WoW! - a new business approach for resource recovery from sewage

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SUMMARY

Did you know that even used toilet paper can get a second life? Sewage contains valuable substances that could be used as circular raw materials for biobased products. The WOW! project aims to capitalise on these opportunities and work towards a more circular approach. We do this by a) demonstrating the technical feasibility for recovery & upcycling techniques for cellulose, lipids and PHA from sewage, b) Investigating the market potential and creating five high potential value chains for raw materials and c) addressing policy barriers for the circular uptake of raw materials from sewage. Preliminary results are promising. So far we successfully produced biobased products from sewage and are currently upscaling the pilots. Furthermore, current market potential shows that the markets for biobased alternatives for conventional products are increasing. Current national and European legislation however doesn't always permit the reuse of raw materials from sewage.

KEYWORDS

Circular economy, end of waste, market potential, raw materials, resource recovery,

INTRODUCTION

Sewage contains valuable substances that could be used as raw materials for biobased products. However, this potential is hardly exploited yet. This results in loss of valuable materials. At the same time, the consideration of CO_2-emmissions and the use of natural resources are increasing. There are market opportunities for circular use of raw materials from sewage water. But for this the following transition is needed: 1) Sewage Treatment Plants (STP's) have to shift from treating sewage to the production of valuable materials. 2) Market parties have to regard sewage as a valuable source instead of 'unsafe water'. 3) Policies should better fit this new circular practice. In the INTERREG VB North West Europe (NWE) project WOW! we aim to contribute to these necessary changes. In the project sustainable value chains for five carbon-based elements (CBE) from wastewater are developed: PHA based bioplastics, biofuel from lipids and cellulose is pyrolyzed into bio-oil, biochar and acetic acid. In addition the market potential for these products has been identified and legal policy plans are being developed to discuss the pathway towards the circular use of raw materials from sewage.

METHODS

Demonstrating recovery and upcycling techniques

In order to realize a successful circular approach for resource recovery in the water cycle, not only the market potential has to be clear, but also the technical feasibility needs to be shown. This applies to the

recovery of the raw materials as well as the possible processing and application of these raw materials. Furthermore, possible policy barriers need to be addressed to solve the current legal barriers in the future. To realize this, three pilots are currently conducted. These pilots focus on PHA, bio-oil from lipids and bio char, acetic acid and bio fuel from cellulose. The aim is to show physical examples of resource recovery at STP's, to increase the Technology Readiness Level of each of the connected recovery techniques and to test samples on possibilities for market uptake.

The PHA pilot combines the production, extraction and application of PHA (Polyhydroxyalkanoates), a fully biodegradable bioplastic. It has already been proven that PHA can be produced by microorganisms using the fatty acids that are present in sewage water. After the production of PHA by the microorganisms, it will be extracted and tested. We will test on the composition and properties of PHA such as strength and flexibility. Before the end of 2020 WOW! wants to produce, extract and test 10 to 20 kg PHA samples.
The PHA pilot consists of three reactors and is installed in a side stream of the sewage treatment plant. First step is the production of volatile fatty acids (VFA) for biomass selection and PHA accumulation. This is done through anaerobic digestion of a waste stream from the treatment process. In the second step the selection and enrichment of the PHA affine biomass is conducted by feeding the VFAs from the previous step. Finally, the enriched biomass is mixed with a low nutrient water and VFAs, dewatered, dried and harvested for PHA extraction.

Lipids (fat, oil and grease) in urban wastewater originate from faeces and kitchen wastewater [1]. The lipids pilot focuses on the enrichment of the bacteria Microthrix parvicella, which are able to accumulate long-chain fatty acids (LCFA). The accumulated lipids can be used to produce biofuel. Since *M. parvicella* are known to cause bulking and foaming problems at STPs, the usage of this bacterium as a valuable source might therefore also solve a major problem for STP operators. Due to the fact that predominant studies on destroying the filamentous bacteria are published, the optimum conditions for M. parvicella growth and lipid accumulation were tested in lab-scale. Derived from the results of the lab-scale testing, a pilot-scale reactor will be installed on a STP to accumulate lipids in a higher quantity. After that, production of biofuel based on the accumulated lipids will be tested. The lipids pilot consists of two reactors plus separation unit and will be placed before the activated sludge tank. Enriched biomass will be harvested and dewatered; lipids content will be quantified and transesterified for biodiesel production.

Cellulose can be found in screening material, due to the retention of cellulose rich fiber material, originating from toilet paper. Averaged toilet paper consumption in North West Europe is 13 kg/y/PE [2]. The cellulose pilot consists of two rotating belt fine screens sieves and is placed at the beginning of the STP. The sieved material will be dewatered, dried, pressed into pellets and pyrolyzed. During pyrolysis, carbon chains are disintegrated into different fractions: biochar, bio-oil, fatty acids and syngas. The biochar will be used for the removal of micropollutants in the sewage water. This is a very interesting short circular loop, enabling wastewater treatment plant operators to produce their own biochar through thermal activation of the pyrolyzed cellulose.The bio-oil can be used as a green heating fuel, the fatty acids as an additional carbon source and the syngas is directly used to generate heat for drying the cellulose.

Market potential for raw materials from sewage waste
To gain insight in the market potential conducted a market potential study. For the five CBE, the production from non-sewage resources is described as well as the state of research on the recovery of other constituents from sewage. As a final step a first estimate of the quantities of the five CBE that might be produced in the future at STPs within North West Europe is given. Calculations have shown that the potential sewage water derived biodiesel is 0.34 % of the annual biodiesel production in the NWE area. In addition the potential to use biochar to remove micropollutants onsite is high. It is estimated that when using the pyrolyzed sievings to produce biochar, an STP can almost fully supply its own demand for activated powdered biochar (source: market potential report of WOW!, expected to be released in December 2020). In a second phase of getting insight in the market potential, contacts with potential interested companies are intensified. Expert discussions, interviews and surveys are currently carried out to determine the producing industry's interest in CBE from sewage and its requirements with regard to quality, delivery quantities, etc. Possible barriers and drivers for implementation shall be identified as well as possible competitors from conventional and other resource recovery initiatives.

Legal framework for wider business opportunities
Recovery and reuse of raw materials from sewage is no common practice yet. National and European legislation and policy does not always permit the reuse of these materials. Regulations are complex and conditions for an 'end of waste status' are not always clear. To encourage the transition towards a circular economy in sewage treatment the WOW! team created a not yet existing clear overview of current legal frameworks in France, Flanders, Germany, Luxembourg the UK and The Netherlands. Also, examples of existing (starting) value chains in north West Europe, including the barriers that were encountered were combined in a best practices report. In addition, a legal action plan for The Netherlands was developed and discussed with an international strategic board of legal experts. The next step is the roll out of the national legal action plans to the other countries, followed by a European roadmap towards the use of biobased products from sewage which we want to bring to the attention of the European Commission.

RESULTS AND DISCUSSION

As WOW! is an ongoing project there are no final results yet. However, preliminary results are promising The PHA pilot has produced its first PHA from sewage sludge in the lab and are now ready for upscaling. The lipids pilot has tested various operational parameters and favorable conditions to the growth selection of *M. parvicella* and lipid accumulation were defined. The cellulose pilot will produce its first material at the end of 2020.
There are already a few successful cases which have created valuable resources from sewage in the six north-west European countries with market potential. These include phosphorus- and nitrogen recovery, cellulose production and extrapolymeric substances. Since markets for biobased products are increasing we expect growing attention for the WOW! materials as well. On the other hand we see that current legal barriers are one of the main reasons that hold back the widespread start of the transition towards the circular use of raw materials from sewage. That is why we pay a lot of attention to provide examples of these barriers from the field, to discuss these with national and international policy experts and to provide input for the pathway towards a more generic European approach in circular use of raw materials.

CONCLUSION
The WOW! project is finalized in 2021. However the first results from the pilots are expected early 2021 so we expect more results to be presented during the Singapore International Water Week in June 2021.First conclusions can be drawn then.

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