High-rate production of volatile fatty acids from cellulosic primary sludge.

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Introduction

VFA are short-chain fatty acids that have a wide range of applications such as in the production of bioplastics , bioenergy, and the biological removal of nutrient from wastewater (Agler et al., 2011). In wastewater treatment plants (WWTP) external VFA addition is becoming necessary to operate biological nutrients removal (BNR) and meet the increasingly stringent effluent limits. The implementation of VFA production inside WWTP should achieve the reduction of cost and chemical consumption (Yuan et al., 2011). Fermentation of primary and waste activated sludge has been frequently studied because of the massive volumes generated from the widespread use of biological wastewater treatment (Lee et al., 2014). Recent studies showed that it possible obtain a cellulose-enriched sludge, called cellulosic primary sludge(CPS), substituting primary clarifier with rotating belt filter (RBF). Paulsrud et al. (2014) compared primary and cellulosic sludge in terms of volatile to total solids ratio (VS/TS) and bio-methane potential (BMP). Cellulosic primary sludge is characterized by higher VS/TS and BMP, indicating greater organic matter content. Ruiken et al. (2013) demonstrated that cellulose in CL is about the 80% of total solids. To date, RBF is generally applied to save space or to handle peaks load (Gikas, 2017). Anyway RBF is a technology to separate particulate organic matter from wastewater that should be properly used. Hu et al. (2004) showed that the main products of anaerobic fermentation of cellulose are acetate and propionate. This results encourage fermentation of CPS to produce VFA useful for nitrogen removal by high-rate denitrification, phosphorus accumulation and selection of polyhydroxyalkanoates.

The aim of this study is analyze the CPS production by a RBF considering wastewater characteristics and CPS properties. Authors want estimated the yields of CPS anaerobic fermentation under mesophilic condition taking into consideration effect of pH also. On basis of VFA concentration and composition an potential use of fermentation liquid phase is proposed in wastewater treatment plant.

Materials and methods

Municipal wastewater used from this study is collected from a 40,000 PE plant. Wastewater is pumped, after physical pre-treatment (fine screen and grit removal), to rotating belt filter (RBF) (Salsnes Filter, PO BOX 279, N-7801 Namsos, Norway). The device removes suspended solids from wastewater by cake filtration using a polyester screen with a openings dimension of 350 µm. The removal efficiencies of the

device is defined considering raw wastewater (influent), wastewater passed through the mesh (effluent) and the cellulosic sludge. Liquid flows are characterized in terms of total and volatile suspended solids (VSS and TSS), total and soluble COD (tCOD and sCOD), total Kijeldhal (TKN) and ammonium nitrogen, total phosphorus (Ptot) and ortho-phosphate. The distribution of particle size of influent is also determined by sieving raw wastewater on meshes with different openings (350, 250, 158, 90, 54 um). Wet sludge is analyzed for total and volatile solids (TS and VS), sCOD and ammonium, while dried sample, while COD, TKN e Ptot is determined on dried sample.

The CPS potential VFA production is determined using batch tests without any inoculum. The tests are maintained under mesophilic condition (37°C) along 2 weeks. Hu et al. (2004) demonstrated that hydrolysis and VFA concentration are affected by initial pH and that alkaline pH is beneficial for the process. Effect of pH is evaluated using raw CPS (pH 6.7) and adjusting initial pH at value of 8 by NAOH addition. The liquid phase of fermented PCS is monitored in terms of pH, sCOD, concentration and composition of VFA, ammonium and ortho-phosphate.

Results and Discussion

Raw wastewater characteristics are reported in Table 1. Solid and COD concentrations varied significantly along the day and in base of whether conditions, as a consequence also the removal efficiency of RBF could change at same operational conditions. Behera et al. (2017) showed that higher solid concentration increases removal of particles and organic fraction of nutrients.

Taking into consideration a 24 hours sample of raw wastewater, the size fractionation showed that 32% of TSS has dimension higher than 350 µm. Considering that the solid removal is 38-44%, the filter allows to remove also smaller particles. This hypothesis is confirmed by COD distribution, solids with size higher than 350 µm contribute for 22% while the COD removal is higher than 30%. Ravndal et al. (2018) analyzed the chemical composition of different solid fractions and demonstrated that solids with size >100µm are mainly composed by carbohydrates. and slowly biodegradable.

Produced sludge has a TS concentration higher than 31 g kg^{-1} which 93% is volatile. Concentration of COD (891-1096 mg g^{-1}TS) is indicative of high biodegradability. Anyway development of a fermentation process able to maximize VFA production and degradation rate is crucial.

The maximal VFA concentrations during the batch tests are 11.7 and 16.5 gCOD l^{-1} in trials with uncontrolled pH and pH 8, respectively. Alkaline condition increases the VFA concentration of 41% but the positive effect is evident from day 5. The specific yield are 0.29 and 0.31 gVFA $g^{-1}VS_{fed}$ without significant difference in VFA composition. The main VFA species are acetate and propionate. In the first operation week, acetate constitute 45% of total VFA while the propionate 35%. In the second week the propionate becomes the most abundant VFA (53%) while acetate counts for 33%.

In order to use the fermentation liquid phase as carbon source BNR processes the VFA/N and VFA/P ratios must be considered. They are favorable for this purpose with VFA/N of about 90 $mgCODmg^{-1}N$ and VFA/P higher than 200 $mgCODmg^{-1}P$.

Conclusions

The study shows that RBF could remove more than 40% of TSS in wastewater without reduce carbon source for main-stream denitrification. The high content of carbohydrate makes the CSL a suitable source of VFA using a dedicate fermentation process. Fermentation in batch mode reached VFA concentration of 16 $gCOD\ l^{-1}$ where acetate and propionate are the main compounds. Long solid retention time significantly increased the percentage of propionate. The fermentation liquid phase appears an interesting carbon source for process aim at phosphorus removal and polyhydroxyalkanoates production.

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References

1. Agler, M. T.; Wrenn, B. A.; Zinder, S. H.; Angenent, L. T. (2011) Waste to bioproduct conversion with undefined mixed cultures : the carboxylate platform. *Trends Biotechnol.*, **29** (2), 70–78.

2. Behera, C. R.; Daynouri-Pancino, F.; Santoro, D.; Gernaey, K. V.; Sin, G. (2017) An Empirical Model for Carbon Recovery in a Rotating Belt Filter and Its Application in the Frame of Plantwide Evaluation, 30–36.

3. Gikas, P. (2017) Towards energy positive wastewater treatment plants. *J. Environ. Manage.*, **203**, 621–629.

4. Hu, Z.-H.; Wang, G.; Yu, H.-Q. (2004) Anaerobic degradation of cellulose by rumen microorganisms at various pH values. *Biochem. Eng. J.*, **21** (1), 59–62.

5. Lee, W. S.; Chua, A. S. M.; Yeoh, H. K.; Ngoh, G. C. (2014) A review of the production and applications of waste-derived volatile fatty acids. *Chem. Eng. J.*, **235**, 83–99.

6. Paulsrud, B.; Rusten, B.; Aas, B. (2014) Increasing the sludge energy potential of wastewater treatment plants by introducing fine mesh sieves for primary treatment. *Water Sci. Technol.*, **69** (3), 560-565.

7. Ravndal, K. T.; Opsahl, E.; Bagi, A.; Kommedal, R. (2018) Wastewater characterisation by combining size fractionation, chemical composition and biodegradability. *Water Res.*, **131**, 151–160.

8. Ruiken, C. J.; Breuer, G.; Klaversma, E.; Santiago, T.; Loosdrecht, M. C. M. Van. (2013) Sieving wastewater e Cellulose recovery , economic and energy evaluation. *Water Res.*, **47** (1), 43–48.

9. Yuan, Q.; Sparling, R.; Oleszkiewicz, J. A. (2011) VFA generation from waste activated sludge: Effect of temperature and

mixing. *Chemosphere*, **82** (4), 603–607.

Table 1 Characteristics of RBF influent and effluent, and corresponding removal efficiency

	TSS	tCOD	sCOD	TKN	Ptot
	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}
Raw wastewater	80-516	145-759	54-113	22-73	4.3-13.4
Filtered wastewater	45-320	99-452	36-89	20-37	3.2-11.7
Removal	38-44%	31-40%	21-33%	16-34%	10-36%

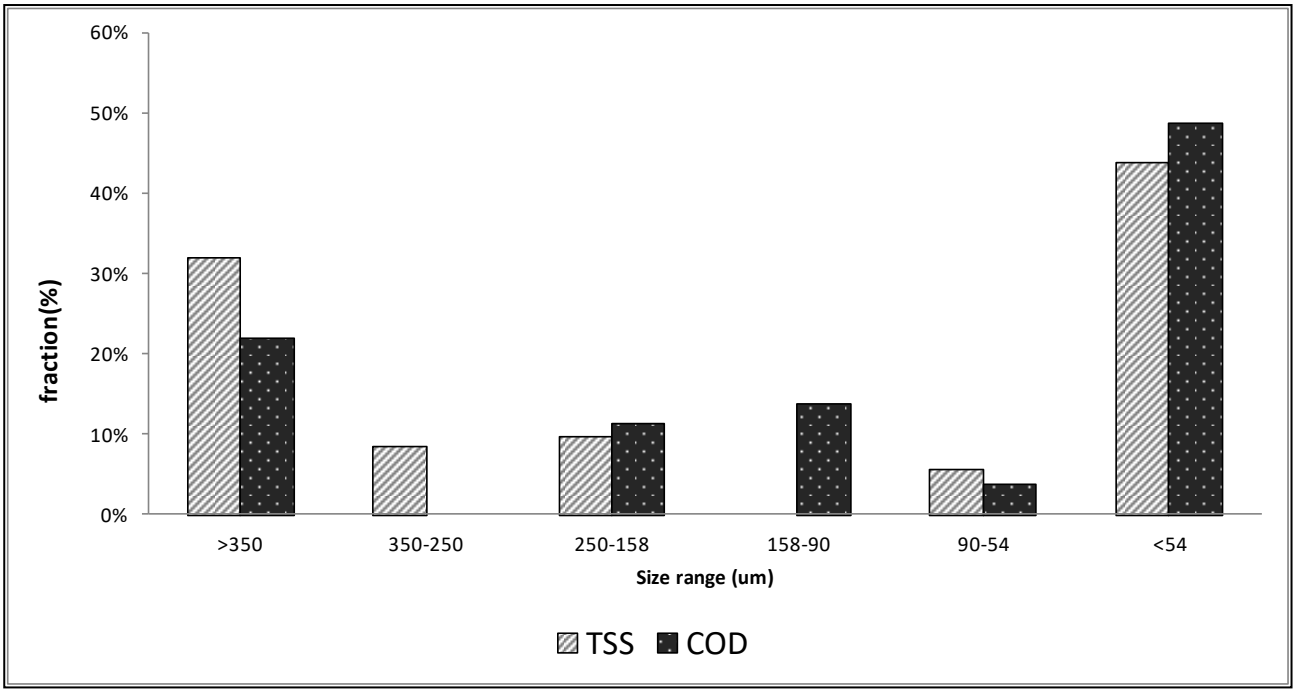

Figure 1 Fractionation of solids and COD in wastewater

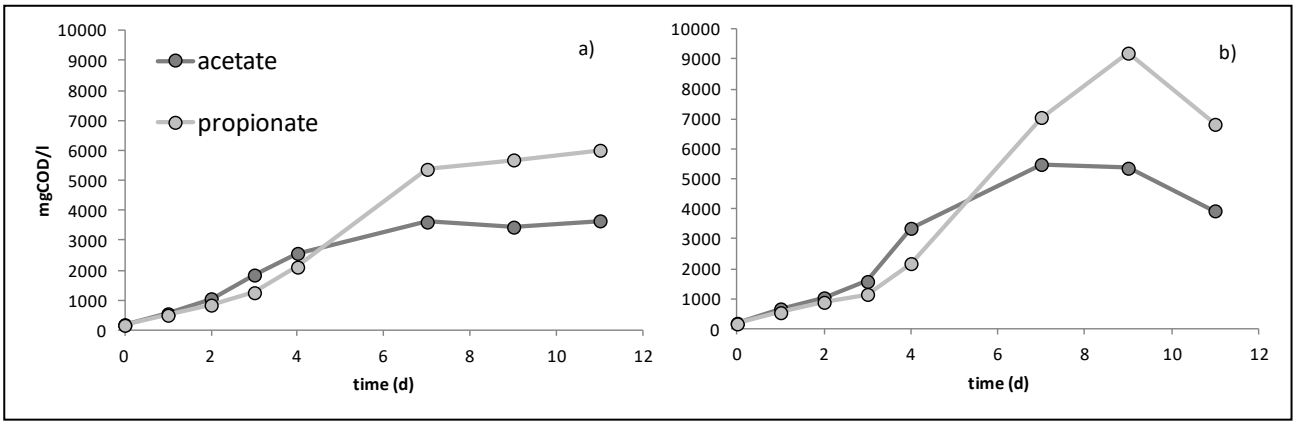

Figure 2 Trend of acetate and propionate in the batch test with initial a)uncontrolled pH and b) pH 8