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Research article

Use of activated sludge biomass as an agent for advanced primary separation

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ABSTRACT

Conventional primary settling is a physical process of solid-liquid separation, normally presenting low removal efficiencies. Improvement of this separation process would result in energetic advantages: lower aeration requirements and higher biogas production form primary and secondary sludges. Secondary sludge has been proposed as a potential agent promoting an increase in primary separation efficiency. Few processes have been proposed, based on the cultivation of sludge under special conditions. However, one can speculate that regular sludge may have a similar effect. The aim of this research was to study that possibility. Sludges from different activated sludge reactors were tested. Results showed that COD removals were up to 55%, 2 times higher than that for simple settling. Under that condition, COD balances showed that aeration requirements would reduce 40%, and biogas production from primary and secondary sludges would increase 50%. It is inferred then that the application of activated sludge as an external agent represents an interesting alternative that have the potential to significantly improve energetic efficiency of sewage treatment plants.

1. Introduction

Sewage is composed by suspended, soluble and colloidal solids. Removal of suspended solids and colloids can be partially accomplished by means of physical, chemical and biological processes. Settling is by far the most used alternative, based on its simplicity and low associated costs (Lee et al., 2014). It consists on the simply deposition of suspended particles, as a results of the action of gravity (Mahdy et al., 2015; Tchobanoglous et al., 2003). When applied to sewage, settling usually can achieve removals of suspended solids and biological oxygen demand (BOD) in the rages 50–60% and 25–40%, respectively (Tchobanoglous et al., 2003).

Coagulation and flocculation mediated by the external addition of chemicals is a common alternative to enhance primary settling (Lee et al., 2014; López-Maldonado et al., 2014; Renault et al., 2009). However, its application is in many cases restricted by economic and environmental reasons. For example, the addition of metals as coagulants can lead to the formation of metallic hydroxides, which are toxic and can cause several diseases (Divakaran and Pillai, 2001; Renault et al., 2009; Tervahauta et al., 2014; Zemmouri et al., 2012). Bioflocculants such as chitosan, tannins and alginate have raised attention as an alternative to traditional synthetic flocculants. However, even though they are biodegradable and non-toxic, its efficiency is only moderated, and may involve high production costs (Ismail et al., 2012; Lee et al., 2014; Salehizadeh and Yan, 2014; Zhao et al., 2000).

Extracellular polymeric substances (EPS) have also been proposed as potential flocculating agents. Indeed, EPS are a key factor determining microbial agglomeration in biofilms, flocs and granules (Badireddy et al., 2010; Logan and Hunt, 1988). EPS can represent up to 80% of the organic content of activated sludge (Görner et al., 2003; Sheng et al., 2010). As a result, activated sludge itself has been also proposed as an agent that could potentially improve the effectiveness of primary settling (Zhao et al., 2000). The biosorption capacity of activated sludge has been already

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reported, which can be used as a tool for COD removal from raw sewage (Guellil et al., 2001; Tan and Chua, 1997). As a result, recycling of activated sludge, or aeration of primary sludge to induce biological activity, have been proposed to enhance primary separation when treating sewage (Huang and Li, 2000; Yetis and Tarlan, 2002). The ability of activated sludge to enhance primary separation would be the result of mechanisms such as bridging, hydrophobic interactions, charge neutralization, particle sweep and adsorption (Diamantis et al., 2014).

The application of activated sludge as a recovery agent for solids and COD is referred to as advance primary settling process. This concept is present in the traditional AB process (adsorption/bio-oxidation), which operates using two activated sludge systems in series: the first system performs pre-degradation and adsorption of organic matter; and the second system provides treatment for soluble organic matter coming from the first reactor. AB process requires high operational loads (F/M between 2 and 10 kg BOD/kg SSML·d), to promote the production of EPS. A low solids retention time is also required (between 0.3 and 0.4 days), in order to avoid excessive mineralization of organic matter (Zhao et al., 2000).

BSS process (bioflocculation-adsorption, sedimentation and stabilization) is also based on the capacity of sludge to enhance primary separation. It involves the use of a bioflocculation-adsorption reactor, where the content is aerated and then pumped to a settler (Lugo, 2014; Verstraete et al., 2009; Zhao et al., 2000). As a result, COD removal of this system would be the combination of settling (62%), bioflocculation (20%) and adsorption (18%) (Zhao et al., 2000). Removal efficiencies of BSS process for COD and TSS can reach between to 70–80% and 80–95% respectively, at doses of sludge between 4 and 5 g/L (Lugo, 2014; Zhao et al., 2000).

Recently, the bioflocculation/biosorption properties of activated sludge have been also tested in conjunction with the use of membranes. Diamantis et al. (2014) tested a biosorptive activated sludge (BAS) as a pre-treatment for an ultrafiltration step. BAS system was able to remove 80% of COD, at organic load rates between 10 and 20 kg/m^3·d. On the other hand, Leal et al. (2010) operated a lab-scale membrane bioreactor for the treatment of grey water. Up to 82% of the COD was recovered in the concentrate, which was interpreted to be the result of bioflocculation of influent organics.

The application of activated sludge to improve primary separation would decrease the energy requirements for aeration during secondary treatment, due to the reduction of organic load. Moreover, biogas production would be increased, because of a higher generation of primary sludge. Therefore, increasing the efficiency of primary treatment would improve the overall energy balance of a treatment system.

ABB, BSS and other reported alternatives involve contacting sewage with a sludge with special properties, produced under special conditions, such as high load or low retention times. However, one can speculate about the capacity of regular sludge to achieve a similar effect. This would enable the application of this concept to existing traditional sewage treatment plants with reduced or minimal investments. Fig. 1 presents a schematic representation of a conventional sewage treatment plant, and one based on the proposed advanced primary separation, where part of the secondary sludge is mixed with raw sewage to enhance primary settling. The aim of this research was to study the use of the activated sludge which can be normally found in traditional sewage treatment systems, as an agent promoting the improvement of primary settling. To achieve such goal, lab experiments were conducted with real sewage and sludge obtained from full-scale installations. Based on the results, potential energetic benefits were evaluated.

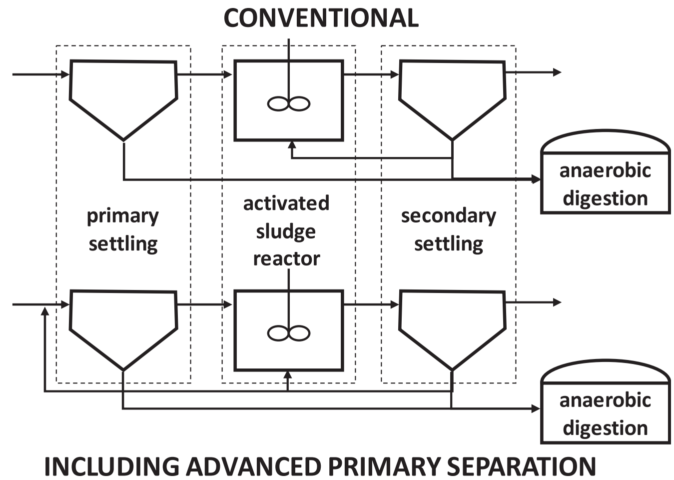

Fig. 1. Comparison between conventional sewage treatment with a system including the advanced primary separation studied in this research.

2. Materials and methods

2.1. Sources of activated sludge

Five different types of sludges were used to conduct this study. Three of them came from full-scale sewage treatment plants (STP), operating in the cities of Traiguén (activated sludge), Temuco (activated sludge) and Pucón (sequential batch reactor, SBR). All these plants are located in Araucanía region, Chile. The remaining two sludges were generated under lab-scale conditions. For that purpose, 2 lab-scale SBR reactors of 2 L of useful volume were inoculated with sludge from Temuco plant, and were operated for 40 days. The same solids retention time (SRT) was applied on both reactors (25 days), but different F/M (1.5 and 3 kg BOD/kg SST) were set. Lab-scale reactors were fed with diluted whole milk as synthetic substrate. Influent concentrations were 1 and 2 g COD/L for reactors cultivating sludges D and E, respectively. Table 1 presents the conditions under which each sludge was produced, and the letter that will be used to refer to each one. Sludge B presented a very high SVI, typical of a bulking sludge. Sludge B was used in this study, despite its high SVI, since it would contribute to have tested sludges with a wide range of characteristics.

2.2. Preliminary tests

Preliminary tests were performed with secondary sludge B and incoming sewage of that plant (STP of Temuco). Sludge and primary influent were mixed in a graduated test tube of 1 L. Table 2 shows the mixing ratios used. Settleable solids after 30 min of settling were determined for each condition. COD and total suspended solids (TSS) of the clarified liquid were measured, in order to evaluate removal efficiencies.

Table 1
Operational characteristics of the secondary sludge used in the tests.

Sludge	Origin	SRT (d)	F/M (kg BOD/kg TSS)	SVI[a] (mL/g)
Sludge A	STP of Traiguén	25	0.5	60
Sludge B	STP of Temuco	2	1	350
Sludge C	STP of Pucón	45	0.1	120
Sludge D	Lab-scale cultivated	25	1.5	24
Sludge E	Lab-scale cultivated	25	3	27

[a] Sludge volumetric index, measured after 30 min of settling.