Waste Management 52 (2016) 96–103

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Impurities in pretreated biowaste for co-digestion: A determination approach

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ARTICLE INFO

Article history:
Received 16 November 2015
Revised 24 March 2016
Accepted 30 March 2016
Available online 4 April 2016

Keywords:
Impurities determination
Biowaste
Co-digestion
Wet fermentation
Mechanical pretreatment

ABSTRACT

Although the mechanical treatment of source separated organic waste typically includes processing steps to remove impurities like plastic bags, smaller particles like glass, stones or sand are often not sufficiently removed. These particles lead to plant malfunctions, increased equipment abrasion and accumulation in the digester. It is possible to remove these small impurities before or during the fermentation process but this requires additional equipment at the waste treatment facilities. For pretreated biowaste with fairly low concentrations of impurities and small particle sizes no appropriate method was found in literature to determine these particles. Therefore various approaches to develop an appropriate method were tested and finally one method was selected. Sample mass calculation showed that for the determination of impurities >2 mm a sample mass of about 6 kg is required to receive statistically sound result. Firstly an elutriation step is used to concentrate the impurities in a sinking fraction, still containing some organic material. The elutriated material is then dried. After drying the elutriated material, impurities can be fairly easily sorted manually. The elutriation process is applicable for the determination of impurities >1 mm. Due to the difficult manual sorting of particles <2 mm and the reduced sample mass required for the determination of particles <2 mm, these particles are determined by a different procedure: A sample mass of about 1 kg is dried and combusted in a muffle furnace. The remaining ashes are sieved from 2 to 0.06 mm. Particles <0.06 mm were not considered as impurities. The data regarding the impurities content and particle size distribution in food- and biowaste are required for assessing separation options as well as the behavior of stones or sand in the digester. This allows describing the quality of the pretreated biowaste. Furthermore the need to adopt or improve the existing pretreatment can be identified and the impact to the fermentation process (impurities accumulated in the digester, etc.) can be evaluated.

1. Introduction

Source separation of the organic fraction of municipal solid waste (OFMSW or biowaste) is a well-established element in modern waste management. Composting and anaerobic digestion are the dominating options for the biological treatment of biowaste. While the bulk of municipal green waste like tree wood and bark, dead and green leaves, grass clippings as well as domestic dwellings are suitable for composting, wet or paste like biowaste fractions (e.g. foodwaste) are more suitable for anaerobic digestion. Within the last years anaerobic co-digestion of biowaste in existing digesters of municipal waste water treatment plants (WWTP) has become a topic of more concern to overcome the drawbacks of mono-digestion and to improve plant's economic feasibility. The implementation of co-digestion in existing waste water treatment plants can be realized with no or only minors modifications of the plant design and surplus capacity of often oversized digesters can be utilized (Bolzonella et al., 2006; Borowski, 2015; Borowski and Kubacki, 2015; Cavinato et al., 2013; Krupp et al., 2005; Mata-Alvarez et al., 2014). For an efficient co-digestion process at a waste water treatment plant an adequate mechanical treatment of the biowaste is mandatory. In many cases the mechanical treatment includes a disintegration step to improve methane production (Agyeman and Tao, 2014) and removal of impurities. There are different options for the mechanical treatment of biowaste like

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http://dx.doi.org/10.1016/j.wasman.2016.03.055
0956-053X/

hammer mills, bag openers, shredders, sieves, water sorting processes (BTA® Process), waste separation presses or pressure extrusion, disc screens, optical sorter, etc. (Borowski, 2015; Dong et al., 2010; Hansen et al., 2007; Jank et al., 2015; Novarino and Zanetti, 2012; Romero-Güiza et al., 2014). Hydrocyclones are another option to remove impurities. They prevent the settling of small particles in the digester and hence the reduction of the available digester volume are hydrocyclones (Bayo et al., 2015). But there are indications that undesired materials (e.g. glass, metal) or residual soil particles (Haynes et al., 2015) remain in the substrate and result in problems in the treatment process like plant malfunctions, increased equipment abrasion and accumulation of impurities in the digester or pipeline clogging (Novarino and Zanetti, 2012; Ratnayaka et al., 2009; Romero-Güiza et al., 2014; Shen et al., 2015). Due to insufficient elimination of these inert impurities from the substrate further investigations of the efficiency of physical pretreatment are necessary (Bernstad et al., 2013; Dong et al., 2010). Therefore accurate and reliable data of the material characteristic of the waste involved are crucial to improve pretreatment (Edjabou et al., 2015). To get these data a characterization of the pretreated biowaste has to be conducted. A frequently used method to analyze the waste composition or to determine improper materials in waste streams is to sieve the waste and sort the sieving fractions into different categories. The manual sorting is typically conducted for materials >10 mm (Montejo et al., 2010). For untreated biowaste Puig-Ventosa et al. (2013) described a manual sorting of the waste without a further screening to obtain impurities fractions. The procedure to analyze improper material in compost includes a drying of the compost and a sieving of the dried material (BGK, 1998; Haynes et al., 2015; Sharifi and Renella, 2015). The limits for maximum foreign matter particles depend on national standards but include limits for stones and limits for glass, plastic and metal (Brinton, 2000). An option to analyze the organic waste composition is the chemical characterization of the organic matter (fat, fibers, sugar) or the determination of the basic elements (la Cour Jansen et al., 2004). Di Maria et al. (2013) described a method to separate fine material from residual waste. Thereby the material is processed in an attrition cell with water and chemicals to receive the inert material and to remove organics, paper or plastics. To analyze the fine fraction of landfilled waste Monkare et al. (2016) described a dry screening of the samples. This procedure was done to analyze particles from 0.5 to 20 mm. Zhang and Banks (2013) investigated the particle size of the organic fraction of municipal solid waste. The procedure includes a dry sieving (5–37.5 mm) for shredded material and a wet sieving (0.3–4.75 mm) for macerated material. The material <0.3 mm was centrifuged to collect the finest particles, dried and the percentage on the whole sample was determined. Jank et al. (2015) characterized mechanical treated biowaste. The waste was processed by a waste press and dried. A manual sorting of particles >2 mm was possible. The fraction <2 mm was combusted and the residual ashes were sieved with a 0.25 mm sieve. In the 0.25–2 mm fraction only the glass content was estimated.

1.1. The challenge to determine impurities in pretreated biowaste

No suitable and acknowledged method for the determination of impurities in wet biowaste is available. The material has a high concentration of fibrous components and therefore wet sieving is very time consuming if possible at all. A manual sorting of the impurities is impossible. An option to separate these particles from the organic is to combust the sample in a muffle furnace which is an applicable procedure for small sample masses. For larger sample masses the procedure of combusting is very time and energy consuming and the formation of smoke in the muffle furnace is a serious problem.

In first investigations it was calculated that a large sample mass is necessary for the determination of impurities >2 mm. In principle mass reduction is a commonly used procedure to analyze waste samples but as Dahlen and Lagerkvist (2008) described, splitting is the main drawback and the obtained standard deviations are associated with the number and mass or volume of the waste samples. Additionally common mass reduction procedures in sampling are applied for dry and granular materials e.g. riffle splitting, grab sampling, rotational dividers or fractional shoveling (Petersen et al., 2005) and not applicable for wet or paste like waste samples.

1.2. Scope of this work

Aim of this work was the development of a method to determine inorganic impurities like glass, gravel and sand in pretreated biowaste to achieve reliable data about the waste characteristics, in particular concentrations and particle size distributions of the impurities. The determination was separated in two parts: Particles <2 mm were determined by drying the sample and combusting it in a muffle furnace. For characterizing particles >2 mm, the organic was separated by elutriation and the remaining material was dried and sorted manually.

2. Material and methods

2.1. Testing material

In this work biowaste was taken from a local waste pretreatment facility where source separated biowaste (mostly wet material, no wood and foliage), food waste from supermarkets, production residues from the local food industry and leftovers from gastronomy and canteens are collected and pretreated for a further biological treatment in WWT digesters. For the pretreatment the biowaste is loaded into a hopper where four screws convey the material to a hammer mill and execute the mechanical pretreatment (opening of plastic bags, etc.). The biowaste is milled to a particle size of 12 mm. With a screening after the milling particles >12 mm, mostly plastic film, are removed. With water from a neighboring compost plant the milled and sieved biowaste is diluted until suitable for pumping. The average dry matter content (DM) of the pretreated biowaste is about 16%. On average 89% of the DM are volatile solids (VS). The pretreated biowaste is stored in a tank before it is transported to the WWTP. The samples for analyzing the impurities content were taken from the storage tank at the WWTP. To obtain characteristic samples, subsamples from different vertical layers of the tank were taken.

2.2. Determination of the impurities content in the pretreated biowaste for the sample mass calculation

As a first step the required sample mass was calculated. Therefore the impurities content was analyzed. 20 samples of 1 L were taken in a period from February to April 2013 (8 samples) and from November 2013 to January 2014 (12 samples). The impurities content was determined in duplicates. The samples were dried at 105 °C to constant weight. The dried samples were then combusted in a muffle furnace at 550 °C until all organic matter was burnt and only the ash was left. The ash was then sieved with a 2 mm, 0.5 mm, 0.1 mm and 0.06 mm sieve to receive the following sieving fractions:

- >2 mm
- 0.5–2 mm
- 0.1–0.5 mm
- 0.06–0.1 mm
- <0.06 mm