Estimation of water load allowed for composting toilets without energy supply

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Composting toilet without energy supply

- Composting toilets
  - -Stabilization of organic matter
  - -Sawdust as matrix
  - -Operational factor: **Water content**
- Developing countries
  - -Low energy consumption
  - -Reduction of energy consumption for water content control

Natural evaporation for water content control
to achieve low energy consumption

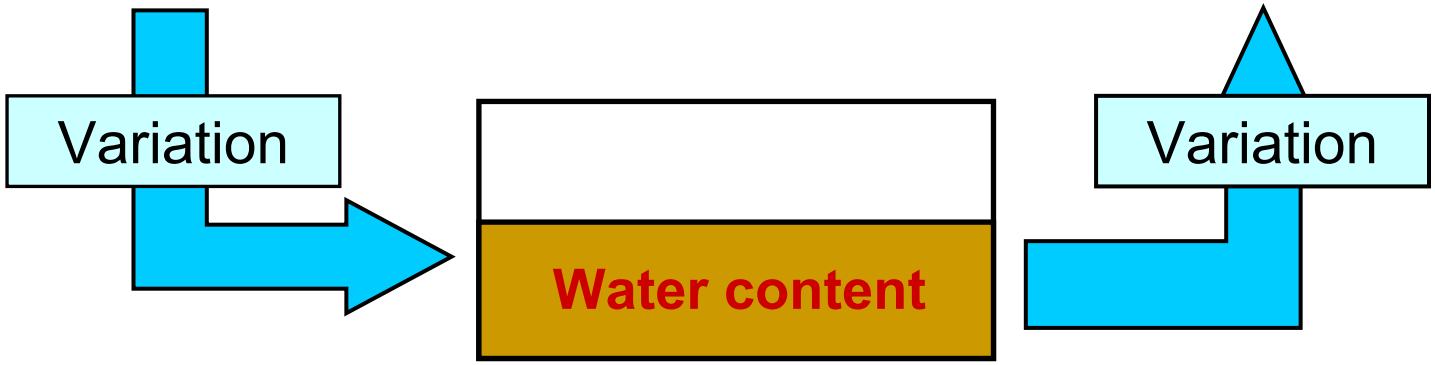
Natural evaporation: How to control water content?

Water load

- Water from Feces
- Water for cleaning body after toilet

Natural Evaporation

- Air temperature
- Relative humidity
- Air flow rate



water load < Evaporation rate

➡ Design evaporation capacity of composting toilets

Objective, Methodology

Objective

Estimation of water load allowed for composting toilets without energy supply by modeling of water evaporation

Methodology

- Development of a model of evaporation

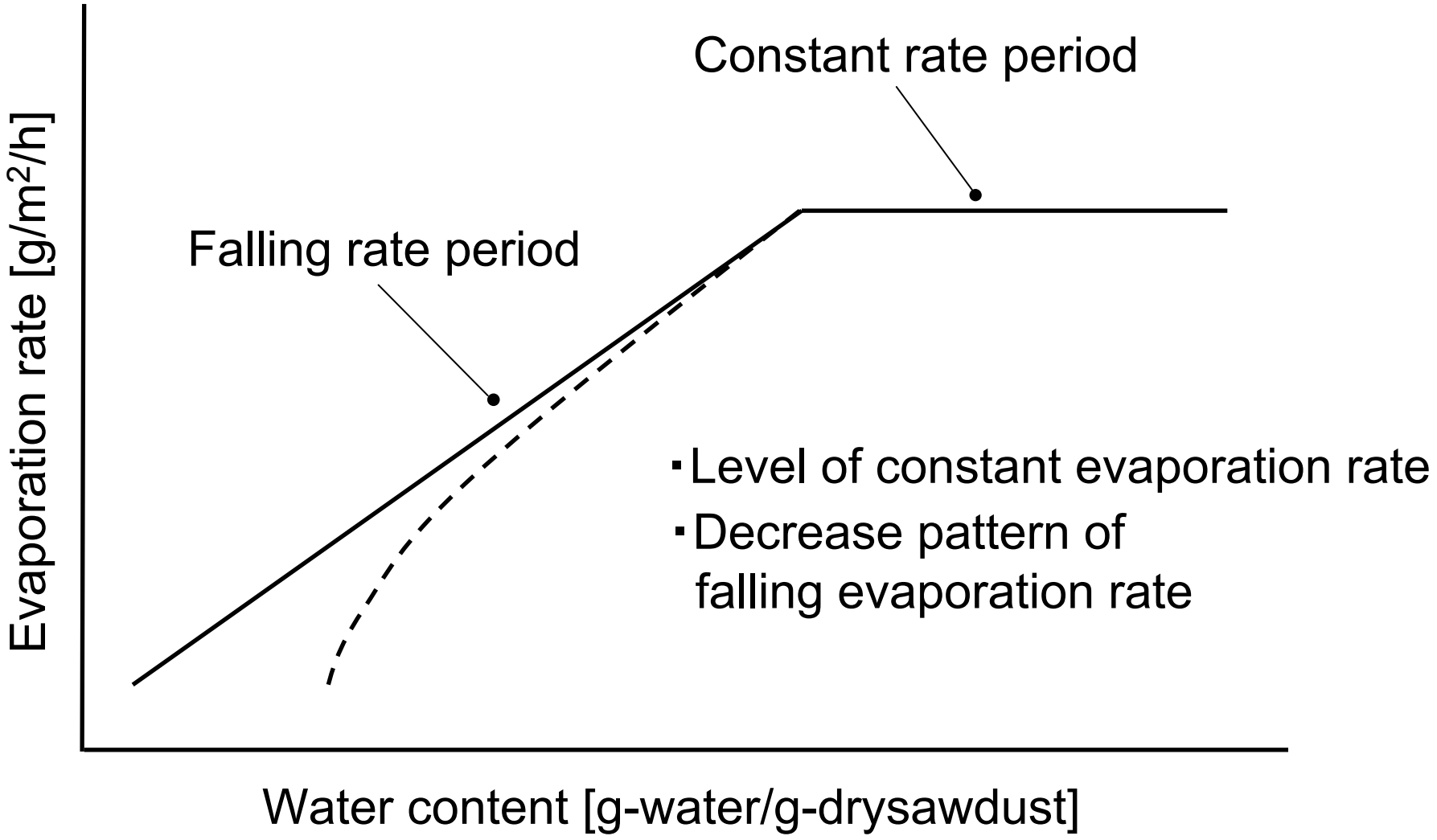
  -Laboratory scale experiment
  Modeling of evaporation

  -Full scale experiment :
  Validation of evaporation model
  Checking the effect of biological activity on evaporation

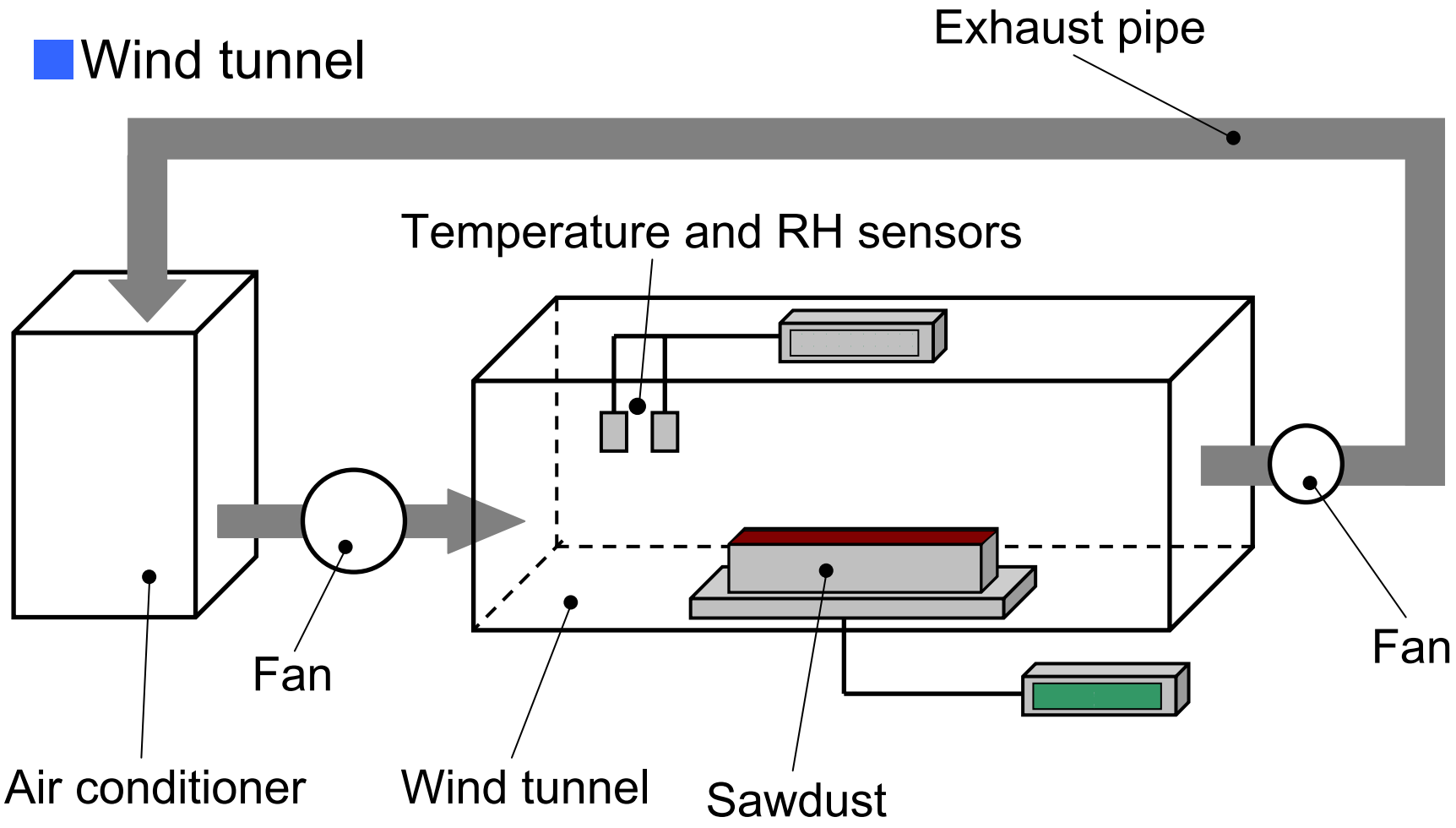
- Estimation of allowable water load

Evaporation theory for porous solids

■ Evaporation rate profile of porous solids



Lab scale experiment : Setup



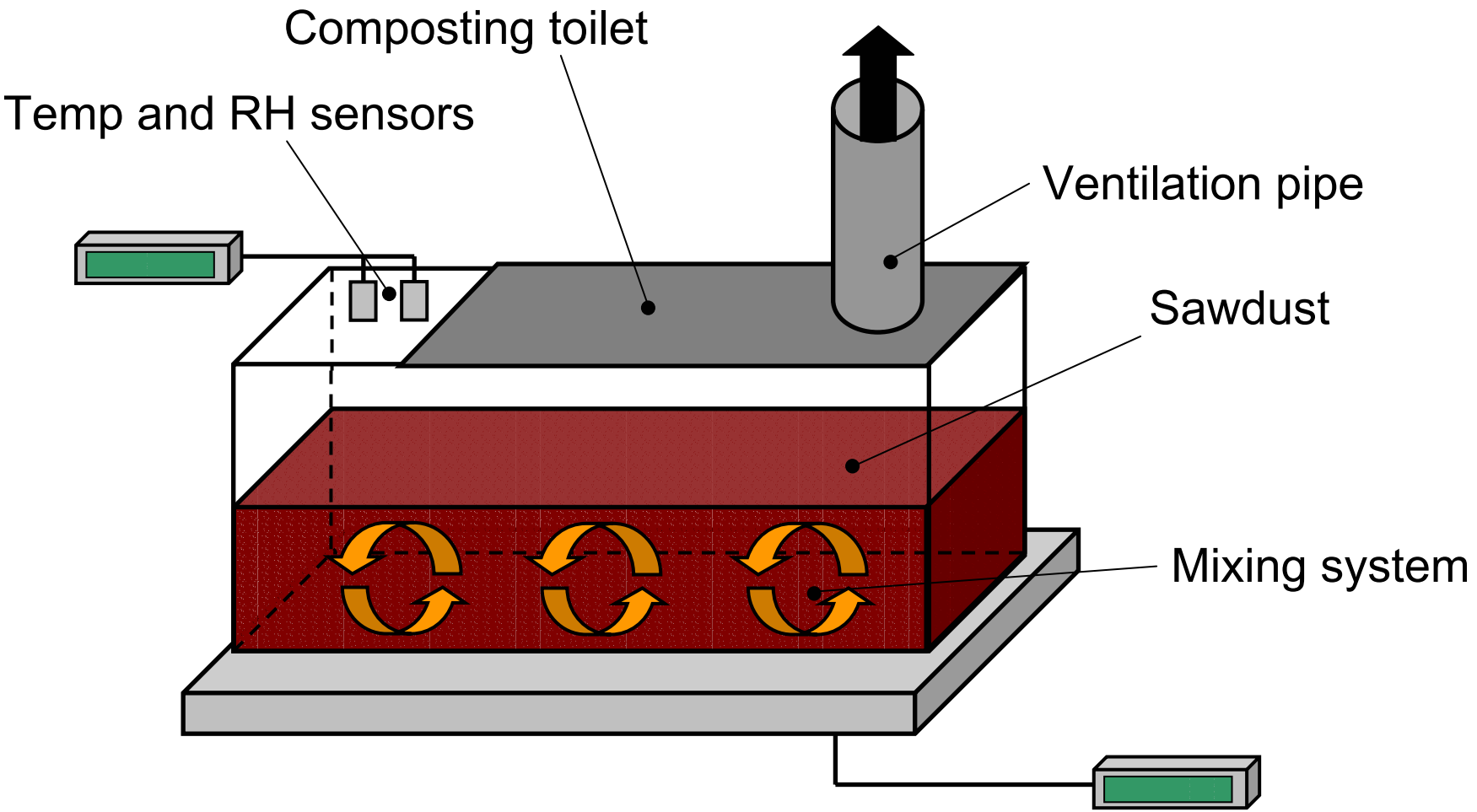
Lab scale experiment : Experimental conditions

Temperature [℃]	Relative humidity [%]	Air flow rate [m/s]
20	65	2
	80	
25	65	2
	80	
30	65	2
	80	
25	65	3
	65	4.5

- Measurement items : Time course of material weight
  Air temperature and RH

Full scale experiment :Setup

- Composting toilet



Full scale experiment : Experimental conditions

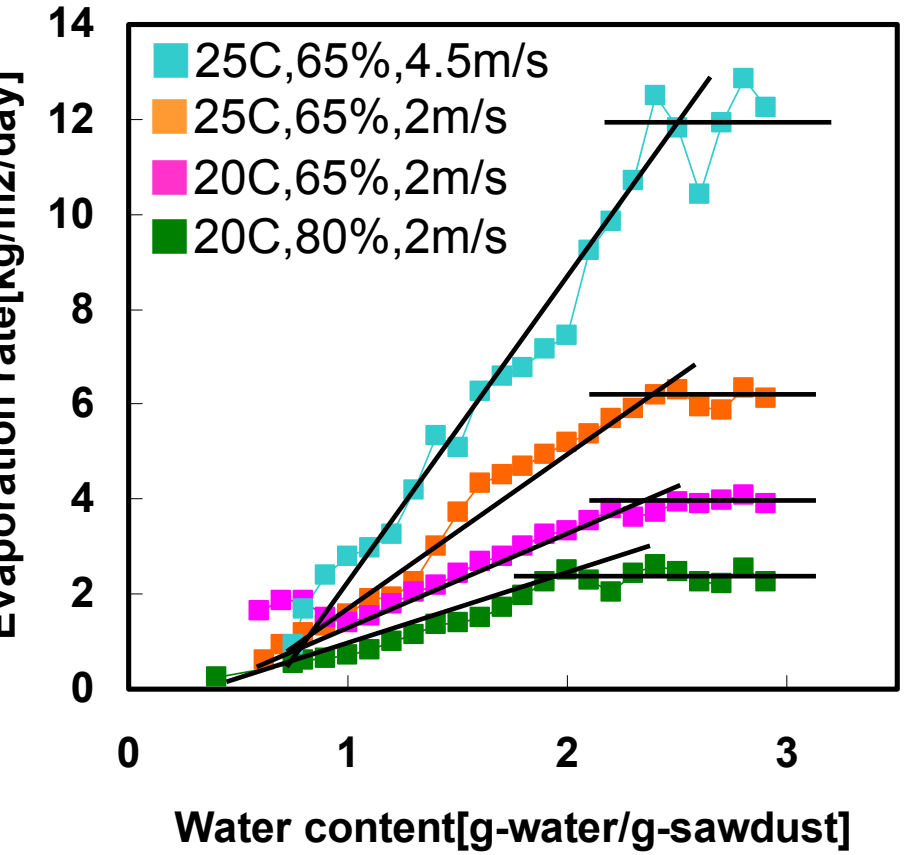
Feces load [g-PM/day]	Air flow rate [m/s]	Mixing frequency [times/day]
0	0.16	24
130		

※130 [g-PM/day] : Feces from one person

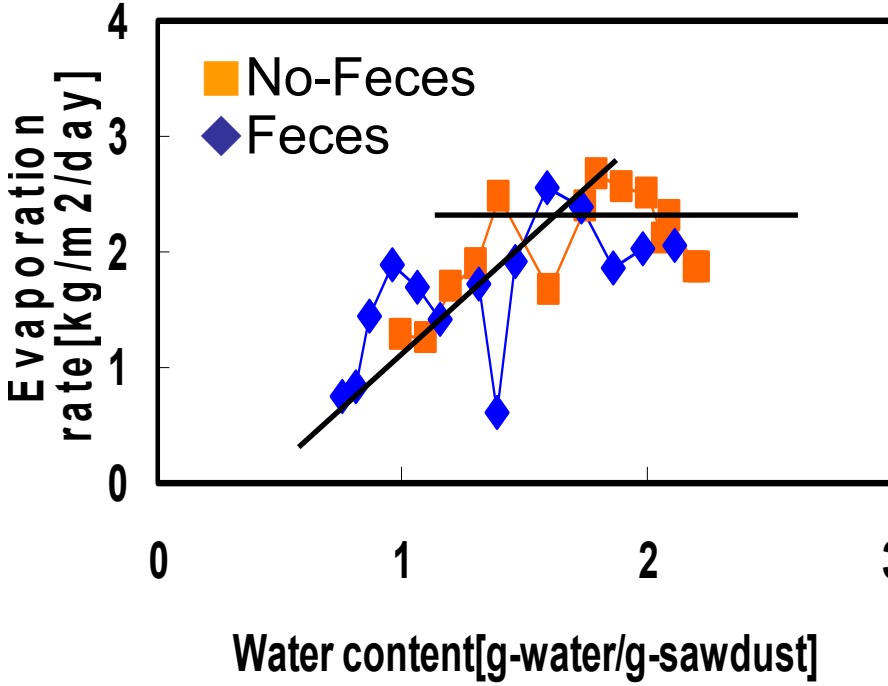
■Measurement items : Time course of material weight
Air temperature and RH

Evaporation rate profiles obtained

Lab scale evaporation experiment

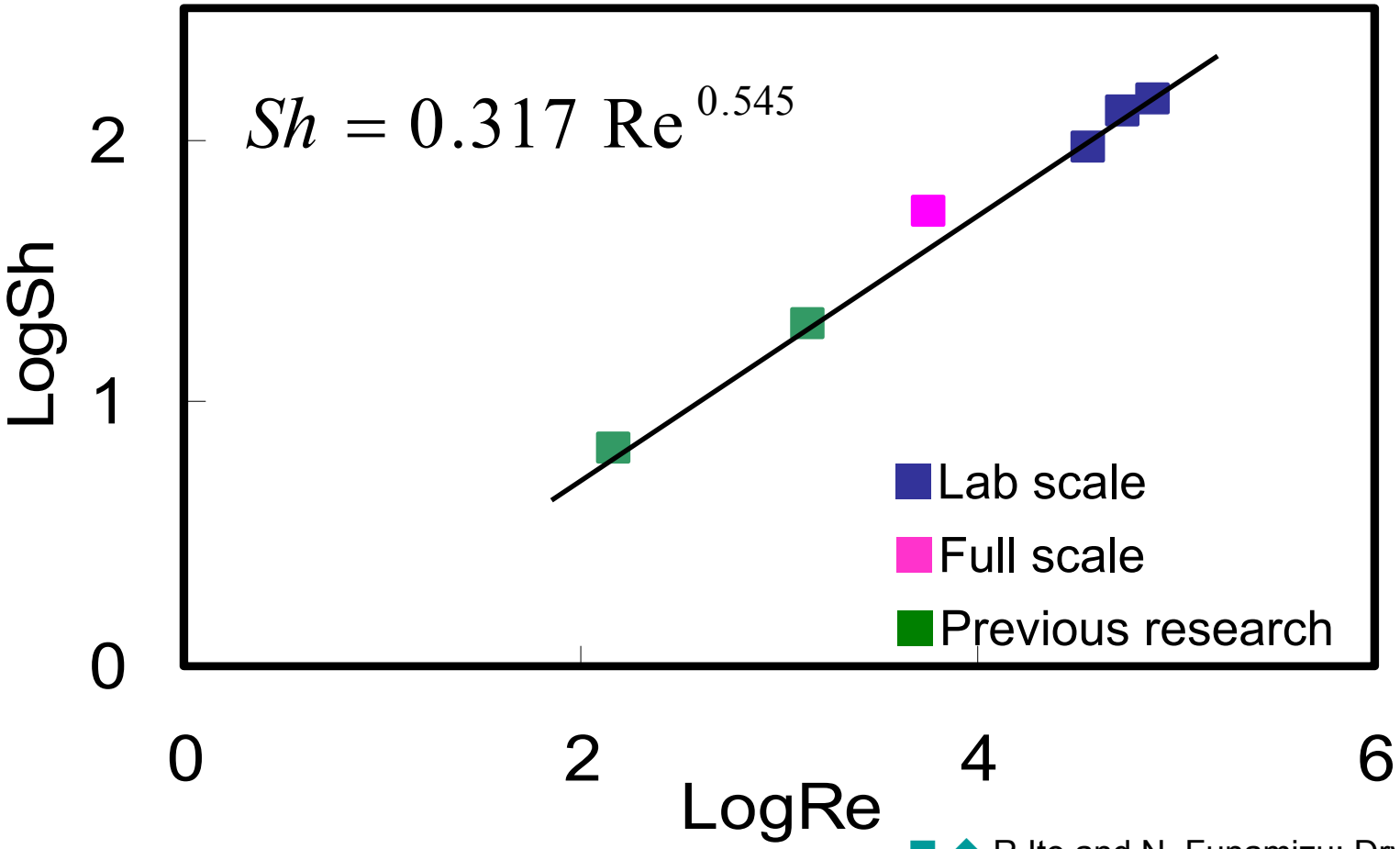


Full scale evaporation experimen



Modeling of constant evaporation rate

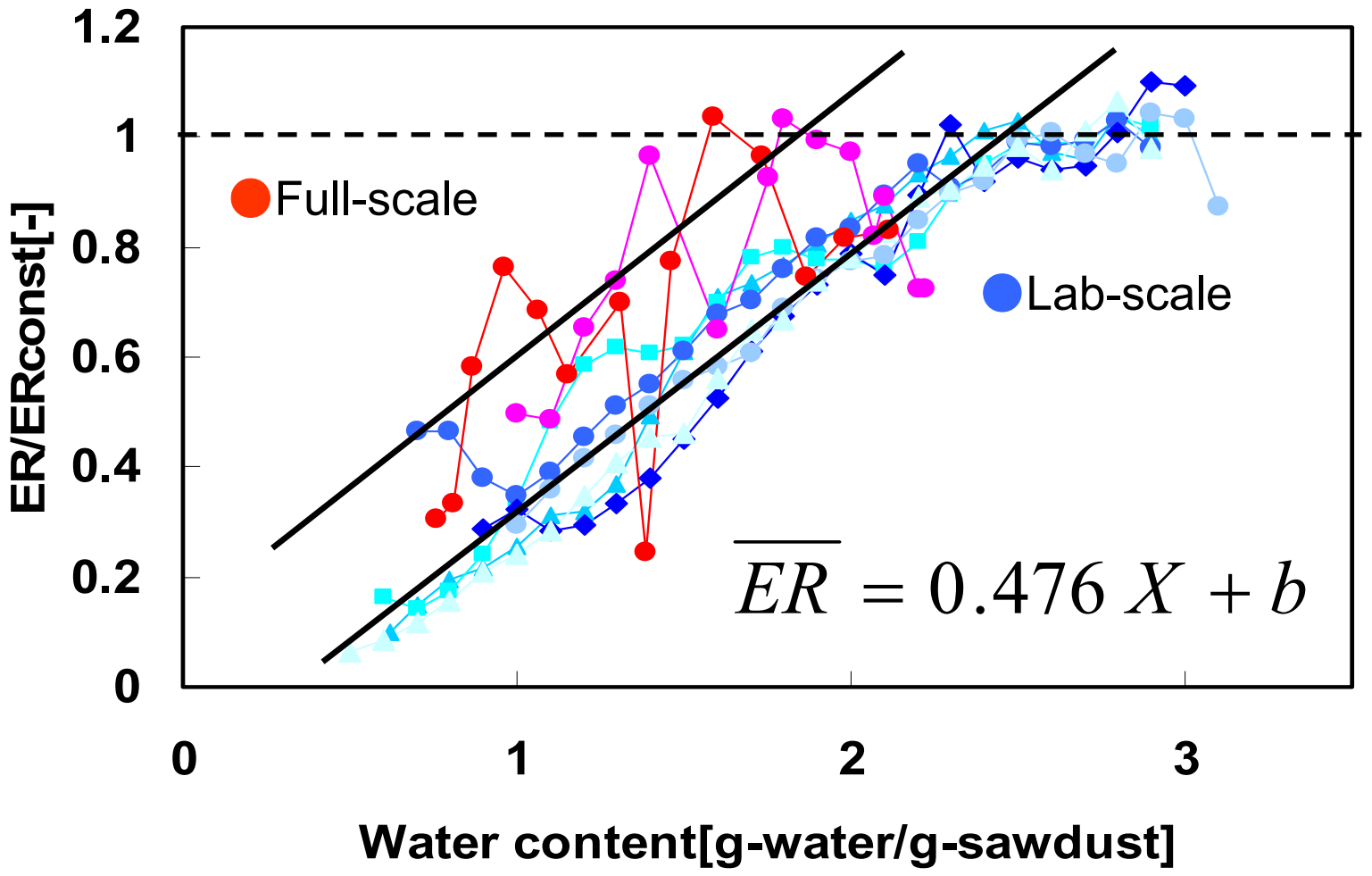
■ Sharwood number vs Raynolds number



■,◆ R.Ito and N. Funamizu: Drying kinetics of sawdust for bio-toilet system Proceedings of the 3rd international symposiu
On sustainable sanitation

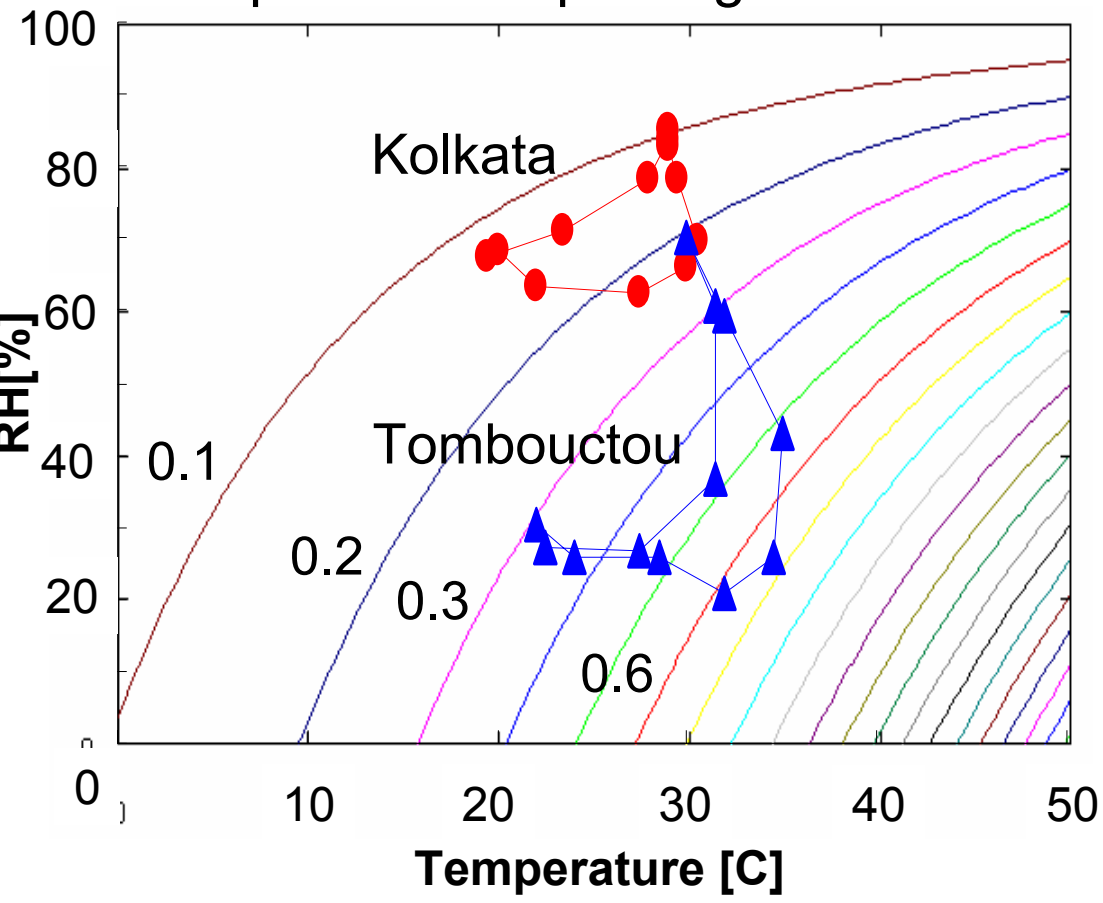
Modeling of falling rate period

■ Normalized evaporation rate profiles



Estimation of Evaporation rate

- Contour map: evaporation rate [kg/day] of one-person composting toilet



- Parameters

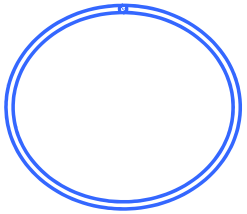
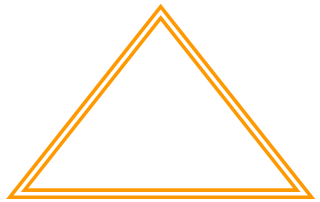
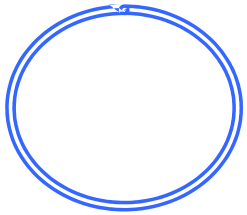
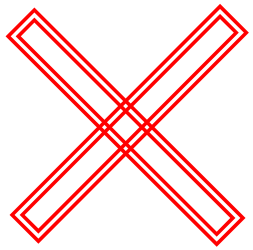
-Surface area: 0.21[m^2]

-Air flow rate: 0.16[m/s]

-Water content
1.5[g-water/g-sawdust]

	ER [kg/day]
Kolkata	0.1~0.2
Tombouctou	0.3~0.6

Allowable water load in tropical and arid zones

Arid zones (Tombouctou) 0.3~0.6[kg/day]	 -Enough evaporation capacity	 -Feasibility depends on season
Tropical zones (Calcutta) 0.1~0.2[kg/day]	 -Enough evaporation capacity	 -Increase in surface **0.21→0.63~1.26** : [m^2]
	Feces: 0.1[kg/day]	Feces + cleaning body : 0.6[kg/day]

Water load for body cleaning: 0.5[kg/day]

Conclusions

Water evaporation from composting toilets was modeled

- Constant rate period
- Falling rate period

Water load allowed for composting toilets was estimated

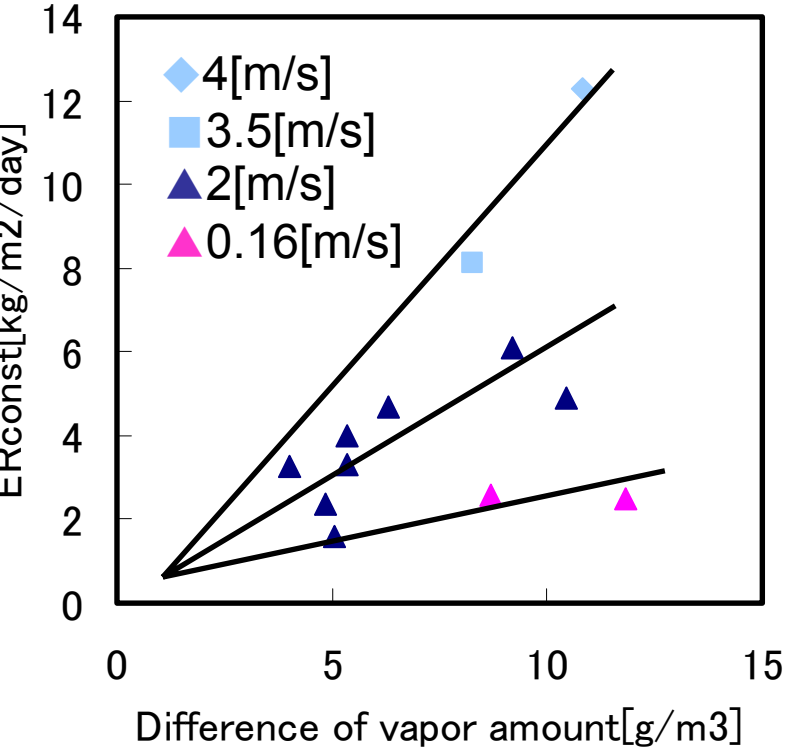
- Arid zones: Feasible
- Tropical zones: Water load = Feces + Body cleaning

Need for surface area increase

Quantitative prediction of required surface area

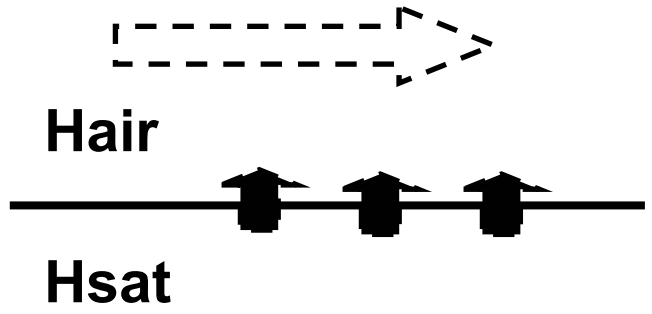
Thank you

Mass transfer theory



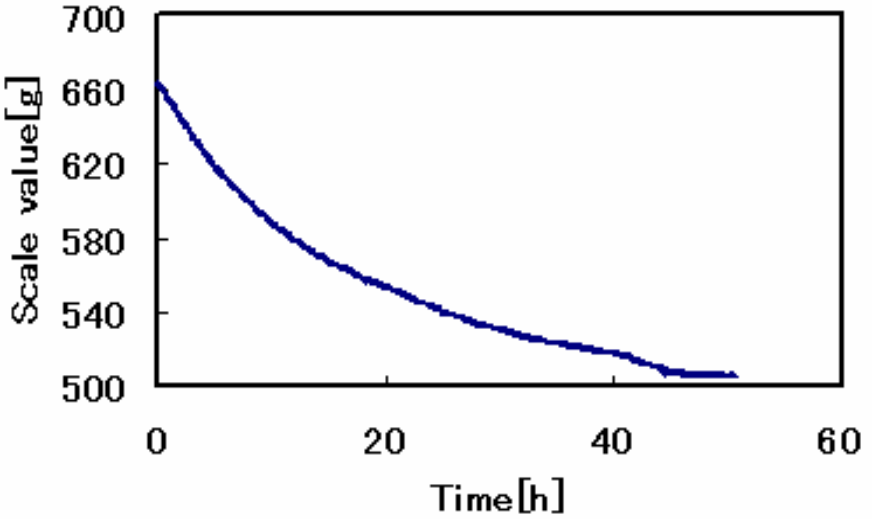
$$ER_{const} = k_L (H_{sat} - H_{air})$$

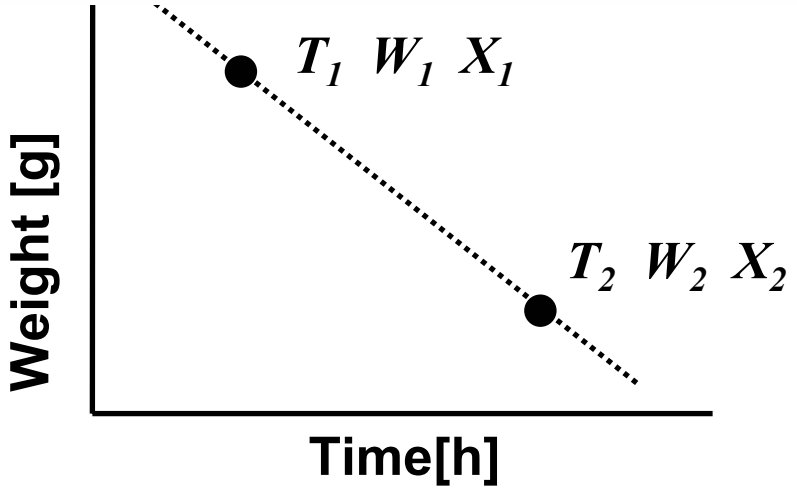
$$Sh = \alpha \, \mathrm{Re}^{\beta} \, Sc^{\gamma}$$



ERconst [g/m2/h]	Constant evaporation rate
k_L[m/s]	Mass transfer coefficient
H_{air}[g/m^3]	Vapor amount of air
H_{sat}[g/m^3]	Saturated vapor amount of ai
Sh[-]	Sharwood number

Calculation of evaporation rate





$$ER\left(\frac{T_1 + T_2}{2}\right) = \frac{W_1 - W_2}{T_2 - T_1}$$

$$X = \frac{X_1 + X_2}{2}$$

Dimensionless numbers

$$Sh = \frac{k_L L}{D} \qquad k_L = \frac{ER}{H_{sat} - H_{air}}$$

$$\mathrm{Re} = \frac{UL}{\nu}$$

k_L : Mass transfer coefficient [m/s]

D : Diffusion coefficient [m2/s]

L : Representative length [m/s]

ER :Evaporation rate [g/s]

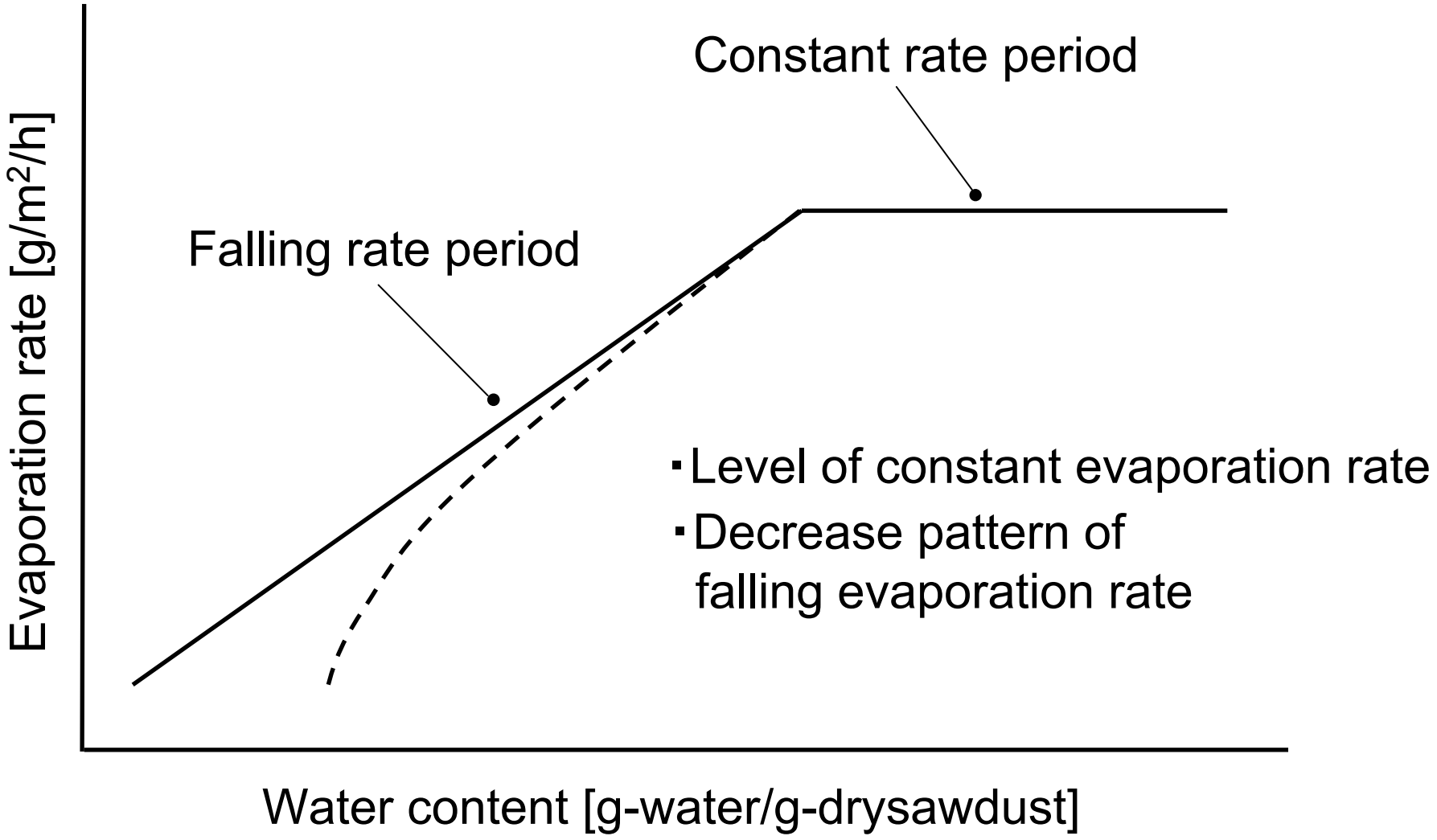
H : Vapor amount per unit volume [g/m^3]

ν : viscosity [m^2/s]

Water load: cleaning body

- In some areas, toilet manners from the view point of cleanliness
- Rules regarding cleanliness, not only toilet, also in every aspect in daily life
- Adaptation of composting toilet to toilet culture
- Southeast Asia, South Asia, Middle East

Evaporation theory



Water load: cleaning body