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A MODEL FOR THE METHANE PRODUCTION MIGRATION IN A SIMULATED SANITARY LANDFILL

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1. Abstract

A mathematical model for the migration of methane production in a simulated sanitary landfill was developed based on the modified Gompertz equation. The present model incorporates the methane productions on the decomposition of components, including carbohydrates, proteins and lipids. Decomposition of municipal solid wastes were investigated by using the solid-bed-columns and -bottles under laboratory conditions with leachate recycle. The batch experiment was performed to monitor methane production rate of each component decomposition.

2. Introduction

Methane is a greenhouse gas of particular concern as its direct and indirect effects are estimated to be 20 times greater than that of an equivalent mass of carbon dioxide (Holzapfel-Pschorn and Seiler, 1986). Methane is released into the atmosphere mainly by a variety of biogenic processes (Bingemer and Crutzen, 1987). Among them, landfills are known to be a significant source of methane. The emission of methane from sanitary landfills can present a significant hazard to the environment if not properly controlled. Therefore, the objective of this study was to develop a mathematical model for the description of methane production migration in the sanitary landfill.

3. Model development

To describe the cumulative methane production curve in the batch experiment, a modified Gompertz equation (Lay et al. 1996) was recently found to the most suitable model, which is written as:

$$M = P \cdot \exp\{-\exp[\frac{R_m \cdot e}{P}(\lambda - t) + 1]\} \qquad \text{....... (1)}$$

The methane production rate for one substrate is derivative of methane production, M_i, with respect to incubation time, t. The expression for the methane production rate, R_i, is:

$$R_i = \frac{dM_i}{dt} = (R_{m,i} \cdot e) \cdot \exp\{-\exp[\frac{R_{m,i} \cdot e}{P_i}(\lambda_i - t) + 1]\} \cdot \exp[\frac{R_{m,i} \cdot e}{P_i}(\lambda_i - t) + 1] \qquad \text{....... (2)}$$

Since refuse has a complex composition, the overall methane production rate in a landfill results in the total methane production rates of each individual component. Thus, the overall methane production rate, R_t, for a landfill can be defined as:

$$R_t = \sum_{i=1}^{n} \frac{dM_i}{dt} = \sum_{i=1}^{n} \left[(R_{m,i} \cdot e) \cdot \exp\{-\exp[\frac{R_{m,i} \cdot e}{P_i}(\lambda_i - t) + 1]\} \cdot \exp[\frac{R_{m,i} \cdot e}{P_i}(\lambda_i - t) + 1] \right] \qquad \text{....... (3)}$$

where, λ_i is lagphase time
M_i is cumulative methane production of refuse component i,
P_i is methane production potential of refuse component i,
$R_{m,i}$ is maximum methane production rate of refuse component i.

Because Eq.(2) is of nonlinear form, both the 'graphing' and 'try an error' methods were applied to find out the initial guesses of P_i, $R_{m,i}$, and λ_i. After that, they were calculated using the program of 'solver' in Microsoft Excel version 5.0, by converging the sum of square error, SSE, between experimemt and estimation to a minimum value. The calculated parameters were examined for statistical significance based on the r^2 and t - test.

Table 1. The composition of synthetic municipal solid wastes

Components	Percentage
Vegetables	27%
Fruits	5.40%
Meat	4.50%
Rice	12%
Paper	0.01%
Sludge cake	51.10%

4. Materials and Methods

Solid-bed-column

The solid-bed-column consisted of a plexiglass column 200 cm in height and 10 cm in diameter. The solid-bed-column processed an empty volume of 7.85 liter and maintained at 41°C. With this apparatus, six kinds of solid wastes packed

(Table 1) were degradated to methane.

Solid-bed-bottle

A total of fourteen 500-mL of solid-bed-bottles were performed to measure the methane production rate for each component decomposition. The solid-bed-bottles had the same solid wastes contents and operation conditions as those of solid-bed-column. Then, every third month, the solids in the solid-bed-bottles were anaerobically transferred to the vials for measuring methane production rates.

Methane production rate of each component decomposition

The batch experiment was performed with a vial of 120 mL incubated at 41°C. Since the municipal solid wastes contented in the solid-bed-column were carbohydrates, proteins, and lipids in this study, the glucose, pepton and linseed oil were respectively used as the substrates of carbohydrates, proteins, and lipids. The biogas was measured by the glass syringes. The percentage of CH_4 and CO_2 were analyzed by GC-TCD.

5. Results and Discussion

Methane production migration in solid-bed-bottle

Based on the data of methane production rate obtaining from the batch experiment, a non-linear regression analysis was used to fit a model described by Eq.(2) for the migration of methane production rate for each component in the solid-bed-bottle. The best values of parameters, P_i, $R_{m,i}$, and λ_i, for methane production rate, R_i, of solid-bed-bottle were determined by apprevious description. These values were used to fit the data shown in Figure 1. The results indicate that Eq.(2) was suitable to describe the methane production rate for each component decomposition.

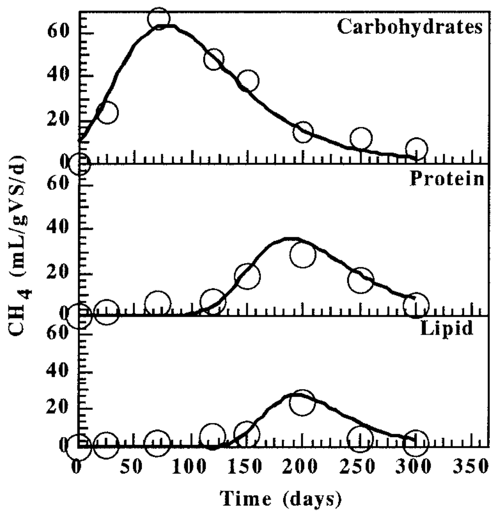

Fig.1 Measured and simulated methane production rates of each component decomposition in the solid-bed bottles.

Methane production migration in solid-bed-column

To simulate the rate of methane production migration in the solid-bed-column, data for solids taken from the solid-bed-bottles on each component decomposition that had been evaluated by Eq.(2) were used. When the methane production rates of solid-bed-column were plotted against their incubation time as experimental observation data, a good fit according to Eq.(3) was obtained (Figure 2). Apparently, the Eq.(3) was suitable to describe the migration of methane production rate in a sanitary landfill.

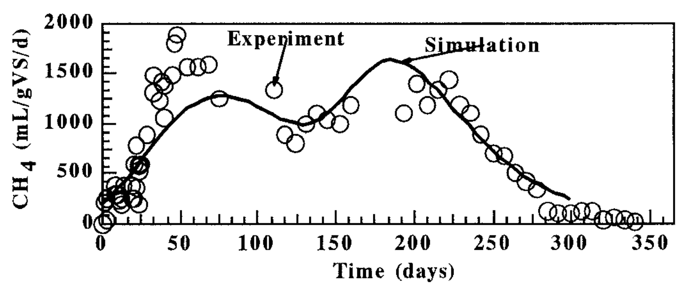

Fig.2 Measured and simulated methane production rates of each component decomposition in the solid-bed-column.

6. Conclusions

The simple model was suitable to describe the migration of methane production in the sanitary landfill. This model incorporates some of key parameters, lagphase time, maximum methane production rate, and methane production potential for component decomposition known to occur in a sanitary landfill during biodegradation of refuse.

7. References

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