Recovery and valorisation of cellulose from waste water

The road to circularity

Pim Marcelis[1] • Coos Wessels[1]

[1] *CirTec B.V., Nijverheidsweg 26, 1442 LD Purmerend (The Netherlands)*

Abstract

Cellulose is one of the materials that can be recovered from sewage water, next to for example Phosphate and Ammonium. Cellulose is recovered by physical separation of cellulosic screenings from the influent of treatment plants with rotating belt filters (RBF). The cellulose is recovered more efficiently with a RBF than with primary clarifiers. Compared to the sludge from a primary clarifier, the cellulose content of the cellulosic screenings from a RBF contains twice the concentration of cellulose. The removal of cellulose from the influent does not only produce a material that can be used in biocomposites and construction, but also reduces the sludge production and energy consumption of a treatment plant.

Introduction

The shift from sewage treatment plant or wastewater treatment works, to water reclamation plant, water factory or energy and resource factory, has changed the way water authorities and companies view sewage water treatment and how the processes for treatment are designed. Technologies which can recover materials, for example cellulose, from wastewater are preferred over the old technologies, as they are not designed for resource recovery. In the Netherlands, the target set by the Raw materials and energy factory is to recover 25% of all the cellulose from the Dutch sewage water in 10 years (Pinkse, et al., 2018). During the past years, a lot of research has been done in the use of RBF as primary treatment, the influence of RBF on the downstream process and the valorisation of the RBF cellulosic screenings (Ahmed, et al., 2018), (Giaccherini, et al., 2018), (Roest, et al., 2018), (Reijken, 2014), (Ruiken, Klaversma, Breuer, & Neef, 2010).

An important question is how the recovered cellulose can be applied as a biobased resource. The application of recovered cellulose, with or without additional treatment, has been researched for various applications (de Vegt & Winters, 2012), (Winters, Pijlman, Maathuis, & Dinkla, 2013), (Pijlman, et al., 2017). These processes include the application in asphalt (Pijlman, et al., 2017), the possibility to convert the cellulose to PLA, anaerobic digestion of the cellulosic screenings to produce biomethane (Ghasimi, 2016) and the application of dried recovered cellulose in biocomposites.

A market analysis has shown that there is large interest from the market for cellulose that is recovered from sewage and that can be used as a sustainable product

Methodology

Most of the research regarding the impact on downstream processes in the Netherlands has been performed at three treatment plants: STP Beemster, STP Aarle-Rixtel and STP Blaricum. At these STP's one or multiple RBF have been placed for the treatment of the influent. The treatment capacity of the STP range from 97 l/s (350 m^3/h) to 695 l/s (2.500 m^3/h) dry weather flow and range from 144 l/s (518 m^3/h) to 1,008 l/s (3,680 m^3/h) at full flow. On these sites the influent is filtered with a CellCap RBF, after which the influent flows through to the aeration basin (in two cases a Carrousel type aeration tank and in the other case a m-UCT type aeration tank).

During the research at STP Aarle-Rixtel, which consists of two identical m-UCT treatment trains, one train received CellCap RBF pre-treated water for over a year, while the other train received the untreated influent. The differences between the trains were monitored during the research.

Research at STP Beemster showed that the average treatment capacity increased with approximately 20% after installation of the CellCap RBF.

In other research, the application of the recovered material is taken into account. This research, that aims to provide a standard material specification for specific applications and the need for additional pre- or post-treatment, is still ongoing.

At all locations the efficiency for TSS was measured and the cellulose content of the product was measured. The TSS was measured according to a couple of different methods. This makes a direct comparison difficult, however, the results are comparable.

Research on the extraction of pure cellulose from cellulosic screenings as a marketable product (ReCell®) is part of the Horizon2020 project SMART-Plant. The operational aspects and impact of return flow from the Cellvation process (the process to extract cellulose) are determined at the demonstration installation at the STP Geestmerambacht.

At STP Beemster, an inventory is made of the reduction in CO_2 emissions, in case cellulosic screenings are digested and in the case that cellulose is used as a raw material. The CO_2 reduction is related to a reference STP with a carousel-type active sludge system without pre-sedimentation having a size of 100,000 PE

Results and Discussion

The research at STP's Aarle-Rixtel and Beemster show a TSS efficiency of 20-30% (when measured with 1.2µm filters) or a TSS efficiency of 36-60% (when measured with 12-25µm filters). The filters have a higher efficiency (>50%) when there is more TSS in the influent (>300 mg/l) (Reijken, 2014). With a CellCap RBF, cellulose is removed very efficiently. The cellulose removal efficiency was 80%, even in cases where the TSS removal efficiency was only 25% (1.2µm filter) (Ahmed, et al., 2018).

The removal of TSS reduces the energy consumption in the aeration tank with 10-15%, because the bacteria have to convert less COD to CO_2 and water. The amount of sludge produced is also 10-15% lower than compared to untreated influent.

The biological removal of nitrogen and phosphate are unaffected in both STP Beemster and STP Aarle-Rixtel.

The recovered cellulosic screenings, without any further treatment/upgrading to Recell®, consists for 67% of fibres (Roest, et al., 2018). Of the 67%, 55% is cellulose, 5% is lignin and 7% is hemicellulose.

For the application of recovered cellulose in asphalt or concrete, it is required that the material is dry (>90% DM) and has loose fibres. For the use of the material in digestion only dewatering is needed. When the cellulosic screenings are digested, the biogas potential (600 Nm^3/tdm) is higher than the biogas potential of secondary sludge (300 Nm^3/tdm), measured over a period of 30 days.

The CO_2 reductions are based on the following scenarios in a WWTP for 100.000 PE:

- A: Production of Glucose from the cellulosic sludge with digestion of the residual product. The digestate will be dewatered and incinerated

- B: Directly digesting the cellulosic sludge, followed by dewatering and incineration of the digestate.

These two scenarios are compared to a WWTP without a RBF for cellulose recovery. In the reference scenario the sludge from the WWTP is dried and incinerated afterwards. Due to a lot of uncertainties in the process of converting the cellulosic screenings to glucose, the A route was estimated at an average reduction of 100 ton CO_2-eq per year. The uncertainties in this route result in a variation between an increase of 320 ton CO_2-eq per year to a reduction of 500 ton CO_2-eq.

The B route is a well known process, with less uncertainties. This route leads to a reduction of 730 ton CO_2-eq per year.

For both routes the reduction of CO_2-eq in the WWTP where the RBF are installed (without the post treatment for the cellulosic screenings, but including the drying and incineration of the sludge) is 360 ton CO_2-eq per year. (Odegard & Broeren, 2018)

Conclusion

There are a lot of potential markets for cellulose recovered from waste water, ranging from co-digestion for additional biogas production to the application in building materials such as asphalt, biocomposites and concrete. In these markets the recovered cellulose has a positive value and is considered a valuable product. The versatility in applications enables the water authority or owner of a STP to choose different processing routes. Since valorisation of resources is not the core task of a water authority, this can be outsourced to an external specialised party.

The use of CellCap RBF as primary treatment, in addition to the benefits of the cellulose production, reduces the power consumption in the aeration tank by 10-15% and reduces the secondary sludge production by 10-15%.

In case cellulosic screenings are separated with an RBF and the cellulose is applied as resource, the total climate impact on the Water Reclamation Plant is 360 tonnes CO_2-eq/year, this is excluding the post treatment of the cellulosic screenings.

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