Treatment of Pulp and Paper Wastewater Using Aerobic Granulation

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INTRODUCTION

Conventional biological processes such as activated sludge struggle to treat pulp and paper wastewater (PPW) to the required standard. Aerobic granulation has emerged with strong potential to provide the desired treatment. Compared to activated sludge, granular sludge provides high biomass retention, resilience to toxicity and shock loads, which are vital to PPW treatment.

Attempts have been made to treat PPW with aerobic granulation. Early results on the application of aerobic granulation technology for PPW indicate very promising removal. However, pilot-scale testing is required to establish optimal operating conditions. Thus, the present work is aimed at determining the removal of Adsorbable Organic Halides (AOX) and other toxic compounds found in PPW.

PULP AND PAPER WASTEWATER INTRODUCTION

The pulp and paper industry is one of Canada's largest and most profitable industries. Pulp and paper mills consume large amounts of water, and this water typically reappears in the effluent that is discharged to the environment. Effluents from the pulp bleaching process are especially harmful as chlorine by-products are persistent in the environment and bioaccumulate in the aquatic life.

Pulp and paper mill effluent discharges are high in organic content, contain nutrients and are toxic. In Canada, a number of provinces have developed regulations to limit the discharge of Adsorbable Organic Halides (AOX) to as low as 1.4 kg/air dry tonne of pulp [1]. Therefore, there is a need for a novel treatment method to deal with these toxic pollutants as they exit the pulp mills prior to discharge.

CURRENT TREATMENT METHODS

Table 1: Various treatment methods and their effectiveness on PPW treatment [2-7]

Type of Treatment	COD* Removal (%)	BOD** Removal (%)	AOX Removal (%)	Chlorinated Phenols Removal (%)
Conventional Activated Sludge (CAS)	70	90	40-60	60-95
Aerobic Stabilization Ponds/Aerated Lagoons	-	95	53	86
Aerobic Biological Reactors	98	80	-	-
Trickling Filter	62	76	48	-
Moving Bed Biofilm Reactor (MBBR)	65	93	50	60

*COD = Chemical Oxygen Demand
**BOD = Biochemical Oxygen Demand

APPLICATION OF AEROBIC GRANULATION TO PPW

This process involves applying stress to the bacterial cells through high shear force and with cycles of feast and famine [9]. This causes the secretion of extracellular polymeric substances that will help form bacterial aggregates, called granules, that are 0.5-2.0 mm in diameter [10]. The bacterial consortium within the granules is comprised of several species capable of degrading phenols and other toxic compounds [10].

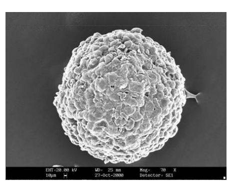


Figure 1: Granule image in a scanning electron microscope

Compared to conventional treatment, granular sludge provides smaller footprints, better settleability, higher biomass retention, tolerance to toxicity, removal of nutrients, and resistance to shock loading. The unique features of resilience to toxicity and shock loads as well as high biomass retention and the ability to remove nutrients are vital to PPW treatment.

Aerobic granulation has achieved 99% and 94% removal of halogenated and aromatic compounds respectively, similar to those of pulp mill wastewater [12]. This technology has been successful in treating paper-making wastewater with COD of 3000 mg/L [13]. High BOD (97%) and COD (90%) removal efficiencies have been reported on PPW treatment using aerobic granulation [13].

PRELIMINARY WORK

The aerobic granular reactor was inoculated with return activated sludge from the Pine Creek Wastewater Treatment Plant. Prior to starting the system, the return activated sludge was allowed to acclimate for three days in batch mode. A superficial air velocity of 2.0 cm/s and residence time of 8 hours was selected with a working volume of 9.5 L.

Granules were observed within 9 days of operation with an average diameter of 350 μm. Average removal of COD, ammonia and phosphorus are 96%, 93%, and 97% respectively after 45 days of operation.

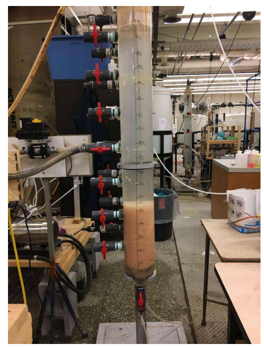


Figure 2: Aerobic granular reactor after sludge has settled

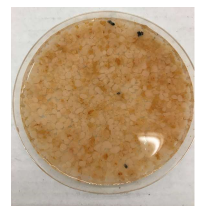


Figure 3: Aerobic granules viewed on a macroscopic level

Figure 4: Removal efficiency of COD

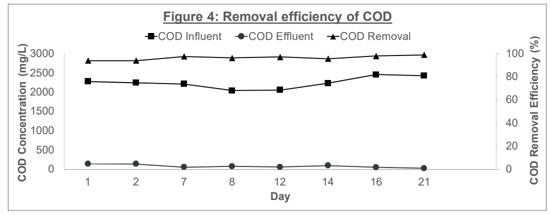


Figure 5: Removal efficiency of ammonia

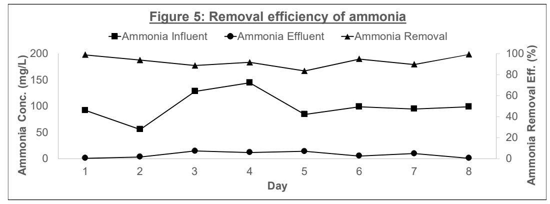
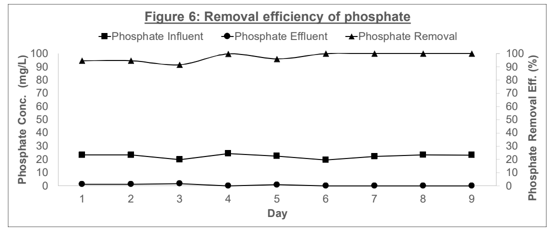


Figure 6: Removal efficiency of phosphate



CONCLUSIONS AND FUTURE WORK

Wood pulping and the production of paper products generate a variety of pollutants in high concentrations. Conventional biological processes are limited in their treatment of PPW to the required standard. Aerobic granulation, with its unique resilience to toxicity and shock loads, shows promising early results on PPW treatment. However, pilot-scale testing is required to determine the optimal operating conditions for the removal of AOX and other toxic compounds.

Currently, granules are being cultivated using benign substrate. Once the reactor attains steady-state, synthetic bleached Kraft mill effluent will be added to the system in step-wise increments to test the effectiveness of treatment against AOX and chlorinated phenols amongst other pollutants. Gas chromatography with mass spectrometry (GC-MS) will be used as the primary analytical method to properly quantify AOX and chlorinated phenols.

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