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Hydrocyclones for the separation of impurities in pretreated biowaste

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ABSTRACT

The aim of the mechanical pretreatment in case of anaerobic digestion of biowaste is to produce a substrate without impurities. To facilitate a failure free operation of the anaerobic digestion process even small impurities like stones or sand should be separated. As a result of an insufficient pretreatment or impurities separation, plant malfunctions, increased equipment wear or pipe clogging are reported. Apart from grit chambers or pulper systems, a hydrocyclone is a cost-efficient and space-saving option to remove impurities. The aim of this work was to investigate the efficiency of hydrocyclones for the separation of impurities. Two hydrocyclones at two different plants were investigated regarding their capability to separate the small inert impurities from pretreated source separated biowaste. In plant A, the hydrocyclone is part of the digester system. In plant B, the hydrocyclone is part of the biowaste pretreatment line (after milling and sieving the biowaste) before digestion. Separation rates of inert impurities such as stones, glass and sand were determined as well as the composition of the concentrated solids separated by the hydrocyclone. Due to the heterogeneity of the biowaste the impurity separation rates showed variations, therefore the following mean results were obtained in average: the investigated hydrocyclones of plant B, part of the biowaste treatment, separated more than 80% of the inert impurities in the waste stream before anaerobic digestion. These impurities had a size range of 0.5–4 mm. The hydrocyclone integrated in the digester system of plant A showed separation rates up to 80% only in the size range of 2–4 mm.

1. Introduction

The biological treatment of OFMSW (organic fraction of municipal solid waste, abbr. biowaste) is an important part of a sustainable waste management and its potential is still growing. Around 40% of the organic waste generated in the EU is still landfilled, the treatment option with the largest environmental impacts. Another 62 million tons of Greenhouse gas emissions could be saved if all European countries met the Landfill Directive's waste diversion targets in 2020 (European Environment Agency, 2011). The comparison of biological treatment options for biowaste, such as composting, biomass fuel production and anaerobic digestion (AD), showed that AD achieves the highest savings concerning greenhouse gas emissions (Ortner et al., 2013). Besides the production of renewable energy, a further positive aspect of AD of biowaste is the flexibility in energy production considering the possibility to store biowaste and produce biogas on demand (Aichinger et al., 2015). Anaerobic co-digestion is the simultaneous AD of at least two different substrates and is an option to improve the economic viability of AD plants due to increased methane production (Mata-Alvarez et al., 2000). The main substrates in an anaerobic co-digestion process can be animal manure, sewage sludge or biowaste. The most reported co-digestion mixture is sewage sludge with biowaste (Mata-Alvarez et al., 2014). Digesters at WWTP (wastewater treatment plants) are usually overdimensioned and therefore could be used to recover methane. However, not all kinds of biowaste are equally suitable for AD. As Lastella et al. (2002) described, clean organic wastes which do not require any pretreatment, seem to be the most attractive substrates. However, most of the available organic waste substrates need to be pretreated mechanically to disintegrate the waste components and to remove impurities. In a study of Bernstad et al. (2013), different mechanical pretreatment options for separately collected food wastes from households at 17 Swedish plants were investigated. These mechanical treatment options prior to AD included shredding, pulping, metal separation, dispersion, screw-pressing, disc-screening, and sieving. Even with these waste

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preparation steps, problems related to the quality of the produced substrate for AD as well as high maintenance costs were still persistent. Hence the requirement to pretreat biowaste for the AD process; it not only needs to be ground and be pumpable, but also must be free from obvious impurities (plastic bags, stones, packaging material, etc.) as well as small impurities in the size range of grit or sand. As a result of an insufficient pretreatment or impurity separation, especially of small impurities, plant malfunctions, increased equipment wear, or pipe clogging are reported (Novarino and Zanetti, 2012; Ratnayaka et al., 2009; Romero-Güiza et al., 2014; Shen et al., 2015). Another considerable issue is the accumulation of sediments in the digester. Automatic scrapers for their removal are not very common and the use with sludge pumps or bulldozers is time-consuming and requires an interruption of the AD process (Bayo et al., 2015). Furthermore, when the digestate is to be used for fertilizer or soil conditioning purposes, impurities are legally limited and reduce the quality (Pahl et al., 2008). Therefore, the installation of appropriate equipment for their removal may be required. The treatment of biowaste with a hydrocyclone is one option to separate small impurities such as stones, glass particles or sand.

1.1. Hydrocyclon: option for impurity separation

Hydrocyclones are known as an option to separate solids from liquids. The size of the separated particles differ among applications but sizes in the range of 10 μm to various millimeters are described (Müller, 2008; Ni et al., 2016). Hydrocyclones are characterized by their high operational reliability and efficiency with increasing flowrates, their high throughput, their simple structure (no moving parts), small size, and low maintenance and support costs (Bayo et al., 2015; Puprasert et al., 2004; Sripriya et al., 2007; Vakamalla et al., 2017; Yang et al., 2013). The application possibilities of hydrocyclones are numerous; they are used in petrochemical engineering, in the chemical industry or the pulp and paper industry to mention just a few (Mäkelä et al., 2014; Tailleur and Salva, 2008; Zubrik et al., 2010). Another field of application is environmental engineering, in particular applications in wastewater treatment and waste treatment. In wastewater treatment processes, hydrocyclones are mainly used for the separation of sand or grit. Bayo et al. (2015) described a hydrocyclone as a cleaning device for anaerobic sludge digesters to avoid a decrease of the available reactor volume and an extensive and time consuming cleaning of the digester. In the work of Puprasert et al. (2004), a hydrocyclone for the separation of suspended solids in surface runoff water is investigated. Yang et al. (2013) reports the separation of fine particles from industrial wastewater by a hydrocyclone. In the area of waste treatment, literature mainly refers to hydrocyclones for the separation of plastic waste (Arvanitoyannis, 2008; Gundupalli et al., 2016; Pascoe, 2006; Yuan et al., 2015). Nayono et al. (2010) reports a hydrocyclone which is used to separate fine sand from a food waste/press water suspension after defibering it with a hydropulper and passing it through a grit floor. Hydrocyclones in combination with pulpers/decanters are described for the wet pretreatment of biowaste (Colazo et al., 2015; Romero-Güiza et al., 2014).

Fig. 1 shows the functional principle of a hydrocyclone: the linear motion of a fluid (feed) is converted into a circular motion. Thereby the dispersed particles in the fluid are accelerated centrifugally and the settling of particles according to their density, size and shape is enhanced (Sripriya et al., 2007). Hence solids move downwards and leave the hydrocyclone at the bottom (underflow). The fluid leaves the hydrocyclone at the top (overflow).

Besides constructional factors such as height, radius, and inlet size (influences the inlet velocity) of the hydrocyclone, also the density difference between the fluid and the solids, and the viscosity of the fluid determine the separation process of the hydrocyclones. With an increasing density difference between the fluids and the particles, also the efficiency of the separation process increases. Segalen et al. (2015) mentions that the rheological properties, such as sludge viscosity, are difficult to determine in situ and the description of these properties is still subject of research.

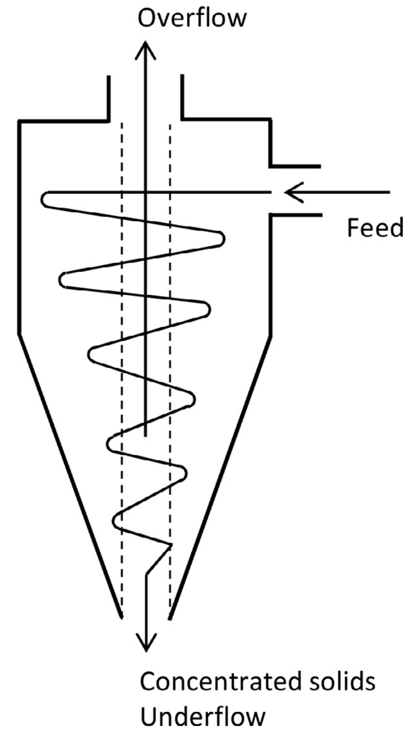

Fig. 1. Functional principal of hydrocyclones (Müller, 2008).

1.2. Scope of this work

The objective of this research was to investigate the efficiency of hydrocyclones for the separation of small inert impurities from pretreated single source collected biowaste. Biowaste is a very heterogeneous matrix which varies naturally due to various reasons: collection scheme, housing structure, season, etc. Each batch contains different proportions of fibrous material, fat and oils, water, impurities, etc. Due to this fact, the calculation of the separation performance is limited. Two different hydrocyclone set-ups were investigated for their suitability to separate the impurities from the organic waste. In plant A, the hydrocyclone is integrated in the recirculation line of the sludge digester. In plant B, the hydrocyclone is part of the mechanical biowaste treatment. The uncertainties concerning the viscosity of the sludge and pretreated biowaste impose additional difficulties for the theoretical modeling of the separation efficiency. Hence, in this work the impurity separation of the hydrocyclone pretreatment was determined by analyzing the input feed of the hydrocyclone, the overflow and the concentrated solids, focusing on the mass balance and separation efficiency. The mass flows were analyzed in terms of composition and size distribution of the impurities.

2. Materials and methods

2.1. Biowaste for further AD and mechanical pretreatment

The biowaste used for this investigation consisted of separately collected organic waste from urban areas, restaurants and canteens, and the food processing industry in Tyrol (Austria). The bio-