EXPERIMENTAL ANALYSIS OF MICROBIAL INACTIVATION THROUGH FECES TREATMENT USING ASH

H. Harada[1*], Y. Kimoto[2], S. Fujii[1]

1 Graduate School of Global Environmental Studies, Kyoto Univ.

2 Graduate School of Engineering, Kyoto Univ.

INTRODUCTION: DRY TOILET AND HEALTH

- In developing contexts
  - Feces in the dry toilet often treated by ash with a proper retention period.
  - Treated feces used for agriculture

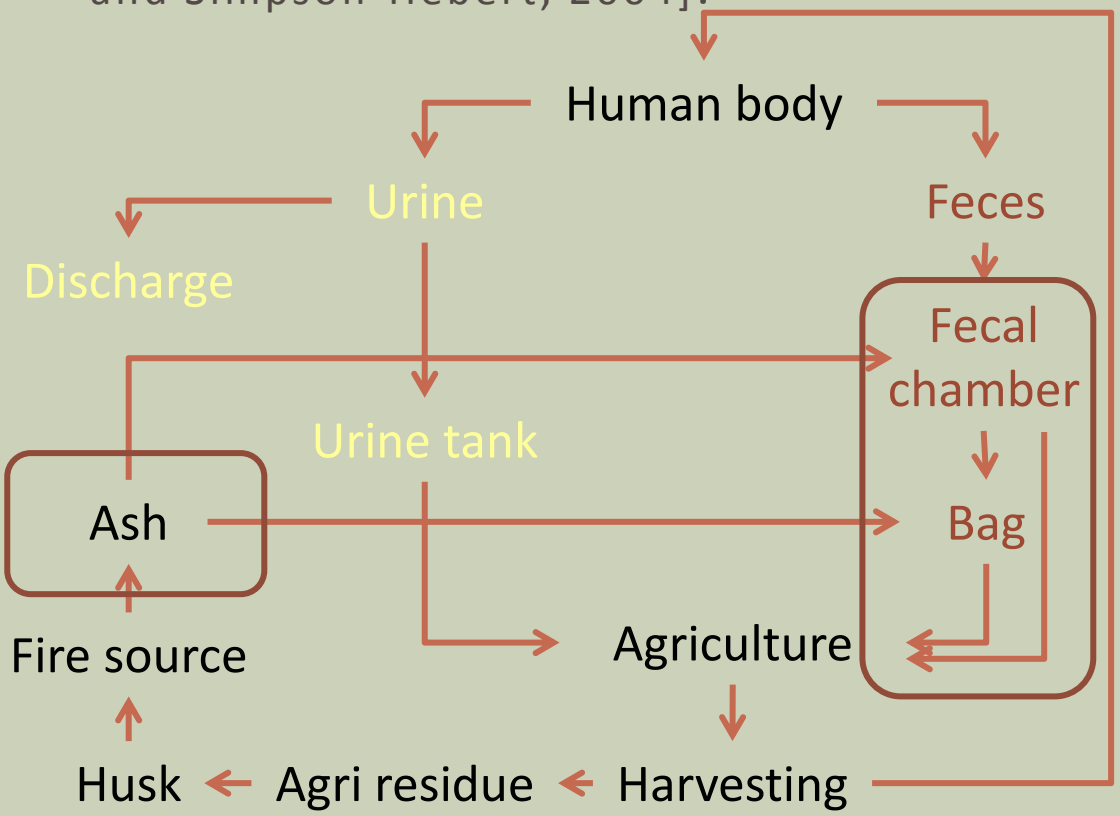
Great potential of sanitary improvement and sound resource management

However,

- Whereas dry toilets are used practically, the recycling of human excreta for agriculture poses a certain level of health risk [Peasey, 2000; Schönning et al., 2007].

AN EXAMPLE IN ACTUAL MANAGEMENT OF DRY TOILET USING ASH

- In Vietnam, double-chamber type dry toilets were introduced in 1965 [Winblad, and Simpson-Hebert, 2004].



Variety in inactivation

- Quality and quantity of locally available ash
- Timing for using fecal matter as fertilizer
- Timing to use ash
- Local climatic conditions such as temperature and humidity
- Fecal chambers with/without ventilation and solar heater etc.

Fig. An example of feces and urine management flow in rural Hanoi

CONCERNS ON INACTIVATION OF PATHOGENS IN DRY TOILETS

What is required for proper sanitization of excreta?

Knowledge on inactivation of pathogens in a dry toilet by ash

- Case study of required retention period of feces with ash
  - Six months at a tropical coastal community [Chien et al., 2001]
  - Ten months at a sub-tropical hilly community [Harada et al., 2004].
- Qualitative and partly quantitative study of effect on inactivation by pH, humidity, temperature and balking agent type [Schönning and Stenström, 2004; Austin and Cloete, 2008]
- Inactivation rate coefficient of indicator bacteria in dry toilets at some specific operating conditions [Niwagaba, 2009]

OBJECTIVES

? **Quantitative effects of potentially influential factors on kinetics of the pathogen inactivation process in dry toilet by ash?**

Essential to design a fecal treatment procedure for proper pathogen inactivation of feces at a given condition

(Ash quality? Ash quantity? Water contenrs/humidity? Temperature? Iron solar heater? Ventilation? Retention time? etc.)

Objectives

- To experimentally study the quantitative effects of influential factors on inactivation kinetics of pathogens in dry toilet using ash

MATERIALS AND METHODS

EXPERIMENTAL SET UP

Mixing with additives ← 300 g of swine excreta

↓

Add water or drying

↓

Retention

↓

Sampling and measurement

↓

Calculation of inactivation ratio

17 sealed reactors at various pH and water content

At 4, 20, 36 °C

pH, water content, indicator bacteria (IB) count

$$\log_{10}(N/N_0) = \log_{10}\left\{\frac{\text{IB count at Day } n \text{ (cfu/g-dry)}}{\text{IB count at Day 0 (cfu/g-dry)}}\right\}$$

Additives

(pH, water content)

Black dart soil (7.2, 33.7%)

Commercial plant ash for gardening (10.6, 16.3%)

Maple wood ash (12.1, 0.95%)

Oak wood ash (12.5, 0.93%)

PH & BACTERIA MEASUREMENT

- pH (-)

10 g of fecal mixture in 100 mL hot water → Shaking (10 min at 140 rpm) → Standing for 1 hour → Supernatant pH as sample pH

- Indicator bacteria: Coliform bacteria, fecal coliform, *E. Coli*, fecal streptococcus

10 g fecal mixture + P buffer (fixed at 100 ml)

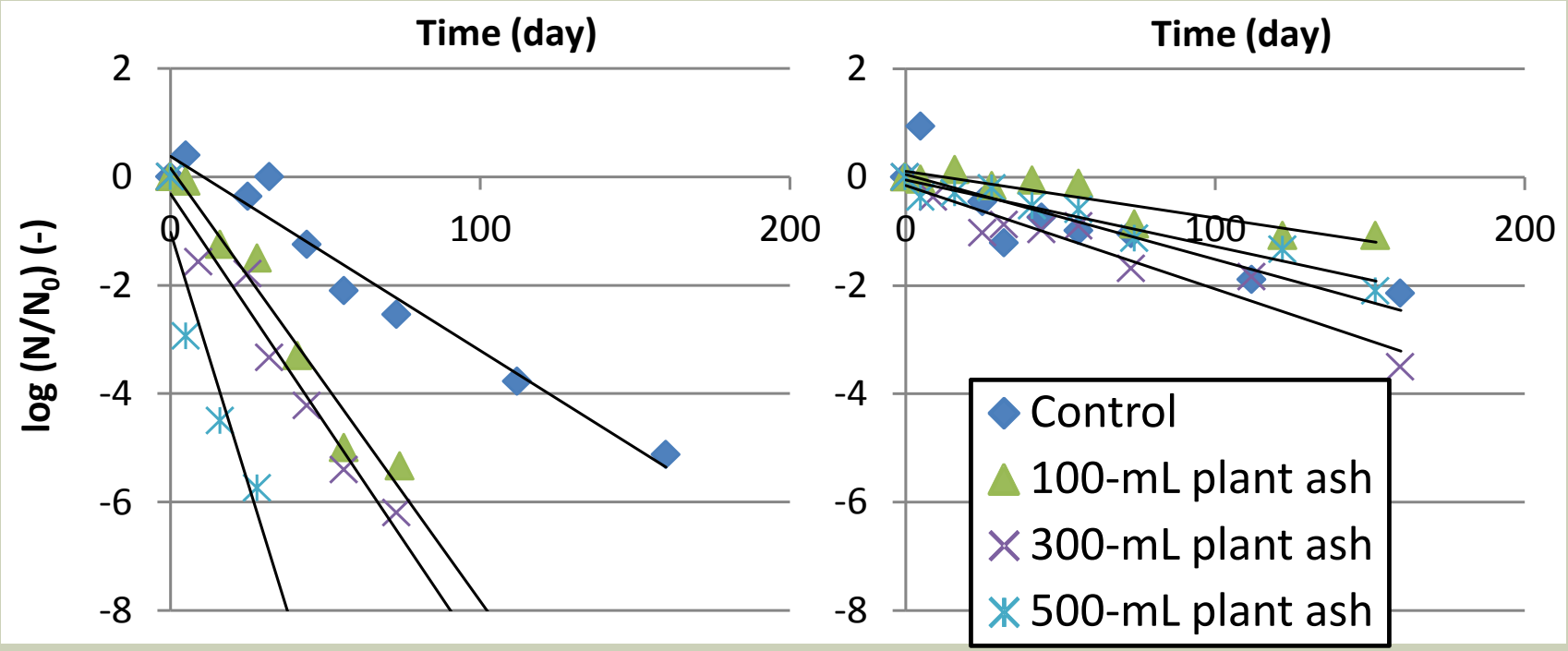
→ Shaking (10 min at 140 rpm)

→ Ultrasonic extraction (3min)

→ Counting indicator bacteria by plate method (*n* = 3)

RESULTS AND DISCUSSION

INACTIVATION UNDER DIFFERENT AMOUNT OF ASH



(a) Coliform bacteria (b) Fecal streptococcus

Fig. Time transition of inactivation ratio with three different amount of plant ash at 20 C°

CB, FC, E.Coli; gram negative; FS: gram positive

EFFECT OF pH

- Stable pH after several days
- Assuming first-order inactivation
  -> Calculating k with each reactor

$$\log\left(\frac{N}{N_0}\right) = -k \times t$$

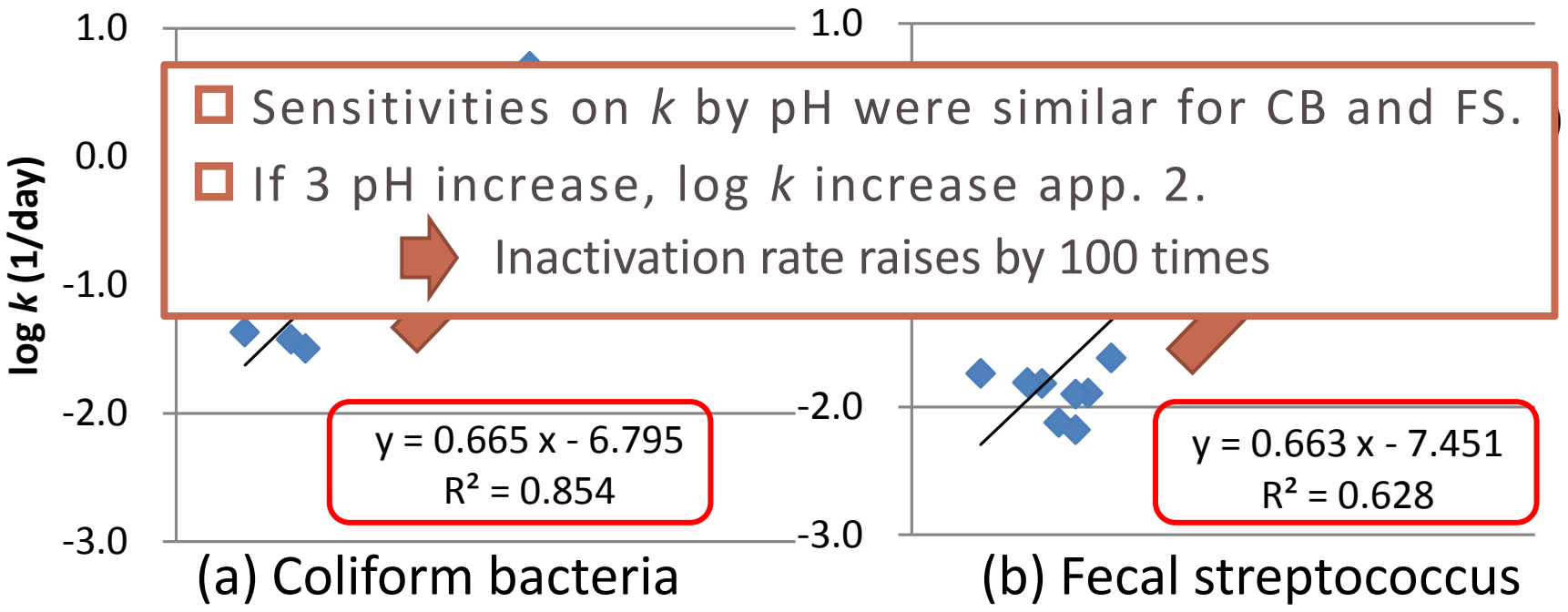
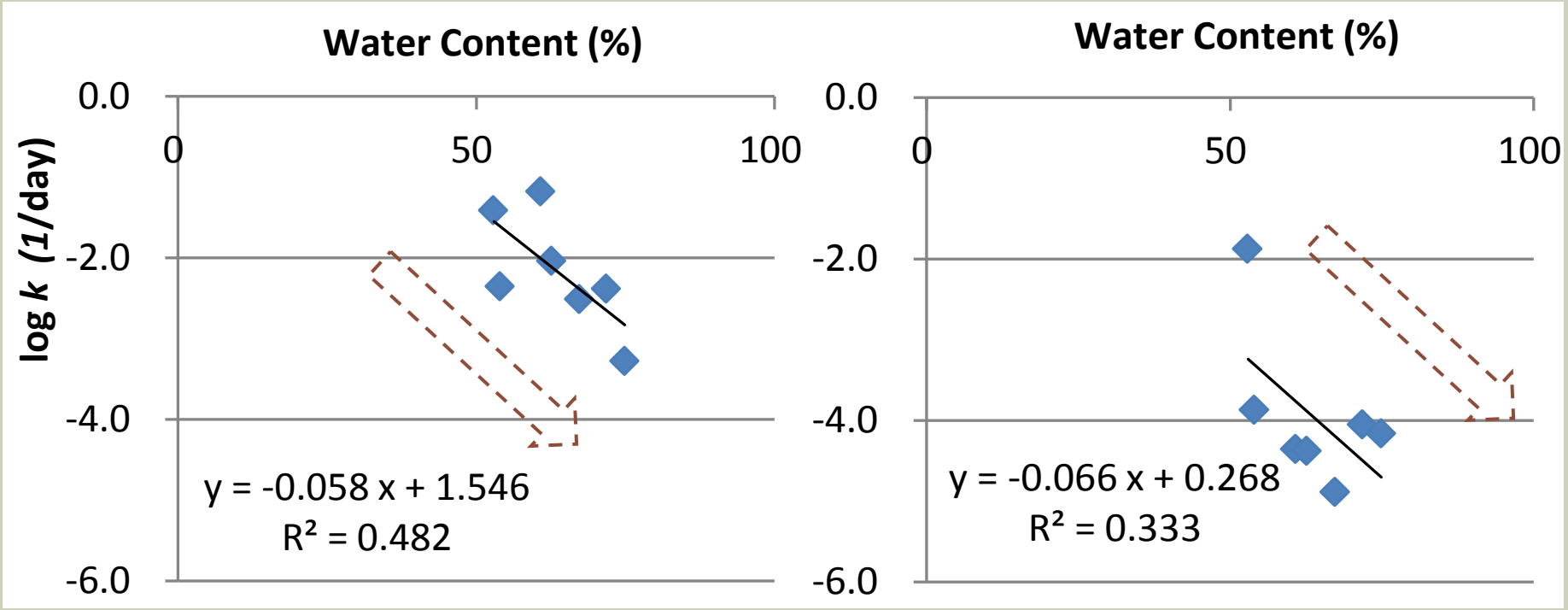


Fig. log *k* according to stable pH for 11 reactors at 20 °C

EFFECT OF WATER CONTENT



(a) Coliform bacteria (b) Fecal streptococcus

Fig. log *k* according to water content for each of 7 reactors at 20 °C. pH was fixed at 8.0-9.0.

EFFECTS OF TEMPERATURE

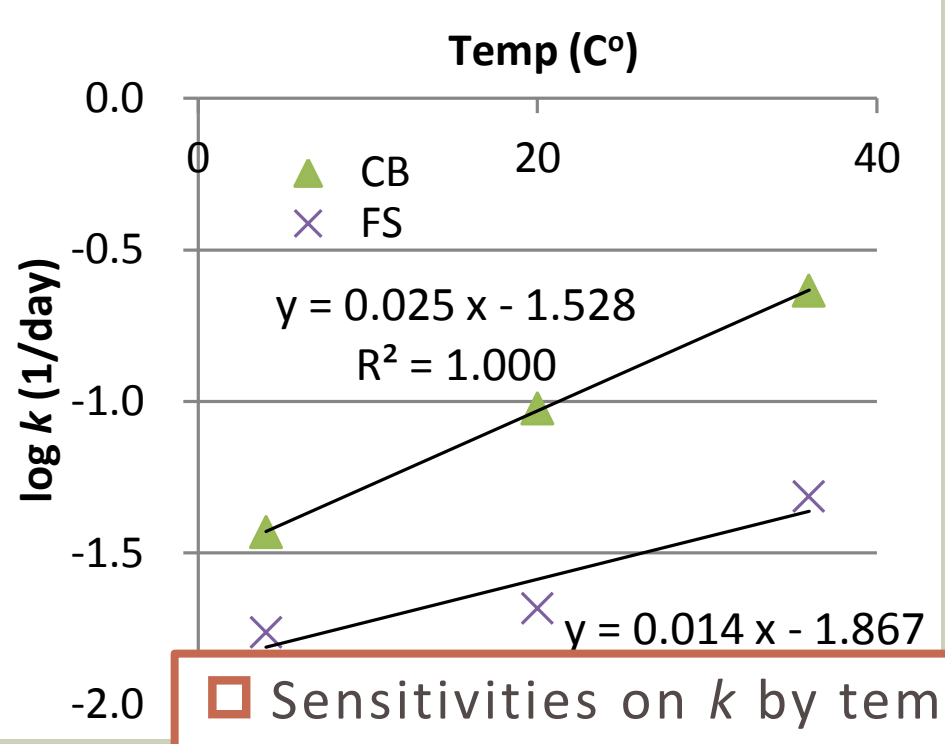


Fig. 3 tempe water and 54

- van't Hoff-Arrehenius relationship

$$\ln\frac{k_2}{k_1} = \frac{E(T_2 - T_1)}{RT_1T_2} = \frac{E}{RT_1T_2}(T_2 - T_1)$$

Since the range of T_1-T_2 is small,

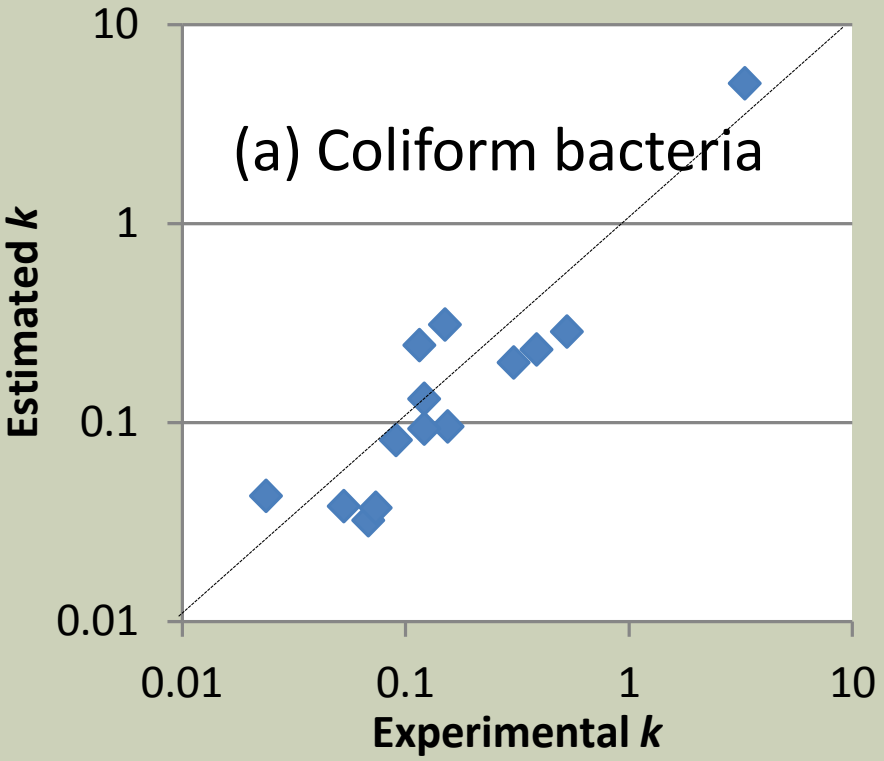
$$\Leftrightarrow \frac{k_2}{k_1} = \theta^{(T_2 - T_1)}$$

$$\Leftrightarrow \log k = \log\theta \times T + C_0$$

- Sensitivities on *k* by temp. was more for CB than FS.
- If 10 °C increases, inactivation rates increase
  by 1.8 times for CB, and
  by 1.3 times for FS.

ESTIMATION OF *K* AND ITS VALIDATION

$$k_{CB}(pH,T) = 10^{(0.665pH-6.795)} \times 1.06^{(T-20)}$$



$$k_{FS}(pH,T) = 10^{(0.663pH-7.451)} \times 1.03^{(T-20)}$$

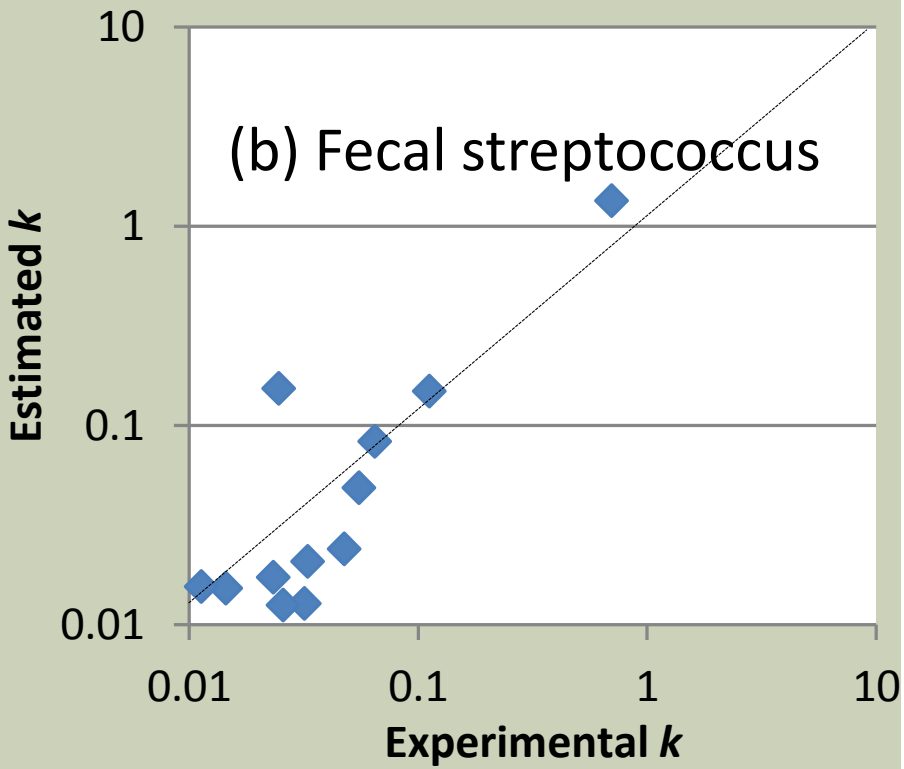


Fig. A plotting of estimated *k* (inactivation rate coefficient) and experimental *k*

AN EXAMPLE OF EVALUATING FECAL MANAGEMENT

Target of treated concentration: 10^3/g-dry solid (US-EPA)

Initial concentration: 1.3 x 10^7 (cfu/gDS) for CB; 3.0 x 10^6 for FS (cfu/gDS)

pH (-)	8.6	10.5	10.5
Temp. (^{o}C)	23.6	25	15

Item	CB	FS	CB	FS	CB	FS
k (1/day)	0.16	0.03	2.05	0.38	1.16	0.28
T_{90} (day)	6.1	31.5	0.5	2.6	0.9	3.6
Required time for the target (day)	26	110	2.1	9.1	3.6	12.6

Bacteria infection control according to local contexts

CONCLUSIONS

- Dry fecal treatment processes using ash under various retention conditions.
  - Inactivation modeled based on a first-order reaction and van't Hoff-Arrehenius relationship.
  - Inactivation rate on CB faster than FS; pH affects similar; temp affect more on CB
    - **When +3 pH**, increasing **by 100 times for CB and FS**.
    - **When +10 C°**, increasing **by 1.8 & 1.3 times for CB & FS**, respectively.
- Challenges:
  - Effect of water content on inactivation process
  - Inactivation process of viruses and parasites
  - Scheme to determine the inactivation conditions for achieving a certain level of health

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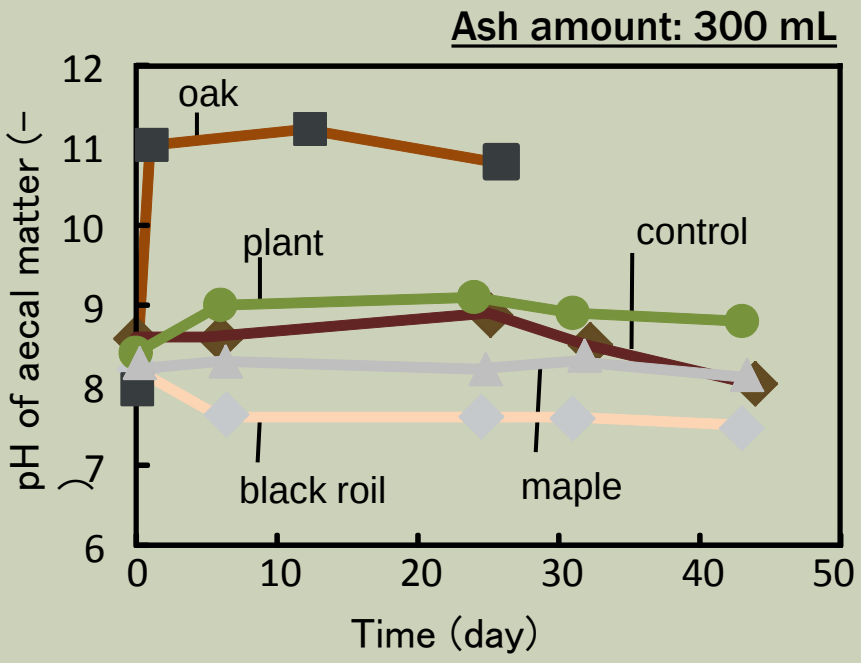
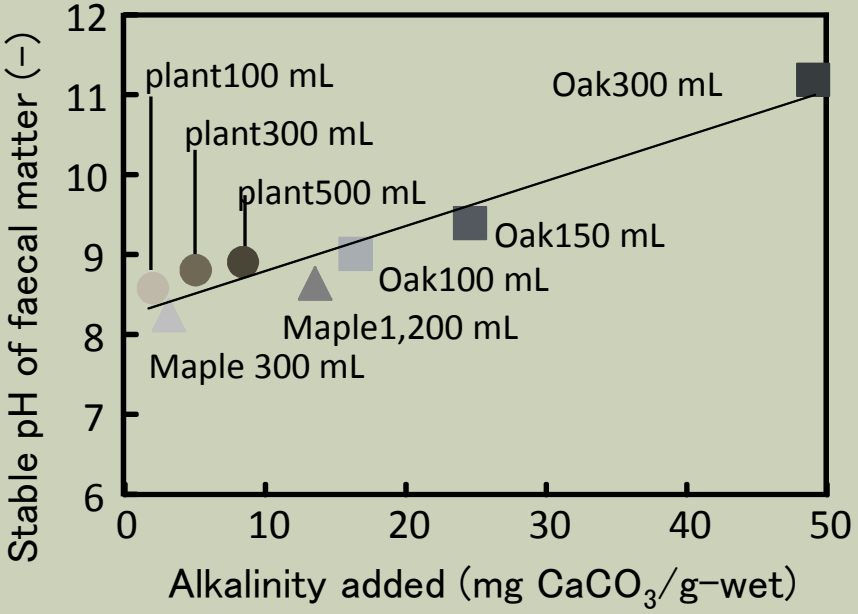

Ash amount: 300 mL
oak
plant
control
black roil
maple
pH of aecal matter (–)
Time (day)
12
11
10
9
8
7
6
0
10
20
30
40
50


plant100 mL
plant300 mL
plant500 mL
Oak300 mL
Oak150 mL
Oak100 mL
Maple1,200 mL
Maple 300 mL
Stable pH of faecal matter (–)
Alkalinity added (mg CaCO3/g–wet)
12
11
10
9
8
7
6
0
10
20
30
40
50