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A comparison of landfill leachates based on waste composition

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ABSTRACT

Samples of leachate were collected from fourteen landfills in the state of Florida, United States that contained primarily putrescible waste (municipal solid waste, MSW, and yard waste), MSW incinerator (MSWI) ash, or a combination of both. Assessment of leachates included trace metals, anions, and nutrients in order to create a mass balance of total dissolved solids (TDS). As expected from previously literature, MSW leached a complex matrix of contaminants while MSWI ash leachate TDS was more than 98% metallic salts. The pH of the MSWI ash leachate samples was slightly acidic or neutral in character, which is contradictory to the results commonly reported in the literature. The cause of this is hypothesized to be a short-circuiting of rainfall in the landfill due to low hydraulic conductivities reported in ash landfills. The difference in pH likely contributed to the findings with respect to MSWI ash-characteristic trace metals in leachates such as aluminum. The authors have concluded that the research findings in this study are an indication of the differences between laboratory leachate quality studies and the conditions encountered in the field. In addition, a characterization of organic matter using qualitative and quantitative analyses determined that COD is not an accurate indicator of organic matter in leachates from landfills with a significant fraction of MSWI ash.

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1. Introduction

Landfill leachate is well understood to be a complex matrix of various chemicals including organic matter, inorganic salts, organic trace pollutants, and heavy metals, each at concentrations that vary based on the physical (e.g., weathering), chemical (e.g., desorption), and microbiological (e.g., degradation of organic waste) processes occurring inside the landfill (Kjeldsen et al., 2002). Several factors are cited that influence leachate composition, including the age of the landfill (Kulikowska and Klimiuk, 2008), the depth of the waste in the landfill (Jang and Townsend, 2003), and the local climate or season (Chu et al., 1994; Gabriela et al., 2011; Rafizul and Alamgir, 2012). Another factor affecting leachate quality is the composition of the waste material present in the landfill. The bulk of the studies on landfill leachate chemical composition have been focused on conventional municipal solid waste (MSW) (Ehrig, 1983; Kjeldsen et al., 2002; Kang et al., 2002; Lü et al., 2009; Kulikowska and Klimiuk, 2008; Oman and Junestedt, 2008) and to a lesser extent construction and demolition (C&D) debris (Weber et al., 2002; Jambeck et al., 2008). Though much work has focused on laboratory-generated leachates from MSW

incinerator (MSWI) ash (Meima and Comans, 1997; Dijkstra et al., 2006; Inanc et al., 2007; Cappuyns and Swennen, 2008; Quina et al., 2009; Rocca et al., 2012), leachate characterization data from operating MSWI ash landfills are limited.

In the United States (US), an estimated 12% of MSW is combusted in MSWI facilities. In some other countries (e.g., Netherlands, Denmark, Germany, France, Sweden), this percentage is much higher (An et al., 2014). Fly ash and bottom ash generated by US facilities are typically combined together prior to final disposal in an ash monofill or a landfill co-disposing the ash with MSW (Oehmig et al., 2015). Leachates from landfills with large quantities of ash are expected to differ in quality compared to leachates from MSW landfills. While literature describing laboratory-generated leachate suggests that leachate produced at MSWI ash landfills will exhibit elevated concentrations of salts, only limited data have been published comparing leachate quality differences among operating landfills with different levels of ash.

Understanding the characteristics of landfill leachate is essential to managing the leachate in the most efficient manner possible. The complex nature of conventional leachate generally requires a variety of treatment technologies to target specific contaminants (Renou et al., 2008; Pi et al., 2009; Singh et al., 2012). In contrast, MSWI ash leachate is expected to exhibit a less diverse constituent composition since the incineration

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process destroys most of the biodegradable material that would otherwise contribute to the presence of nitrogen and organic matter in leachate. A significant number of research experiments have been conducted on the treatment of conventional MSW landfill leachate (Wiszniewski et al., 2006; Renou et al., 2008); for example, researchers routinely focus on MSW landfill leachate organic matter and how properties and treatability change as the landfill ages (Renou et al., 2008; Kawai et al., 2012). However, minimal research has been reported on the treatment of non-conventional leachates such as those from ash monofills or ash co-disposal facilities (Linde et al., 1995).

With the increased prevalence of the MSWI process and therefore MSWI ash disposal into landfills, investigating the characteristics of MSWI ash leachates at operating landfills is important for the development and refinement of effective leachate treatment strategies. This research examines how the disposal of MSWI ash in landfills influences leachate composition and chemistry. Leachate properties – (including pH, dissolved ions, carbonate alkalinity, ammonia-nitrogen, trace inorganic elements, and organic matter) from multiple full-scale landfill sites are evaluated to develop a better understanding of the influence of MSWI ash disposal on leachate character.

2. Methods and materials

2.1. Sample collection

Landfill leachate samples were collected from July through August of 2014 from fourteen landfills distributed throughout Florida, US. Samples were collected from five conventional landfills receiving only MSW; three bulky debris landfills that received a mixture of yard waste, C&D debris, and other non-putrescible MSW; and three facilities receiving only MSWI ash. In addition, three samples were collected from landfills that co-dispose MSWI ash and MSW; each co-disposal landfill contained different percentages of ash (12%, 15%, and 70% on a mass basis). The percentage of total combined fly and bottom ash associated with a landfill was provided by the landfill operator and based on waste tipping receipts. Each of the landfills in this study that disposed of MSWI ash disposed of the incinerator's combined fly ash and bottom ash streams.

In an effort to obtain a sample that best represented the landfill leachate, samples were collected from the closest accessible sampling location to the discharge pipe of the landfill; in most cases this was a leachate collection sump or pump station located near the perimeter of the facility. A sampling pump was used to continuously collect leachate through a flow block. The flow block contained a YSI Model 556 Multiparameter meter that continuously measured pH, temperature, and conductivity. Laboratory samples were not collected until these parameters stabilized. Samples were stored in a 500-mL HDPE bottle on ice until they were returned to the laboratory for analysis and/or preservation, which varied by the method of analysis.

2.2. Leachate chemistry analysis

All methods are provided in Table 1 along with a brief description. The trace inorganic elements analyzed included Al, As, B, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Sr, and Zn. Leachate samples were acid digested and analyzed using a Thermo Scientific iCAP series 6000 ICP-AES Spectrometer. During the analysis of the trace inorganic elements, two internal quality assurance checks were completed. The relative difference between sample duplicates was monitored and analyses were only accepted if this value was less than 15%; known standards were also analyzed and results were only accepted if the analyzed standard was within 20% of the known value. Inorganic anions including SO₄, PO₄, F, Br, and Cl were analyzed using a Dionex ICS-3000 ion chromatograph equipped with a IonPac AG22 guard column and an AS22 analytical column. Similar to the trace inorganic elements, relative difference was required to be below 10%; known standards were required to be within 10% of the known value.

American Standard Test Methods (2009) were used for the measurement of total organic carbon (TOC), dissolved organic carbon (DOC), and total dissolved solids (TDS). TOC and DOC were analyzed using a Shimadzu TOC-V_{CPH} total organic carbon analyzer equipped with an ASI-V auto-sampler. COD and ammonium were measured using a DR/4000U Hach spectrophotometer. Chloride can interfere with the measurement of COD by consuming the chemical oxidant. During this study, mercuric sulfate was used to reduce the interference of chloride when the concentration exceeded 2000 ppm as recommended by the method (ASTM, 2009). Alkalinity measurements were used to estimate the concentration of inorganic carbon in each sample.

The characteristics of organic matter in the samples were studied using two spectroscopic methods. Ultraviolet (UV) absorbance was measured using a Hitachi U-2900 spectrophotometer with a 1-cm quartz cell. This analysis measured the absorbance of wavelengths from 200 to 700 nm at 4 nm increments. UV absorbance is useful in the detection of aromatic bonds between carbon atoms in the organic matter and is commonly used as an indicator of organic matter strength in water samples prior to coagulation (Matilainen et al., 2010). Additionally, fluorescence excitation-emission matrix (EEM) spectroscopy was completed using a Hitachi F-2500 fluorescence spectrophotometer by the excitation of the organic matter compounds at 5-nm increments from 220 to 500 nm and measuring the emission wavelength at 5 nm increments. Fluorescence EEM has previously been used by researchers in various applications focused on identifying organic matter source (e.g., humic substances, fulvic acids). These methods have been followed from previous research conducted on landfill leachate (Baker and Curry, 2004; Comstock et al., 2010).

2.3. Statistical analysis of results

To assess differences between leachate samples from landfills disposing of high amounts of MSWI ash and those not, the landfills

Table 1
Water quality analytical methods (Horn and Squire, 1967; EPA, 1995; APHA, 1997; ASTM, 2009).

Parameter	Method number	Description
Chemical Oxygen Demand	Standard Methods: 5220D	Closed reflux, colorimetric Method
Biochemical Oxygen Demand	Standard Methods: 5210	5-day incubation with oxygen monitoring
Total Organic Carbon	ASTM Method D7573	680 °C Combustion catalytic oxidation
Dissolved Organic Carbon		
Total Dissolved Solids	Standard Methods: 2540C	Gravimetric Filtration and drying at 180 °C
Alkalinity	Standard Methods: 2320B	Titration to pH of 4.5 by sulfuric acid
Ammonia-nitrogen	Hach Method 10031	Salicylate Method
Inorganic Anions	Standard Methods: 4110	Chemical suppressant with eluent conductivity measurements
Inorganic Cations	EPA Method 3010a	Acid digestion with heated reflux at 95 °C

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