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Greenhouse gas emissions from landfill leachate treatment plants: A comparison of young and aged landfill

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ABSTRACT

With limited assessment, leachate treatment of a specified landfill is considered to be a significant source of greenhouse gas (GHG) emissions. In our study, the cumulative GHG emitted from the storage ponds and process configurations that manage fresh or aged landfill leachate were investigated. Our results showed that strong CH_4 emissions were observed from the fresh leachate storage pond, with the fluxes values (2219–26,489 mg C m^{-2} h^{-1}) extremely higher than those of N_2O (0.028–0.41 mg N m^{-2} h^{-1}). In contrast, the emission values for both CH_4 and N_2O were low for the aged leachate tank. N_2O emissions became dominant once the leachate entered the treatment plants of both systems, accounting for 8–12% of the removal of N-species gases. Per capita, the N_2O emission based on both leachate treatment systems was estimated to be 7.99 g N_2O–N capita^{-1} yr^{-1}. An increase of 80% in N_2O emissions was observed when the bioreactor pH decreased by approximately 1 pH unit. The vast majority of carbon was removed in the form of CO_2, with a small portion as CH_4 (<0.3%) during both treatment processes. The cumulative GHG emissions for fresh leachate storage ponds, fresh leachate treatment system and aged leachate treatment system were 19.10, 10.62 and 3.63 Gg CO_2 eq yr^{-1}, respectively, for a total that could be transformed to 9.09 kg CO_2 eq capita^{-1} yr^{-1}.

1. Introduction

Less than 5% of the global anthropogenic GHG emissions are derived from the waste sector (Bogner et al., 2007), and in China, this estimation accounts for 1.5% of the total anthropogenic GHG emissions (National Communication, 2013). With respect to municipal solid waste, landfilling will remain the mainstream method of waste management for future decades in China, where 2204 Gg of CH_4 was emitted from waste sites in 2005. Thus, mach attention has been focused on CH_4 emissions from landfilled refuse, mainly focusing on CH_4 oxidation, landfill age, installation of landfill gas recovery systems, cover soil and various environmental factors (e.g., temperature, atmospheric pressure and soil moisture) (Spokas et al., 2006; Zhang et al., 2008, 2012).

Landfill leachate is a complex liquid, with a high concentration of ammonia and organic compounds, and hence, its disposal can be an environmental problem. In China, three main techniques are generally adopted when solving leachate disposal issues, which are recirculation, combined treatments and specific treatments. (1) Recirculation is an in situ treatment technique in which a landfill is employed as a large bioreactor. With this method, the leachate volume is significantly reduced, but the GHG emissions may increase during leachate recirculation (Lee et al., 2002); (2) Another adoptable technique is a combined leachate–sewage treatment (Ye et al., 2012), which is widely used in rural and mountain areas. Such a combined treatment may bring loading shock and operational influence to a wastewater treatment plant (WWTP), thus, the volume ratio of leachate-to-influent of municipal wastewater is recommended to be below 0.05%. The above two leachate treatment processes are simple, yet they have with limited treating abilities; (3) High strength and substantial amounts of leachate are produced daily in city landfills, therefore, cautiously handling the leachate using specific treatment facilities is necessary. Currently, newly-built and on-going landfills are obligated

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to construct integrated treatment plants in accordance with the Chinese National Standard (GB16889-2008).

Waste sites are significant sources of GHG but are not the sole source, where up to 300 kg of CO_2-eq can be emitted directly from each ton of mixed waste contributed to the GHG accounting (Manfredi et al., 2009). GHG emissions from landfill leachate treatments are also of concern. In a lab-scale study, the highest contents of dissolved N_2O and N_2O flux were estimated to be 1309 and 58.8 ng mL^{-1} h^{-1}, respectively, among the leachate samples withdrawn from five landfills in South China (Lin et al., 2008). However, to the best of our knowledge, no systemic work has been conducted on GHG emissions from relevant leachate treatment processes, and accurate and reliable data regarding this subject have not yet to be obtained. Field experiments are more concerned with the actual GHG emissions from landfills (Capaccioni et al., 2011; Di Trapani et al., 2013; El-Fadel et al., 2012); thus, few observations regarding the GHG emissions from leachate treatment are available. In term of wastewater treatments, much attention has been recently paid to managing municipal sewage (Foley et al., 2010; Kampschreur et al., 2009). With high contents of ammonia and carbon chemicals, leachate is assumed to be active in GHG emissions; however the data are scarce.

Herein, we present a study of comprehensive emissions from storage ponds and full-scale biological treatment systems with fresh and aged leachate with different characteristics, allowing for a more detailed profiling of GHG release from individual treatment units. Moreover, the annual cumulative GHG emissions for both leachate storage and treatment are evaluated, aiming to provide basic data for assessing GHG emissions during leachate treatment processes.

2. Materials and methods

2.1. Field sampling sites

2.1.1. Dongbu landfill

Dongbu sanitary landfill, located in the Xiang'an District of Xiamen, Fujian Province, is an on-going site. This landfill has been accepting municipal solid waste with an average daily load of 2100 t since 2009. The fresh leachate flows into the homogenization tank (Fresh-A) and is then pumped into the inlet works. Moreover, two storage ponds (Fresh-B, Fresh-C) are used for leachate temporary storage during rainstorms or emergencies. The storage pond (SP) includes Fresh A/B/C, total area of wihch is 27,000 m^2. Moreover, the detailed treatment process is shown in Fig. 1(a) and mainly includes an anoxic denitrifying tank (DN), a highly aerated nitrifying tank (N-1) and a less aerated nitrifying tank (N-2) as well as ultrafiltration and nanofiltration to reach a high discharge standard. The filtrate from the ultrafiltration process is transferred and subjected to a nanofiltration step, whereas the remaining concentrated activated sludge is stored in the sludge thickening tank (STT) and then further mechanically dewatered. The supernatant is collected in the supernatant storage tank (SST) and returned to the DN, and the excess sludge is periodically discharged from the system. The nanofiltration concentrate is stored in the filtration concentrate tank (NCT). The mixed liquor suspended solid (MLSS), hydraulic retention time (HRT), sludge retention time (SRT) and permeate flux were about 18.3 g L^{-1}, 5 d, 97 d and 17 m^3 h^{-1}, respectively. The leachate treating capacity is stable at approximately 470 m^3/d, and subsequently 80 m^3 of nanofiltration concentrate, 390 m^3 of effluent and 8.4 t of excess sludge is produced daily.

2.1.2. Dongfu landfill

The currently closed Dongfu landfill, located in the northwest suburb of Xiamen City, was operated from 1997 to 2009. The in situ leachate treatment plant remains operational even after its site closure and has similar treatment procedures and process configurations as Dongbu but only adopts ultrafiltration for further disposal (Fig. 1(b)). The operational conditions were 10 g L^{-1} of MLSS and 10 d of HRT. Moreover, glucose is added in the DN as an external carbon source to promote nitrogen removal because the carbon source in influent for denitrification is inadequate. The routine operation data are 250 m^3/d of loading capacity, with no biosolids generated due to low biodegradable organic carbon.

2.2. Samples collection and analyses

Fresh leachate from the Dongbu landfill and aged leachate from the Dongfu landfill were sampled. For each leachate treatment system, three sampling rounds (Rd 1–3) were conducted over a two-month timeframe during April and May of 2013. The weather was

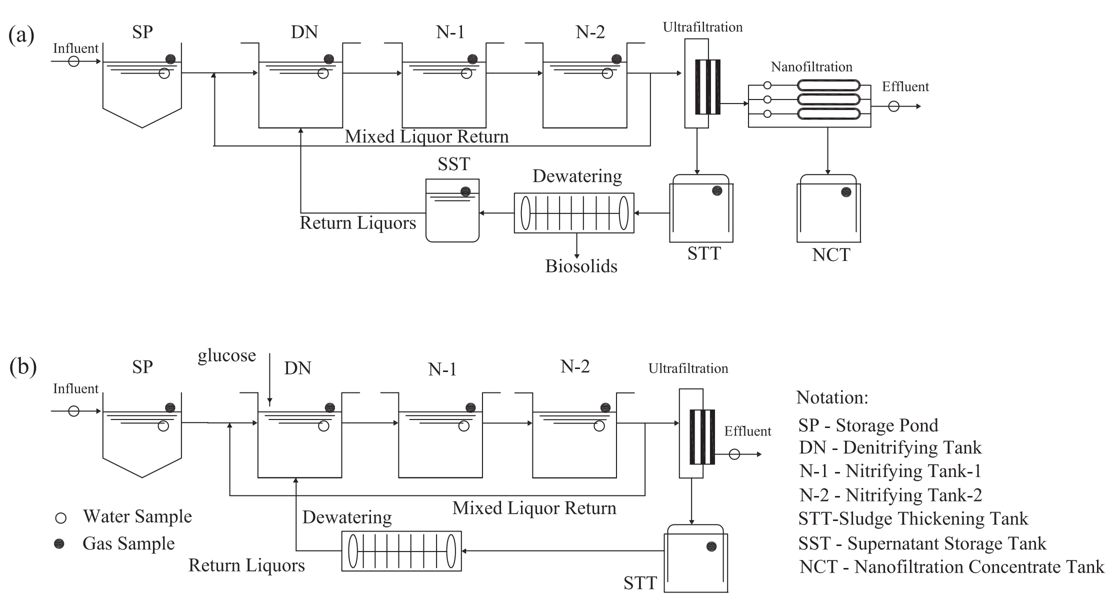

Fig. 1. Sampling sections of leachate storage and treatment processes. (a) Dongbu for the young leachate, (b) Dongfu for the aged leahcate.