# Chapter 10
# Conclusion and Future Perspectives

**Abstract** Anaerobic treatment systems are viable technologies for wastewater pollution control in the pulp and paper industry and can be used as an essential part of an integrated treatment resource preservation system. The anaerobic treatment system include certain pretreatments (precipitation and oxidative pretreatments) that eliminate or detoxify aromatic compounds or modify aromatic compounds to improve their anaerobic biodegradability.

**Keywords** Anaerobic treatment · Wastewater pollution control · Pulp and paper industry · Resource preservation system · Pretreatment · Precipitation pretreatment · Oxidative pretreatment · Detoxification · Anaerobic biodegradability

Anaerobic treatment systems are viable technologies for wastewater pollution control in the pulp and paper industry and can be used as an essential part of an integrated treatment resource preservation system (Zhang et al. 2015; Hubbe et al. 2016). Advantages of anaerobic treatment are net production of renewable energy (biogas), reduced biosolids production and reduced emission of greenhouse gases. As a means of waste treatment, and apart from the energy content and value of the biogas, anaerobic treatment offers substantial savings in electrical power and other benefits which can result in significant savings. In many cases, it has been found that these savings are sufficient to offer a return on investment. For pulp and paper industry wastewaters, sulphate and sulphite reduction during anaerobic digestion can be combined with sulphur recovery systems. Particularly, biological recovery of elemental sulphur from hydrogen sulphide in anaerobically treated pulp and paper industry effluents has a promising future (Bajpai et al. 1999). The anaerobic method under thermophilic conditions offers attractive potentials for hot pulp and paper industry effluents allowing the application of higher organic loading rates and eliminating the need for cooling.

Anaerobic treatment has also the potential to remove environmentally harmful organochlorine compounds which are generated during chlorine bleaching of chemical pulps. The removal of AOX by two stage anaerobic-aerobic treatment is



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much higher than a single stage anaerobic and aerobic treatment alone (Hubbe et al. 2016; Bajpai 2000, 2013).

Various anaerobic reactors/digesters are commercially available, which include anaerobic lagoon/covered lagoon reactor, stirred reactor/contact reactor, plug-flow anaerobic reactor, anaerobic filter reactor, upflow anaerobic sludge blanket reactor, expanded granular sludge bed reactor, and internal circulation reactor, among others. These reactors can be specifically tailored for practical applications dealing with various feedstocks. A number of producers of these anaerobic reactors are available on the global market. Much potential do exist in terms of the more efficient and widespread use of anaerobic digestion technologies, which calls for technological advancements and breakthroughs related to biochemical, biological, and processing machinery aspects of the process. Future anaerobic digestion technologies such as those related to the concept of integrated biorefinery would play a significant role in meeting the high demand of environmental protection and bioenergy production. The enhancement of the efficiency of anaerobic reactors through scientific and technological innovations would also serve as the key to more widespread commercial use of anaerobic digestion.

In terms of the noticeable advantages of EGSB and IC, the systems show higher resistance to impact, higher organic loading, up-flow velocity and sufficient attachment between sludge and biomass (Mao et al. 2015). With respect to the sustainability of biogas technology, developing optimal cost-optimal input/output ratio of digestion process could be a promising technology. Anaerobic digesters having internal settlers such as UASB reactors are the main reactor systems for the treatment of pulp and paper mill wastewaters. These reactors have shown a moderate to high performance to reduce the COD and various removal efficiencies for other parameters including TSS, BOD, AOX, etc., depending on the operating conditions, reactor design, and the properties of the streams (Kamali et al. 2016).

The results obtained in the full-scale plants show that anaerobic technology should be definitely recognized as a viable alternative to aerobic treatment in a number of cases. In almost all pulp and paper industry, full-scale applications, anaerobic treatment is followed by aerobic post-treatment (Hubbe et al. 2016; Pokhrel and Viraraghavan 2004). The performance of anaerobic-aerobic treatment is superior or at least identical to aerobic treatment (Kamali et al. 2016). The suitability and cost of the anaerobic-aerobic and aerobic treatment systems are largely affected by a variety of mill-specific factors.

In order to facilitate the anaerobic treatment of difficult pulp and paper industry waste waters, numerous measures can be taken involving either the operation or design of the wastewater treatment system. These measures can be used to surpass the previously discussed limitations confronting the application of anaerobic treatment technologies to pulp and paper industry effluents.

During the operation of the bioreactors, anaerobic bacteria should be acclimatized to toxic organic compounds. The wastewaters should be diluted to subtoxic concentrations during reactor start-up and the dilution of the wastewater should be reduced in an incremental fashion in accordance with the degree by which the microorganisms adapt to the toxicity and develop capacities to degrade the organic compounds. Additionally, immobilizing anaerobic bacteria and maintaining high concentrations of biomass in the reactor, are factors which are known to improve the tolerance to toxic substances by anaerobic treatment systems.

The design of the anaerobic treatment system can include certain pretreatments that eliminate or detoxify aromatic compounds or otherwise modify aromatic compounds to improve their anaerobic biodegradability. These pretreatments include precipitation pretreatments and oxidative pretreatments. Precipitation pretreatments have been applied to anaerobic wastewater treatment systems to either remove toxic compounds or remove recalcitrant fractions.

At higher temperatures, biochemical reactions can proceed more rapidly which implicates a decrease of retention times or a smaller reactor volume of the wastewater treatment plants. Many effluents of pulp and paper industry are discharged at high temperatures which make them attractive for thermophilic treatment as no further energy input is required. Thermophilic treatment is shown to be suitable for several types of wastewaters. High-strength wastewaters can be treated at very high loading rates with high COD removal efficiency. At high temperature, the liquid viscosity is lower, which might benefit the biomass hold-up in upflow reactors if low strength wastewater is treated. To ensure the highest process stability, excess temperature fluctuations should be prevented. The activity of thermophilic sludge decreases with decreasing temperature but is still considerable and comparable with mesophilic sludge at temperatures of 40–45 °C. This is due to the fact that the growth rate and maintenance consumption of thermophilic bacteria is 2–3 times higher than the mesophilic counterparts. Startup of the thermophilic reactors was demonstrated to be easy and can be done by increasing the reactor temperature directly to the desired level or following a gradual increase with only a few degrees difference during several months. Besides temperature, process stability is also dependant on the chosen reactor type. Systems with a high biomass retention tend to be less sensitive than completely mixed reactors because of the higher variety of available selection criteria and thus variety of biomass, inside the reactor.

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