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Evaluation of leachate dissolved organic nitrogen discharge effect on wastewater effluent quality

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ABSTRACT

Nitrogen is limited more and more frequently in wastewater treatment plant (WWTP) effluents because of the concern of causing eutrophication in discharge waters. Twelve leachates from eight landfills in Florida and California were characterized for total nitrogen (TN) and dissolved organic nitrogen (DON). The average concentration of TN and DON in leachate was approximately 1146 mg/L and 40 mg/L, respectively. Solid-phase extraction was used to fractionate the DON based on hydrophobic (recalcitrant fraction) and hydrophilic (bioavailable fraction) chemical properties. The average leachate concentrations of bioavailable (bDON) and recalcitrant (rDON) DON were 16.5 mg/L and 18.4 mg/L, respectively. The rDON fraction was positively correlated, but with a low R^2, with total leachate apparent color dissolved UV_{254}, chemical oxygen demand (COD), and humic acid (R^2 equals 0.38, 0.49, and 0.40, respectively). The hydrophobic fraction of DON (rDON) was highly colored. This fraction was also associated with over 60% of the total leachate COD. Multiple leachate and wastewater co-treatment simulations were carried out to assess the effects of leachate on total nitrogen wastewater effluent quality using removals for four WWTPs under different scenarios. The calculated pass through of DON suggests that leachate could contribute to significant amounts of nitrogen discharged to aquatic systems.

1. Introduction

Management of leachate generated by municipal solid waste (MSW) landfills poses significant challenges to landfill operators. Leachate characteristics vary dramatically over time because of changing conditions within the landfill. Leachate generated from recently placed waste has high organic compound concentrations; treating this leachate requires a combination of biological and physical-chemical processes. As the waste in the landfill ages, leachate volume declines, however, remaining constituents tend to be recalcitrant and treatment requirements become increasingly complex (Batarseh et al., 2007a; Batarseh et al., 2007b; Cortez et al., 2011; Morris et al., 2003). In particular, organic constituents transition from aliphatic, small molecular weight compounds to highly aromatic humic substances (HS) (with high molecular weights) which originate from the condensation and polymerization of microbial degradation byproducts. These older leachates are also characterized by relatively large concentrations of nitrogen-containing compounds. The persistence of these compounds requires management of leachate for many decades, potentially extending the costly post-closure care period. Leachate dissolved organic nitrogen (DON) is not typically included in MSW leachate analysis plans, therefore concentrations are not well documented. The nature of these compounds is also not well understood; fewer than 15% of the compounds contributing to DON have been identified (Dotson et al., 2009).

Leachate is frequently discharged to local municipal wastewater treatment plants (WWTPs) because of the cost and complexity of on-site treatment. Biological treatment processes utilized at WWTPs are designed to remove carbonaceous BOD and ammonia-N and consequently leachate recalcitrant organic matter may pass through. Therefore the constituents in leachate have the potential to negatively affect effluent quality (Zhao et al., 2013). Chlorination of these organic compounds can generate toxic disinfection byproducts (e.g., N-Nitrosodimethylamine (Mitch et al., 2003)). An additional concern is that aromatic compounds tend to absorb ultraviolet (UV) light, which may lead to interference with the alternative method of wastewater disinfection using UV at leachate volumetric contributions as low as 0.01% of the WWTP influent (Reinhart and Bolyard, 2015).

Permit limits for WWTP effluent total nitrogen (TN) are typically between 3.0 and 10 mg/L, depending on the discharge

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location (Rohrbacher et al., 2011). DON concentrations in domestic wastewater effluents, in the absence of other industrial sources, can range from 0.5 to 2.5 mg/L (Matthews et al., 2011). WWTP effluent nutrients can facilitate eutrophication and, depending on the severity of resulting algal blooms, dead zones can occur due to a decrease in dissolved oxygen. In 2003, a dead zone in the Chesapeake Bay spanned 241 km from Baltimore to the York River (Chesapeake Bay Foundation, 2003) due to increased nutrient levels. WWTPs were the second largest source of nitrogen pollution in the Chesapeake Bay. In order to combat these water quality issues, the U.S. Environmental Protection Agency developed Numeric Nutrient Criteria (NNC) for WWTPs aimed at lowering the TN and total phosphorus limits (EPA, 2015). These regulations will affect the effluent limits for WWTPs if there is reasonable potential for these sites to discharge nitrogen and phosphorus at concentrations that can cause or contribute to nutrient impairment of receiving waters.

Liu et al. (2011) estimated that approximately 80% of wastewater DON was bioavailable based on the fact that it stimulated algal growth under laboratory conditions. The bioavailability of DON in the Liu et al. (2011) study was correlated with the hydrophilic nature of the organic matter and referred to as bioavailable DON (bDON). DON that was characterized as hydrophobic was considered to be recalcitrant (rDON). Leachate DON is often comprised of low molecular weight material that may not be removed in conventional activated sludge processes. There is also concern that the rDON passing through WWTPs could become bioavailable after entering aquatic systems. Photochemical reactions in aquatic systems can convert DON to more labile compounds (Bushaw-Newton and Moran, 1999) such as primary amines or ammonia-N (Bushaw et al., 1996; Vähätalo and Zepp, 2005). To date, there is no literature pertaining to the nature of leachate DON, its bioavailability, or the potential pass-through of this organic matter when co-treated with domestic wastewater.

This study focused on (1) quantifying TN and DON in leachate, (2) determining the bioavailability of these nitrogen species based on hydrophobic (rDON) and hydrophilic (bDON) fractions, and (3) simulating multiple leachate and wastewater co-treatment scenarios to assess the potential impact of leachate on WWTP effluent quality. Bulk leachate properties were compared to rDON and bDON concentrations to examine possible trends based on landfill age. rDON and bDON fractions were also characterized for apparent color, chemical oxygen demand (COD), and UV absorbance at 254 nm, 465 nm, and 665 nm.

Table 1
Summary of municipal solid waste landfill types and associated leachates.

Landfill type	Leachate samples	Sampling location
Conventional MSW	A, B, E, F, and L	Combined[a]: A, F, and L Closed Cell: B and E
Conventional MSW	C	Combined[a]
Conventional MSW	D	Combined[a]
Conventional MSW	G	Combined[a]
Slurry Wall	H	Combined[a]
Conventional MSW	I	Combined[a]
Slurry Wall	J	Combined[a]
Conventional MSW	K	Closed Cell

[a] Combined: Leachate from Closed and Active Cells.

Using TN, DON, and rDON concentrations for the studied leachate samples, it was possible to simulate multiple scenarios of leachate and wastewater co-treatment. The contribution of leachate to TN effluent quality was estimated by using published TN removal efficiencies for four operating U.S. WWTPs described using summary statistics for three years of WWTP plant data (Bott and Parker, 2011). The advantage of this approach is to bracket the expected DON concentrations in typical WWTPs. These results could be used to develop a targeted field sampling plan based on leachate characteristics and volumetric contributions and TN WWTP effluent limits to evaluate the effect of leachate co-treatment on effluent quality.

2. Materials and methods

2.1. Leachate collection and characterization

Leachate samples were collected from eight Florida and California municipal solid waste landfills which are summarized Table 1. These sites represent two types of landfills (e.g. conventional and slurry wall) and different ages of waste. Leachate from slurry wall landfills are impacted by groundwater therefore the overall quality is weaker relative to conventional operation. Samples were collected directly from a lift station or final discharge point and placed in clean high-density polyethylene bottles. These bottles were placed on ice during transport. Prior to analysis these samples were stored at 4 °C. Samples were analyzed for DON, COD, dissolved organic carbon (DOC), pH, ammonia-N, nitrate-N, nitrite-N, total Kjeldahl nitrogen (TKN), and UV absorbance,

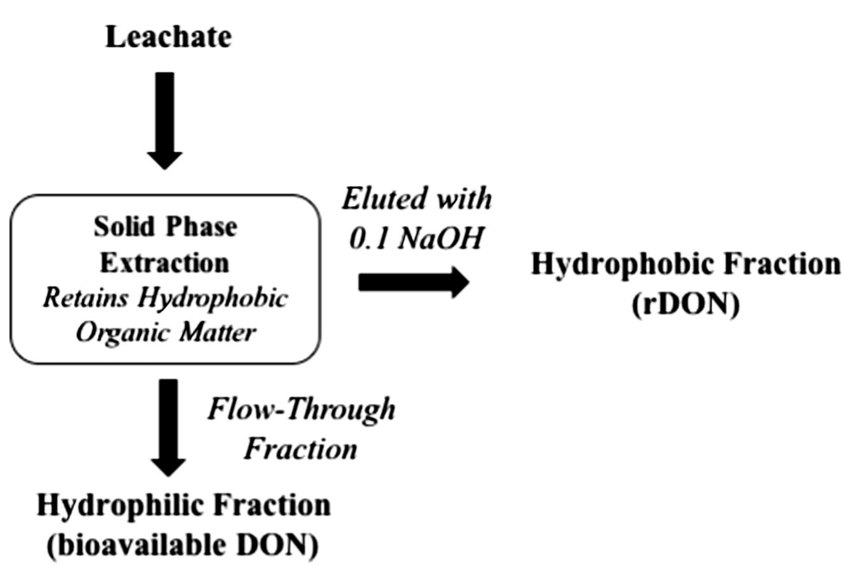

Fig. 1. DON fractionation method.

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