WOW! Sewage is valuable!

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Abstract: There are market opportunities for raw materials from sewage, but for this the sewage treatment plants and the industry need alignment. This calls for a transition: sewage treatment plants need to switch from treating sewage to producing valuable materials. On the other hand, market parties need to regard sewage as a valuable source instead of 'dirty unsafe water'. Last but not least, the policies should better fit this new circular practice. To realize these opportunities WOW! aims to develop value chains for three different raw materials from sewage: cellulose, PHA bioplastics and lipids.

Keywords: Cellulose; lipids (FAME), PHA, sewage valorisation

Introduction

Sewage contains valuable substances that can be used as raw materials for bio-based products. However, in North-West Europe (NWE) this potential is hardly exploited yet, which results in loss of valuable materials. NWE Interreg project WOW! aims to make the transition to a more circular approach by matching supply and demand of cellulose, lipids and PHA (polyhydroxyalcanoates, bioplastics) from sewage. The project objectives are to i) find companies that could use raw materials for their bio-based products to set up high potential value chains, ii) build and run three pilots to optimise and implement recovery and upcycling techniques, iii) create bioproducts (biochar, biofuel and bioplastics), iv) develop a decision support tool for guiding sewage treatment plants in their transition towards a circular approach on sewage, and v) create a policy roadmap on national and EU-level for a legal framework.

Urban sewage composition in the different NWE countries varies due to differences in user consumption, portion of industrial loads and kind of sewer system. Very little data is available on the cellulose and lipid constituents, because there are no standard operational analytical methods, thus they are not regularly measured at sewage treatment plants (STPs), although they contribute to the parameter COD (chemical oxygen demand). So, only few theoretical estimates can be given usually based on research studies. **Cellulose** in sewage mainly originates from the use of toilet paper, therefore the screening material is rich in fibrous cellulose. The average EU-26 toilet paper consumption is 13 kg/PE/y; it is estimated that about 25-30% of the inflow COD is cellulose [1]. Assuming that 89% of the toilet paper consists of cellulose, we get a specific cellulose load in wastewater of ~32 g/PE/d. The main source of **lipids** (fat, oil, grease; FOG) in urban wastewater are faeces and kitchen wastewater [2]. Concentration of FOG varies a lot within countries and reports, representing ~30% of COD in urban wastewater influent [3] which corresponds to a specific load of ~36 g/PE/d at 120 g COD/PE/d. **PHA** are naturally occurring water-insoluble and linear biopolyesters that are formed by many bacteria as reserve substances for carbon and energy [4]. These biopolymers are biodegradable and are used in the production of bioplastics. Estimated daily production capacity ranges between 4 and 14 g/PE/d.

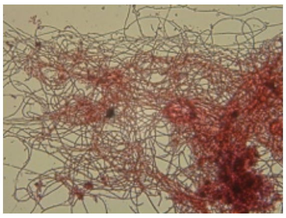
Methodology – implementation of pilots in an urban STP

Cellulose pilot is intended to be located after the grid chamber in a STP. It consists of two rotating belt fine screens sieving about 55% of the total suspended solids, containing ~70% cellulose. After dewatering, the harvested cellulosic screenings are dried, compacted into pellets and pyrolyzed. During pyrolysis, carbon chains are disintegrated into different fractions (biochar, bio-oil, fatty acids, syngas). The fixed carbon of biochar can be activated and thereafter used for removal of micropollutants from sewage effluent, as example. The bio-oil can be used as a green heating fuel, the fatty acids as a carbon source at the STP and the syngas combusted to generate heat for drying the cellulose. **Lipid** pilot is proposed to be placed before the activated sludge tank. It is being designed based on lab-scale investigations determining key parameters for selection of Microthrix parvicella, a filamentous bacterium able to greatly accumulate long-chain fatty acids (LCFAs). Enriched biomass will be harvested and dewatered, lipid content will be quantified and transesterified for biodiesel production. **PHA** pilot is installed in a side stream of the primary sedimentation and fed with primary sludge. It consists of three reactors. First, the primary sludge gets anaerobically digested to produce volatile fatty acids (VFA) for biomass selection and PHA accumulation, second, biomass with a high PHA production capacity is selected and enriched feeding on the VFAs from the previous step, third, enriched biomass is mixed with a low nutrient water and VFAs, dewatered, dried and harvested for PHA extraction.

Results and Perspectives

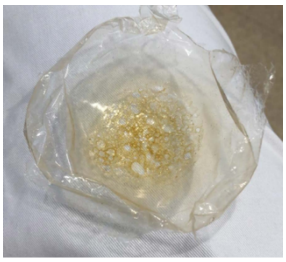
The different pyrolysis products from a test run with a cellulose derived from sewage are displayed in Figure 1. In a clockwise orientation: biochar (used as activated carbon for adsorption of micropollutants in effluent), bio-oil (green fuel used externally for heat generation), fatty acids (used as carbon source in a WWTP) and syngas being combusted (to generate process heat for the dryers). The pilot at a WWTP is currently under construction.

Figure 1 Different pyrolysis products from cellulose (biochar, bio-oil, fatty acids and syngas).



The first scenarios in the laboratory for selection of Microthrix parvicella were tested, and favourable operation conditions, e.g., aeration mode, were identified. Short cycle intermittent aerobic-anaerobic conditions made Microthrix grow (Figure 2). In addition, accumulation of LCFAs in Microthrix rich biomass was observed. Other parameters need to be considered and further assessed.

Figure 2 Microthrix parvicella grown at filamentous index 4 in a lipid pilot selector.



For the first step of the PHA process, so far emphasis was given to the acidification of primary sludge. Within lab scale pretests it was examined if a time and cost-efficient operational mode could achieve a high yield of VFA, which is important for a successful pilot operation (Figure 3). With a batch mode acidification without pH-control a degree of acidification of only 10-15% could be achieved. To ensure proper process development, the VFA-yield must be further increased.

Figure 3 Extracted PHA from the enriched biomass.

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