Life Cycle Assessment of Material Recovery from Municipal Wastewater: Circular Economy with Environmental Benefits?

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Abstract: Recovery of valuable materials from municipal wastewater is one approach to realize circular economy in the wastewater sector. Different technologies have been tested and applied to recover products such as cellulose, bioplastics, or struvite within a wastewater treatment plant (WWTP). However, material recovery also introduces new process steps into the treatment scheme, which require additional energy or chemicals and related greenhouse gas emissions. From an environmental perspective, Life Cycle Assessment (LCA) is a suitable tool to analyse the entire system of material recovery from WWTPs, including the potential value chains for product valorisation. The present paper investigates different technologies for material recovery with LCA based on data of industrial-scale demonstration trials and shows that material recovery can be realized with distinct environmental benefits, also due to positive side effects on the overall treatment scheme of the WWTP.

Keywords: Life Cycle Assessment, material recovery, municipal wastewater

Material recovery from municipal wastewater is one element of circular economy which can be applied in the wastewater sector. Raw wastewater contains a range of valuable substances such as cellulose fibres, organic carbon, and plant nutrients nitrogen and phosphorus. Innovative processes have been developed and demonstrated to recover these substances in wastewater treatment plants (WWTPs) and harvest valuable products, e.g. cellulose as structural material or biofuel, bioplastics such as polyhydroxyalkanoate (PHA) or struvite as phosphorus fertilizer.

However, material recovery also introduces new technologies and processes into the wastewater treatment scheme, which will need additional energy and chemicals and cause related environmental effects. From an environmental and policy perspective, it is interesting to analyse if material recovery will lead to an overall environmental benefit for the wastewater sector, or if additional efforts fully off-set the benefits of product recovery and lead to a net increase in energy demand and related greenhouse gas emissions.

Life Cycle Assessment (LCA) as defined in ISO [ISO 14040 2006] is a suitable tool to analyse the environmental impacts of complex product systems and compare different scenarios in their energy demand and greenhouse gas emissions. LCA takes into account direct and indirect effects, i.e. emissions at the WWTP and also emissions related to the production of electricity, chemicals or materials. In addition, the complete value chain of material recovery can also be included to consider the environmental benefit coming from the substitution of primary materials by WWTP-derived products.

The present study analyses three different products (cellulose, PHA, and struvite) originating from municipal WWTPs and their corresponding value chains with LCA (Table 1.1). Data for recovery processes and value chains have been collected from industrial-scale demonstration units during long-term trials at specific WWTPs in the H2020 innovation action SMART-PLANT (Grant No. 690323), while remaining data gaps have been closed in cooperation with process providers and research partners.

Table 1.1 Recovered products, related process steps and corresponding value chains for material recovery scenarios

Product	Test location	Recovery process	Value chain
Cellulose	WWTP Geest-merambacht (NL)	Fine sieve	Biodrying → biofuel
Cellulose	WWTP Geest-merambacht (NL)	Fine sieve	Pelleting → sludge plastic composite
PHA	WWTP Manresa (ES)	SCEPPHAR in mainstream	PHA extraction → sludge plastic composite
PHA	WWTP Carbonera (IT)	SCEPPHAR in sidestream	PHA extraction → sludge plastic composite
Struvite	WWTP Carbonera (IT)	SCEPPHAR sidestream	Fertilizer

Value chains for the recovered products include bio-drying to obtain a bio-fuel from cellulosic sludge, the production of sludge plastic composite from cellulose fibres and PHA which has been extracted from PHA-rich biomass of the SCEPPHAR process [Frison et al 2015], and use as agricultural fertilizer of recovered struvite.

Overall, preliminary results show that environmental benefits of material recovery from municipal WWTPs originate not only from substituting primary materials in the value chain, but to a major part from positive side effects such as energy savings or emission reduction (e.g. N_2O) for the WWTP process. Materials recovered from WWTPs which may not be able to directly compete with primary products in their environmental profile could be favourable in a holistic life-cycle perspective due to e.g. savings in aeration or sludge disposal. Finally, circular economy approaches in WWTPs should also target to improve the wastewater treatment process itself, which can then lead to win-win situations of WWTPs with lower environmental footprint and integrated recovery of valuable materials.

REFERENCES

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