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A combined method of hydrodynamic cavitation and alkaline treatment for waste-activated sludge solubilization; N/P recovery from anaerobic granular sludge

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ABSTRACT

Waste-activated sludge (WAS) is typically processed very slowly and only to a certain extent in anaerobic digestion (AD), typically necessitating pre-treatment. In this study, we developed a new and powerful way of pre-treating WAS, which is a combination of hydrodynamic cavitation (HC) and alkaline treatment, and examined it for its efficacy. The combined treatment yielded the highest disintegration degree (DD) of 48.4%, while HC alone produced only 11.9% of DD and alkaline alone did 16.2%. The pre-treated sludge led to much enhanced methane production compared with the untreated one; 80.7 ml/g COD_{added} was the largest amount of CH_4 obtained with the pre-treated sludge, while 37.3 ml/g COD_{added} with the untreated one. The distinctive efficacy of the HC was further exploited to remove nutrients from anaerobic granular sludge (AGS) in a beneficial way: namely, the HC-mediated recovery of N/P by way of struvite precipitation. The highest phosphate removal was found at pH 10 with HC, which was more than twice the value of a simple stirring (63 mg PO_4^{3-}/L by simple stirring versus 150 mg PO_4^{3-}/L by HC). It appeared that HC is indeed a sure option for WAS pre- and post-treatment to improve biodegradability and nutrient recovery, respectively.

1. Introduction

Wastewater treatment based on activated sludge system (AST), though a core technology when it comes to the removal of organic wastes, generates an enormous amount of waste-activated sludge (WAS). For instance, in 2010, 8.2 million tons of WAS were produced in the USA alone [1] and 10 million tons in the European Union in 2005 [2]. It is necessary to reduce the volume prior to disposal. Anaerobic digestion (AD) can be used to reduce the sludge volume, in the process recovering bioenergy as a form of biogas. This bioprocess removes organics via four steps including hydrolysis, acidogenesis, acetogenesis and methanogenesis [3,4]. AD has many advantages for the purpose of WAS disposal, such as low consumption of energy and proven records of operation. However, the suboptimal degradability of WAS during the first step of hydrolysis remains an issue [3,5,6].

WAS, because of being whole cells, is recalcitrant to any biological attacks [7–10]. It is this reason that WAS, before being processed in the AD, typically goes through pre-treatment based on thermal or physical or chemical treatments or combined ones so as to improve its biodegradability [10,11]. Thermal treatment is known to increase AD efficiency, but the need of extra energy for heating makes it rather a costly option [12]. Physical treatments, if rightly selected and optimally operated, are considered uniquely advantageous in terms of energy consumption and effectiveness [13]. Sonication disintegrates WAS through destructive cavitation in a powerful and effective manner, but its effectiveness comes with high energy consumption; and the limited scalability is another critical problem for its application for WAS pre-treatment [14–16]. High-speed homogenization is another physical means that could give rise to high shear and cavitation effects [17], and it has been widely used in energy intensive processes such as homogenization, chemical reaction, dispersion and cell disruption processes [18]. However, when it comes to its application, operation and scalability, it entail high-development costs, numerous material waste and start-up problems [18,19].

Hydrodynamic cavitation (HC), which is a less explored physical means, is probably best suited for the purpose of WAS treatment; it has

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