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# Impact assessment of intermediate soil cover on landfill stabilization by characterizing landfilled municipal solid waste

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ABSTRACT

Waste samples at different depths of a covered municipal solid waste (MSW) landfill in Beijing, China, were excavated and characterized to investigate the impact of intermediate soil cover on waste stabilization. A comparatively high amount of unstable organic matter with 83.3 g $kg^{-1}$ dry weight (dw) total organic carbon was detected in the 6-year-old MSW, where toxic inorganic elements containing As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn of 10.1, 0.98, 85.49, 259.7, 530.4, 30.5, 84.0, and 981.7 mg $kg^{-1}$ dw, respectively, largely accumulated because of the barrier effect of intermediate soil cover. This accumulation resulted in decreased microbial activities. The intermediate soil cover also caused significant reduction in moisture in MSW under the soil layer, which was as low as 25.9%, and led to inefficient biodegradation of 8- and 10-year-old MSW. Therefore, intermediate soil cover with low permeability seems to act as a barrier that divides a landfill into two landfill cells with different degradation processes by restraining water flow and hazardous matter.



## 1. Introduction

Over 80% of municipal solid waste (MSW) in China is still being disposed of in anaerobic landfills at present (He et al., 2011; Hong et al., 2010). Moisture is essential for metabolism of all microorganisms (Bäumler and Kögel-Knabaner, 2008; Bilgili et al., 2007; Staub et al., 2010; Valencia et al., 2009) and is accordingly acknowledged as one of the most important factors influencing MSW degradation inside a landfill site. Relatively high moisture content improves the mixing and general availability of nutrients and carbon-rich organic matter, and thus stimulates bacterial growth directly and leads to enhanced degradation of waste materials (Wreford et al., 2000). At the same time, however, moisture can dissolve and transport organic and inorganic compounds and some metabolic inhibitors (Rees, 1980), such as heavy metals. Water may infiltrate through solid waste as an unsaturated flow inside a landfill (Korfiatis et al., 1984), carrying organic and inorganic pollutants that may pose a severe pollution threat to both microbial activities and surrounding environment (Mor et al., 2006). For example, a certain proportion of toxic heavy metals in deposited wastes, which can disrupt microorganisms (Bååth, 1989; Giller et al., 1998) would be largely mobilized with dissolved organic matter (*e.g.*, volatile fatty acid) in leachate during initial acidification period (pH 5–6) (Qu et al., 2008; Chai et al., 2007).

Serving as hydraulic barriers (Albright et al., 2006), soil covers with low permeability can decrease the filtration of leachate through waste and reduce the migration rate of toxic pollutants, including heavy metals (Yanful et al., 1988a; Navia et al., 2005). Placement of an intermediate cover of soil over every waste cell is required in the national technical guideline in China (Ministry of Construction of the People's Republic of China, 2004) as well as in many other countries, and the thickness of the cover is recommended to be more than 30 cm.

Chinese MSW has been characterized with high organic and moisture content (Wang and Nie, 2001; Zhang et al., 2010) since kitchen waste makes up the highest proportion at approximate 60% (Yuan et al., 2006). Particularly, moisture is always varied from 30 to 60% vs. 20–30% in the U.S. and European countries (Cheng and Hu, 2010; Meng et al., 2012) sometimes even up to 70% (on wet basis) (Wang and Nie, 2001). Hence, leachate, a

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certain proportion of which is from landfilled MSW, is produced in huge volume in Chinese landfills every year. In this case, intermediated soil covers as hydraulic barriers inside the landfill would make significance in transport and distribution of both leachate and accompanied organic and inorganic pollutants, and the biodegradation and stabilization process of solid wastes would be subsequently affected. However, the comprehensive impact of intermediate soil covers on waste stabilization in landfills with extremely high moisture content was rarely investigated. While simulated experiments in laboratories are vulnerable to feed materials and experimental conditions and cannot reflect actual condition, field excavation of landfilled solid waste is capable of revealing the real situation inside a landfill. Therefore, waste samples of different landfill ages were excavated from an old landfill site in China and were characterized and profiled in terms of physical composition, moisture, organic matter, humic substances (HSs), toxic inorganic elements, and microbial community dynamics, to examine the function of intermediate soil cover on landfilled MSW degradation. Based on the above investigation data, both the impact of intermediate soil cover on MSW biostabilization and possible key factors controlling the decomposition degree of MSW were identified and discussed.

## 2. Materials and methods

### 2.1. Solid waste sampling and preparation

Solid waste sampling was conducted at a sanitary landfill site located in Beijing, China in May 2010. The landfill site, operated from 1996 to 2008, annually received 350,000 metric tons of wastes consisting of MSW and a small proportion of commercial and industrial waste. The final height of the closed landfill was 30 m. It was a typical anaerobic sanitary landfill designed with artificial lining, leachate drainage, and biogas collection systems. In particular, only one 50 cm-thick intermediate soil cover (sandy clay) existed at depth of approximately 19 m from the top of landfill. Above the intermediate cover (from the top to the depth of 19 m), wastes were received from 2004 to 2008. Meanwhile, below the intermediate layer (from the depth of 20 m–25 m), landfill ages of wastes were more than seven years.

To eliminate heterogeneity of MSW, solid waste samples were collected from four boreholes, 25 m deep each, designated as I, II, III, and IV. In addition, the correlation between landfill ages and landfill depths was established based on landfill operation records. The collected solid wastes were preserved in self-sealing plastic bags immediately before being transferred to laboratory for analysis. Waste samples of 6–10 kg each were collected at depths of 5–6 m, 8–9 m, 11–12 m, 17–18 m, 21–22 m, and 24–25 m corresponding to 3-, 4-, 5-, 6-, 8- and 10-year-old wastes, respectively. Duplicate samples were collected for each depth. Small proportions of solid wastes (approximate 200 g) from borehole IV, used as the basis in analyzing the microbial community structure, were preserved in self-sealing plastic bags and stored at 4 °C before being transported to the laboratory, and the samples were analyzed within 24 h. In order to assure the representative of subsamples for further analysis, the four excavated solid wastes from the same depth of different holes were well mixed and sampled in laboratory according to "Sampling and Analysis Method for Domestic waste (CJ/T 313-2009)" (MOHURD, 2009) to obtain the first-degree sample (<200 mm).

### 2.2. Analytical methods

The excavated solid wastes were characterized in terms of physical composition, moisture content, organic matter [total organic carbon (TOC), total organic nitrogen (TON), and leachable organic carbon (leachable OC)], HSs [including humic acid (HA) and fulvic acid (FA)], and toxic inorganic elements (including heavy metals Zn, Mn, Cu, Cd, Cr, Ni, Pb and toxic metalloid As).

#### 2.2.1. Physical composition of solid waste

The wastes were dried at 50 °C in an electric-blast drying oven for 48 h–72 h prior to analysis. The solid wastes were then sorted into ash and fines (<20 mm), animals, plants, tiles and ceramics, papers, textiles, glasses, metals, bamboos, and others according to "Sampling and Analysis Methods for Municipal Domestic Refuse" (MOHURD, 2009). The percentage of each fraction was calculated on a dry weight basis.

#### 2.2.2. Moisture content

Approximately 150 g of solid waste was randomly collected from sub-samples and was dried under 105 ± 5 °C for 24 h. The moisture content was determined from the difference between the initial and dried waste. Each sample was collected in duplicate.

#### 2.2.3. Organic matter content

The well-mixed and homogenized waste was first dried in an electric-blast drying oven at 50 °C for approximately 48 h. The bulk materials were removed, and the remaining dry waste was then lightly ground to less than 0.3 mm size. The analysis issues were as follows:

TOC was determined by oxidizing the solid wastes with potassium dichromate (Chan et al., 2001).

TON was obtained by subtracting the ammonia nitrogen ($NH_3$–N) and nitrate nitrogen ($NO_3$–N) from the total nitrogen (TN); TN was determined using the Kjeldahl method. $NH_3$–N was determined using sodium chloride extraction in combination with the sodium hypochlorite colorimetric method, and the $NO_3$–N content was obtained by sodium chloride extraction combined with phenol disulfonic acid colorimetric method (Markus et al., 1985).

The VS content of the solid wastes was obtained from the weight loss of approximately 10 g of samples burned in the muffle furnace at 550 °C for 2 h (on plastic-free basis).

The leachable OC was determined using leaching test. The waste was rotary-oscillated with distilled water at a ratio of 1:10 (w/v) for 24 h, and the suspension was then centrifuged. The leaching procedure was repeated twice, and the combined supernatant was passed through a 0.45 μm filter to remove the particles. Finally, the filtrate DOC was measured using a TOC analyzer (TOC-5000A, Shimadzu, Japan).

#### 2.2.4. HSs content

The content of HSs in excavated solid wastes was determined according to the procedure described by Fukushima et al. (2009) with minor modification. Dry waste (dried at 50 °C, bulk materials were removed, and lightly ground to pass through 20-mesh sieve prior to use) was extracted using aqueous alkaline solution (0.1 M NaOH + 0.1 M $Na_4P_2O_7$, $v/v = 1/1$) under a $N_2$ atmosphere ($m/v = 1/20$). After being shaken for 24 h, the suspension was centrifuged and the supernatant was filtered. A 5 mL aliquot of the filtrate was adjusted to pH 1 using concentrated HCl, stirred overnight, and filtered through a 0.45 μm filter using a 2.5 mL aseptic syringe. The precipitate (HA) was washed with distilled water, dissolved using 0.1 M NaOH, neutralized, and was measured DOC (TOC-5000A, Shimadzu, Japan). The supernatant, combined with the distilled water for precipitate washing, was passed through a mini-column packed with 1 mL DAX-8 resin to adsorb FA. Afterward, the column was washed with distilled water until effluent was colorless, and FA was then desorbed, collected and neutralized to measure DOC. The HA and FA contents were calculated and expressed as gram C per kilogram waste on a dw basis, whereas the