Activated sludge activity improvement by glow discharge plasma

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INTRODUCTION

Worldwide large amounts of wastewater are produced, both municipal and industrial, for which a proper treatment is required before discharge into the environment. The activated sludge process is the most commonly used method for treating these large quantities of wastewater, mainly due to the relative ease of operation at an acceptable cost. However, due to the increasing amount of wastewater to be treated, caused by (*i*) a growing population and industry, and (*ii*) increased purification rates, a continuous improvement of the activated sludge process is essential. One approach to achieve this target is by increasing the activity of the activated sludge biomass. From previous research, it is seen that the metabolic activity of activated sludge can be stimulated by physical-chemical methods like ultrasound (Zhang *et al.*, 2008) or ozone (Järvik *et al.*, 2011). In this research the possibility of using a novel, alternative technique, glow discharge plasma (GDP), is investigated and compared to ultrasound, a technique already known for its positive effect. Additionally, the effects of both techniques on sludge properties are investigated.

MATERIALS AND METHODS

All experiments were conducted with activated sludge samples from the full-scale municipal wastewater treatment plant of Aquafin Mechelen-Noord, Belgium (population equivalent: 81000).

GDP and ultrasound treatment

GDP treatment tests were performed in a 500mL glass batch reactor, continuously cooled via a water jacket and magnetically stirred. Anode and cathode materials are platinum and stainless steel, respectively. The electrodes are connected to a power supply with a voltage range of 0-720V and a current range between 0-15A. For treatment the voltage is set at 660V, which corresponds to a current of 0.11A at a conductivity of approximately 950µS/cm. When necessary, the conductivity of the activated sludge was adjusted by adding Na_2SO_4. The energy input was altered by changing the treatment time. Ultrasound experiments were conducted in a 1000mL glass batch reactor, also equipped with a water jacket for temperature control and magnetically stirred. As ultrasonic source, an ultrasound horn was used with a frequency of 20kHz and a maximum power output of 100W. For the experiments the power was set at 60W.

Activated sludge properties

The sludge characteristics that were monitored before and after each treatment are conductivity, pH, release of cellular material via soluble COD (sCOD), mixed liquid (volatile) suspended solids (ML(V)SS) and sludge settleability via the (diluted) sludge volume index ((D)SVI).

Respiration activity

After ultrasound or GDP treatment of the activated sludge, the effect of both techniques on biomass activity was assessed by respirometry. The setup consisted of six identical 1L glass batch reactors with cooling jacket, to control the temperature at 20°C. The content was mixed via magnetic stirrers. The dissolved oxygen concentration was monitored and controlled between 2 and 5mgO_2/L. During the non-aerated periods, the oxygen concentration decreases due to respiration and the rate of this decrease is taken as a measure for the biomass activity (oxygen uptake rate, OUR). By dividing OUR by the MLVSS-value, SOUR (specific OUR) is calculated. After the sludge reached endogenous conditions, an overload of sodium acetate (NaAc) was added as a carbon source or NH_4Cl as an ammonium source to assess the maximum carbon oxidation rate or nitrification rate, respectively. The maximum respiration rate is a measure for the activity and is referred to as $SOUR_{max}$.

RESULTS AND DISCUSSION

Effect of GDP and ultrasound on respiration activity of activated sludge

Some previous papers already describe the positive effect of ultrasound on respiration activity (Zhang *et al.*, 2008; Tyagi *et al.*, 2013). Based on these results, specific energy levels ranging from 0 up to approx. 7000 kJ/kgMLSS were selected for the experiments. As depicted in Figure 1, it is seen that all 4 tested US treatment conditions resulted in higher $SOUR_{max}$ values compared to the reference (untreated) sample. The best results were obtained for a treatment time of 30s (946 kJ/kgMLSS), leading to to a $SOUR_{max}$ improvement of 16.2%. On average, the respiration activity increased by 18%. Also GDP has a positive effect on the respiration activity as long as the treatment time did not exceed 6min (11051 kJ/kgMLSS). A treatment time of 2min (3863 kJ/kgMLSS) yielded the best results, with an average activity increase of 16.3% and an increase of $SOUR_{max}$ by 20.5%. When exposing the sludge to an extreme treatment of 40 min (81042 kJ/kgMLSS), initially the respiration rate is significantly lower compared to the reference sample. However, the sludge appears to recover gradually during the respiration test and the $SOUR_{max}$ even exceeds the reference sample by more than 50%.

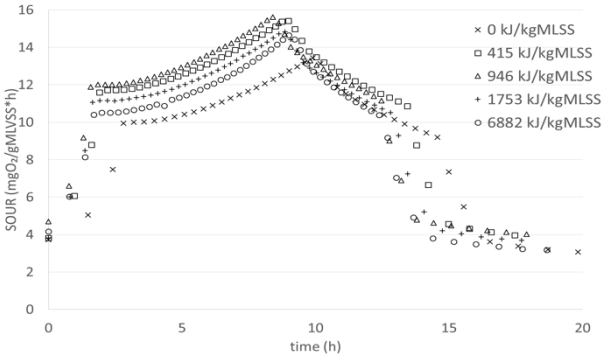

Figure 1. SOUR-profiles for ultrasound treated activated sludge sample after reaching the endogenous phase and after addition of NaAc (t=0h).

The effect of an ultrasound treatment on the nitrification activity of activated sludge was tested for 5 different energy levels, ranging from 0 to 9185 kJ/kgMLSS. No significant difference was observed between the nitrification activity with or without treatment, indicating that these energy levels do not affect nitrification. Similar results were obtained when applying GDP between 0 and 6700 kJ/kgMLSS (0-3 minutes). However, for higher energy inputs, the nitrification activity deteriorated, whereas these levels were shown to result in an increase in $SOUR_{max}$ for carbon removal as reported above. (Figure 2).

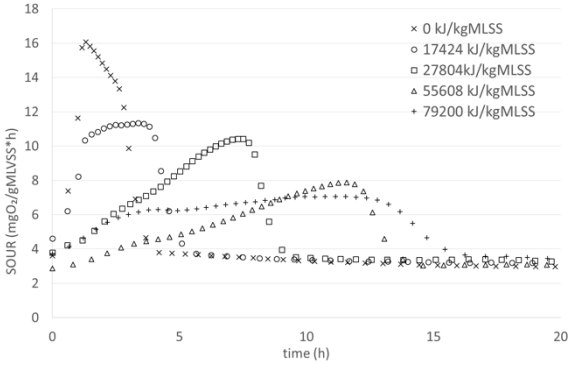

Figure 2. SOUR-profiles for GDP treated activated sludge samples at high energy levels after reaching endogenous respiration and after NH_4Cl addition (t=0h).

Effect of GDP and ultrasound on sludge properties

The results show that in the used energy range both GDP and ultrasound have no noticeable influence on the biomass concentration or pH. Conductivity and sCOD both increased after the activated sludge was treated with GDP or ultrasound. Ultrasound, however, has a larger influence than GDP. This indicates that cell lysis and the release of cell material to the water phase are more efficient when using ultrasound, making ultrasound a more efficient technique for solubilisation. Also for activated sludge activity improvement the lower energy requirements for ultrasound compared to GDP are found.

Settleability of the activated sludge is one of the most important sludge properties, since the wastewater treatment efficiency is partially determined by the separation of the activated sludge and the purified water in the secondary clarifier. From the literature, it is known that ultrasound has a negative influence on the settling of activated sludge (Dewil *et al.*, 2006). This is confirmed by the results in this study. Even at very low energy inputs, DSVI-values start to increase, indicating a deteriorating settleability. For GDP, no significant difference was observed when applying low energy levels. At higher energy levels improvements up to 50% were found (63360 kJ/kgMLSS).

CONCLUSION

A novel and alternative technique, glow discharge plasma, was used to stimulate the activity of activated sludge. From the respirometric experiments, it was seen that GDP can improve biomass activity, with the highest average improvement at 3863 kJ/kgMLSS (2 min). However, it remains difficult for GDP to compete with ultrasound, since improvements are comparable, but ultrasound is 4 times more energy efficient. It might be interesting to use very high energy GDP treatments since, after recovery, $SOUR_{max}$ improvements up to 50% are found. However, at these energy levels nitrification is negatively affected. Additionally, GDP can be more interesting than ultrasound, since exposures to ultrasound have a negative effect on sludge settling (even at low energies) and GDP does not affect sludge settling negatively (at high energy levels settleability is even improved). This is important for a good separation between the purified water and the activated sludge.

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