Chapter 1
General Background

Abstract General background and introduction on anaerobic treatment technology is presented in this chapter.

Keywords Anaerobic digestion · Biogas · Fossil fuel · Methane · Hydrogen · Biological treatment · Heat · Waste streams · Power

Anaerobic digestion is a well-established biological process for converting carbon-rich feedstocks into biogas, which can be used to replace fossil fuels in heat and power generation and as a transportation fuel, facilitating the development of a sustainable energy supply (Hubbe et al. 2016; Zhang et al. 2015; Bialek et al. 2014; Li et al. 2014; Weiland 2010; Ziganshin et al. 2013; Al Seadi 2001). This process does not require any air or oxygen; converts biomass in waste streams into a renewable energy source, and it also contributes to the treatment of these waste streams (Table 1.1).

Anaerobic treatment technology has been receiving growing interest since its first application (Van Lier 2008). There is no need to pay for the pumping of air into the system in the anaerobic system and the amounts of sludge produced are usually less than in conventional aerated biological treatment systems (Maat and Habets 1987; Ashrafi et al. 2015; Kamali and Khodaparast 2015). Anaerobic processes generate gases such as methane, requiring their collection and safe disposal. Nevertheless, the retrieving and reuse of biogases such as methane and hydrogen as a source of energy during full-scale treatment operations can provide substantial economic benefits to the treatment plants. The methane and hydrogen either can be sold or they can be burnt for the generation of heat (Tabatabaei et al. 2010). The essential conditions for efficient anaerobic treatment are shown in Table 1.2.

Several reviews have been published on the treatment of pulp and paper mill effluents using anaerobic technology (Graves and Joyce 1994; Rintala and Puhakka 1994; Rajeshwari et al. 2000; Savant et al. 2006; Meyer and Edwards 2014; Kamali and Khodaparast 2015; Ali and Sreekrishnan 2001; Kosaric and BlaszczyK 1992). Several authors have reported evaluations of factors affecting the anaerobic treatment of pulp and paper mill wastewaters (Kortekaas et al. 1998; Bengtsson et al.

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Table 1.1 Anaerobic treatment

Energy consumption Low Biogas production 0.05–0.10 kWh/kg COD
Sludge production Low 0.0300.05 kg/kg COD, Market value
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Wilson (2014). www.seai.ie/…Energy…/Waste-to-Energy—Anaerobic-digestion-for-large-industry.p

Table 1.2 Important conditions for efficient anaerobic treatment

Absence of toxic/inhibitory compounds in the influent
Maintain pH in the neutral range - 6.8–7.2
Sufficient presence of alkalinity
Low volatile fatty acids
Temperature in the mesophilic range (30–38 °C)
Enough nutrients (nitrogen and phosphorous) and trace metals especially, Fe, Co, Ni, etc. COD:N:P: 350:7:1 (for highly loaded system) 1000:7:1 (lightly loaded system)
Avoidance of excessive air/oxygen exposure

Based on www.sswm.info/…/MANG%20ny%20Introduction%20in%20the%20technical%20des

2008; Sierraalvarez et al. 1991; Korczak et al. 1991; Vidal et al. 1997; Ruas et al. 2012; Krishna et al. 2014; Larsson et al. 2015).

Anaerobic digestion offers a platform for waste water treatment in terms of environmental management in addition to biogas production. The integrated biorefinery involving the conversion of biomass into biofuels, bio-based chemicals, biomaterials can also be developed and implemented based on anaerobic digestion (Uellendahl and Ahring 2010; Uggetti et al. 2014). Generally, in the context of the integration of forest biorefinery with traditional pulp and paper manufacturing processes, anaerobic digestion of organic wastes from these processes for biogas production would fit well into the biorefinery concept (Van Heiningen 2006; Amidon and Liu 2009; Jahan et al. 2013; Wen et al. 2013; Ahsan et al. 2014; Dansereau et al. 2014; Dashtban et al. 2014; Hou et al. 2014; Rafione et al. 2014; Wang et al. 2014; Liu et al. 2015; Matin et al. 2015; Oveissi and Fatehi 2014). The waste streams from the traditional pulp and paper making processes can be converted to valuable products by using anaerobic digestion. The use of anaerobic digestion process in the pulp and paper industry appears to be promising. In the other sectors also, the use of anaerobic digestion would create new possibilities.

By using anaerobic treatment instead of activated sludge about 1 kWh (fossil energy) kg-1 COD removed is saved, depending on the system which is used for aeration of activated sludge. Furthermore, under anaerobic conditions, the organic matter is converted in the gaseous energy carrier methane, producing about 13.5 MJ methane energy kg-1 COD removed, giving 1.5 kWh electric (assuming 40% electric conversion efficiency). In Netherlands, over 90% reduction in sludge production significantly contributed to the economics of the plant, whereas the high loading capacities of anaerobic high-rate reactors allowed for 90% reduction in space requirement, both compared to conventional activated sludge systems. These advantages resulted in the rapid development of anaerobic high-rate technology for industrial wastewater treatment. In this development, Dr. Lettinga group at Wageningen University, in close cooperation with the Paques BV and Biothane Systems International played a very important role (Lettinga 2014). Anaerobic high-rate technology has improved significantly in the last few decades with the applications of differently configured high-rate reactors, particularly for the treatment of industrial wastewaters. The rapid implementation of high-rate anaerobic treatment actually coincided with the implementation of the new environmental laws in Western Europe and the co-occurrence of very high energy prices in the 1970 s. High amounts of high strength wastewaters from distilleries, food processing and beverages industries, pharmaceutical industries, and pulp and paper industry required treatment. The first anaerobic full scale installations showed that during treatment of the effluents, significant amounts of useful energy in the form of biogas could be obtained for possible use in the production process (Van Lier 2008; Ersahin et al. 2007). The extremely low sludge production, was another very important advantage of high-rate anaerobic treatment systems. Interestingly, the production of granular sludge, gave a market value to excess sludge, as granular sludge is sold in the market for starting up new reactor. From the 1970s onwards, high-rate anaerobic treatment is particularly applied to organically polluted industrial wastewaters, which come from the agro-food sector and the beverage industries. Currently, in more than 90% of these applications, anaerobic sludge bed technology is used, for which the presence of granular sludge is of great importance. The number of anaerobic reactors installed and the application potential of anaerobic wastewater treatment is expanding rapidly. Currently, the number of installed anaerobic high rate reactors exceed 4000 (Van Lier et al. 2015). Nowadays wastewaters are treated that were earlier not considered for anaerobic treatment, such as wastewaters with a complex composition or chemical wastewaters containing toxic compounds. For the more extreme type of wastewaters novel high rate reactor system have been developed. Intensive pilot and laboratory studies and full-scale applications have demonstrated the suitability of anaerobic processes for the treatment of several types of pulp and paper industry wastewaters (Maat and Habets 1987; Korczak et al. 1991; Minami et al. 1991; Sierraalvarez et al. 1991; Vidal et al. 1997; Kortekaas et al. 1998; Ahn and Forster 2002; Buzzini and Pires 2002, 2007; Yilmaz et al. 2008; Tabatabaei et al. 2010; Lin et al. 2011; Saha et al. 2011; Elliott and Mahmood 2012; Bayr et al. 2013; Ekstrand et al. 2013; Hagelqvist 2013; Hassan et al. 2014; Meyer and Edwards 2014; Larsson et al. 2015).

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