Start-up of the first pilot plant for Short-Cut Enhanced Phosphorus and PHA Recovery (S.C.E.P.P.H.A.R.) from real sieved wastewater

Vincenzo Conca*, Arianna Cherubin*, Cinzia da Ros*, Nicola Frison*, Anna Laura Eusebi, Francesco Fatone****

*Department of Biotechnology, University of Verona, Strada Le Grazie 15, Verona, Italy
**SIMAU Department, Università Politecnica delle Marche, Via Brecce Bianche, 12, Ancona 60100, Italy. E-mail: a.l.eusebi@univpm.it

Abstract:
Wastewater treatment is a growing segment of the water industry, from which the recovery of valuable resources could make more efficient the water sector. In this regard, the Horizon 2020 project SMART-plant aims the upgrading of existing WWTPs by the integration of novel Smartechs for the biological carbon upgrading (as PHAs), phosphorus and cellulose fibers recovery and the implementation of innovative energy-efficient biotechnologies. Among the others, in this work is presented the pilot Smartech 5 which accomplishes the Short-Cut Enhanced Phosphorus and PHA recovery (S.C.E.P.P.H.A.R.) in the sidestream of the anaerobic digestion. The S.C.E.P.P.H.A.R. system is just started up at the municipal WWTP of Carbonera (Treviso, North of Italy) and the expected production of PHA-bioplastic is 0.7-0.8 kgPHA/day using real cellulosic primary sludge from sieved wastewater as carbon source.

Keywords: S.C.E.P.P.H.A.R., bioplastics, phosphorus, Smart-Plant, Horizon 2020

Introduction

The possibility to recover resources from municipal wastewater treatment plants (WWTPs) is currently drawings a worldwide attention since it is driven by environmental, economic and ecological benefits. During the last decades, the methane produced from the anaerobic digestion of sewage sludge was the main resource gained from the wastewater (Verstraete et al 2014). However, novel forms of resources with higher economical value could be abstracted from the existing WWTP and major research efforts are focused recovery of cellulose, short and medium-chain carboxylic acids, phosphorus and polyhydroxyalkanoates (PHAs, bioplastics).
In this scenario, the SMART-Plant project in the framework of Horizon 2020, aims to validate and to address to the market a portfolio of SMARTechnologies (Smartechs) that, singularly or combined, can be integrated in existing wastewater treatment plants and give the added value towards efficient wastewater-based biorefineries.
Recently (30 days), the pilot Smartech 5 (S.C.E.P.P.H.A.R., Frison et al., 2015) of the SMART-plant project was started-up at the municipal WWTP of Carbonera for the sidestream production of PHAs by the use of sieved wastewater. Smartech 5 adopts a novel approach to integrate the sidestream biological nitrogen removal via nitrite from the anaerobic supernatant of sewage sludge and selection of PHA storing biomass. In this work, the set-up of the units and the preliminary results of its operation were presented.

Material and Methods

The installation of the pilot S.C.E.P.P.H.A.R. (Smartech 5, **Figure 1**) was installed in the facilities of Carbonera WWTP (Treviso, North of Italy), which every day it treats between 15-20000 m^3 of municipal wastewater.

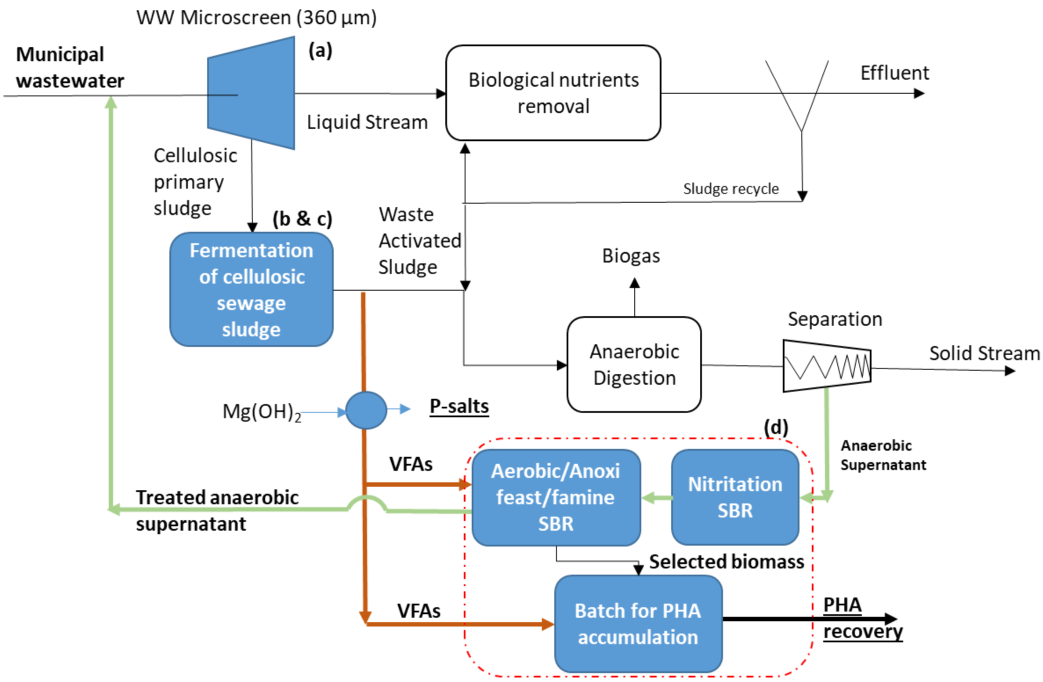

Figure 1 Schematic representation of the integrated pilot S.C.E.P.P.H.A.R system

The main units of the S.C.E.P.P.H.A.R. are the following:

- *Sieving of wastewater.* The municipal wastewater is pumped after the grit and grease removal at around 30 m^3/h (range 30-54 m^3/h), while the sieving is carried out through a containerised SF1000 (Salnses Filter, Norway) with a pore size of 360 µm (Figure 2a). The sieving of the wastewater is performed within 15 hours of operation, while the cellulosic primary slugde (CPS) is discontinuously pumped to the fermentation unit with a concentration of TS of around 48-55 gTSS/L. The sieved wastewater is discharged to the main wastewater treatment line.
- *Fermentation and solid/liquid separation.* The fermentation unit is a sequencing batch reactor with 2.6 m^3 of working volume which is fed daily with around 650 L of CPS (**Figure 2b**). The fermentation unit is coupled with a ceramic membrane (Sepra, Italy) for the ultrafiltration at 0.2 µm of around 550 L/d of permeate (**Figure 2c**). During the ultrafiltration, the concentrate fraction is continuously recycled back to the fermentation unit. After around 5 hours of ultrafiltration, the exceeded volume in the fermentation is discharged in order to maintain ad hydraulic retention (HRT) time of around 4 days and a solid retention time (SRT) between close to 8 days. Before the storage, magnesium hydroxyde is added in exceed in the fermentation liquid to allow the precitation of phosphate (P) in form of P-salts;
- *Nitritation.* Daily, around 3.5 m^3 of anaerobic supernatant is fed into a SBR (N-SBR) with a 1.4 m^3 of working volume (**Figure 2d**). Here, the oxidation of ammonia to nitrate by NOB is suppressed by high level of free ammonia obtained at relatively high volumetric nitrogen loading rate (vNLR, 1.4 kgN/m^3 per day) and pH between 7.8-8 by the addition of NaOH. The SRT is mantained stable at 12 days.
- *Selection of PHA storing biomass.* The selection of PHA storing biomass is carried out in a SBR (S-SBR) with a 2.9 m^3 of working volume (**Figure 2d**). The S-SBR accomplishes around 4 cycles per day, where feast and famine regime are alternated under aerobic and anoxic conditions respectively. At the beginning of the aerobic-feast conditions, the VFAs from the CPS permeate are fed and once the VFAs are depleted, the effluent from the N-SBR is fed to drive the nitrite denitritation using

PHA as carbon source under anoxic-famine conditions. The treated effluent is discharged in the mainline, while the SRT is maintained stable at 5 days.

- *Accumulation reactor.* The selected PHA biomass growth in the S-SBR where used as inoculum in the aerobic accumulation reactor with a 1 m^3 of working volume (**Figure 2d**). The increase of the PHA content in the biomass is carried out under sequencing addition of VFAs from the CPS permeate, so to achieve around 1 $gCOD_{VFAs}$/L in the reactor each spike. After 5-6 hours of accumulation, the activity of the biomass is automatically quenched by the addition of sodium hypoclorite (10 mg/L) in order to block the biological degradation of the produced PHA. Currently, the PHA were extracted using sodium hypoclorite and quantified gravimetrically to evaluate the PHA production yields.

Result and discussion

The designed flowrate and the loadings involved in unit of S.C.E.P.P.H.A.R. pilot system were reported in **Table 1.**

Table 1 Designed Flowrate and main loadings involved in S.C.E.P.P.H.A.R. pilot scale.

Line for the production of Carbon Source (a, b & c)		
Parameter (Flowrate)	**Flowrate (m^3/d; L/d)**	**Loadings (kg/d)**
Sieved WW (a)	400-500 m^3/d	
Cellulosic Primary Sludge (a)	650-750 L/d	20-30 kgTSS/d
Fermentation Liquid (b & c)	520-650 L/d	7.8-9.1 kgCOD/d
P-salts	-	0.25-0.30 kg/d
Fermentation Solids (b & c) for anaerobic digestion	85-100 L/d	12-21 kgCOD/d
Line for the treatment of the anaerobic supernatant and PHA storing biomass selection (d)		
Parameter (Flowrate)	**Flowrate (m3/d; L/d)**	**Loading (kg/d)**
Anaerobic supernatant	3.0-4.5 m^3/d	2.0-2.5 kgN/d
Treated anaerobic supernatant	2.45-3.85 m^3/d	0.25-0.40 kgN/d
Selected PHA storing biomass	550-650 m^3/d	1.4-2.3 kgMLSS/d
Line for production of PHA (d)		
Parameter (Flowrate)	**Flowrate (m3/d; L/d)**	**Loading (kg/d)**
PHA in selected biomass	70-100 L/d	0.7-0.8 kgPHA/d

However, during 30 days of operation of the pilot preliminary but promising results were collected and analysed.

The VFAs production from CPS was around 0.25-0.27 $gCOD_{VFAs}$/gTVS fed. Moreover, relevant amount of phosphates were released in a range of 80-110 mgP/L and up to 98% was recovered in the form of P-salts. The latter will be characterized and analysed in the next period to assess the purity and the quality as fertilizer.

Currently, the N-SBR and S-SBR performed a nitrogen removal efficiency of around 85% operating at a total vNLR up to 0.50 kgN/m^3 day. The feast to famine ratio in the S-SBR was between 0.15 to 0.20 (min/min), while the observed biomass growth was 0.27 gMLVSS/gCOD fed.

During around 1 month of operations, two PHA accumulation were performed obtaining a total PHA of 0.5 kgPHA, which is lower than the designed value (0.7-0.8 kgPHA/day) but very promising. However, further improvement and better operating conditions will be applied during the next months.

Figure 2 (a) Salsnes Filter SF1000 for the sieving of wastewater; (b) fermentation unit for the production of VFAs; (c) ceramic membrane for the solid/liquid separation and crystallizer for P-salts production; (d) Units in SBRs-modules for nitritation, PHA storing biomass selection and PHA accumulation.

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