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Estrogenic trace contaminants in wastewater — possibilities of membrane bioreactor technology

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Abstract

Municipal wastewater treatment and landfill leachate treatment are typical state-of-the-art applications of the membrane bioreactor technology. Therefore, in this study the possibilities of MBRs with regard to the elimination efficiency of estrogenic trace contaminants are considered for these two applications. Investigations of phase distributions of the trace contaminants were conducted. The membrane bioreactor process was considered with respect to possibilities of the membrane unit to enhance the rejection of selected estrogenic trace contaminants.

Keywords: Membrane bioreactor; Estrogenic compounds; Landfill leachate treatment; Municipal wastewater treatment; Bisphenol A; Nonylphenol

1. Introduction

With more than 100 identified substances, the group of endocrine disrupting compounds (EDCs) is a major concern with respect to environmental pollution, because they can affect the development and reproduction of humans and animals. Among the natural hormones like estron and estradiol, the synthetic hormones like ethinylestradiol, which is used in contraceptives and substances produced by plants and fungi, the so called phytohormones belong to the group of EDCs. Moreover there are potential endocrine disrupting industrial chemicals. This study is focused on anthropogenic compounds (xenoestrogens). With respect to criteria like occurrence in wastewater, biodegradability, estrogenic activity and possibilities of analytical detection, bisphenol A (BPA) and nonylphenol (NP) were selected as representative trace contaminants. The estrogenic activity of these xenoestrogens is significantly lower than that of natural and synthetic hormones [1]. They are relevant due to their widespread production and the much

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higher detected concentrations in the aquatic environment. Estrogenic contaminants were detected in wastewater, surface water, groundwater and drinking water [2–4]. Apart from agricultural utilisation of sewage sludge, effluents of wastewater treatment plants are the main sources of EDCs in the aquatic environment. The conventional activated sludge process (CAS) reduces the estrogenic burden only to a limited level, particularly when experiencing hydraulic peaks, short sludge retention times or low temperatures. Therefore, additional measures have to be considered or the application of more advanced technologies becomes desirable. Apart from advanced oxidation processes like ozone combined with other oxidation agents, adsorption processes like powdered or granular activated carbon adsorption and non-biological membrane processes like reverse osmosis and nanofiltration, the membrane-assisted biological treatment or membrane bioreactor technology (MBR) is one of the appropriate options. Municipal wastewater treatment and landfill leachate treatment are typical state-of-the-art applications of the membrane bioreactor technology. Therefore, in this study the possibilities of MBRs with regard to the elimination efficiency of estrogenic trace contaminants are considered for these two applications. The investigations have been carried out on industrial scale, pilot scale and on a membrane test cell, respectively.

2. Background

Bisphenol A (BPA) is an organic compound that is widely used in the production of polymers such as polycarbonate and epoxy resins, both of which are used in a wide variety of applications such as digital media (CD and DVDs). Furthermore BPA is applied as a constituent of dental sealants, as developing agent in the coating of thermal papers and as an anti-oxidant in the production of plasticisers and processing polyvinyl chloride. It is well-known and previously documented that BPA hydrolyses and leaches from these products under strong heat and alkaline conditions [5–7]. Howdeshell et al. [8] described a significant release of BPA from polycarbonate cages into water at room temperature. Comprehensive studies in Japan found landfill leachates as one of the most likely sources of BPA in the aquatic environment [9–11]. The authors detected BPA in the raw leachate with concentrations up to 17,200 μg/L. They explained these high findings by high leaching rates of largely produced and widely used polyvinyl chloride products and the deposition of waste plastics.

Whereas the estrogenic burden of landfill leachate is mainly caused by xenoestrogens, natural and synthetic hormones dominate the estrogenic activity of municipal wastewater. Therefore, investigations on estrogenic potential of municipal wastewater mainly focused on the most powerful natural and synthetic estrogens, such as estradiol, estron and ethinylestradiol. Nevertheless, there are some studies which detected industrial chemicals in municipal wastewater [2,3,12,13]. Principally they found alkylphenol polyethoxylates and their degradation products, such as nonylphenol (NP). The comparison of these studies showed that higher concentrations of alkylphenolic compounds in municipal wastewater are closely related to the input of industrial wastewater. The highest measured concentration of alkylphenol polyethoxylates was 10,600 μg/L [12]. Without the input of industrial wastewater the concentrations of BPA in municipal wastewater normally range near the detection limit. Clara et al. [14] detected BPA in the range of 0.7–2.4 μg/L.

As the conventional activated sludge process reduces the EDCs only to an unsatisfactory level, the MBR could improve the elimination efficiency [13,15]. Although many articles have been reported on the application of MBRs to treat municipal and industrial wastewater, there are only a few papers that consider the fate of estrogenic com-