Adding Growth-Promoting Ingredients in Activated Sludge Process as a Troubleshooting Strategy for Pulp and Paper Mill Wastewater Treatment

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The activated sludge process is a well-established technology in the secondary treatment of pulp and paper mill wastewater. Maintaining the activities of microorganisms and allowing them to thrive, metabolize, and grow robustly is essential for efficient biological reactions. To this end, a scientific formulation of growth-promoting ingredients (containing stimulants, buffers, micronutrients, *etc*) provides a useful strategy for addressing the impact of fluctuations in process conditions involved in the pulp and paper production. Lots of potential exists in terms of the use of these "smart" ingredients to meet stricter discharge limits.

Keywords: Pulp and paper; Activated sludge process; growth-promoting ingredients; Microbial activities

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Water Use and Treatment in the Pulp and Paper industry

The pulp and paper industry is highly water-intensive. Basically, water is used in nearly all processing steps or unit operations associated with the production of lignocellulosic fibers and paper-based products. It is noted that the water is largely used as process water. As a consequence, large volumes of contaminated liquid streams are generated, calling for the need to address water-based challenges. The properly-treated wastewater can then be discharged into receiving waterways or reused.

In general, existing wastewater treatment technologies include physical, chemical, and biological processes (Hubbe *et al.* 2016). Sedimentation, dissolved air flotation, membrane filtration, and chemical oxidation are examples of physical and chemical processes, whereas biological processes can be divided into aerobic, anaerobic, and fungal processes (Pokhrel and Viraraghavan 2004). Integrated systems involving these processes, also known as hybrid systems, has gained considerable attention in an effort to enhance treatment efficiency and improve effluent quality (Ashrafi *et al.* 2015).

The combination of primary treatment and secondary treatment is currently the typical practice for handling pulp and paper mill wastewater streams. The primary treatment is mainly responsible for eliminating the suspended solids *via* sedimentation, dissolved air flotation, and filtration. Subsequently, the secondary biological treatment largely removes the organic contaminants on the basis of microbial metabolism. Advanced or tertiary treatment of secondarily-treated wastewater may be practiced to reach a higher level of pollution control or reuse (Zodi *et al.* 2011; Lucas *et al.* 2012).

Activated Sludge Process and the Impact of Adding Growth-Promoting Ingredients

The concept of activated sludge treatment dates back to the 1900s. Despite the fact that the anaerobic process is gaining popularity, the activated sludge process is still commonly used in secondary treatment of pulp and paper mill wastewater (Bäckman and Gytel 2015). Fundamentally, this process uses a mixed culture of various microorganisms that degrade/consume the wastewater aerobically, producing carbon dioxide, water, and new biomass (Mayhew and Stephenson 1997). It is noted that the integration of anaerobic process with activated sludge process is also promising for efficient secondary treatment (Wang *et al.* 2015).

As the efficiency of activated sludge process is correlated with the activities of microorganisms, it is essential to provide favorable living conditions for them to thrive, metabolize, and grow. It is well known that pulp and paper mill wastewater treatment usually requires the handling of a combination of streams from various process units, and the composition of the combined stream may vary due to possible shock loading and spills (Peters 1998). Also, pulp and paper mills may add new chemicals or otherwise modify mill operations. Under these circumstances, the living conditions of the microorganisms can be impacted, oftentimes inhibiting microbial actions (Whitmer 2015). To this end, the concept of adding growth-promoting ingredients can be an effective strategy in wastewater treatment practices (Jia 2015). The process flow involving this concept is schematically illustrated in Fig. 1.

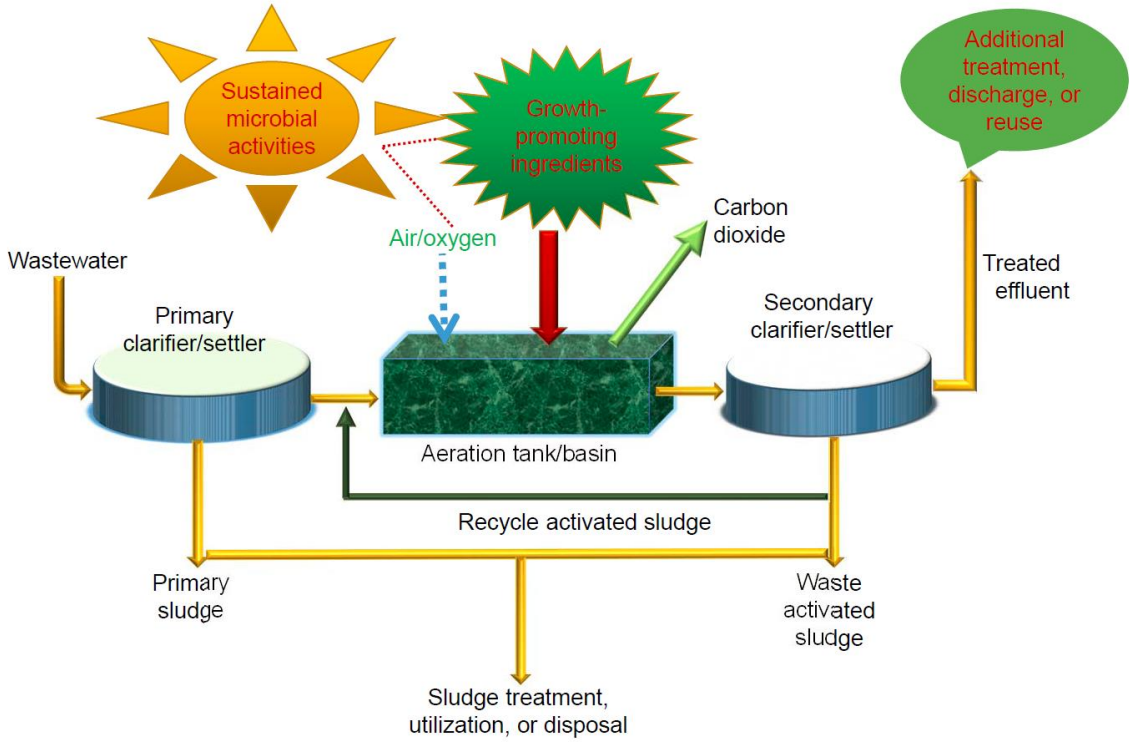
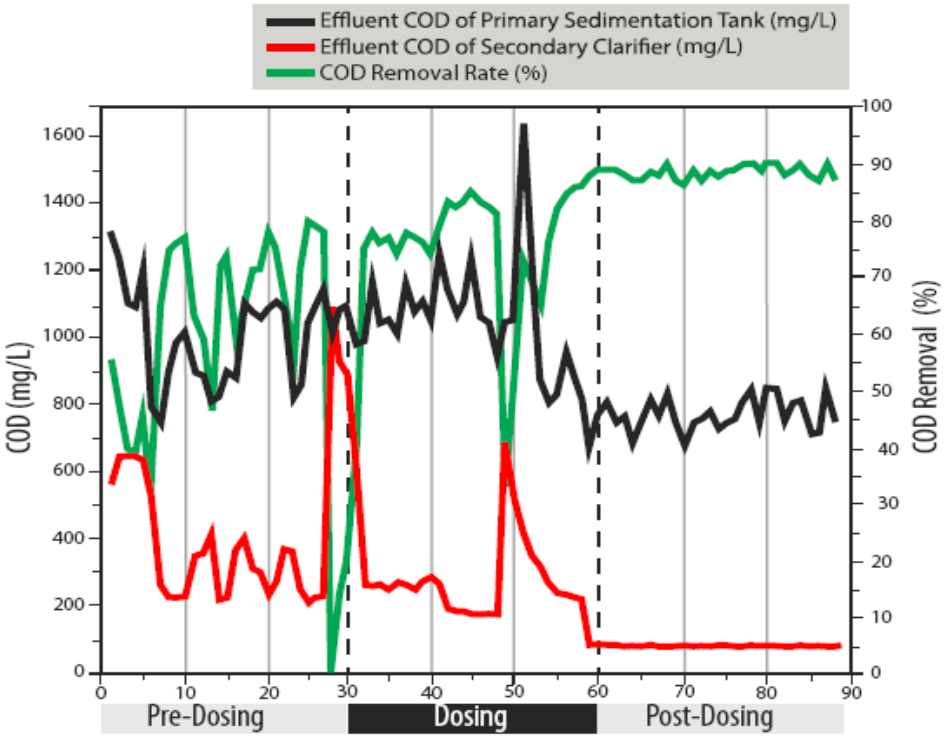
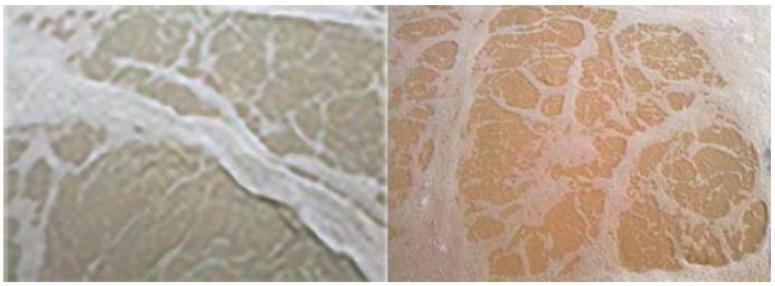


Fig. 1. Schematic illustration of using growth-promoting ingredients in activated sludge process as a troubleshooting strategy for pulp and paper mill wastewater treatment involving the use of primary treatment and secondary treatment. Note that the growth-promoting ingredients can also be added into the return activated sludge, allowing for pre-interactions of the microorganisms with the ingredients. In some sense, the secondary treatment largely removes the dissolved organics/contaminants, while the primary treatment basically eliminates the suspended solids.

Noticeably, the Probiotic Solutions® family of products (Bio Huma Netics, Inc., Arizona, United States), *i.e.*, growth-promoting ingredients for sustaining the microbial activities in wastewater treatment, have been developed to improve water quality and reduce operating costs. Encouragingly, two Probiotic Solutions® products were recently successfully used to address process upsets at a paper mill in China (Fig. 2) (Ashrafi *et al*. 2015). Specifically, these products are: (1) Bio Energizer (BE), a formulation of organic acids, buffers, natural biological stimulants, micronutrients, and energy systems, and (2) Micatrol (MT), a product that uses organic acid as a substrate to buffer wastewater microbial life. By proper dosing of the growth-promoting ingredients, the effluent COD was reduced to an average value of about 80 mg/L, which meets the current strict discharge limit (100 mg/L) in China.



(a) Effluent COD and COD removal.



(b) Activated sludge wastewater before and after the dosing of the ingredients: (left) immediately after COD load; (right) 5 days after dosing.

Fig. 2. Impact of using growth-promoting ingredients (a case study in China). Note: (1) the wastewater treatment system with a capacity of 30,000 m^3/d consisted of a primary sedimentation tank and aeration basins, followed by secondary clarification; (2) the ingredients were added into the return activated sludge at a dosage of 1 ppm for a duration of 30 days, and the relevant results were compared with 30 days of pre-application and 29 days of post-application; (3) the ingredients were used to manage hydraulic loading from new upstream processes that led a system upset, and during the dosing time, the system received a high load of COD (1575 mg/L).

Some growth-promoting ingredients can be used to stimulate microbial activities in both activated sludge process and anaerobic process (*e.g.,* the EC-4000 micronutrient biostimulant, a commercial product from EcoChem Canada Ltd). In addition to providing troubleshooting solutions, the use of growth-promoting ingredients can definitely improve process efficiency (McMillen 1998). At this point, it is pretty clear that the use of growth-promoting ingredients in activated sludge process has lots of potential in the development of "greener" pulp and paper industry.

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