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Study on the effect of landfill leachate on nutrient removal from municipal wastewater

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ABSTRACT

In this study, landfill leachate with and without pre-treatment was co-treated with municipal wastewater at different mixing ratios. The leachate pre-treatment was achieved by air stripping to removal ammonia. The objective of this study was to investigate the effect of landfill leachate on nutrient removal of the wastewater treatment process. It was demonstrated that when landfill leachate was co-treated with municipal wastewater, the high ammonia concentration in the leachate did not have a negative impact on the nitrification. The system was able to adapt to the environment and was able to improve nitrification capacity. The readily biodegradable portion of chemical oxygen demand (COD) in the leachate was utilized by the system to improve phosphorus and nitrate removal. However, this portion was small and majority of the COD ended up in the effluent thereby decreased the quality of the effluent. The study showed that the 2.5% mixing ratio of leachate with wastewater improved the overall biological nutrient removal process of the system without compromising the COD removal efficiency.

Introduction

Landfill leachate contains large amounts of organic matter in biodegradable and refractory forms, as well as high concentrations of ammonia, heavy metals, chemicals of emerging concern and inorganic salts. These contaminants play an important role in groundwater and soil pollution. It is necessary to treat the leachate in order to meet the standards for discharge in receiving waters. The type of treatment to be selected for the leachate depends primarily on the chemical and biological parameters of the leachate itself like pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP) and metals, which in turn are usually related to the "age" of the leachate (Kjeldsen et al., 2002). Younger leachates (from landfills with less than 5 years of operation) will usually present a more biodegradable composition, which can be treated with biological options like activated sludge or anaerobic digestion. Leachate from a more mature landfill (over 5 years) will most likely present a lower concentration of biodegradable material, and correspondingly, a higher concentration of refractory compounds such as humic and fulvic acids (Renou et al., 2008), which make biodegradation very limited and require chemical treatment to be safely discharged.

Leachate treatment options include recycling and re-injection into the landfill cells, on-site treatment, and discharge to a municipal water treatment facility, or a combination (Neczaj et al., 2008). Co-treating the leachate together with municipal sewage is preferred for its easy maintenance and low operating costs. In addition, the degradation of organic pollutants is favored because of the dilution and adaptation ability of the activated sludge (Welander et al., 1998). However, considering that high concentrations of certain compounds (e.g. ammonia and toxic compounds) may inhibit the activated sludge treatment process,

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many wastewater treatment plants require the leachate to be pre-treated before it can be mixed and enter the municipal wastewater treatment process. It is believed that pre-treating the leachate is beneficial for the subsequent biological treatment at the plant.

Currently, leachate generated at the Brady Road landfill in Winnipeg is approximately 200 m^3/day. Leachate is hauled daily to the NorthEnd Wastewater Treatment Plant (WWTP) to be co-treated with wastewater. NorthEnd WWTP which is located 35 km away from the landfill is the largest wastewater treatment plant in the city with an average daily flow of 300 Mega liters per day (MLD). Due to the high dilution factor (1:1500) leachate is directly mixed with wastewater without any pre-treatment. There is a small WWTP (SouthEnd WWTP) near the landfill with a daily average flow of 25 MLD. It will be economically and environmentally beneficial if the leachate can be co-treated at the SouthEnd WWTP. However, there is a concern that the leachate may have a negative impact on the plant performance, especially in the area of nutrient removal performance due to the smaller wastewater flow rate of the plant. SouthEnd WWTP currently is under upgrading from a carbon removal plant to a nutrient removal plant. The new license requires effluent in terms of BOD_5 should be less than 25 mg/L, TN and TP should be less than 15 mg/L and 1 mg/L respectively. Due to leachate from Brady Road Landfill has similar BOD_5 and TP concentration to the raw wastewater with significant high ammonia concentration (Table 1), it was proposed by the city that the pre-treatment of leachate to reduce ammonia content will be necessary before the co-treatment.

There are numerous studies that present a range of physical and chemical pre-treatment options for landfill leachate (Kurniawan et al., 2006; Wiszniowski et al., 2006; Renou et al., 2008; Cotman and Gotvajn, 2010). These studies provide a general overview of the different options and can help in selecting a proper treatment for a specific set of leachate characteristics and desired effluent parameters. Some of these treatment processes include air stripping (Cheung et al., 1997; Collivignarelli et al., 1998; Yilmaz et al., 2010), coagulation (Amokrane et al., 1997; Marañón et al., 2008) and oxidation (Pignatello et al., 2006; Cortez et al., 2011). Since air stripping is the most effective method to remove ammonia, it was selected in this study as the pre-treatment method of leachate.

Up to date, few studies provide actual evaluations of the effect of the pre-treated leachate on additional biological treatment (Wang et al., 2009; Guo et al., 2010; Silva et al., 2013), a step that is considered necessary when dealing with leachate's complex characteristics. Most of the research studies evaluate the biodegradability of the leachate based only on a relationship between the BOD/COD ratio of the effluent as an indicator of the treatability of the leachate by biological means. There is a lack of information on if and how the leachate affects the biological nutrient removal of the wastewater treatment, especially on the nitrification process, as nitrifiers are very sensitive to the environment. In addition, how the pre-treatment of leachate will benefit the wastewater treatment process has not been well studied. Therefore, the goal of this research is to investigate the impact of leachate on the nutrient removal from municipal wastewater by comparing: (1) the leachate with and without pre-treatment; and (2) different mixing ratios of leachate with wastewater.

Table 1 – Characteristics of wastewater and leachate.

Parameter	Wastewater	Leachate
pH	7.4 ± 0.2	7.2 ± 0.4
COD (mg/L)	363 ± 158	2366 ± 526
TSS (mg/L)	196 ± 15	280 ± 207
BOD_5 (mg/)	198 ± 35	248 ± 20
NH_4^+-N (mg/L)	41.1 ± 9.2	699 ± 112
TN (mg/L)	50.0 ± 8.6	772 ± 65
PO_4^--P (mg/L)	5.1 ± 1.1	5.0 ± 1.2
TP (mg/L)	6.5 ± 1.2	5.9 ± 1.7

1. Material and methods

Wastewater used for this research was from the SouthEnd WWTP. It was delivered to the lab twice a week. Leachate was obtained from the Brady Road Landfill weekly. Both wastewater and leachate were stored in a cold chamber. The characteristics of wastewater and leachate used in this experiment are shown in Table 1. Through this experiment, we observed the increase of ammonia concentration in the wastewater with time. The ammonia nitrogen concentration gradually increased from 35 mg/L (at the end of July, August) to 45 mg/L (at the end of December). However, COD and phosphorus (P) concentrations in the wastewater were fairly constant with time/season. The parameters of the leachate were also constant with time although there were some variations in each batch.

1.1. *Leachate pre-treatment*

The pre-treatment of leachate was achieved by air stripping. The goal of pre-treatment was to reduce the ammonia nitrogen concentration in the leachate. The pH of leachate was first adjusted to 11 using a 25% (W/W) solution of sodium hydroxide (NaOH). This was followed by 48 hr of aeration. Then the pH was neutralized to 7.5 using an 18% (W/W) hydrochloric acid (HCl) solution.

1.2. *Reactor setup*

Three sequencing batch reactors (SBR) with working volumes of 3 L were setup. All three SBRs were seeded with the sludge from the SouthEnd WWTP and were operated with 4 cycles per day and solid retention time of 10 days. Each cycle included feeding (5 min), anaerobic (1.5 hr), aerobic (4 hr), settling (20 min), and decant periods (5 min). Three SBRs were fed with wastewater and operated for over a month to reach a stable stage before the experiment. SBR1 served as a control reactor which was fed with wastewater only. SBR2 was fed with the mixture of wastewater and raw leachate. SBR3 was fed with the mixture of wastewater and pre-treated leachate. Three mixing ratios of leachate (with and without pre-treatment) with wastewater of 2.5%, 5% and 10% were tested. Test with a mixing ratio of 2.5% lasted for 22 days. This was followed by the test with a mixing ratio of 5% for 38 days and then one with mixing ratio of 10% for 57 days.