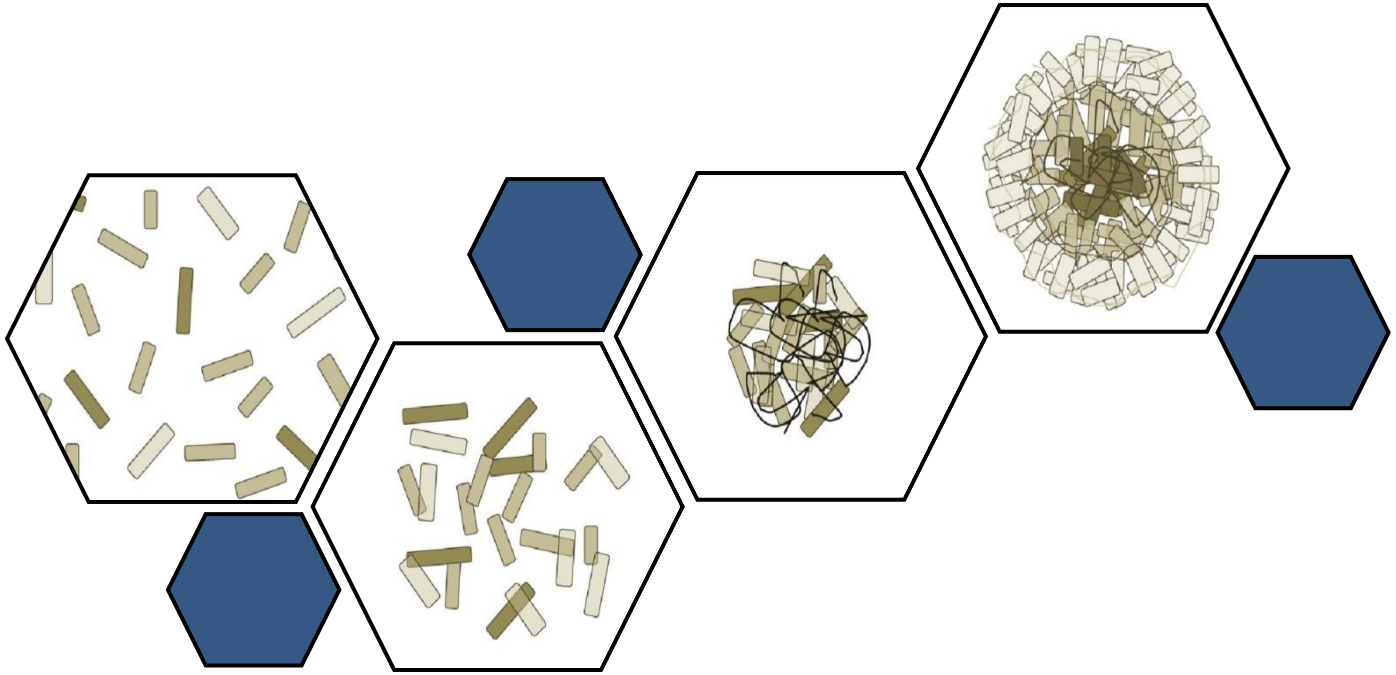
Morgenroth et al., 1997





Morgenroth et al., 1997

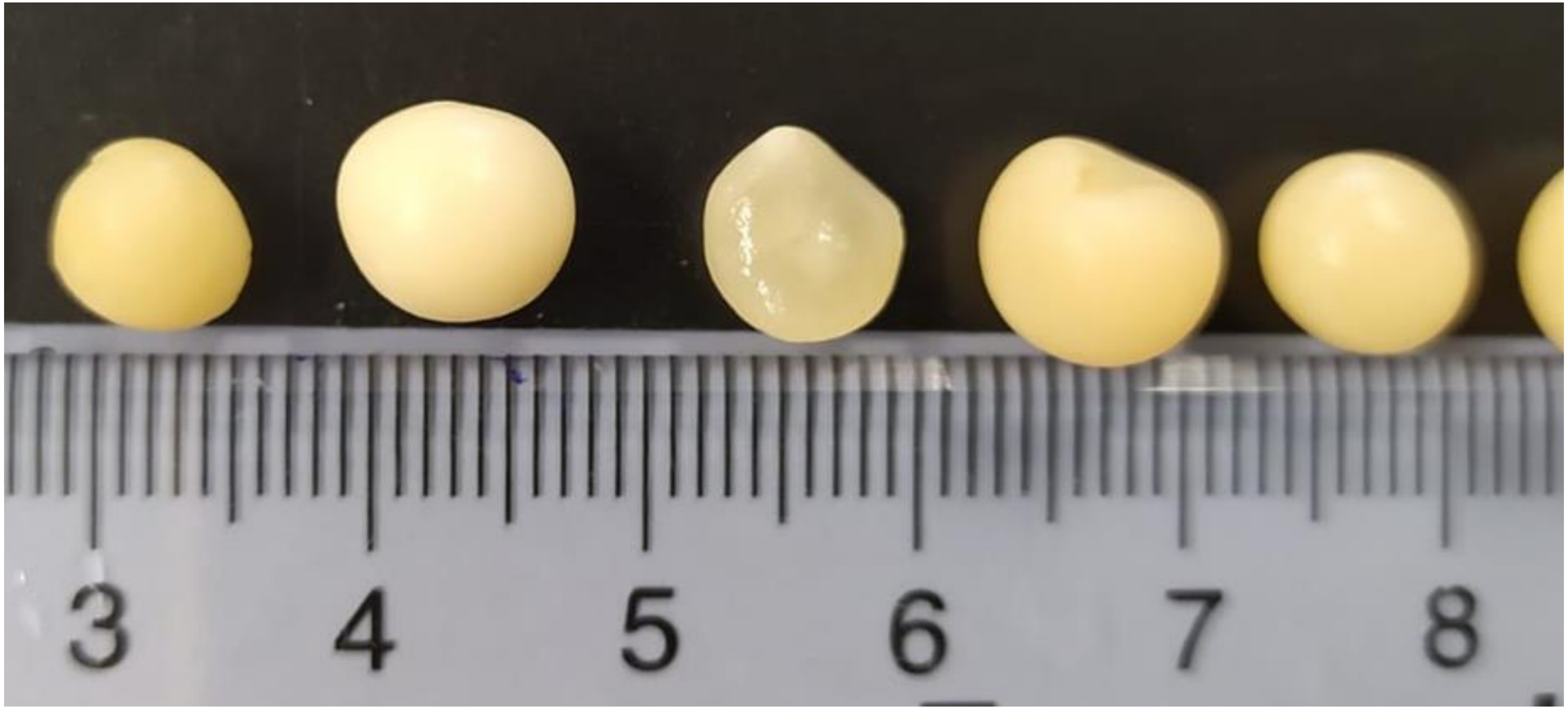
Formación del gránulo



Imágenes tomadas de Franca et al., 2018

Ventajas

Ventajas



Ventajas

- Mayor concentración de microorganismos
- Rápida separación agua-biomasa
- Resistencia a sustancias tóxicas y cambios en el influente
- Eliminación simultánea de distintos contaminantes

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Ventajas

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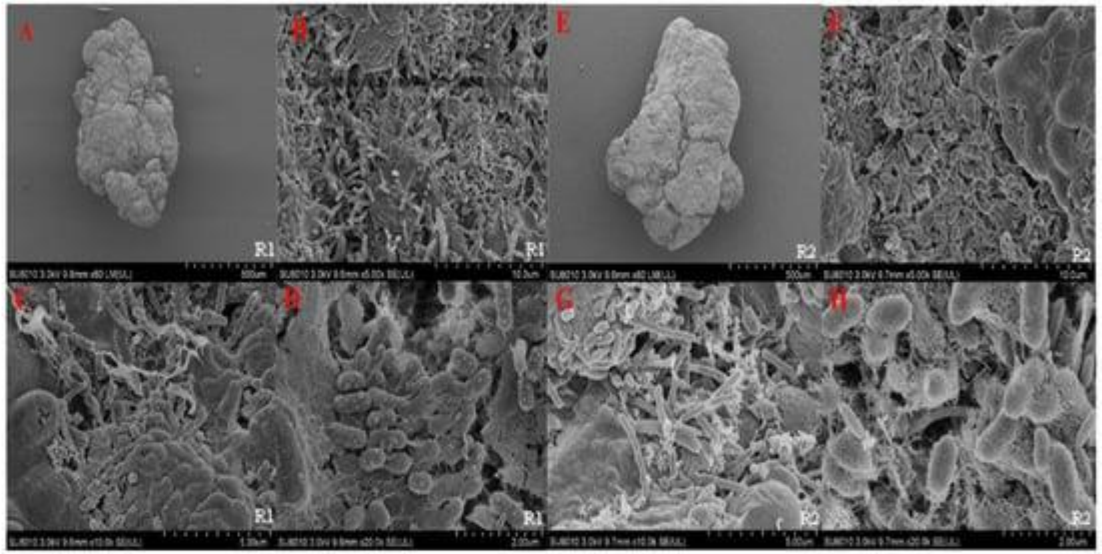
Mayor concentración de microorganismos

Rápida separación agua-biomasa

Resistencia a sustancias tóxicas y cambios en el influente

Eliminación simultánea de distintos contaminantes



Zhang et al., 2022

Ventajas

- Mayor concentración de microorganismos
- Rápida separación agua-biomasa
- Resistencia a sustancias tóxicas y cambios en el influente
- Eliminación simultánea de distintos contaminantes

Aqua-Aerobic Systems

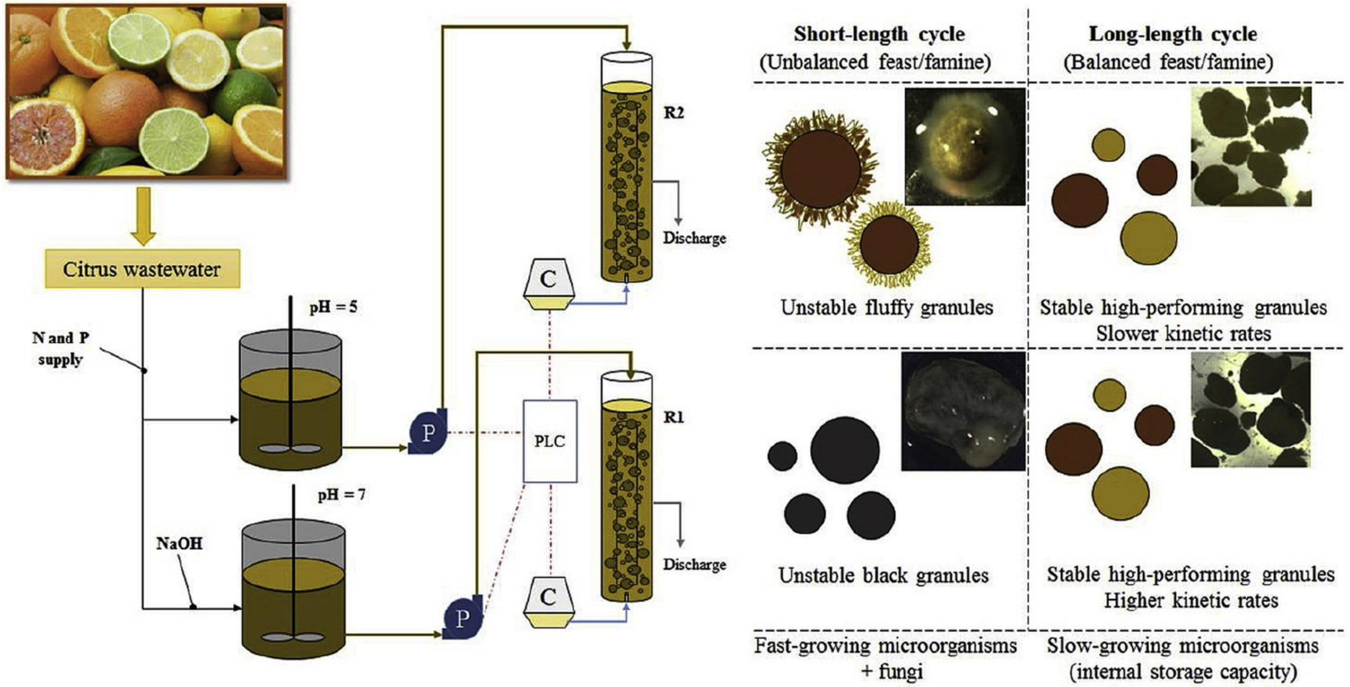
Ventajas

Mayor concentración de microorganismos

Rápida separación agua-biomasa

Resistencia a sustancias tóxicas y cambios en el influente

Eliminación simultánea de distintos contaminantes



Corsino et al., 2018

Ventajas

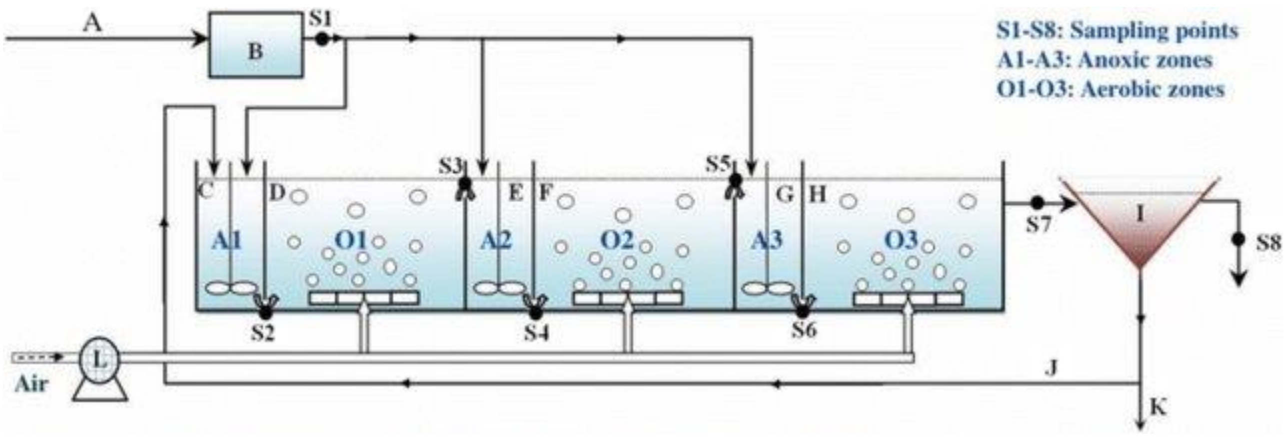
MasterClass patrocinada por:

Mayor concentración de microorganismos

Rápida separación agua-biomasa

Resistencia a sustancias tóxicas y cambios en el influente

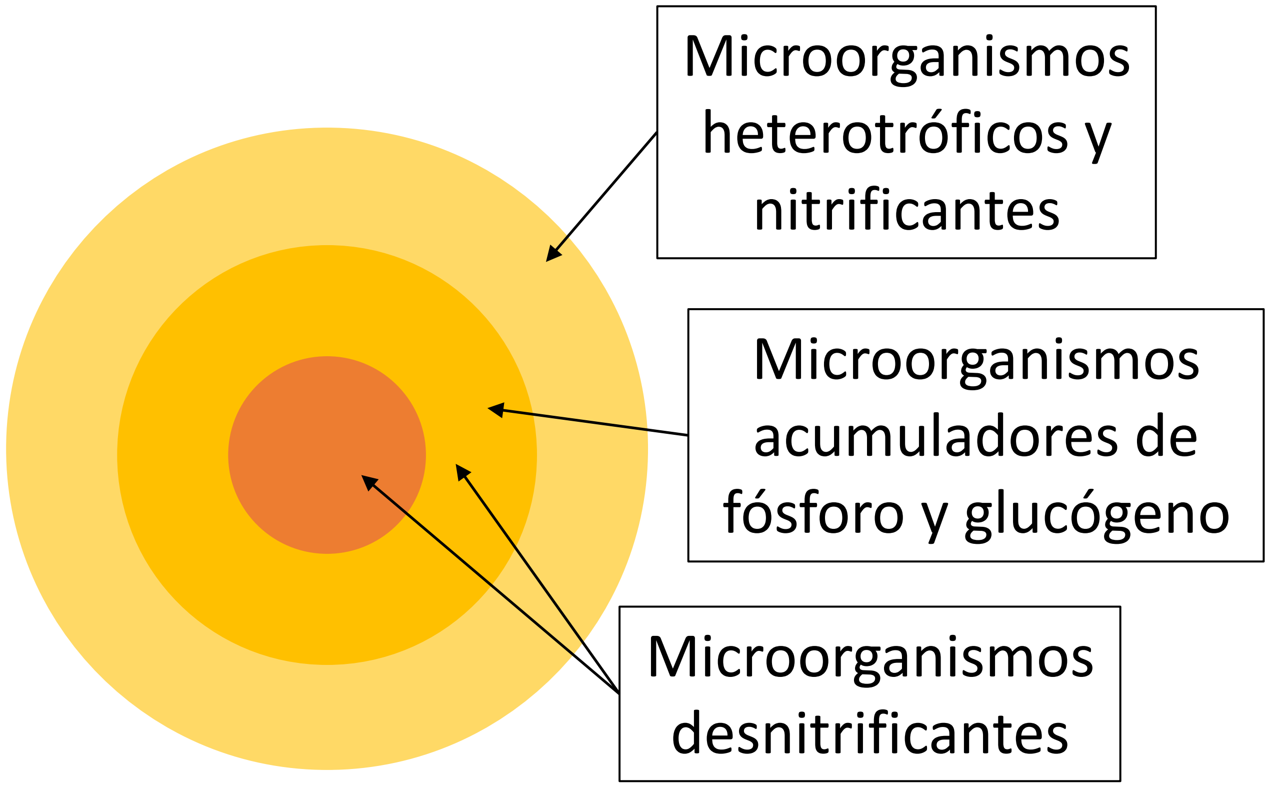
Eliminación simultánea de distintos contaminantes



Chen et al., 2018

Ventajas

- Mayor concentración de microorganismos
- Rápida separación agua-biomasa
- Resistencia a sustancias tóxicas y cambios en el influente
- Eliminación simultánea de distintos contaminantes



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Ventajas

MasterClass patrocinada por:

Operación

II Ciclo de 20 MasterClass AGUASRESIDUALES.INFO

Secuencial

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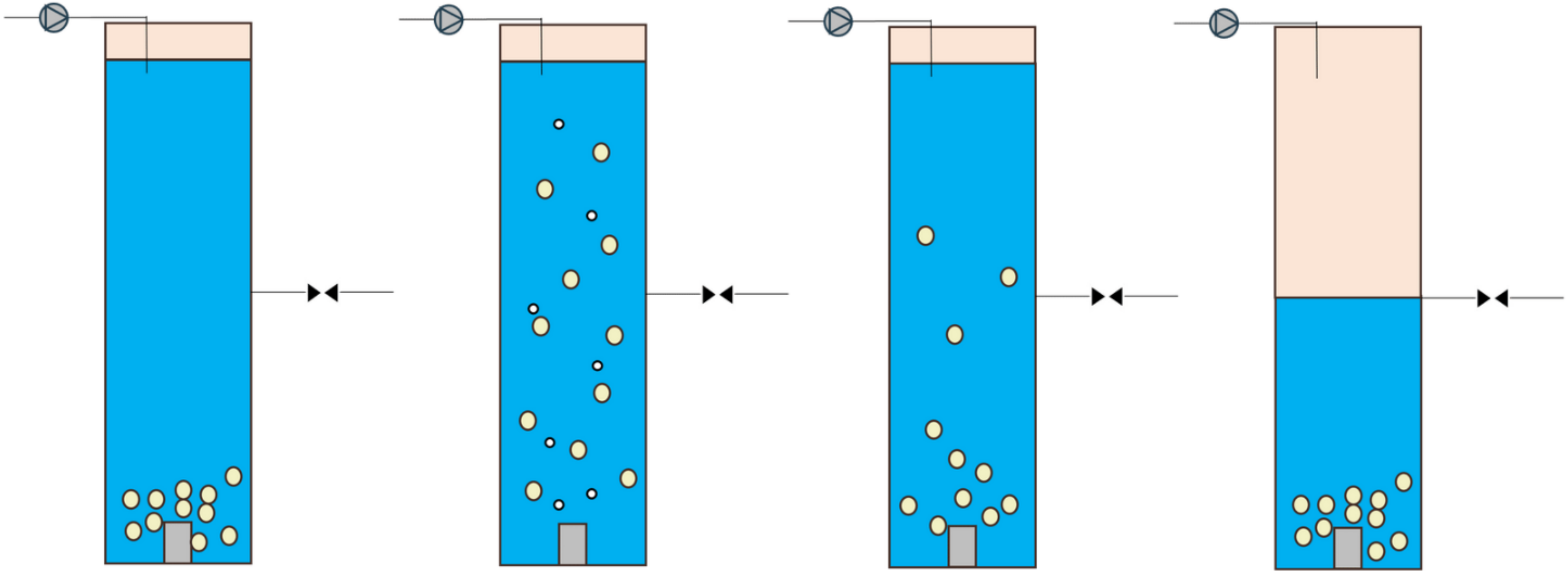

Secuencial

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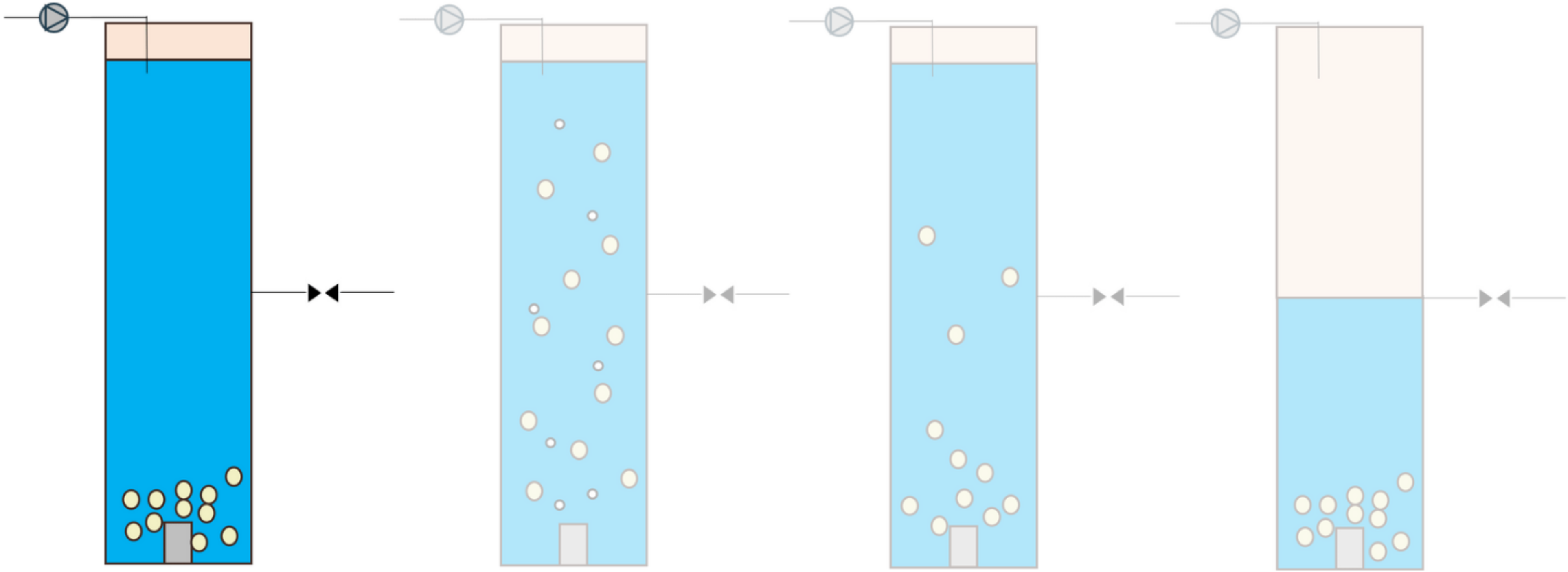
Llenado



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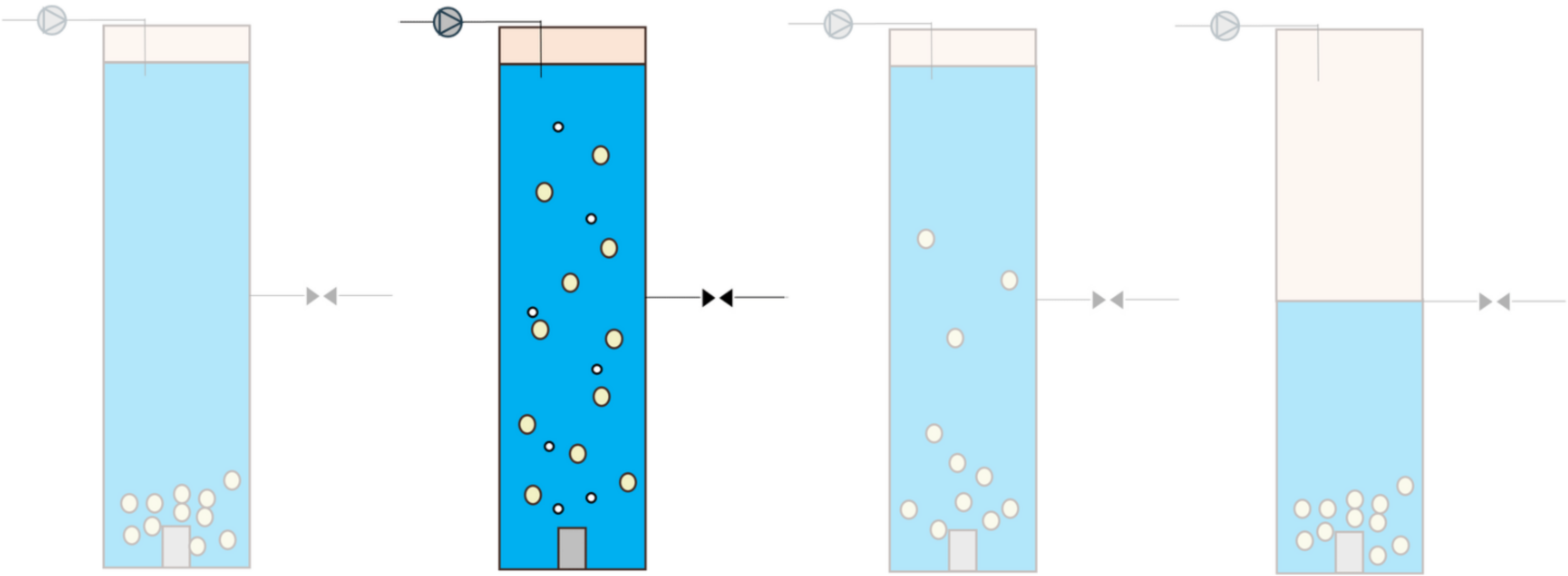
Secuencial

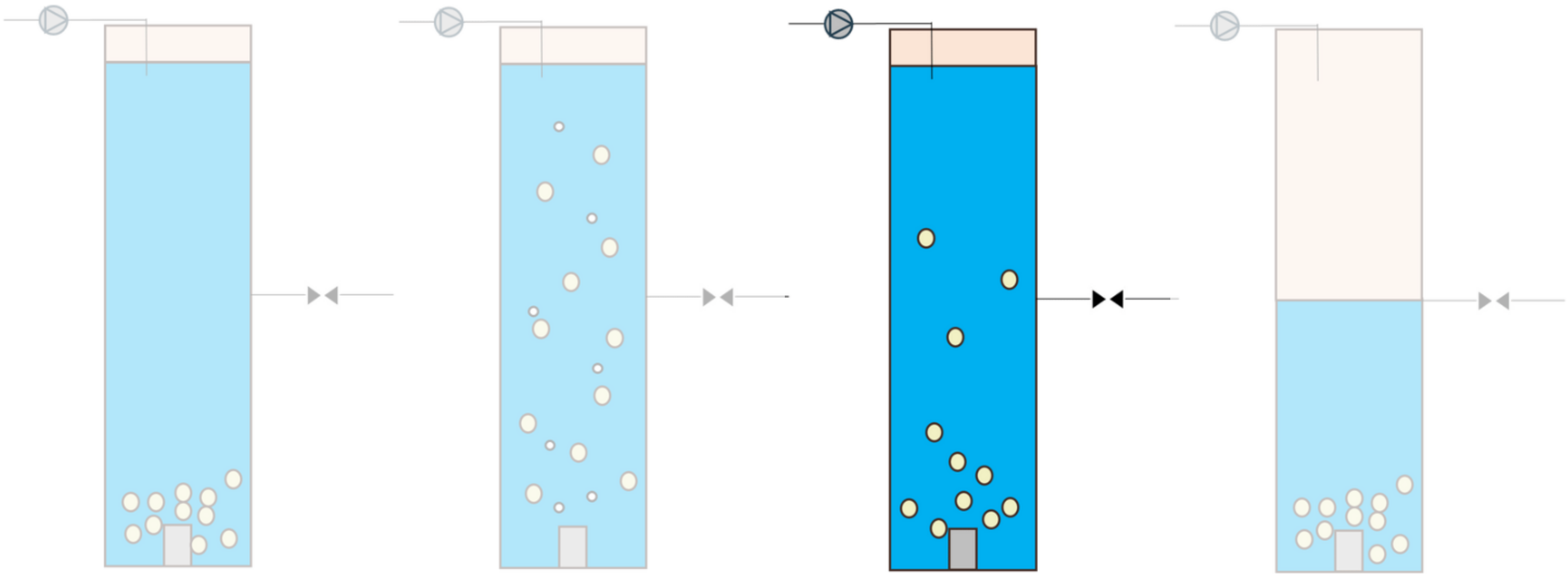
MasterClass patrocinada por:

Aireación



Secuencial

Decantación



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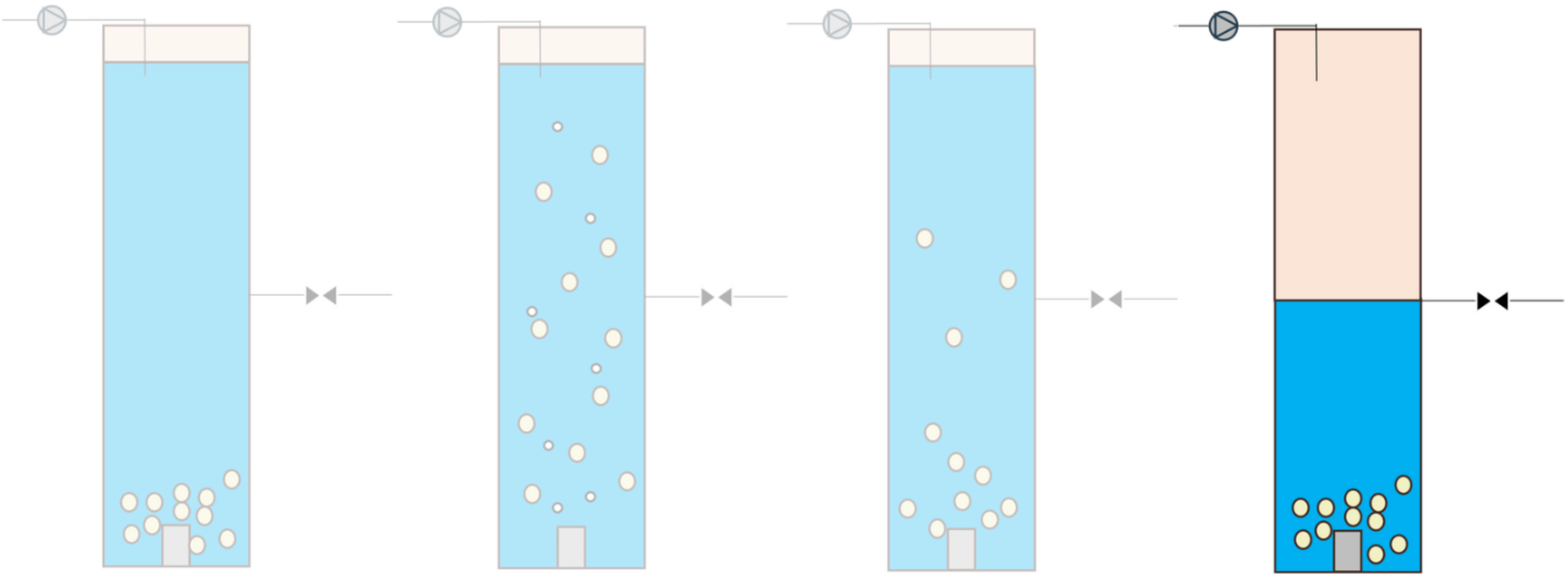
Secuencial

Vaciado



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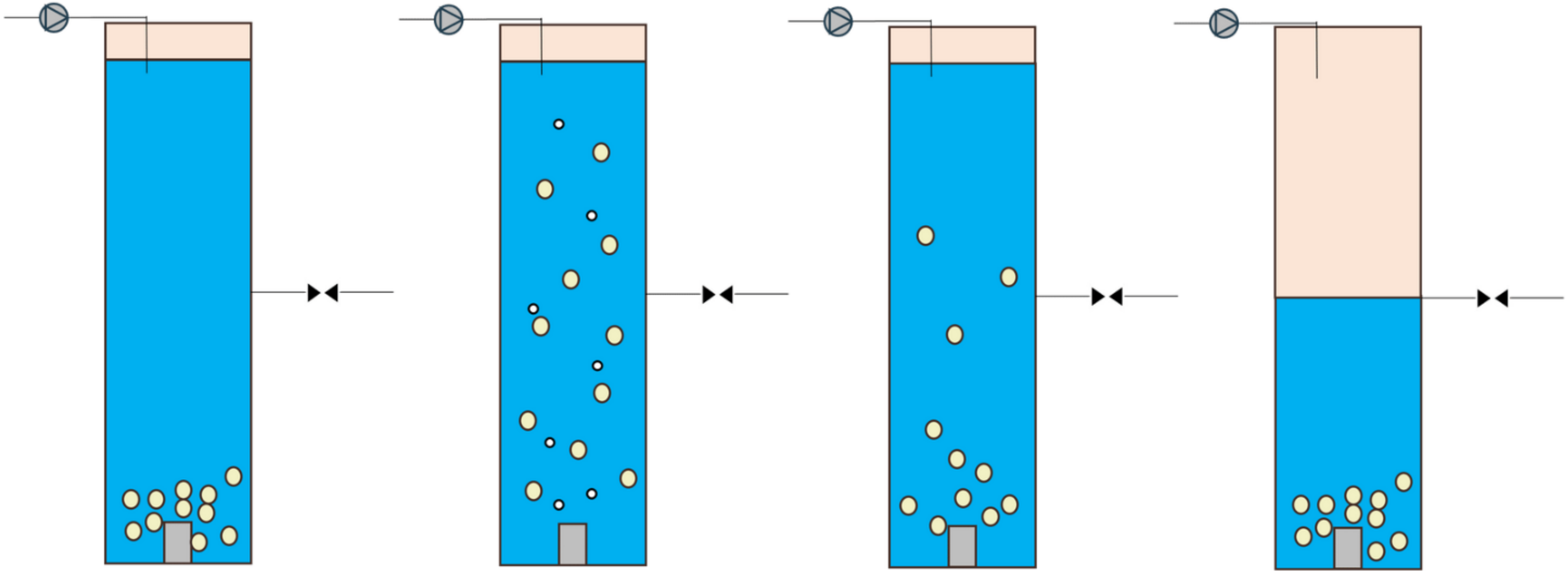
Secuencial



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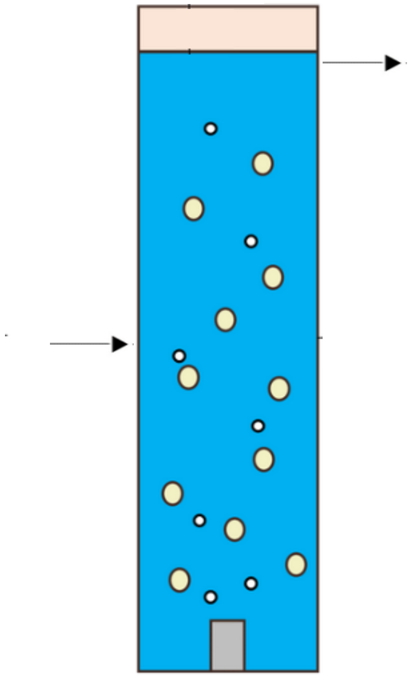

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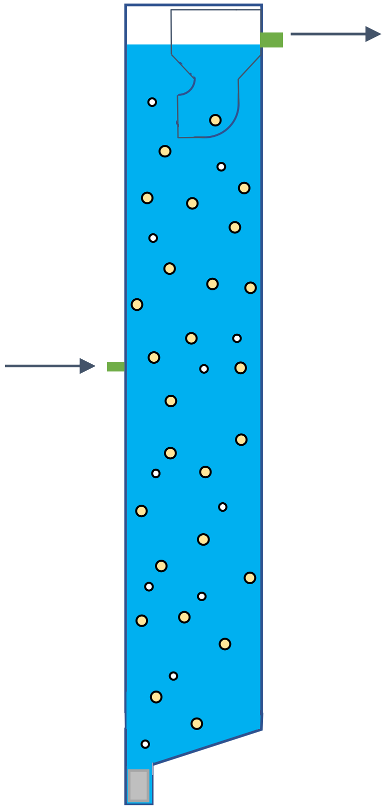

Journal of Environmental Chemical Engineering 11 (2023) 109938

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Description of new single-chamber continuous-flow reactors of aerobic granular sludge: Technical and biological study

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ARTICLE INFO

Editor: <Despo Fatta-Kassinos>

Keywords:
Aerobic granular sludge
Continuous-flow reactor
Granular stability microbial community
QPCR
Single-chamber

ABSTRACT

Aerobic granular sludge reactors usually operate in sequential batch mode, although this configuration limits the treatment of large volumes of wastewater, and they require a storage system. To implement this technology at full-scale, it would be necessary to design a simple and compact continuous-flow bioreactor able to treat larger volumes of wastewater. In this study, four aerobic granular sludge single-chamber continuous-flow reactors (R1, R2, R3 and R4) were designed and operated at the lab scale to evaluate and select a bioreactor configuration that achieves high organic matter removal performance while maintaining a stable granulation for long-term operation, promoting the washout of filamentous microorganisms. Results confirmed that the bioreactor including a lateral decanter (R1), was able to work in a steady state without loss of granular biomass and reached 95% of organic matter removal performance. Its granules had excellent compaction, with settling velocity values above 100 $m \cdot h^{-1}$. The R1 bioreactor also allowed rapid biomass adaptation and therefore a fast start-up (11 days). Results of this preliminary study at the lab scale suggested that the new and simple bioreactor design could be promising for its implementation at full scale. For that, future research is required to optimise the current model and to determine the most suitable operational parameters to treat domestic wastewater at full scale.

1. Introduction

Aerobic granular sludge (AGS) is a promising biological system for the treatment of wastewater due to its advantages in comparison with other technologies, such as conventional activated sludge (CAS) [1–3]. The hydrodynamic shear force and the continuous circular motion generate compact granules formed by microorganisms fixed and stabilised in a polymeric matrix [4,5]. This dense structure gives rise to the advantages of this technology because the high density of AGS promotes a better settleability [6,7], which can be translated into the implementation of more compact wastewater treatment plants (WWTPs) in comparison with CAS, due to lower time and space required to separate liquid-solid phases [2,5,8]. Moreover, the dense granular structure encourages a high accumulation of biomass. According to Nancharaiah et al. [9], AGS technology can reach a biomass concentration greater than 10 $g \cdot L^{-1}$. Besides this, the round shape maximises the granular surface, and the high compactness promotes mass transfer, which creates differences in terms of oxygen and nutrients from the external to internal layers [10–12]. This fact promotes the stratification of microorganisms along the layers, and consequently, it is possible to find different metabolisms in the same granule [2–4,13]. Therefore, AGS can remove organic matter, phosphorous, nitrogen and other substances, including pharmaceuticals, endocrine disrupters, phenolic compounds, dyes, heavy metals, particulate matter, nuclear waste and sulphur amino acids in the same chamber [1,3,8,13–17]. Changes in abiotic factors could modify influent characteristics [18]. However, AGS is a robust technology able to adapt to oscillating influent composition [19]. This capability is promoted by the large amount of extracellular polymeric substances (EPS) excreted by microorganisms in these aggregates, encouraging resistance to toxic compounds and high organic loading rates [13,20]. For all these reasons, AGS systems can be used to treat urban and industrial wastewater [13,21] as well as drinking water [22].

This technology has usually been operated in sequential batch reactors (SBRs), with the following cycles: 1) reactor filling with the raw water, 2) aeration, 3) settling of granules to separate the treated water from the biomass and 4) effluent discharge. In the last stage, light flocs

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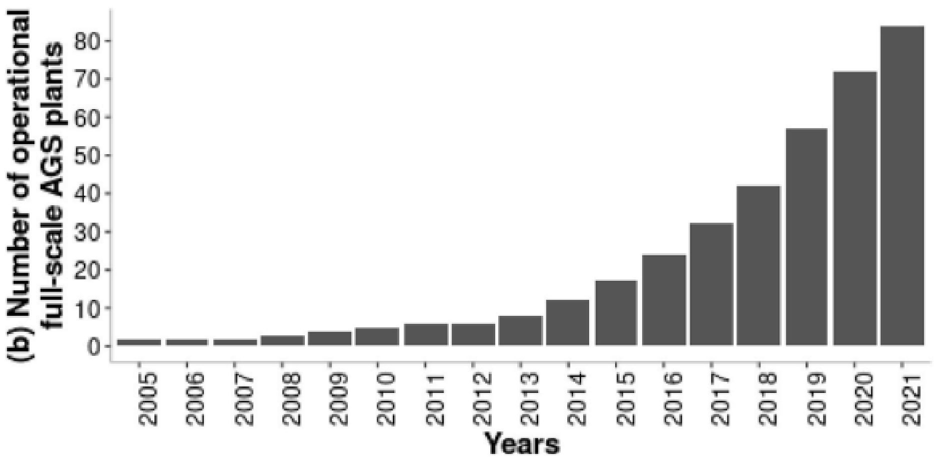
Rosa-Masegosa et al., 2023

Aplicaciones



Hamza et al., 2022

Location	Operation start	Wastewater type
★ Ede, The Netherlands*	2005	Industrial - Diary
★ Rotterdam, The Netherlands*	2005	Industrial - Edible oil processing
Gansbaai, South Africa*	2008	Municipal
★ Oosterwolde, The Netherlands*	2009	Industrial - Food processing
Haining, China**	2010	30% domestic + 70% industrial
Epe, The Netherlands*	2011	Municipal
Vroomshoop, The Netherlands*	2013	Municipal
Dinxperlo, The Netherlands*	2013	Municipal
Garmerwolde, The Netherlands*	2014	Municipal
Frielas, Lisbon*	2014	Municipal
Switzerland‡	2014	Municipal
Utrecht, The Netherlands (pilot)*	2014–2021	Municipal
Clonakilty, Ireland*	2015	Municipal
Ryki, Poland*	2015	Municipal
IJsselstein, The Netherlands*	2015	Industrial
Wemmershoek, South Africa*	2015	Municipal
Germany‡	2015	Municipal
Carrigtwohill, Ireland*	2016	Municipal
Deodoro, Brazil*	2016	Municipal
Kingaroy, Australia*	2016	Municipal
Simpelveld, The Netherlands*	2016	Municipal
Deodoro, Rio de Janeiro, Brazil*	2016	Municipal
Sha Tin, Hong Kong *	2016	Municipal
Germany‡	2016/2017	Municipal
Rockford, USA*	2017	Municipal
Alpnach, Switzerland*	2017	Municipal
Cork Lower Harbour, Ireland*	2017	Municipal
Jardim Novo, Rio Claro, Brazil*	2017	Municipal
Dublin Ringsend, Ireland*	2017	Municipal
Dublin - Ringsend, Ireland*	2017	Municipal
Germany‡	2017	Municipal
Israel‡	2017	Municipal
Faro – Olhão Portugal*	2018	Municipal
Great Dunmow, United Kingdom*	2018	Municipal
	2018	Municipal
Morecambe, United Kingdom*	2018	Municipal
Utrecht, The Netherlands*	2018	Municipal
★ Zutphen, The Netherlands*	2018	Industrial - Diary
Lanaken, Belgium*	2018	Industrial – Fiber processing
Strömstad, Sweden*	2018	Municipal
Poland‡	2018	Municipal
Chile‡	2018	Municipal
Dungannon, United Kingdom*	2019	Municipal
Inverurie, United Kingdom*	2019	Municipal
Radcliffe, United Kingdom*	2019	Municipal
Walsall Wood, United Kingdom*	2019	Municipal
Weert, The Netherlands*	2019	Municipal
Wolf Creek Alabama, USA*	2019	Municipal
Araguaína, Tocantis, Brazil*	2019	Municipal
Tatu, Limeira, Brazil*	2019	Municipal
Tijuco Preto, Sumaré, São Paulo, Brazil*	2019	Municipal
Paulo, Brazil*		
Quezon City, Philippines*	2019	Municipal
Breskens, The Netherlands*	2019	Municipal
Germany‡	2019	Municipal
Germany‡	2019	Industrial
Denmark‡	2019	Municipal
Denmark‡	2019	Municipal
Bangu, Brazil*	2020	Municipal
Dodewaard, The Netherlands*	2020	Municipal
Failsworth, United Kingdom*	2020	Municipal
Kloten – Opfikon, Switzerland*	2020	Municipal
Newham, United Kingdom*	2020	Municipal
Oissery, France*	2020	Municipal
Quakers Hill, Australia*	2020	Municipal
Saoneor, France*	2020	Municipal
Stein, The Netherlands*	2020	Municipal
Jardim São Paulo, Recife, Brazil*	2020	Municipal
Fleury, France*	2020	Municipal
Hartebeesfontein, South Africa*	2020	Municipal
Panheel, The Netherlands*	2020	Municipal
Switzerland‡	2020	Municipal
Fortaleza, Ceará, Brazil*.	2020	Municipal
Altena, Germany*	2021	Municipal
Longford, Australia*	2021	Municipal and industrial
Região Sul de Palmas, Brazil*	2021	Municipal
São Lourenço, Brazil*	2021	Municipal
Santo Antônio, Goiânia, Brazil*	2021	Municipal
São Lourenço da Mata, Recife, Brazil*	2021	Municipal
Vriezenveen, The Netherlands*	2021	Municipal
Westnewton, United Kingdom*	2021 (Design)	Municipal
Wolcott Kansas, USA*	2021 (Construction)	Municipal
Whitefish Montana, USA*	2021 (Construction)	Municipal
Norman Oklahoma, USA*	2021 (Design)	Municipal
Idaho Springs Colorado*	2021 (Start-up pending)	Municipal
Jaboatão, Recife, Brazil*	2022	Municipal
Jeddah, Saudi Arabia*	2023	Municipal
Muskiz, Spain*	2023	NA
Camaragibe, Brazil*	2025 (Design)	Municipal

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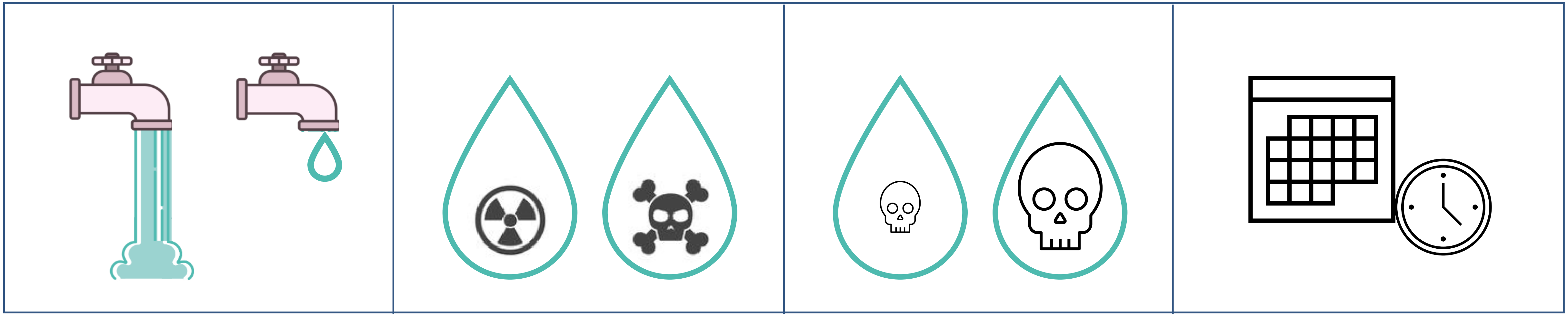
Industrial



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Industrial

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Industria agroalimentaria

Contaminantes

- Materia orgánica
- N, P, S…
- Sólidos en suspensión
- Salinidad
- pH
- Pesticidas
- Grasas
- Compuestos fenólicos
- Detergentes
- Patógenos

Industrial:

Almazara

Contaminantes

- Materia orgánica
- Grasas
- Sólidos en suspensión
- Compuestos fenólicos
- Sales (conductividad)
- pH ácido

Industrial:

Almazara (ácidos fenólicos)

Reactor: SBR, escala laboratorio.

TRH: 6 h.

Inóculo: gránulos.

Mezcla de Ácido caféico, ácido hidroxibenzoico, ácido protocatecuico. 50, 100, 300, 600 y 1000 mg/L.

Journal of Hazardous Materials 376 (2019) 58–67

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Performance and microbial community structure of an aerobic granular sludge system at different phenolic acid concentrations

Barbara Muñoz-Palazon*, Alejandro Rodriguez-Sanchez, Miguel Hurtado-Martinez, Ines Manuel de Castro, Belén Juarez-Jimenez, Alejandro Gonzalez-Martinez, Jesus Gonzalez-Lopez

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ARTICLE INFO

Keywords:
Phenolic compounds
Aerobic granular sludge
Toxic compounds
Olive washing water (OWW)
Microbial community structure

ABSTRACT

The present work aims to use aerobic granular sludge technology for the treatment of wastewater containing high organic matter loads and a mixture of phenolic compounds normally present in olive washing water. The physicochemical performance of five bioreactors treating different concentrations of mixture of phenolic acid was monitored to observe the response of the systems. The bioreactors that operated at 50, 100 and 300 mg L^{-1} did not show relevant changes in terms of performance and granules properties, showing high ratio of phenolic compound removal ratio. However, the bioreactors operated with high phenolic compound concentrations showed low rates of organic matter, nitrogen and phenolic acid removal. In the same way, high concentrations of phenolic compounds determined the disintegration of the granular biomass. Next-generation sequencing studies showed a stable community structure in the bioreactors operating with 50, 100 and 300 mg L^{-1} of phenolic acids, with the genera *Lampropedia* and *Arenimonas*, family *Xanthobacteraceae* and *Fungi Pezizomycotina* as the dominant phylotypes. Conversely, the reactors operated at 500 and 600 mg L^{-1} of phenolic substances promoted the proliferation of *Oligohymenophorea* ciliates. Thus, this study suggests that aerobic granular sludge technology could be useful for the treatment of wastewaters such as olive washing water.

1. Introduction

Phenolic compounds are chemical substances that make important contributions to the pollutant and recalcitrant character of different industrial and agricultural wastewaters [1,2]. Different industrial and agri-food effluents present high concentrations of phenolic acids, those of the olive oil industry being of particular importance in the Mediterranean area, with more than 3 million tons produced annually mainly by Spain, Portugal, Italy and Greece [6]. The main effluent generated during the production of olive oil is olive washing water (OWW) [7–9]. Regarding olive oil by-products, phenolic compounds are quantitatively abundant [10], with total phenol content between 200 and 300 mg L^{-1}. The main families of phenolic compounds identified by authors in olive mill wastes are phenolic acids, secoiridoids and flavonoids [10,11]. Moreover, OWW presents a high organic matter load, with a chemical oxygen demand (COD) of up to 5 g L^{-1}. Moreover, phenolic compounds deserve special attention due to their influence as antibacterial and phytotoxic products [3], even at very low concentrations, limiting the use of biological processes. In this context, advanced oxidation, membrane filtration, biological digestion, heterogenous photocatalysis and Photo-Fenton degradation have been used for phenolic acid degradation [1,4], although these technologies have serious disadvantages such as their economic cost and not being very friendly to the environment. It is for this reason that the search for biological alternatives for the treatment of effluents polluted with phenolic compounds is a challenge of great biotechnological interest. Thus, in the last decade, aerobic-biodegradation processes such as submerged biofilter or photobioreactor(PBR) systems have been proposed due to the robustness for the treatment of agricultural wastewaters polluted with high concentrations of phenolic substances [1,5] The PBR was used for treating real olive wastewater, and the results confirmed that the biofilm formed showed a high capacity to remove phenols, nitrogen, phosphorous and organic matter, also the system reached the steady-stable in a short period under 2 h of hydraulic retention time. On the other hand, it was proposed a innovative biological technology denominated aerobic granular sludge technology for treating phenols and pesticides, between among pollutants, which are common compounds present in agriculture effluent, being more

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Muñoz-Palazón et al., 2019

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Industrial:

Almazara (ácidos fenólicos)

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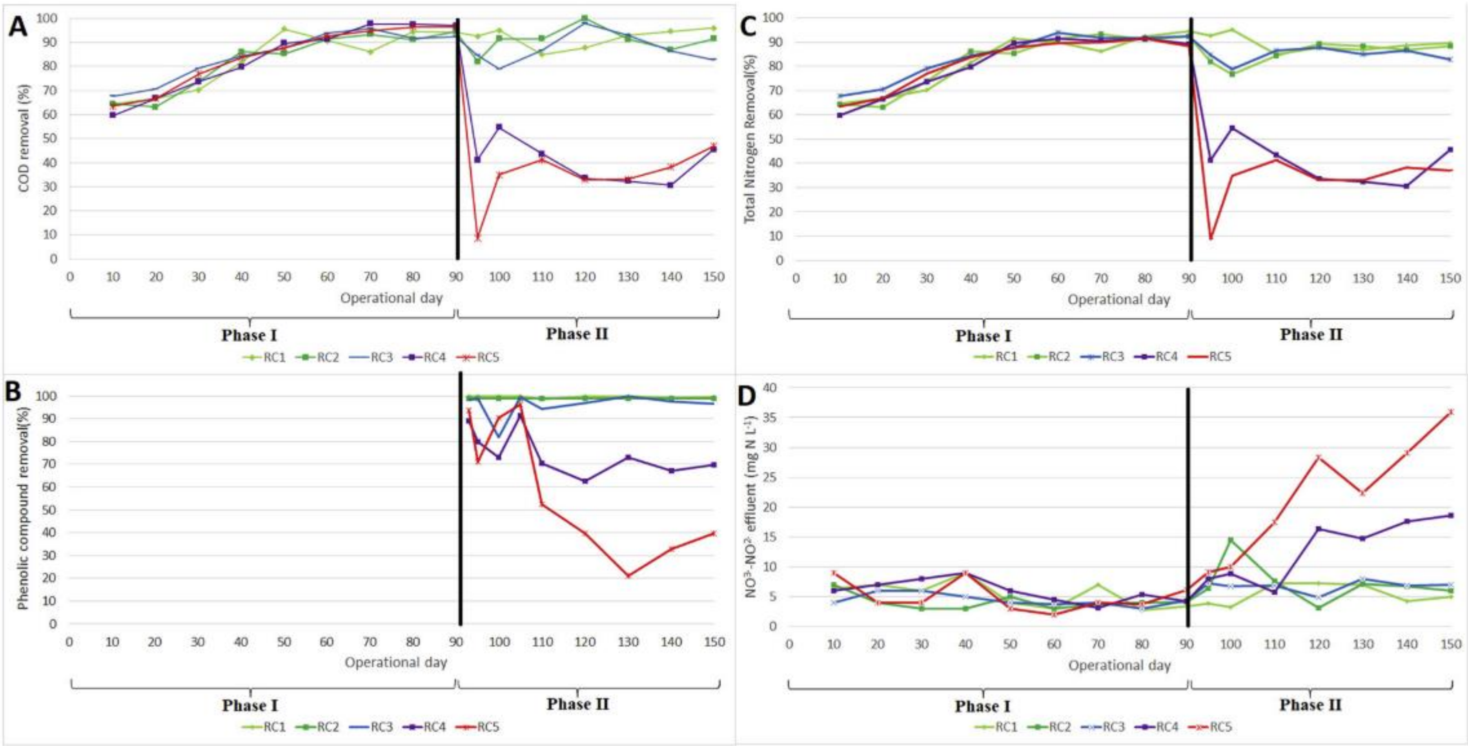

Fig. 2. Physic-chemical performance for COD removal ratio (A); phenolic compounds removal (B); TN removal ratio (C); nitrite and nitrate concentration in the effluent (D).

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Performance and microbial community structure of an aerobic granular sludge system at different phenolic acid concentrations

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ARTICLE INFO

Keywords:
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Aerobic granular sludge
Toxic compounds
Olive washing water (OWW)
Microbial community structure

ABSTRACT

The present work aims to use aerobic granular sludge technology for the treatment of wastewater containing high organic matter loads and a mixture of phenolic compounds normally present in olive washing water. The physicochemical performance of five bioreactors treating different concentrations of mixture of phenolic acid was monitored to observe the response of the systems. The bioreactors that operated at 50, 100 and 300 mg L^{-1} did not show relevant changes in terms of performance and granules properties, showing high ratio of phenolic compound removal ratio. However, the bioreactors operated with high phenolic compound concentrations showed low rates of organic matter, nitrogen and phenolic acid removal. In the same way, high concentrations of phenolic compounds determined the disintegration of the granular biomass. Next-generation sequencing studies showed a stable community structure in the bioreactors operating with 50, 100 and 300 mg L^{-1} of phenolic acids, with the genera *Lampropedia* and *Arenimonas*, family *Xanthobacteraceae* and *Fungi Pezizomycotina* as the dominant phylotypes. Conversely, the reactors operated at 500 and 600 mg L^{-1} of phenolic substances promoted the proliferation of *Oligohymenophorea* ciliates. Thus, this study suggests that aerobic granular sludge technology could be useful for the treatment of wastewaters such as olive washing water.

1. Introduction

Phenolic compounds are chemical substances that make important contributions to the pollutant and recalcitrant character of different industrial and agricultural wastewaters [1,2]. Different industrial and agri-food effluents present high concentrations of phenolic acids, those of the olive oil industry being of particular importance in the Mediterranean area, with more than 3 million tons produced annually mainly by Spain, Portugal, Italy and Greece [6]. The main effluent generated during the production of olive oil is olive washing water (OWW) [7–9]. Regarding olive oil by-products, phenolic compounds are quantitatively abundant [10], with total phenol content between 200 and 300 mg L^{-1}. The main families of phenolic compounds identified by authors in olive mill wastes are phenolic acids, secoiridoids and flavonoids [10,11]. Moreover, OWW presents a high organic matter load, with a chemical oxygen demand (COD) of up to 5 g L^{-1}. Moreover, phenolic compounds deserve special attention due to their influence as antibacterial and phytotoxic products [3], even at very low concentrations, limiting the use of biological processes. In this context, advanced oxidation, membrane filtration, biological digestion, heterogenous photocatalysis and Photo-Fenton degradation have been used for phenolic acid degradation [1,4], although these technologies have serious disadvantages such as their economic cost and not being very friendly to the environment. It is for this reason that the search for biological alternatives for the treatment of effluents polluted with phenolic compounds is a challenge of great biotechnological interest. Thus, in the last decade, aerobic-biodegradation processes such as submerged biofilter or photobioreactor(PBR) systems have been proposed due to the robustness for the treatment of agricultural wastewaters polluted with high concentrations of phenolic substances [1,5] The PBR was used for treating real olive wastewater, and the results confirmed that the biofilm formed showed a high capacity to remove phenols, nitrogen, phosphorous and organic matter, also the system reached the steady-stable in a short period under 2 h of hydraulic retention time. On the other hand, it was proposed a innovative biological technology denominated aerobic granular sludge technology for treating phenols and pesticides, between among pollutants, which are common compounds present in agriculture effluent, being more

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Industrial:

Almazara (ácidos fenólicos)

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Performance and microbial community structure of an aerobic granular sludge system at different phenolic acid concentrations

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Industrial:

Cítricos

Contaminantes

- Materia orgánica
- Aceites esenciales
- pH < 3
- Sólidos en suspensión
- Ausencia de N y P

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Industrial:

Cítricos

MasterClass patrocinada por:

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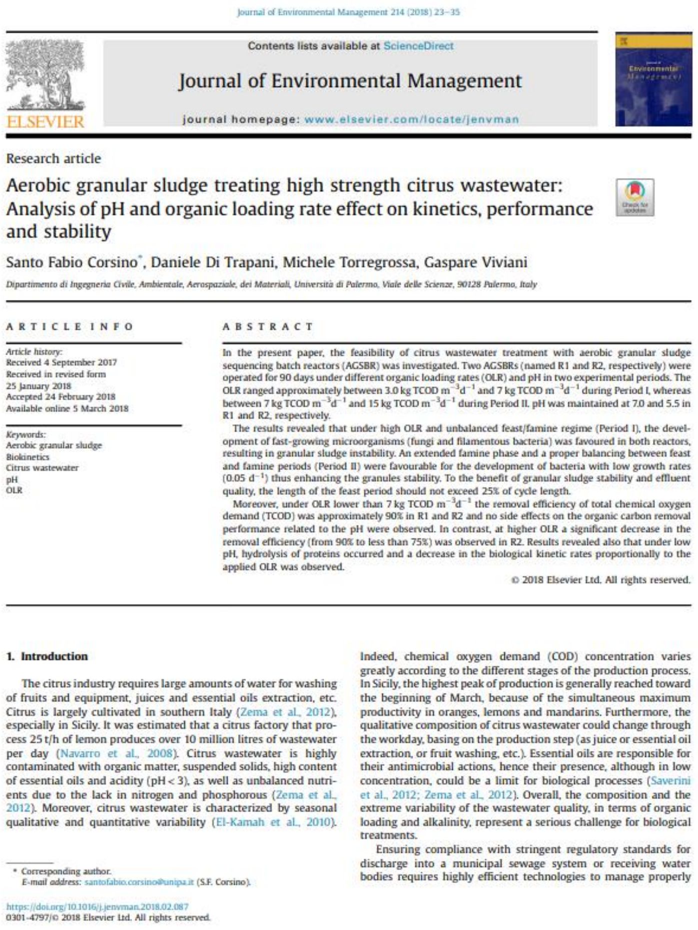
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Research article

Aerobic granular sludge treating high strength citrus wastewater: Analysis of pH and organic loading rate effect on kinetics, performance and stability

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Keywords:
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Biokinetics
Citrus wastewater
pH
OLR

A B S T R A C T

In the present paper, the feasibility of citrus wastewater treatment with aerobic granular sludge sequencing batch reactors (AGSBR) was investigated. Two AGSBRs (named R1 and R2, respectively) were operated for 90 days under different organic loading rates (OLR) and pH in two experimental periods. The OLR ranged approximately between 3.0 kg TCOD $m^{-3}d^{-1}$ and 7 kg TCOD $m^{-3}d^{-1}$ during Period I, whereas between 7 kg TCOD $m^{-3}d^{-1}$ and 15 kg TCOD $m^{-3}d^{-1}$ during Period II. pH was maintained at 7.0 and 5.5 in R1 and R2, respectively.

The results revealed that under high OLR and unbalanced feast/famine regime (Period I), the development of fast-growing microorganisms (fungi and filamentous bacteria) was favoured in both reactors, resulting in granular sludge instability. An extended famine phase and a proper balancing between feast and famine periods (Period II) were favourable for the development of bacteria with low growth rates (0.05 d^{-1}) thus enhancing the granules stability. To the benefit of granular sludge stability and effluent quality, the length of the feast period should not exceed 25% of cycle length.

Moreover, under OLR lower than 7 kg TCOD $m^{-3}d^{-1}$ the removal efficiency of total chemical oxygen demand (TCOD) was approximately 90% in R1 and R2 and no side effects on the organic carbon removal performance related to the pH were observed. In contrast, at higher OLR a significant decrease in the removal efficiency (from 90% to less than 75%) was observed in R2. Results revealed also that under low pH, hydrolysis of proteins occurred and a decrease in the biological kinetic rates proportionally to the applied OLR was observed.

1. Introduction

The citrus industry requires large amounts of water for washing of fruits and equipment, juices and essential oils extraction, etc. Citrus is largely cultivated in southern Italy (Zema et al., 2012), especially in Sicily. It was estimated that a citrus factory that process 25 t/h of lemon produces over 10 million litres of wastewater per day (Navarro et al., 2008). Citrus wastewater is highly contaminated with organic matter, suspended solids, high content of essential oils and acidity (pH < 3), as well as unbalanced nutrients due to the lack in nitrogen and phosphorous (Zema et al., 2012). Moreover, citrus wastewater is characterized by seasonal qualitative and quantitative variability (El-Kamah et al., 2010). Indeed, chemical oxygen demand (COD) concentration varies greatly according to the different stages of the production process. In Sicily, the highest peak of production is generally reached toward the beginning of March, because of the simultaneous maximum productivity in oranges, lemons and mandarins. Furthermore, the qualitative composition of citrus wastewater could change through the workday, basing on the production step (as juice or essential oil extraction, or fruit washing, etc.). Essential oils are responsible for their antimicrobial actions, hence their presence, although in low concentration, could be a limit for biological processes (Saverini et al., 2012; Zema et al., 2012). Overall, the composition and the extreme variability of the wastewater quality, in terms of organic loading and alkalinity, represent a serious challenge for biological treatments.

Ensuring compliance with stringent regulatory standards for discharge into a municipal sewage system or receiving water bodies requires highly efficient technologies to manage properly

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Corsino et al., 2018

<u>Reactor</u>: SBR, escala laboratorio.
<u>TRH</u>: 24 y 12 h.
<u>Inóculo</u>: fango granular
pH 7 y pH 5

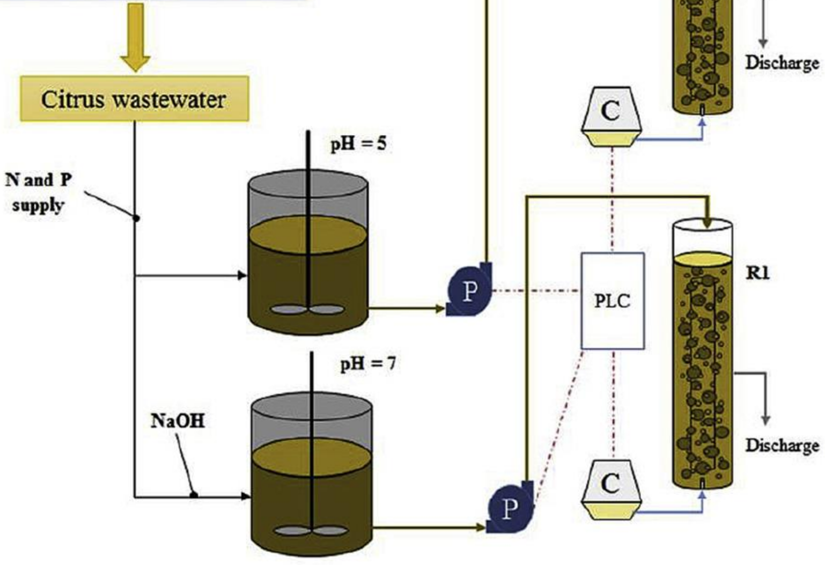
Composition of the feeding wastewater in R1 and R2.

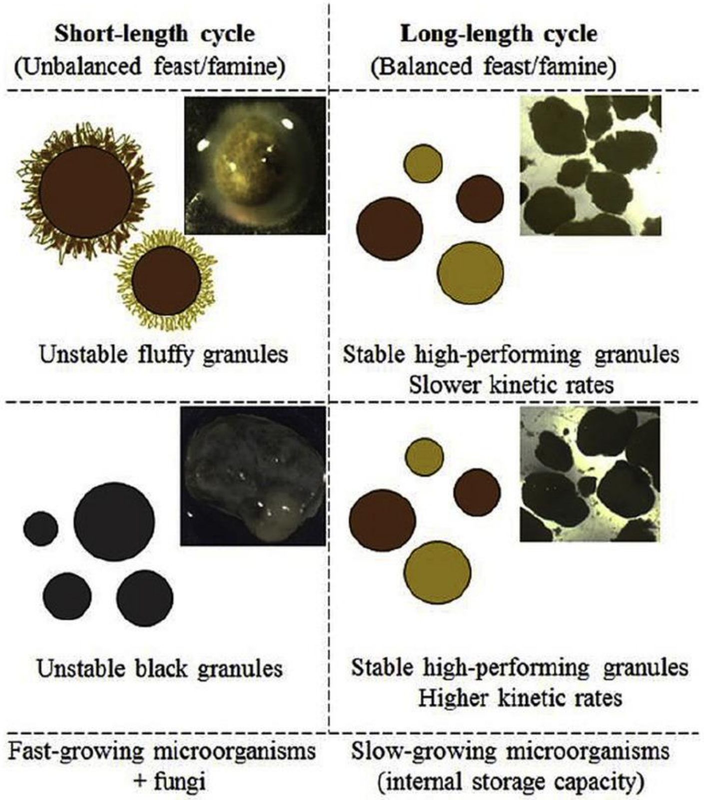
Parameter	Unit measure	Raw citrus wastewater	Period I (30 days)		Period II (30 days)	
			R1	R2	R1	R2
Total COD (TCOD)	mg L^{-1}	3065–7512 (5464 ± 1291)	3065-7300 (5579 ± 1434)	3065-7300 (5579 ± 1434)	3175–7512 (5296 ± 1319)	3175–7512 (5296 ± 1319)
Soluble COD (SCOD)	mg L^{-1}	1595–6480 (3823 ± 1473)	1595-6045 (4029 ± 1349)	1595-6045 (4029 ± 1349)	1920-6480 (3525 ± 1615)	1920-6480 (3525 ± 1615)
Total Nitrogen (TN)	mg L^{-1}	12 ± 3.5	40–151 (101 ± 13)	40-151 (101 ± 13)	48–162 (88 ± 9)	48–162 (88 ± 9)
Total Phosphorous (TP)	mg L^{-1}	3.5 ± 1.1	8–30 (20 ± 3)	8–30 (20 ± 3)	9.3–32.4 (17.6 ± 2)	9.3–32.4 (17.6 ± 2)
Total suspended solids (TSS)	mg L^{-1}	300–1914 (1219 ± 652)	300–1604 (906 ± 321)	300–1604 (906 ± 321)	1004-1914 (1324 ± 426)	1004-1914 (1324 ± 426)
pH	–	5.2 ± 0.2	7.2 ± 0.3	5.3 ± 0.2	7.4 ± 0.4	5.1 ± 0.2

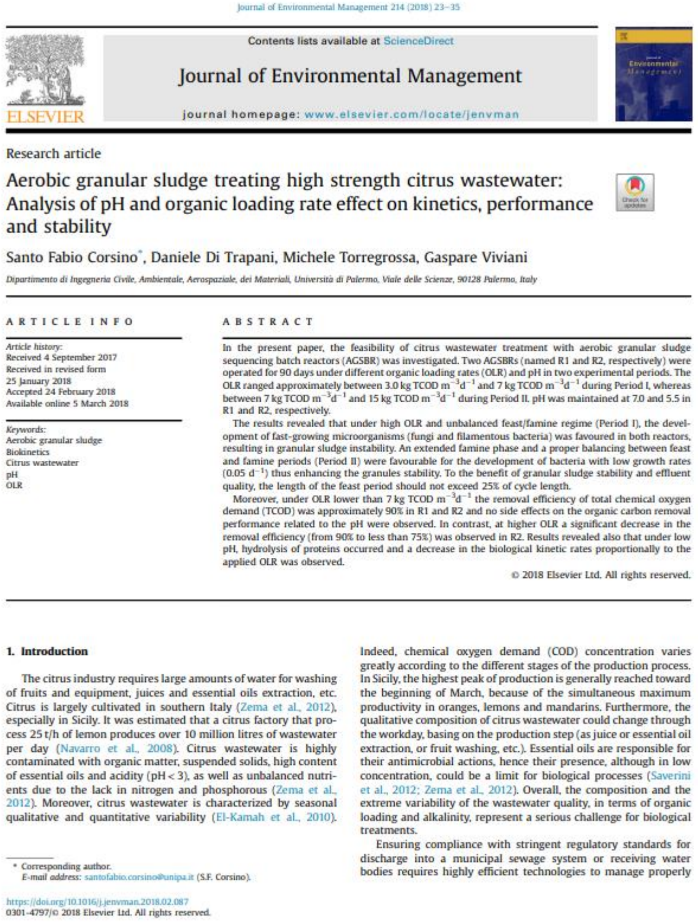
Legend: min-max (average ± std.dev) values.

Industrial:

Cítricos







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ELSEVIER

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Moreover, under OLR lower than 7 kg TCOD $m^{-3}d^{-1}$ the removal efficiency of total chemical oxygen demand (TCOD) was approximately 90% in R1 and R2 and no side effects on the organic carbon removal performance related to the pH were observed. In contrast, at higher OLR a significant decrease in the removal efficiency (from 90% to less than 75%) was observed in R2. Results revealed also that under low pH, hydrolysis of proteins occurred and a decrease in the biological kinetic rates proportionally to the applied OLR was observed.

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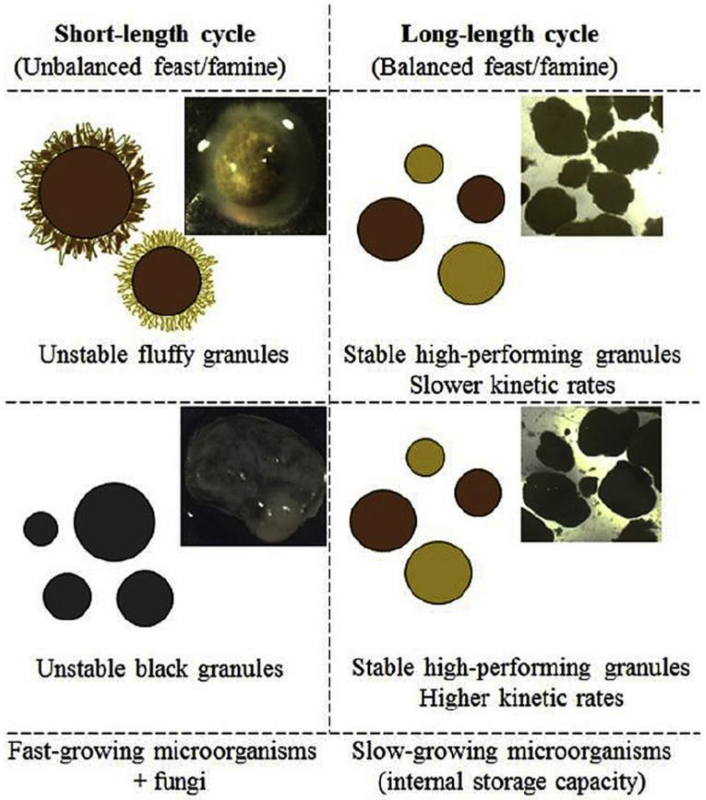
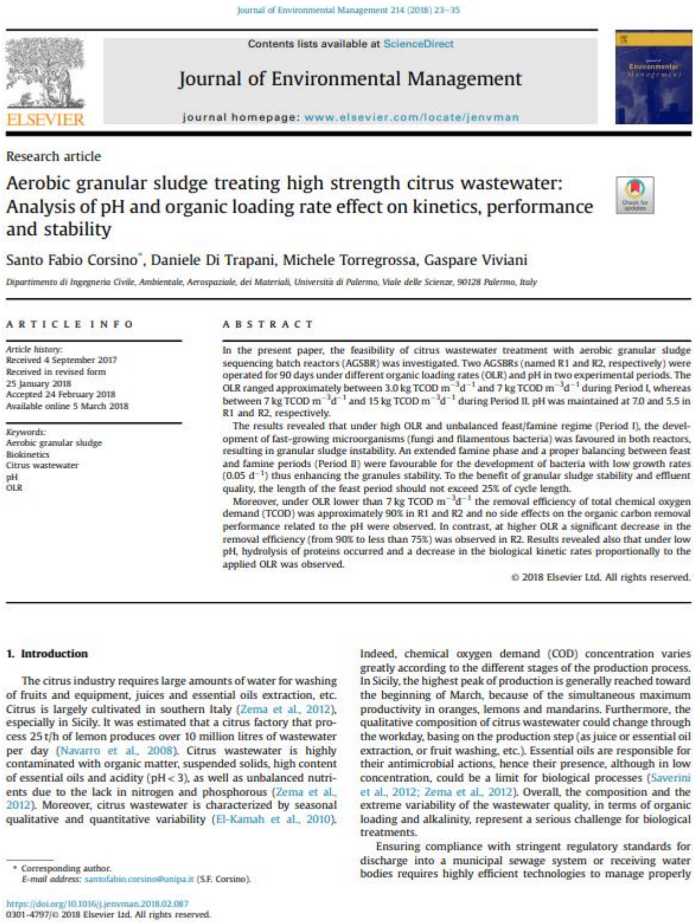
Corsino et al., 2018

Industrial:

Cítricos

DQO % eliminación	TRH 12 h	TRH 24 h
pH ácido	75 %	90 %
pH neutro	90 %	90 %





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Corsino et al., 2018

Industrial:

Troceado de fruta

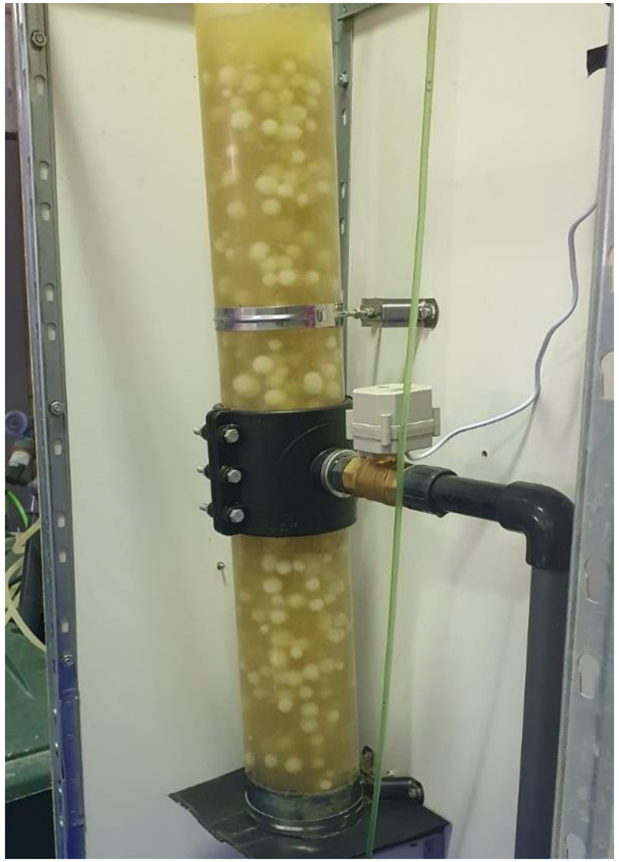
Contaminantes

- Materia orgánica
- Sólidos en suspensión
- pH ácido
- Ausencia de nutrientes

Industrial:

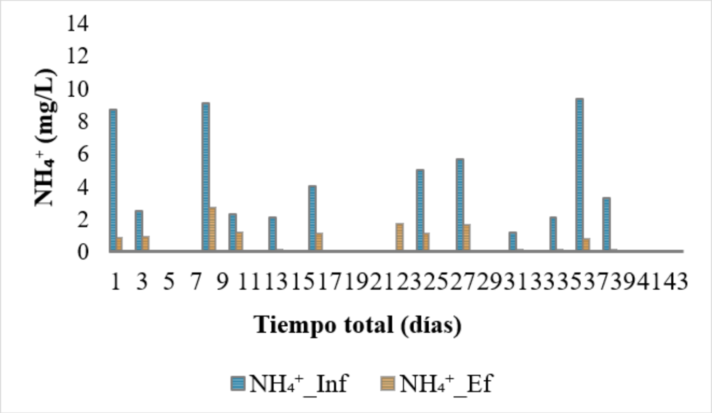
Troceado de fruta

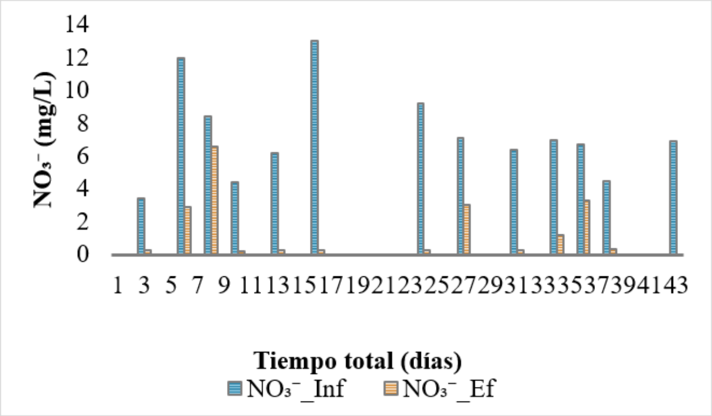
Reactor: SBR, escala laboratorio.
TRH: 6 h.
Pretratamiento: neutralización

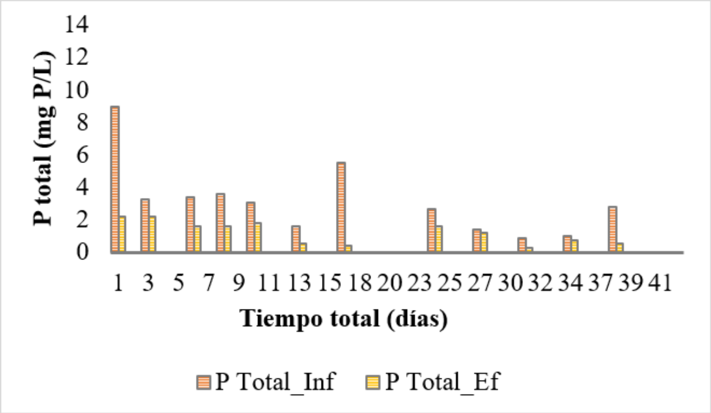


Industrial:

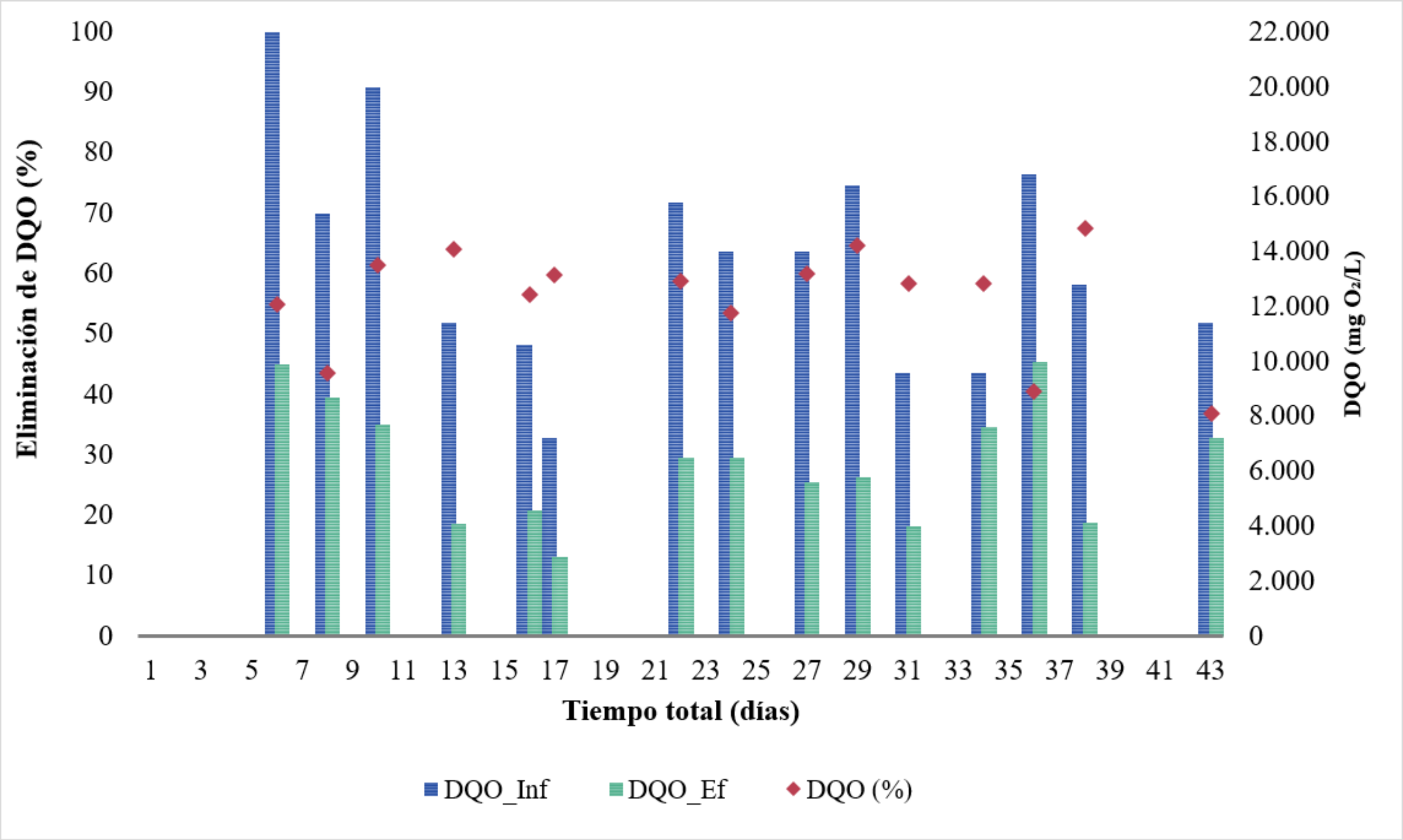
Troceado de fruta





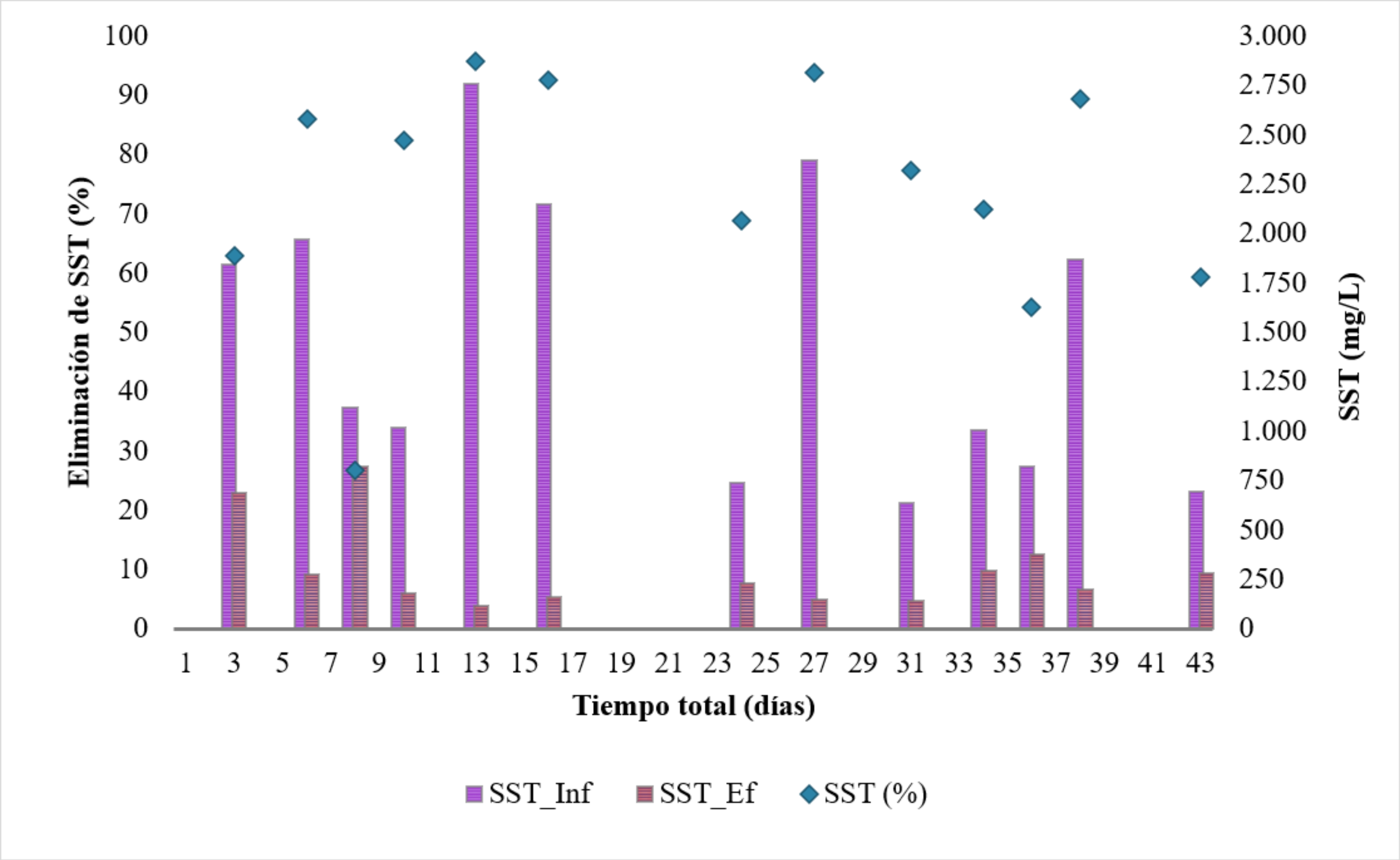


Industrial:
Troceado de fruta



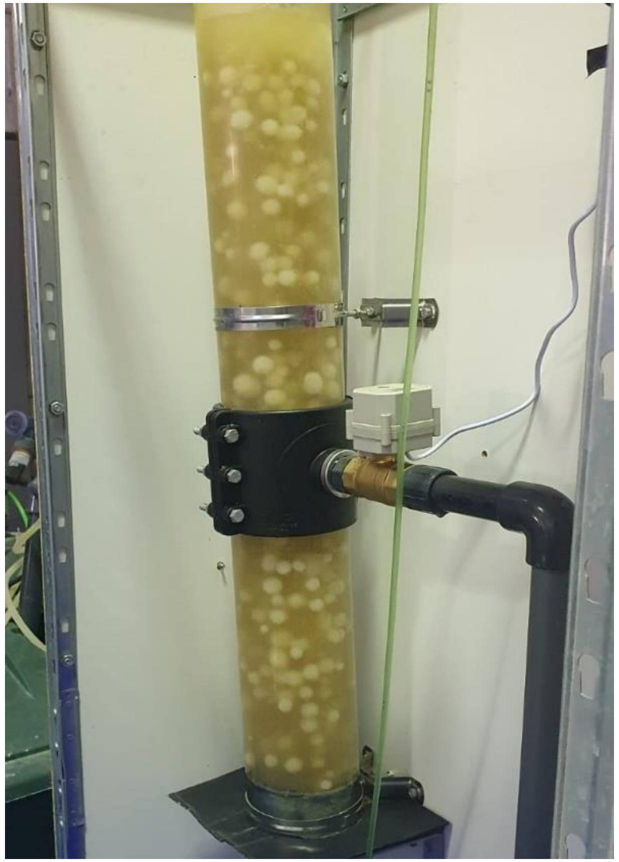
Industrial:
Troceado de fruta

MasterClass patrocinada por:



Industrial:

Troceado de fruta



Industrial:

Matadero

Contaminantes

- Materia orgánica
- Grasa
- N, P
- Sólidos en suspensión

Industrial:
Matadero

Reactor: SBR, escala laboratorio.
TRH: 8 h.
Inóculo: fango flocular

Average characteristics of the influent wastewater

Parameter (units)	Measured value
pH	7.3 ± 0.4 (29)[a]
Total COD ($mg\,l^{-1}$)	7685 ± 646 (24)
SCOD ($mg\,l^{-1}$)	5163 ± 470 (24)
TKN ($mg\,l^{-1}$)	1057 ± 63 (24)
NH_4–N ($mg\,l^{-1}$)	50 ± 12 (24)
NO_3–N ($mg\,l^{-1}$)	0 ± 0 (24)
NO_2–N ($mg\,l^{-1}$)	0 ± 0 (24)
Total P ($mg\,l^{-1}$)	217 ± 38 (24)
Alkalinity ($mg\,l^{-1}$ as $CaCO_3$)	872 ± 42 (8)
SS ($mg\,l^{-1}$)	1742 ± 116 (23)
VSS ($mg\,l^{-1}$)	1520 ± 128 (23)

[a]Mean ± standard deviation (number of measurements).

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Nitrogen and phosphorus removal from an abattoir wastewater in a SBR with aerobic granular sludge

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Abstract

The formation and performance of granular sludge was studied in an 8 l sequencing batch reactor (SBR) treating an abattoir (slaughterhouse) wastewater. Influent concentrations averaged $1520\,mg\,l^{-1}$ volatile suspended solids (VSS), $7685\,mg\,l^{-1}$ Chemical oxygen demand (COD), $1057\,mg\,l^{-1}$ total kjeldahl nitrogen (TKN), $217\,mg\,l^{-1}$ total P. The COD loading was $2.6\,kg\,m^{-3}\,d^{-1}$. The SBR was seeded with flocculating sludge from a SBR with an 1 h settle time, but granules developed within 4 days by reducing the settle time to 2 min. The SBR cycle also had 120 min mixed (anaerobic) fill, 220 min aerated react, and 18 min draw/idle. The granules had a mean diameter of 1.7 mm, a specific gravity of 1.035, a density of $62\,g\,VSS\,l^{-1}$, a zone settling velocity (ZSV) of $51\,m\,h^{-1}$, and a sludge volume index (SVI) of $22\,ml\,g^{-1}$. Without optimizing process conditions, removal of COD and P were over 98%, and removal of N and VSS were over 97%. Nitrification and denitrification occurred simultaneously during react. The results indicate that conventional SBRs treating wastewaters with flocculating sludge can be converted to granular SBRs by reducing the settle time.

Keywords: Abattoir; Aerobic granules; Biological phosphorus removal; Denitrification; Nitrification; SBR; Slaughterhouse; Wastewater

1. Introduction

Granular sludge was first described in strictly anaerobic systems, such as upflow anaerobic sludge blanket (UASB) reactors (Lettinga et al., 1980), biofilm airlift reactors (van Loosdrecht et al., 1995), and anaerobic sequencing batch reactors (SBRs) (Wirtz and Dague, 1996). Granules have a greater density and diameter than flocs, allowing a bioreactor to maintain high biomass concentrations with excellent settling properties (van Loosdrecht et al., 1995). The resulting increase in reactor efficiency explains why over 900 UASB reactors have been built around the world (Alves et al., 2000).

Recently, the formation of granules under aerobic and alternating aerobic/anaerobic conditions has been reported in SBRs seeded with flocculating sludge. Several factors promote the formation of aerobic granules from flocs. A short settle time is required to wash out free-living and floc-forming microorganisms and apply selective pressure for granule formation (Morgenroth

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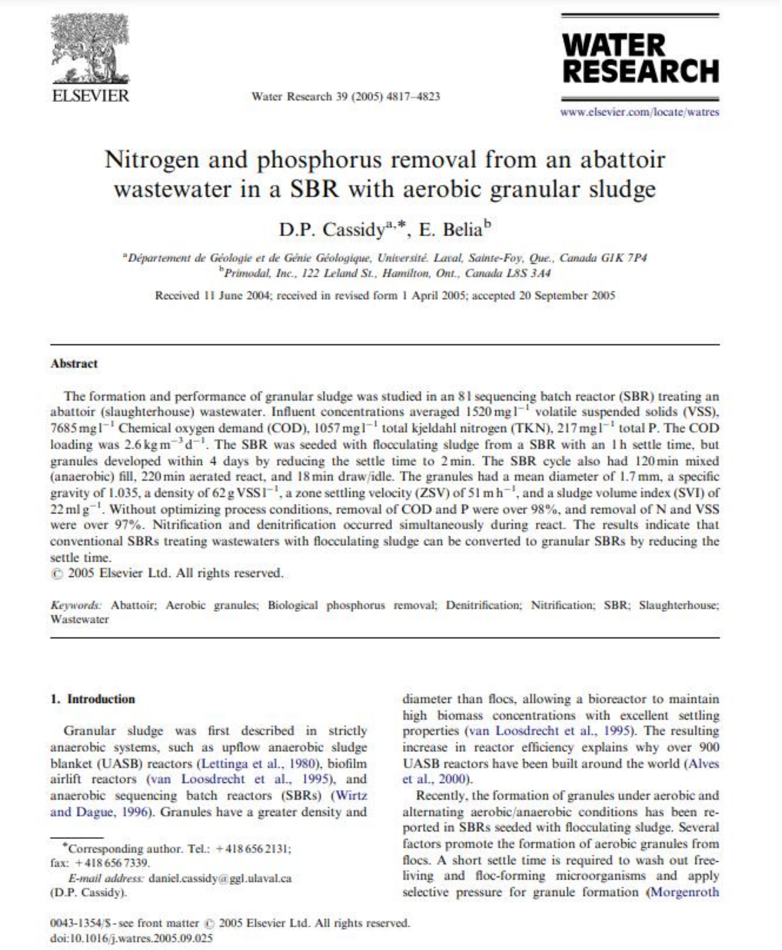
Cassidy & Belia, 2005

Industrial:
Matadero

Average effluent measurements and performance calculations for the SBR during steady state operation (day 16–day 76)

Parameter (units)	Measured value
pH	7.1 ± 0.3 (64)[a]
Total COD ($mg\,l^{-1}$)	106 ± 18 (64)
SCOD ($mg\,l^{-1}$)	95 ± 17 (64)
Total COD removal (%)	98.6
TKN ($mg\,l^{-1}$)	2 ± 2 (64)
NH_4–N ($mg\,l^{-1}$)	0 (64)
NO_3–N ($mg\,l^{-1}$)	26 (64)
NO_2–N ($mg\,l^{-1}$)	0 (64)
N Removal (%)	97.4
Total P ($mg\,l^{-1}$)	4 ± 2 (64)
P Removal (%)	98.2
P Content of biomass (% by weight)	5.7 ± 0.8 (31)
EVSS ($mg\,l^{-1}$)	42 ± 8 (64)
VSS removal (%)	97.2

[a]Mean ± standard deviation (number of measurements).



ELSEVIER
Water Research 39 (2005) 4817–4823
WATER RESEARCH
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Nitrogen and phosphorus removal from an abattoir wastewater in a SBR with aerobic granular sludge

D.P. Cassidy[a,*], E. Belia[b]

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doi:10.1016/j.watres.2005.09.025

Cassidy & Belia, 2005

MasterClass
patrocinada por:

Industrial:
Matadero

Reactor: SBR, escala laboratorio, 20 L.
TRH: 12 h.
Inóculo: fango activo


Bioresource Technology 190 (2015) 487–491

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Bioresource Technology

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Performance of aerobic granular sludge in a sequencing batch bioreactor for slaughterhouse wastewater treatment

Yali Liu [a], Xiaorong Kang [a,b,*], Xin Li [a], Yixing Yuan [a]

[a] School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, China
[b] School of Civil Engineering, Yancheng Institute of Technology, Yancheng 224051, China

H I G H L I G H T S

- Biological nutrient removal was positive correlated to sludge granulation.
- The external feature of granular sludge was studied by 3D-EEM and EPS.
- Particle size distribution showed the superior size for AOB and NOB growth.
- The SOUR was used to analyze the activity of AOB and NOB.

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Article history:
Received 22 December 2014
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Available online 6 March 2015

Keywords:
Aerobic granular sludge
Slaughterhouse wastewater
Particle size
Extracellular polymeric substances
Specific oxygen demand rates

A B S T R A C T

Lab-scale experiment was conducted to investigate the formation and characteristics of aerobic granular sludge for biological nutrient removal of slaughterhouse wastewater. Experimental results showed that removal performances of chemical oxygen demand (COD), ammonia and phosphate were enhanced with sludge granulation, and their removal efficiencies reached 95.1%, 99.3% and 83.5%, respectively. The aerobic granular sludge was matured after 90 days cultivation, and protein-like substances were the main components. Simultaneously, the mass ratio of proteins and polysaccharides (PN/PS) was enhanced to 2.5 from 1.7. The granules with particle sizes of 0.6–1.2 and 1.2–1.8 mm, accounting for 69.6%, were benefit for the growth of ammonia oxidizing bacteria (AOB) and nitrate oxidizing bacteria (NOB), and corresponding specific oxygen demand rates (SOUR) of AOB and NOB were 31.4 and 23.3 mgO_2/gMLSS h, respectively.

1. Introduction

Slaughterhouse wastewater is characterized by high concentrations of organic matters, suspended solids, oil and grease, nitrogen and phosphate (Merzouki et al., 2005). Due to the high concentrations of organic matters and nitrogen, biological treatment of this wastewater is usually accomplished in units sequentially arranged to remove organic matter prior to nitrogen. Anaerobic processes normally remove a significant fraction of organic matters, but low nitrogen. Conventional nitrogen removal systems involve the installation of several units of sequential operations, requiring large areas for the deployment of full scale systems. One way to reduce the deployment areas is by systems that integrate nitrification and denitrification within a single unit (Bassin et al., 2012). After anaerobic hydrolysis and/or physical pretreatment of this wastewater, a nitrification/denitrification system based on the aerobic granular technology can fulfill the environmental requirements (Zhao et al., 2013).

Aerobic granular sludge has attracted increasing attention in recent years, for its high metabolic activity, large granule diameter, remarkable settle ability, and high biomass retention without any support media, ability to withstand shock loadings and unfavorable environmental conditions, and especially, the excellent simultaneous nitrification and denitrification capacity (Adav et al., 2009; Wei et al., 2012). However, reports of successful aerobic granulation system were mainly focused on readily biodegradable synthetic wastewater (Nancharaiah and Venugopalan, 2011). Information on application of aerobic granules for the treatment of refractory wastewaters with high-strength ammonium, like phenol wastewater (Adav et al., 2007), agro-based wastewater (Abdullah et al., 2011), livestock wastewater (Othman et al., 2013), rubber wastewater (Rosman et al., 2014) and domestic wastewater (Coma et al., 2012) is still very initiated, even though biological treatment of these wastewaters has been practiced for

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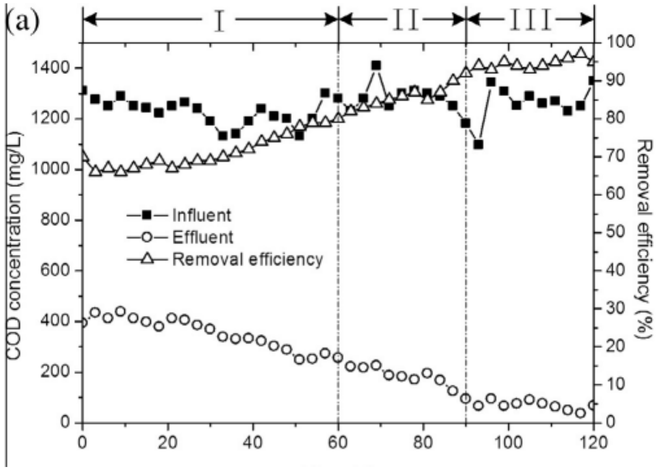
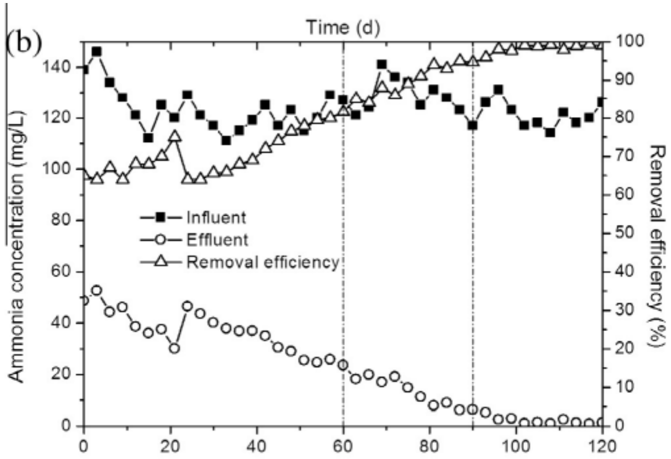
Liu et al., 2015

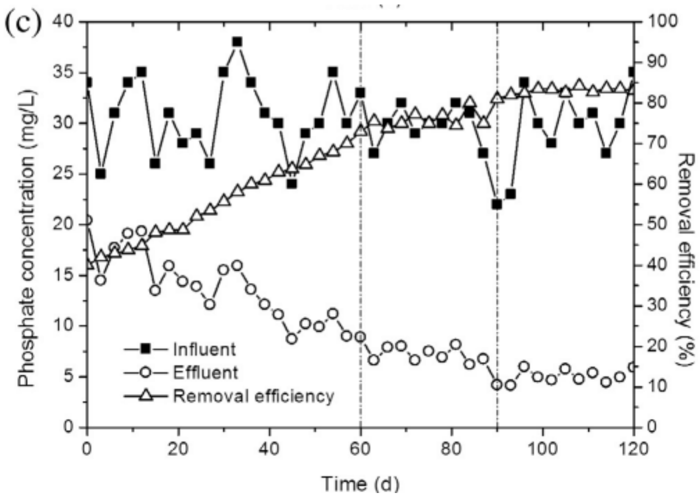
Industrial:

Matadero

MasterClass patrocinada por:







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HIGHLIGHTS

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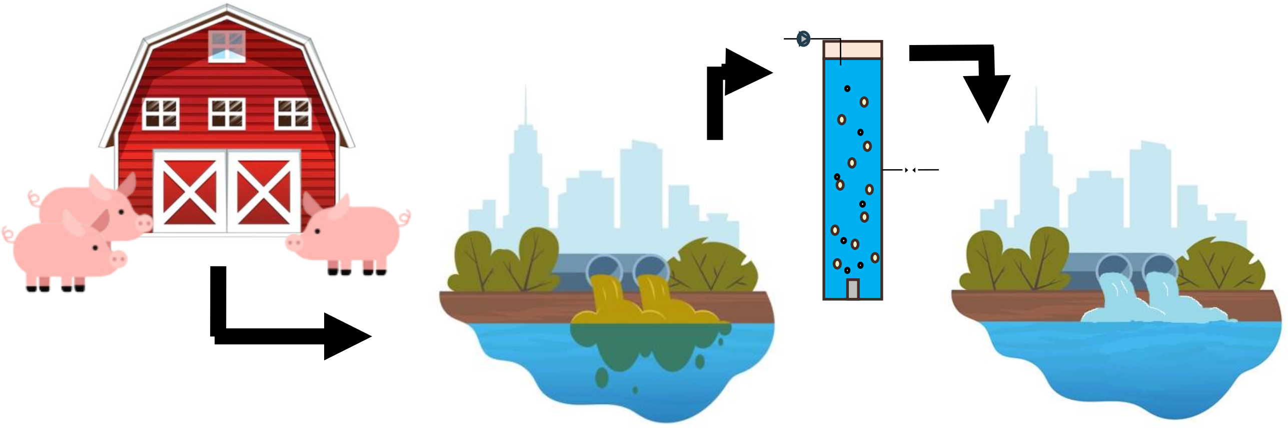
Liu et al., 2015

Industrial:
Granjas

Contaminantes

- Materia orgánica
- N, P
- Sólidos en suspensión
- Aminoácidos
- Antibióticos



MasterClass patrocinada por:

Industrial:

Granjas (N y P)

Reactor: SBR, escala laboratorio.
TRH: 8 h.
Inóculo: mezcla de fango activo y lodo de la granja.
Agua: orina, sangre, heces y agua de lavado (tamiz 1 mm)

Parameters[a]	Livestock wastewater (cattle farm)
pH	8.05
Chemical oxygen demand (COD)	3600
Biochemical oxygen demand (BOD)	1750
Total suspended solid	230
Total nitrogen	650
Total phosporus	380

a

All other parameters are in $mg L^{-1}$ except pH.

Bioresource Technology 133 (2013) 630–634

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Short Communication

Livestock wastewater treatment using aerobic granular sludge

Inawati Othman[a], Aznah Nor Anuar[b,*], Zaini Ujang[b], Noor Hasyimah Rosman[a], Hasnida Harun[a], Shreeshivadasan Chelliapan[b]

[a] Department of Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
[b] Institute of Environmental and Water Resource Management, WATER Research Alliance, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

HIGHLIGHTS

- Matured aerobic granules were observed in the reactor with the size up to 4.1 mm.
- Aerobic granules grown in livestock wastewater had excellent settling properties.
- Removal efficiency of 74% COD, 73% TN and 70% TP can be achieved at 4-h cycle time.

ARTICLE INFO

Article history:
Received 19 November 2012
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Keywords:
Aerobic granular sludge
Livestock wastewater
Mineral composition
SBR

ABSTRACT

The present study demonstrated that aerobic granular sludge is capable of treating livestock wastewater from a cattle farm in a sequencing batch reactor (SBR) without the presence of support material. A lab scale SBR was operated for 80 d using 4 h cycle time with an organic loading rate (OLR) of 9 kg COD m^{-3} - d^{-1}. Results showed that the aerobic granules were growing from 0.1 to 4.1 mm towards the end of the experimental period. The sludge volume index (SVI) was 42 ml g^{-1} while the biomass concentration in the reactor grew up to 10.3 g L^{-1} represent excellent biomass separation and good settling ability of the granules. During this period, maximum COD, TN and TP removal efficiencies (74%, 73% and 70%, respectively) were observed in the SBR system, confirming high microbial activity in the SBR system.

1. Introduction

In the past, a number of research was performed using aerobic granular sludge in laboratory-scale reactors treating different types of wastewater such as soybean-processing wastewater (Su and Yu, 2005), brewery wastewater (Wang et al., 2007), abattoirs wastewater (Cassidy and Belia, 2005), dairy wastewater (Schwarzenbeck et al., 2005), saline wastewater (Figueroa et al., 2008), and palm oil mill effluent (POME) (Abdullah et al., 2011). Although aerobic granular sludge has been investigated extensively using synthetic wastewater, there is hardly any in aerobic granular sludge under real wastewater.

The growth of Malaysian's livestock industry increased significantly and accelerated gradually each year (Ngo, 2004). In general, livestock wastewater contains high chemical oxygen demand (COD), biological oxygen demand (BOD), color, nitrogen, phosphorus and suspended solids (Lee and Shoda, 2008). High levels of phosphorus and nitrogen in discharging livestock wastewater contribute to eutrophication of receiving wastewater particularly lakes and slow moving rivers. Therefore, a specific treatment process is required in treating wastewater.

In the past, small quantity of livestock wastewater was discharged without proper technology and contributed substantially to environmental pollution. Most of the livestock industries are employing conventional process for livestock wastewater treatment. The negative impact will be greater if the volume and frequency of the untreated discharged of livestock are higher. Since high costs of the reagent and poor performance of physico-chemical process in removal of soluble organics, biological treatment process are most preferred. Aerobic granular sludge is one of the biological treatment technologies that can successfully cultivated in treating livestock wastewater in a sequencing batch reactor (SBR).

Therefore, this study attempts to demonstrate the cultivation of aerobic granules applied for the effective bioprocess that is able to treat livestock wastewater. The study focuses on the aerobic granular sludge removal efficiency and the effluent quality treating real wastewater. Moreover, biomass profile and settling properties for the treatment of livestock wastewater were also presented in this study. Considering the advantages of aerobic granular sludge over conventional sludge flocs, aerobic granular sludge is a reasonable

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Othman et al., 2013

II Ciclo de 20 MasterClass AGUASRESIDUALES.INFO

MasterClass patrocinada por: TORO WASTEWATER EQUIPMENT INDUSTRIES®

Industrial:

Granjas (N y P)

Eliminación DQO: 74%

Eliminación NT: 73%

Eliminación PT: 70%

Bioresource Technology 133 (2013) 630–634

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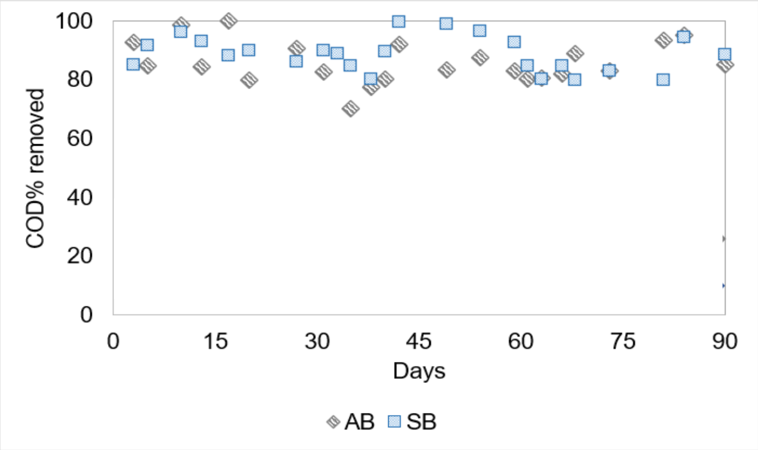
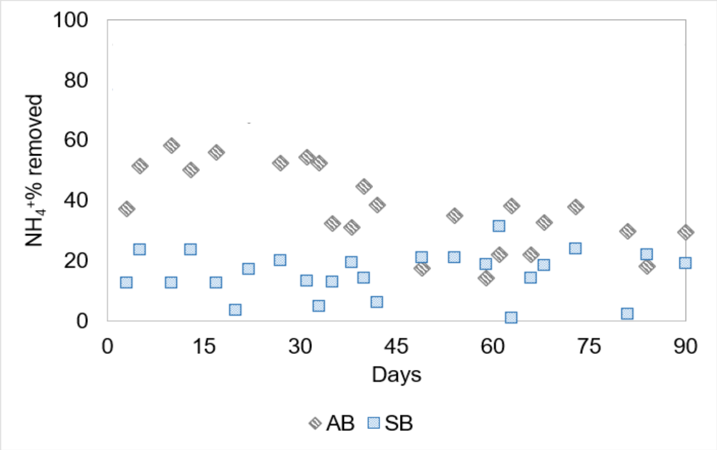
Othman et al., 2013

MasterClass patrocinada por:

Industrial:
Granjas





Amino Acids
https://doi.org/10.1007/s00726-022-03168-y

ORIGINAL ARTICLE

Effects of sulphur amino acids on the size and structure of microbial communities of aerobic granular sludge bioreactors

Aurora Rosa-Masegosa[1,2] · Lizandra Perez-Bou[2,3] · Barbara Muñoz-Palazon[1,2] · Antonio Monteoliva-García[4] · Alejandro Gonzalez-Martinez[1,2] · Jesus Gonzalez-Lopez[1,2] · David Correa-Galeote[1,2]

Received: 3 January 2022 / Accepted: 27 April 2022

Abstract
Granular activated sludge has been described as a promising tool in treating wastewater. However, the effect of high concentrations of sulphur amino acids, cysteine and methionine, in the evolution, development and stability of AGS-SBRs (aerobic granular sludge in sequential batch reactors) and their microbial communities is not well-established. Therefore, this study aimed to evaluate microbial communities' size, structure and dynamics in two AGS-SBRs fed with two different concentrations of amino acids (50 and 100 mg L^{-1} of both amino acids). In addition, the impact of the higher level of amino acids was also determined under an acclimatization or shock strategy. While N removal efficiency decreased with amino acids, the removal of the organic matter was generally satisfactory. Moreover, the abrupt presence of both amino acids reduced even further the removal performance of N, whereas under progressive adaptation, the removal yield was higher. Besides, excellent removal rates of cysteine and methionine elimination were found, in all stages below 80% of the influent values. Generally considered, the addition of amino acids weakly impacts the microbial communities' total abundances. On the contrary, the presence of amino acids sharply modulated the dominant bacterial structures. Furthermore, the highest amino acid concentration under the shock strategy resulted in a severe change in the structure of the microbial community. *Acidovorax*, *Flavobacterium*, *Methylophilus*, *Stenotrophomonas* and *Thauera* stood out as the prominent bacteria to cope with the high presence of cysteine and methionine. Hence, the AGS-SBR technology is valuable for treating influents enriched in sulphur Aa inclusively when a shock strategy was used.

Keywords Cysteine · Methionine · qPCR · Illumina sequencing · N-removal · AGS-SBR

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Aurora Rosa-Masegosa and Lizandra Perez-Bou contributed equally to this article.

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Introduction

The global population is currently increasing exponentially, and it is expected to rise around 30% in the following years, reaching 9.9 billion people by 2050 (Bahar et al. 2020). In addition, many of the essential human activities, such as crop and livestock production, manufacturing of goods, power generation, or domestic activities, rely upon the availability of water in both adequate quantities and of acceptable quality (Huang et al. 2018). Therefore, the increase in the global population is coupled in parallel with higher water requirements (Jones et al. 2021). Concomitantly, sustainable water management is imperative to ensure water availability and easy access worldwide (Mole and Brooks, 2019). On the other hand, the increase in water requirements resulted in the generation of higher quantities of wastewater (WW), making its management a major concern for people's health. Also, it is an environmental hazard due to the ineffective and

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Springer

Rosa-Masegosa et al., 2022

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Industrial: Granjas

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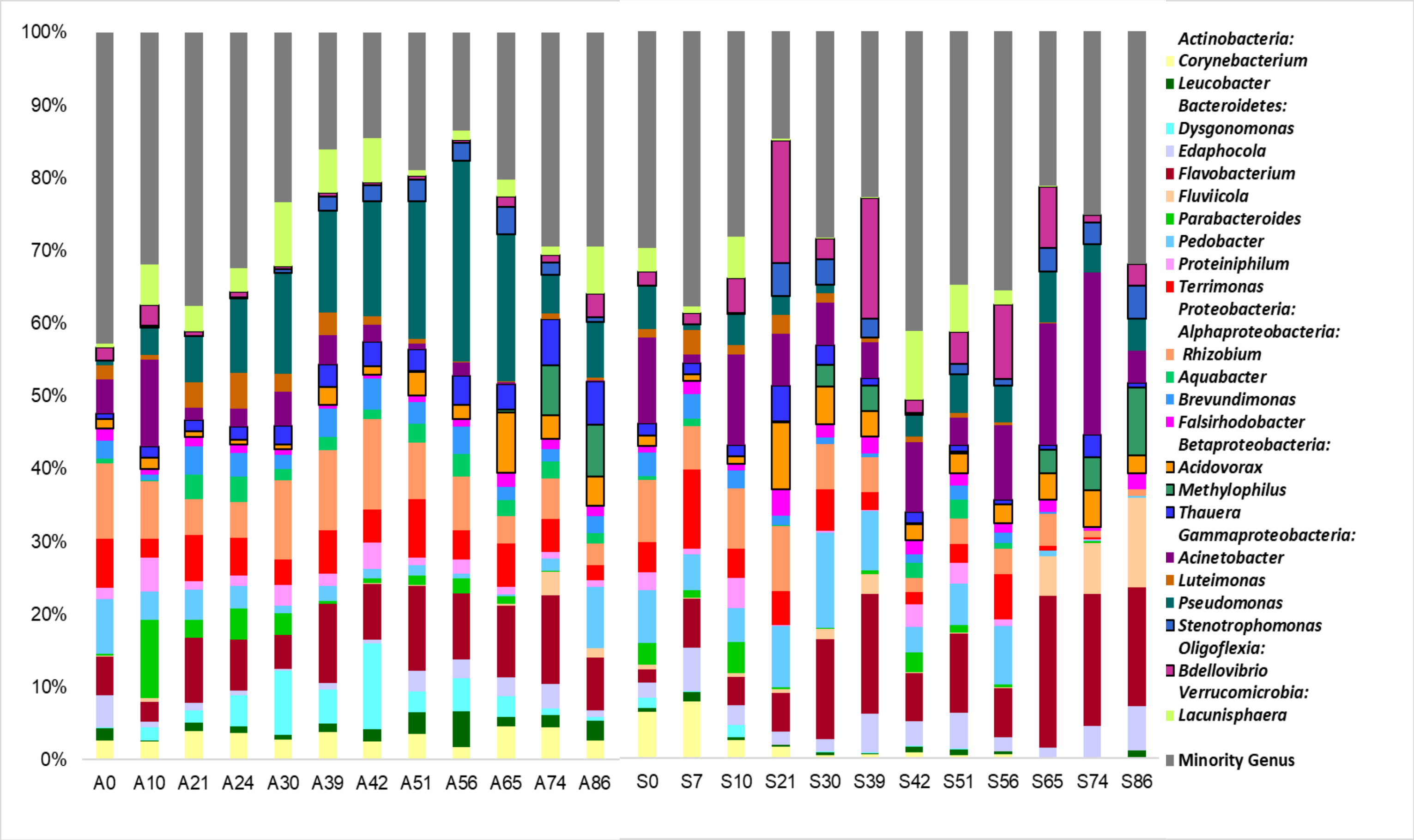

Amino Acids
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ORIGINAL ARTICLE

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Effects of sulphur amino acids on the size and structure of microbial communities of aerobic granular sludge bioreactors

Aurora Rosa-Masegosa[1,2] · Lizandra Perez-Bou[2,3] · Barbara Muñoz-Palazon[1,2] · Antonio Monteoliva-García[4] · Alejandro Gonzalez-Martinez[1,2] · Jesus Gonzalez-Lopez[1,2] · David Correa-Galeote[1,2]

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Abstract

Granular activated sludge has been described as a promising tool in treating wastewater. However, the effect of high concentrations of sulphur amino acids, cysteine and methionine, in the evolution, development and stability of AGS-SBRs (aerobic granular sludge in sequential batch reactors) and their microbial communities is not well-established. Therefore, this study aimed to evaluate microbial communities' size, structure and dynamics in two AGS-SBRs fed with two different concentrations of amino acids (50 and 100 mg L^{-1} of both amino acids). In addition, the impact of the higher level of amino acids was also determined under an acclimatization or shock strategy. While N removal efficiency decreased with amino acids, the removal of the organic matter was generally satisfactory. Moreover, the abrupt presence of both amino acids reduced even further the removal performance of N, whereas under progressive adaptation, the removal yield was higher. Besides, excellent removal rates of cysteine and methionine elimination were found, in all stages below 80% of the influent values. Generally considered, the addition of amino acids weakly impacts the microbial communities' total abundances. On the contrary, the presence of amino acids sharply modulated the dominant bacterial structures. Furthermore, the highest amino acid concentration under the shock strategy resulted in a severe change in the structure of the microbial community. *Acidovorax*, *Flavobacterium*, *Methylophilus*, *Stenotrophomonas* and *Thauera* stood out as the prominent bacteria to cope with the high presence of cysteine and methionine. Hence, the AGS-SBR technology is valuable for treating influents enriched in sulphur Aa inclusively when a shock strategy was used.

Keywords Cysteine · Methionine · qPCR · Illumina sequencing · N-removal · AGS-SBR

Introduction

The global population is currently increasing exponentially, and it is expected to rise around 30% in the following years, reaching 9.9 billion people by 2050 (Bahar et al. 2020). In addition, many of the essential human activities, such as crop and livestock production, manufacturing of goods, power generation, or domestic activities, rely upon the availability of water in both adequate quantities and of acceptable quality (Huang et al. 2018). Therefore, the increase in the global population is coupled in parallel with higher water requirements (Jones et al. 2021). Concomitantly, sustainable water management is imperative to ensure water availability and easy access worldwide (Mole and Brooks, 2019). On the other hand, the increase in water requirements resulted in the generation of higher quantities of wastewater (WW), making its management a major concern for people's health. Also, it is an environmental hazard due to the ineffective and

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Industrial:

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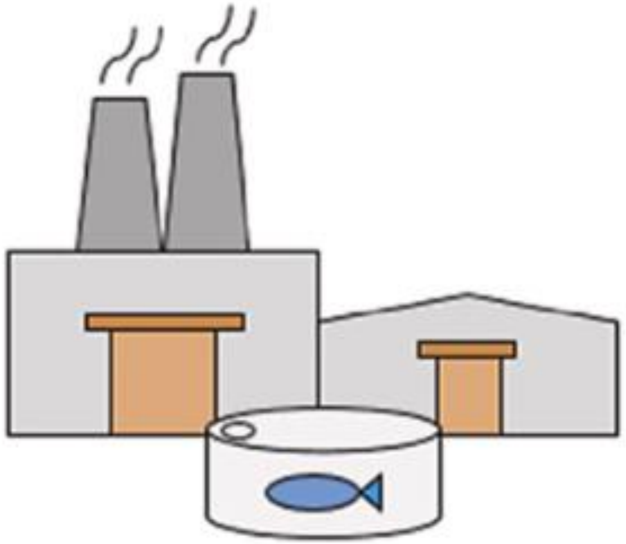
Contaminantes

- Materia orgánica
- N
- Alta salinidad
- Grasas



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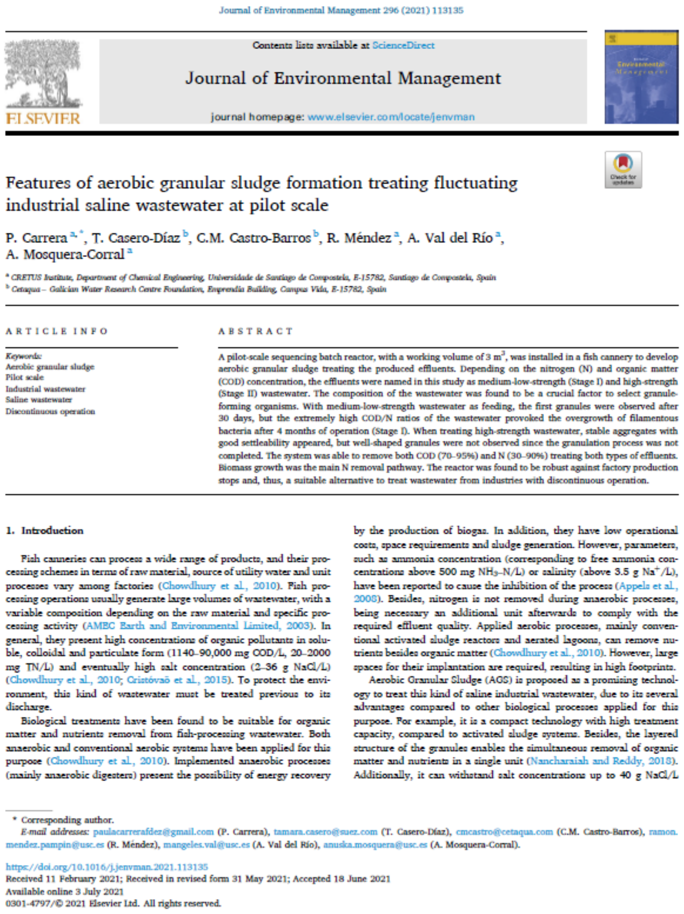
Reactor: SBR, 3000 L.
TRH: 6 h y 15 h (MS-WW y HS-WW, respectivamente).
Inóculo: fango activo adaptado a alta salinidad

Table 1
Average values of medium-low strength wastewater (MS-WW) and high strength wastewater (HS-WW) composition.

Parameter	Unit	MS-WW	HS-WW
Conductivity	mS/cm	22.1 ± 12.5	18 ± 3.6
pH	–	6.26 ± 0.85	6.59 ± 0.23
TSS	g/L	0.250 ± 0.137	2.37 ± 1.79
VSS	g/L	0.213 ± 0.140	1.07 ± 0.26
Total COD	mg/L	1203.8 ± 671.9	10,843.0 ± 4898.2
Soluble COD	mg/L	507.4 ± 282.0	7352.2 ± 2227.0
Greases	mg/L	145.7 ± 120.3	1608.2 ± 1208.8
VFAs	mg COD/L	169.7 ± 206.2	3373.8 ± 2295.3
- Acetic acid	mg COD/L	41.4 ± 53.1	1272.5 ± 814.8
- Propionic acid	mg COD/L	64.8 ± 11.3	548.2 ± 271.6
- Butyric acid	mg COD/L	9.2 ± 18.4	1092.5 ± 802.9
- Valeric acid	mg COD/L	20.1 ± 40.0	460.5 ± 417.9
NH_4^+-N	mg N/L	8.18 ± 7.45	557.7 ± 395.6
TN	mg N/L	21.23 ± 8.36	1025.0 ± 117.4
PO_4^{-3}-P	mg P/L	3.05 ± 2.46	129.0 ± 71.2
Proteins	mg/L	86.46 ± 48.08	2059.6 ± 296.1
Carbohydrates	mg/L	46.28 ± 29.76	514.8 ± 723.7
Chloride	g Cl^-/L	7.37 ± 5.6	4.21 ± 1.01
Sulphate	g SO_4^{-2}/L	1.00 ± 0.77	0.25 ± 0.04
Sodium	g Na^+/L	4.24 ± 2.90	2.77 ± 0.60
Salinity	g NaCl/L	14.35 ± 5.76	7.41 ± 2.06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Features of aerobic granular sludge formation treating fluctuating industrial saline wastewater at pilot scale

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ARTICLE INFO
Keywords:
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Pilot scale
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Discontinuous operation

ABSTRACT
A pilot-scale sequencing batch reactor, with a working volume of 3 m^3, was installed in a fish cannery to develop aerobic granular sludge treating the produced effluents. Depending on the nitrogen (N) and organic matter (COD) concentration, the effluents were named in this study as medium-low-strength (Stage I) and high-strength (Stage II) wastewater. The composition of the wastewater was found to be a crucial factor to select granule-forming organisms. With medium-low-strength wastewater as feeding, the first granules were observed after 30 days, but the extremely high COD/N ratios of the wastewater provoked the overgrowth of filamentous bacteria after 4 months of operation (Stage I). When treating high-strength wastewater, stable aggregates with good settleability appeared, but well-shaped granules were not observed since the granulation process was not completed. The system was able to remove both COD (70–95%) and N (30–90%) treating both types of effluents. Biomass growth was the main N removal pathway. The reactor was found to be robust against factory production stops and, thus, a suitable alternative to treat wastewater from industries with discontinuous operation.

1. Introduction

Fish canneries can process a wide range of products, and their processing schemes in terms of raw material, source of utility water and unit processes vary among factories (Chowdhury et al., 2010). Fish processing operations usually generate large volumes of wastewater, with a variable composition depending on the raw material and specific processing activity (AMEC Earth and Environmental Limited, 2003). In general, they present high concentrations of organic pollutants in soluble, colloidal and particulate form (1140–90,000 mg COD/L, 20–2000 mg TN/L) and eventually high salt concentration (2–36 g NaCl/L) (Chowdhury et al., 2010; Cristóvaõ et al., 2015). To protect the environment, this kind of wastewater must be treated previous to its discharge.

Biological treatments have been found to be suitable for organic matter and nutrients removal from fish-processing wastewater. Both anaerobic and conventional aerobic systems have been applied for this purpose (Chowdhury et al., 2010). Implemented anaerobic processes (mainly anaerobic digesters) present the possibility of energy recovery by the production of biogas. In addition, they have low operational costs, space requirements and sludge generation. However, parameters, such as ammonia concentration (corresponding to free ammonia concentrations above 500 mg NH_3–N/L) or salinity (above 3.5 g Na^+/L), have been reported to cause the inhibition of the process (Appels et al., 2008). Besides, nitrogen is not removed during anaerobic processes, being necessary an additional unit afterwards to comply with the required effluent quality. Applied aerobic processes, mainly conventional activated sludge reactors and aerated lagoons, can remove nutrients besides organic matter (Chowdhury et al., 2010). However, large spaces for their implantation are required, resulting in high footprints.

Aerobic Granular Sludge (AGS) is proposed as a promising technology to treat this kind of saline industrial wastewater, due to its several advantages compared to other biological processes applied for this purpose. For example, it is a compact technology with high treatment capacity, compared to activated sludge systems. Besides, the layered structure of the granules enables the simultaneous removal of organic matter and nutrients in a single unit (Nancharaiah and Reddy, 2018). Additionally, it can withstand salt concentrations up to 40 g NaCl/L

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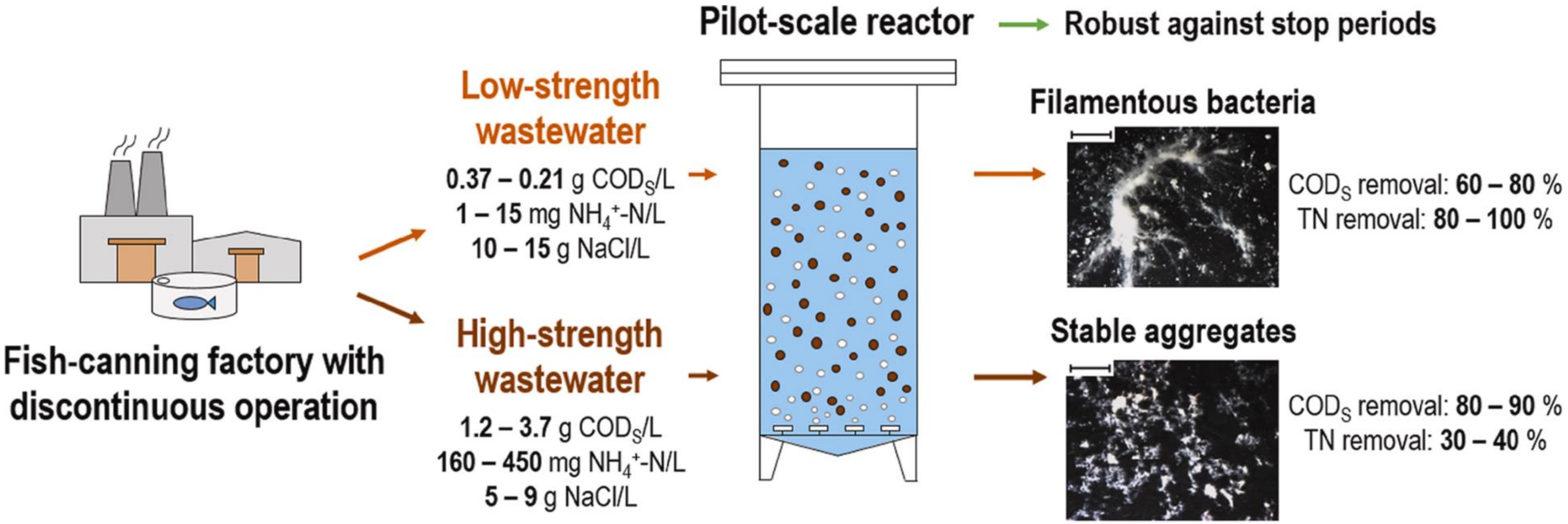

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Table 3
Fulfilment of the discharge requirements in Stages I and II.

Parameter	Limit concentration	Stage I	Stage II
pH	5.5–9.5	6.5–7.2	7.9–9.1
TSS (mg/L)	125	70–100	200–400
Total COD (mg/L)	350	400–500	400–900
BOD_5 (mg/L)	150	100–200	40–200
TP (mg/L)	12.5	0.3–2.5	50–100
NH_4^+-N (mg/L)	25	1–6	80–300
TN (mg/L)	57.5	2–8	80–320
Greases (mg/L)	25	70–200	2–10

*The concentrations correspond to the effluent of the pilot plant (outlet of the settler).

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Urbana

Potable

3 SBR
Volumen total 4986 L.
Torre Cardela (Granada)
Eliminación nitrato

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Conclusiones

Conclusiones

Tecnología prometedora. Gran variedad de aplicaciones gracias a sus ventajas.

Muy compacta, ahorra espacio y energía. Es una alternativa poco costosa.

Colaboración entre Industria-Universidad necesaria.

Referencias

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Referencias

MasterClass patrocinada por:

- Carrera, P., Casero-Díaz, T., Castro-Barros, C. M., Méndez, R., Del Río, A. V., & Mosquera-Corral, A. (2021). Features of aerobic granular sludge formation treating fluctuating industrial saline wastewater at pilot scale. *Journal of Environmental Management*, *296*, 113135.
- Cassidy, D. P., & Belia, E. (2005). Nitrogen and phosphorus removal from an abattoir wastewater in a SBR with aerobic granular sludge. *Water research*, *39*(19), 4817-4823.
- Chen, Q., Li, Z. & Hua, X. Fate of estrogens in a pilot-scale step-feed anoxic/oxic wastewater treatment system controlling by nitrogen and phosphorus removal. *Environ Sci Pollut Res* **25**, 12981–12991 (2018). https://doi.org/10.1007/s11356-018-1584-3
- Corsino, S. F., Di Trapani, D., Torregrossa, M., & Viviani, G. (2018). Aerobic granular sludge treating high strength citrus wastewater: Analysis of pH and organic loading rate effect on kinetics, performance and stability. *Journal of environmental management*, *214*, 23-35.
- Franca, R. D., Pinheiro, H. M., van Loosdrecht, M. C., & Lourenço, N. D. (2018). Stability of aerobic granules during long-term bioreactor operation. *Biotechnology Advances*, *36*(1), 228-246.
- Hamza, R., Rabii, A., Ezzahraoui, F. Z., Morgan, G., & Iorhemen, O. T. (2022). A review of the state of development of aerobic granular sludge technology over the last 20 years: Full-scale applications and resource recovery. *Case Studies in Chemical and Environmental Engineering*, *5*, 100173.
- Liu, Y., Kang, X., Li, X., & Yuan, Y. (2015). Performance of aerobic granular sludge in a sequencing batch bioreactor for slaughterhouse wastewater treatment. *Bioresource technology*, *190*, 487-491.

Referencias

- Morgenroth, E., Sherden, T., Van Loosdrecht, M. C. M., Heijnen, J. J., & Wilderer, P. A. (1997). Aerobic granular sludge in a sequencing batch reactor. *Water research*, *31*(12), 3191-3194.

- Muñoz-Palazon, B., Rodriguez-Sanchez, A., Hurtado-Martinez, M., de Castro, I. M., Juarez-Jimenez, B., Gonzalez-Martinez, A., & Gonzalez-Lopez, J. (2019). Performance and microbial community structure of an aerobic granular sludge system at different phenolic acid concentrations. *Journal of hazardous materials*, *376*, 58-67.

- Othman, I., Anuar, A. N., Ujang, Z., Rosman, N. H., Harun, H., & Chelliapan, S. (2013). Livestock wastewater treatment using aerobic granular sludge. *Bioresource technology*, *133*, 630-634.

- Rosa-Masegosa, A., Perez-Bou, L., Muñoz-Palazon, B., Monteoliva-García, A., Gonzalez-Martinez, A., Gonzalez-Lopez, J., & Correa-Galeote, D. (2022). Effects of sulphur amino acids on the size and structure of microbial communities of aerobic granular sludge bioreactors. *Amino Acids*, *54*(10), 1403-1419.

- Rosa-Masegosa, A., Muñoz-Palazon, B., Gorrasi, S., Fenice, M., Gonzalez-Martinez, A., & Gonzalez-Lopez, J. (2023). Description of new single-chamber continuous-flow reactors of aerobic granular sludge: Technical and biological study. *Journal of Environmental Chemical Engineering*, *11*(3), 109938.

- Wang, X., Chen, Z., Kang, J., Zhao, X., & Shen, J. (2018). Removal of tetracycline by aerobic granular sludge and its bacterial community dynamics in SBR. *RSC advances*, *8*(33), 18284-18293.

- Zhang, H.; Liu, Y.-Q.; Mao, S.; Steinberg, C.E.W.; Duan, W.; Chen, F. Reproducibility of Aerobic Granules in Treating Low-Strength and Low-C/N-Ratio Wastewater and Associated Microbial Community Structure. *Processes* **2022**, *10*, 444. https://doi.org/10.3390/pr10030444

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