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Dissemination of Antibiotic Resistance Genes during Sludge Anaerobic Digestion: The Roles of Temperature, Sludge Pretreatment and Nanoparticles

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Abstract

Activated sludge is an important source of Antibiotic resistance genes (ARGs), which will pose a potential risk to human and livestock health if treating inappropriately. Anaerobic digestion is an efficient way for reducing ARGs quantities, and there is a need to study the effect of factors on dissemination of ARGs during sludge anaerobic digestion for the effectiveness on the ARGs control. This review summarizes current literature on the influence of temperature, sludge pretreatment and nanoparticles (NPs) on the fate of ARGs during anaerobic digestion. Studies have shown that thermophilic sludge and sludge pretreatment can lessen the risk of ARGs diffusion to some extent. Effect of NPs as emerging materials on ARGs is a potential research prospect and further research is needed to control the possible risks of NPs on the dissemination of ARGs during anaerobic digestion.

Keywords: Antibiotic resistance genes; Anaerobic digestion; Temperature; Sludge pretreatment; Nanoparticles

Introduction

Antibiotic resistance genes (ARGs) have been regarded as emerging contaminants in recent years [1,2], and they were extensively detected in activated sludge [3]. The potential land use of activated sludge may result in the dissemination of ARGs [4]. Anaerobic digestion is an efficient way for reducing ARG quantities, thereby lessening the land-applied risks of activated sludge [5]. Temperature and sludge pretreatment are the significant influencing factors for the reduction of ARGs [6,7], and nanoparticles, as an emerging contaminant, is a potentially valuable factor for ARGs control during anaerobic digestion [8]. This mini review highlights current literatures on the influence of temperature, sludge pretreatment and nanoparticles on the fate of ARGs during anaerobic digestion to assess the potential of the three factors for the attenuation or increase of ARGs, and benefits to understand the risk of releasing ARGs into the environment.

Effect of Temperature on ARGs during Sludge Anaerobic Digestion

Temperature was demonstrated as a crucial variable for specific ARGs removal. With the increasing anaerobic digestion temperatures from 22 to 55 °C, tetracycline resistant genes (tet) and class I integron gene (intI1) were increasingly removed [9]. Ma et al. [10] have also found that erythromycin resistant genes (erm(B), erm(F)) and tet(O), tet(W) were more effectively reduced in thermophilic anaerobic digesters compared to mesophilic anaerobic digestion. In two-phase anaerobic digestion, the quantity of ARGs was reduced in the acidogenic phase of thermophilic digestion, whereas a rebound in their quantity was caused in subsequent methanogenic phase. High temperature can efficiently destroy bacterial cells with ARGs to reduce vertical transferability of ARGs [11]. Moreover, thermophilic sludge had a smaller mobilome, such as plasmids, insertion sequences and integrons, suggesting that high temperature could lower the horizontal transfer potential of ARGs [6]. However, Zhang et al. [6] has found that the abundance of total ARGs or their diversity in either the thermophilic or mesophilic treatment showed no measureable change using metagenomic approach [12].

Effect of Sludge Pretreatment on Args during Sludge Anaerobic Digestion

Sludge pretreatment was obviously necessary to improve the low efficiency of sludge hydrolysis during anaerobic digestion

process. It was widely demonstrated that sludge pretreatment is able to improve subsequent sludge anaerobic digestion efficiency [13-15]. Additionally, different pretreatments in sludge anaerobic digestion have been reported to affect the reduction of ARGs. Thermal hydrolysis (TH) pretreatment significantly reduces all ARGs compared with that receiving untreated sludge during anaerobic digestion [10]. Sludge anaerobic digestion with microwave andmicrowave-H2O2-alkaline pretreatments showed slightly better ARGs attenuation efficiency [7]). TH pretreatment in three sludge pretreatments, including microwave, TH and ozone pretreatment, resulted in greater ARGs reduction [16]. Additionally, microwave- H2O2 could also reduce the absolute quantity of all ARGs and promote the relative abundance of most ARGs at the pretreatment process [17]. After subsequent anaerobic digestion, both total ARGs quantities and relative abundance were enriched, and only two-stage AD showed some advantages over ARGs abundance reduction.

Effect of NPs on ARGs during Sludge Anaerobic Digestion

Widely using of the nanotechnology resulted in more and more nanoparticles have inevitably entered into sludge, which affect sludge anaerobic digestion processes. The presence of nanoscale zero-valent iron (nZVI) during anaerobic digestion contributed to the abatement of odor and the improvement of biogas production [18]. nZVI could also disrupt cell membranes and has negative effect on methanogenesis in anaerobic digestion [19]. Different nanoparticles probably impacted distinctly to sludge anaerobic digestion [20,21].

The effect of nanoparticles on ARGs occurrence is a meaningful research prospect during sludge anaerobic digestion. Several studies have found that in thermophilic anaerobic digester process, Ag NPs had no significant effect on ARGs occurrence [22]. They are converted to Ag2S NPs during anaerobic digestion process, which sequester Ag and prevent biological interactions with the digester microbial community [8,23,24]. To date, other nanoparticles and their influence mechanism on ARGs during the digestion process have seldom investigated. However, in other environmental systems, Al2O3 NPs and TiO2 NPs have been reported to injure cell membrane and stimulate the transcription activity of RP4 transfer gene, thus they facilitate conjugation mediated by RP4 [25,26]. Graphene oxide (GO) have also been demonstrated to promote the conjugative transfer of plasmid from 1 to over 3 folds in the water environment [27]. Consequently, in future studies, a large number of studies should be carried out to investigate the effects of nanoparticles on dissemination of ARGs during sludge anaerobic digestion.

Conclusions and Future Outlook

To date, thermophilic sludge and sludge pretreatment have been demonstrated as an efficient way for specific ARGs removal. However, some ARGs are not completely removed, and higher temperature or more advanced pretreatment method may be needed to denature DNA and completely degrade ARGs. Additionally, as NPs are widely available in sludge, they impact significantly the sludge anaerobic digester process. However, the effect of various NPs on dissemination of ARGs is rare reported. Moreover, the interaction mechanism between NPs and ARGs are urgently needed to be investigated so as to control the potential risk of ARGs enrichment and transfer. In our ideal expectation, the properties of nanoparticles as much as possible can be used to promote anaerobic digestion process and to reduce dissemination of ARGs.

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