

The effect of household coal ash on solid waste degradation in a lab-scale landfill reactor with leachate recirculation: A case study of Ulaanbaatar, Mongolia

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I. Introduction

In Mongolia, 2.9 million tons of solid waste was generated in 2015 and the amount has been rapidly increasing. The recycling rate of solid waste was only 0.31%; most of the generated solid waste is directly added to landfill¹⁾. One of the characteristics of solid waste in Mongolia is the presence of household coal ash, which contains hazardous metals such as As and Se. Therefore, there is a concern about the leaching of heavy metals from the landfill sites. Because of the harsh climate in Ulaanbaatar, including low temperature and precipitation, the production of leachate from landfill sites is low. However, there is a higher risk of groundwater contamination because of the existence of hazardous materials in the landfill site. Furthermore, household sewage water treatment has provoked other environmental problems in Ulaanbaatar. For example, the efficiency of sewage water treatment is only 60 – 70% and the remaining sewage water is discharged into the Tuul river without further treatment²⁾. Therefore, it would be effective that household waste water could be used as the source of moisture in landfill sites to enhance the biodegradation of organics in the sewage water and organic waste in landfill sites³⁾. The aim of this study was to determine the effect of household coal ash solid waste in landfill on the leachate quality by using lab-scale landfill reactors.

II. Experimental setup and chemical analysis

Acrylic column reactors with an internal diameter of 9 cm and a height of 50 cm were used in this study. Four different conditions of reactors were prepared. The compositions of the packed waste in the reactors are shown in Table 1. Each reactor contained 1.2 kg of modeled waste. Fresh household waste was used in the tests and its composition was determined based on the composition survey of household waste conducted in Ulaanbaatar in March, 2017. Household coal ash was collected from 12

households in ger district (Mongolian traditional residence) Ulaanbaatar on March, 2017. The household coal ash was pulverized to a particle size of less than 1 mm.

The experimental conditions are shown in Table 2. At the beginning of the experiment, 400 mL of simulated sewage water (SSW, 100 mg/L of dissolved organic carbon and 334.3 mg/L of NH_4^+) was injected into the reactor. R1 (control) and R3 contained no household coal ash and the composition was the same as that of the apartment area Ulaanbaatar (Table 1). For R1, 40 mL of water was injected once a week to simulate the average precipitation (238 mm/year) in Ulaanbaatar. For R2, R3, and R4, 200 mL of leachate was collected from the reactors and put back in each reactor. First, the reactors were recirculated with 400 mL of SSW to provide moisture. After collecting the leachate sample, 200 mL of SSW was injected with leachate (1:1) once a week. The temperature was constantly adjusted to 35 °C by using a heater with a temperature controller. R1 and R2 were under anaerobic conditions and R3 and R4 were under aerobic conditions. During the test, leachate samples were regularly collected from each reactor. The leachate samples were filtered through a 0.45 µm membrane filter. After the filtration, the pH of the filtrate was measured with a pH meter (F-74BW, Horiba), the NH_4^+ ion was detected with a spectrophotometer (U-1800, Hitachi), and the As (Arsenic) content was measured by AAS (Z-2000, Hitachi). The gas concentration was measured by gas chromatography (GC-8A) before and after the collection of the leachate. The generated gas volumes were measured by using a gas holder. Each reactor was duplicated two times and the results were averaged.

III. Characteristics of the leachate samples

Fig 1 shows the pH value of the leachates from the reactors. The leachates of R1 and R3 had an initial pH value at 4.8 and reached a pH of 5.0 – 5.5 during the test period. The initial pH of the leachates from R2 and R4 was 5.8 and the values increased and stabilized at 7.0 – 7.5 after 26 d. The

Table 1. Household waste composition

Components, %	R1 and R3	R2 and R4
Food waste	38.8	29.8
Paper	25.0	6.5
Plastic	12.1	5.8
Glass	21.7	7.2
Metal	2.3	0.9
Household coal ash	-	49.8

Table 2. Types of reactor

Types of reactor	R1	R2	R3	R4
	Anaerobic		Aerobic	
Water injection (once a week)	Water percolation	Recirculation		
	40 mL			

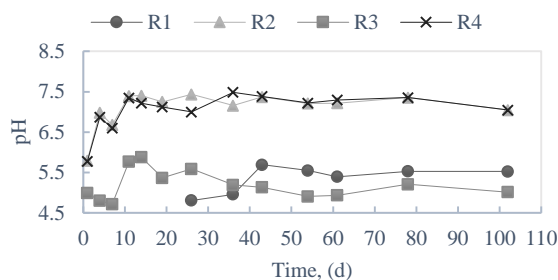


Figure 1. pH values of leachate samples

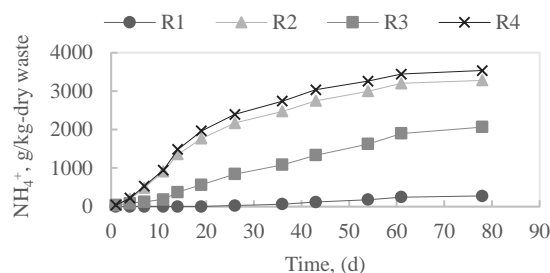


Figure 2. Cumulative ammonium production

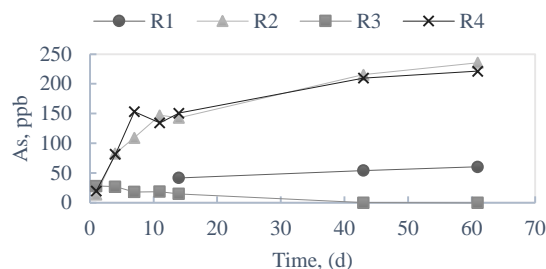


Figure 3. As concentration in leachates

conditions in R2 and R4 were more alkaline compared to those of R1 and R3 because they contained coal ash (pH 11.36). The cumulated NH_4^+ emission from the columns is shown in Fig 2. The ammonium production was approximately 38.8 g/kg-dry waste of NH_4^+ in R2, R3, and R4 in the first leachate samples collected after day 2. After 78 d, the values increased to 3277 – 3534 g/kg-dry waste for R2 and R4 and 2065 g/kg-dry waste of NH_4^+ for R3. Conversely, the leachate generation started after 26 d in R1. The initial NH_4^+ production in R1 was 24.8 g/kg-dry waste and reached a 272 g/kg-dry waste of NH_4^+ . Because there was no difference in the NH_4^+ concentrations in the leachate samples of R2 and R4, the conditions in the reactor might not influence the ammonium concentration. Even though R3 contained a lower food waste composition compared to that in R2 and R4, the NH_4^+ concentrations were lower. Because of the low pH conditions in R3 owing to the acid formation phase, the degradation of food waste was inhibited.

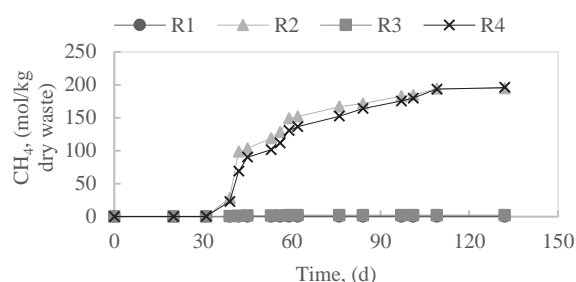


Figure 4. Cumulative methane production

The As concentration in the leachates is shown in Figure 3. The initial As concentration in the leachate from R3 was 28.1 ppm and reached 0.2 ppm after 61 d. The leachate concentration increased from 13.9 to 235.6 ppm in R2 and from 19.9 to 221.3 ppm in R4.

The cumulative methane production is shown in Figure 4. Approximately 195 mol/kg-dry waste of CH_4 was produced in R2 and R4. Because anaerobic spaces could not be completely eliminated by air injection into R4, anaerobic conditions might exist in R4 and methane microorganisms could produce methane gas. Conversely, little methane production was detected in R1 and R3.

IV. Conclusion

The presence of household coal ash and recirculation of leachate impact the degradation of solid waste by changing the pH value and producing ammonium ions and methane. A much higher As content was detected in R2 and R4 because it contained household coal ash as a main source of heavy metals. Therefore, when disposing of household waste with household coal ash, the quantity and quality of the leachates needs to be controlled at real landfill sites in Ulaanbaatar.

References

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