



Review

Hydrothermal processes as treatment paths for biogenic residues in Germany: A review of the technology, sustainability and legal aspects



Daniel Reißmann ^{a, *}, Daniela Thrän ^{a, b}, Alberto Bezama ^a

^a Helmholtz Centre for Environmental Research - UFZ, Department of Bioenergy, Permoser Straße 15, 04318, Leipzig, Germany

^b Deutsches Biomasseforschungszentrum gGmbH (DBFZ), Torgauer Straße 116, 04347, Leipzig, Germany

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ABSTRACT

A considerable part of especially wet and sludgy biogenic residues is currently not in material or energetic usage in Germany. Therefore, a key issue for current research is to identify which technologies are most suitable at mobilizing these wet and sludgy materials. Hydrothermal Processes (HTP) appear to be promising treatment options for moist substrates because they require a high water content of 70%–90% for optimal processing. This review provides information on the state of the art and knowledge on HTP, and attempts to determine how suitable these processes are for mobilizing biogenic residues in Germany. We identified technological, economic, environmental and legal potentials and barriers of HTP using a modified content-analysis. About 120 relevant references were identified and analyzed using a structured sampling scheme. The results show considerable advantages of HTP for utilizing wet and sludgy biogenic residues in contrast to comparable biomass treatment processes. Especially, their high process energy-efficiency and low Global Warming Potential from a life cycle perspective. Nevertheless, technological, economic, environmental and legal barriers (e.g. missing data and knowledge on process kinetics; missing legal standards) must be taken into consideration. Finally, research needs are illustrated that must be fulfilled through structured and target-oriented research.

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* Corresponding author.

E-mail address: daniel.reissmann@ufz.de (D. Reißmann).

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1. Introduction

Biogenic residues from industrial, commercial and municipal activities are valuable resources. Residues like liquid manure, straw, wood residues from the forestry industry, industrial wood residues, demolition wood, kitchen and garden waste, sewage sludge, and municipal solid waste, can be utilized in a value-enhancing way through appropriate technological applications (Leible et al., 2003; Tröger et al., 2013). The German Government already fosters the material and energetic utilization of biogenic residues by several programs, initiatives and legal regulations aiming to increase the resource efficiency of process chains (BMUB, 2016a). Due to disposal regulations specified through the German Law on Closed Cycle Management and Waste (KrWG, 2012), most industrial residues like plant oils and animal fats as well as municipal waste streams such as food and bio-waste are already being utilized (Brosowski et al., 2016). Regarding the technical potential - describing the part of all physically existing biogenic residues for a certain region and time that is applicable under consideration of availability, environmental barriers (e.g. erosion), technical feasibility, competing uses and legal requirements (Brosowski et al., 2016) - approximately 30% is currently used to produce materials (e.g. compost; fertilizers; cosmetics; pharmaceuticals; bio-plastics) through mainly chemical and physical conversion processes (cf. Thrän and Bezama, 2017; Spiridon et al., 2016; Türk, 2014). A further 27% of the technical potential is energetically used to produce electricity, fuels and heat through thermochemical and biochemical processes (cf. Long and Karp, 2013; Okoro et al., 2017). However, in addition to the substrates that are already tied to material and energetic treatment paths, a technical potential of around 30 million tons of biogenic residues are currently not being used in Germany (Brosowski et al., 2016). Wood residues, cereal straw, animal excreta and sewage sludge are particularly often not in energetic or material use in Germany. Moreover, many biogenic residues used in thermal processes are not suitable because their heating value is under 11 MJ/kg (Brosowski et al., 2016). In addition, some treatment paths for biogenic residues have the potential to increase efficiency through process cascades, i.e. the expansion of existing process chains through material recovery and recycling (Bezama, 2016; Thonemann and Schumann, 2016). With this in mind, the question arises as to whether and how this unused potential can be mobilized, and which processes are most suitable for this purpose.

Hydrothermal processes (HTP) appear to be a promising technology platform for processing wet and sludgy biogenic residues. These technologies use water as their main process medium to convert biomass into materials and fuels at high pressures and temperatures. Because a very moist environment is needed to ensure that the process runs effectively, less energy and thus costs are required in contrast to conventional treatment paths because process steps like substrate thickening and drying are not needed anymore. This makes HTP interesting from an economic and environmental point of view (Schindler, 2015). Thus, HTP seem to be a

suitable way to mobilize the wet and sludgy part of the unused biogenic residues in Germany. However, the novelty of the technology platform is associated with uncertainties and barriers for stakeholders (e.g. investment decisions, development of legal standards, funding decisions etc.). Hence, this review aims to contextualize HTP based on technological, economic, environmental and legal criteria.

2. Structure of the review and methods

This review follows the sequence illustrated in Fig. 1. The process is oriented on a modified content-analysis with the aim to provide new insights and enhance the understandability of certain issues through a structured procedure (cf. Moldavska and Welo, 2017).

2.1. Step 1: Preparation phase

First, the review focus was defined according to the study purpose that is to evaluate the extent to which HTP represent a viable option for processing currently unused biogenic residues in Germany. Thus, the central focus was set to identify technological, economic, environmental and legal potentials and barriers of HTP, to derive corresponding future research needs and to provide information on how to fulfill the research gaps. Based on the review focus, the unit of research was defined as scientific and practical information on the technological, economic, environmental and legal potentials and barriers of Hydrothermal Processes as options for treating biogenic residues in Germany.

Second, a sampling focus including the definition of the time period, type of documents, information sources and document languages must be defined. Because the research on Hydrothermal Processes has gained rising attention since 2000, the period of consideration was set from 2000 to 2017. A large range of different document types was included into the review. Particularly, scientific articles and textbooks, presentations on scientific conferences, conference proceedings, technical reports, legislative texts and websites written in both German and English. The reason for the selection of these document types is that current research on HTP includes much applied-oriented research that is often published via technical reports. Next to this, most recent results are often presented on conferences or websites before they are published in scientific journals or textbooks. Thus, these types of documents should be considered next to scientific articles and textbooks. The information sources used were Google, Google Scholar, Science Direct and Scopus.

Third, to identify documents that are most relevant considering the review focus, we used a sampling scheme (Fig. 2). For every process step of HTP it was determined which information about the aspects under consideration (Technology; Economy; Environment; Legislation) was needed to fulfill the review purpose and thus the defined focus. Based on suggestions of Thrän et al. (2013) the most relevant keywords for each process step and aspect were identified accordingly.

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