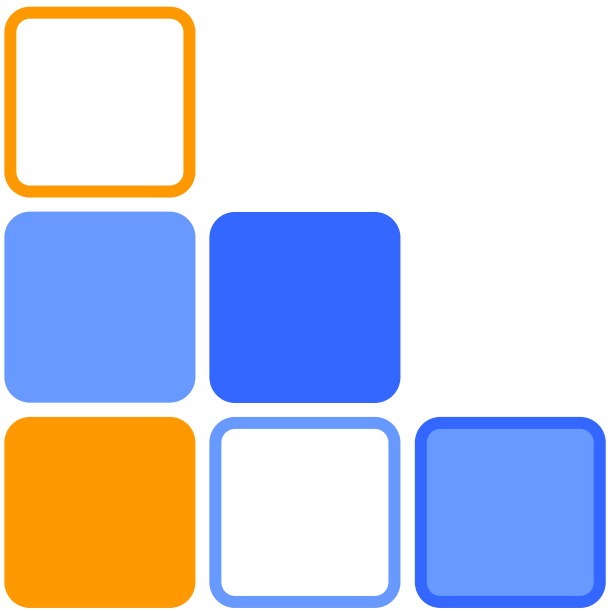
Experimental application of sustainable sanitation system in Japan



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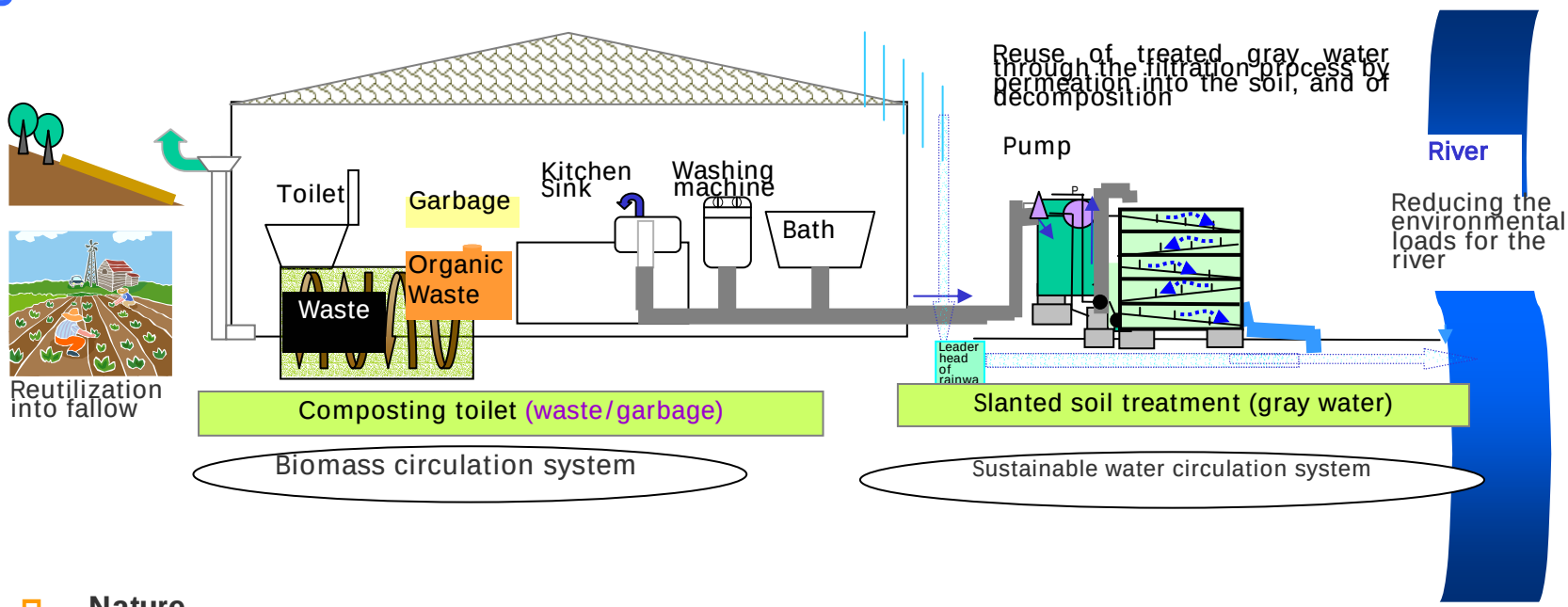
Introduction

- Limit of improved sanitation system by centralized wastewater treatment system
  - Not enough capital in the world
- Demand to improved sanitation system
  - Innovation of social system
    - Culture, nature, history
  - New sanitation system
- Model project site for evaluating a potential of new social model with OWDTS
  - Black water treatment
  - Gray water treatment
  - Material circulation

Chichibu pilot project site



- **Nature**
  - **Upper stream of Arakawa river, one of the most polluted river**
  - **Rich forests (rich sawdust)**
- **Life style**
  - **Human waste recycling culture**
- **Cooperation of local community and government**
- **2 people in this house.**
- **Some people often comes there.**
- **Motivation – Cleaning the river. Enjoying life style with river.**

Improved points:
black water
Just stored -> composting toilet
gray water
Just discharged into a river
-> slanted soil treatment system

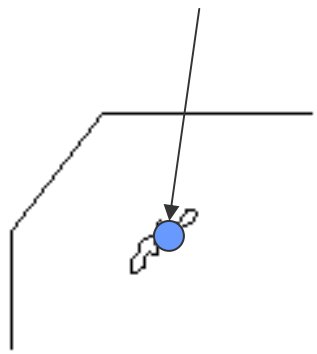
Photographs in Chichibu project site

Research site in Japan

Hokudai, Sapporo
- Composting toilet

Chichibu, Saitama
- Composting toilet
- Slanted soil treatment system

Nago, Okinawa
- Composting toilet
- Slanted soil treatment system



Photographs in Hokudai project site

Photographs in Nago project site

Research topics on pilot projects

- Energy consumption
  - Consuming structure
  - Another energy source
- Accumulation of materials
  - Nutrients
  - Heavy metals
  - Pharmaceuticals
  - Estrogenic compounds
- Risk assessment
  - Coliform count
  - Simulation of decay process for pathogens
- Adaptability into local community
- Development of monitoring and analyzing system for management

Black water treatment

Composting toilet system monitoring system

Toilet

Fan

Monitoring items
- Air temperature, relative humidity of inlet air
- Air temperature, relative humidity of outlet air
- Heater power consumption
- Rotational speed of fan

- Heater temperature
- Moisture content meter of sawdust
- Ammonia concentration
- CO2 concentration

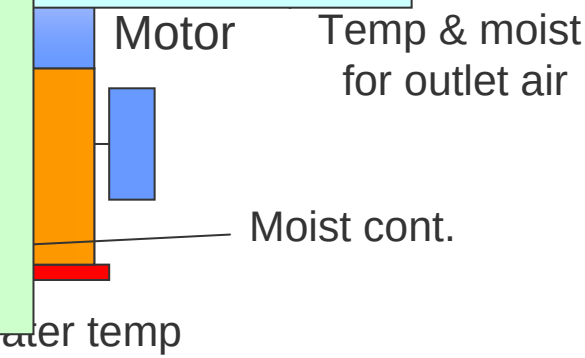
Features
- 60% of moisture content of sawdust
- Composting at 50~60°C

- Aerobic stabilization of organic matter
- Complete recovery of accumulative

ns

Calculation items
Drying rate
Energy balance

Measurement items from sampling
Moisture content of compost
Minerals concentration in compost
Counting of coliform



Operation conditions

	Date	Ventilation air flow rate [m^3/h]	Heater temp. [^oC]	Automatically mixing interval [h]	Mixing time [min]	Maximum heater output [W]
I	May.9, 2005	56.34	45	2	3	180
II	Jul.8, 2005	56.34			3	180
III	Aug.23, 2005	42.42			3	180
IV	Sep.6, 2005	50.94	45	2	3	180
V	Sep.13, 2005	32.04	45			180
VI	Oct.26, 2005	32.04	50	2	3	180
VII	Nov.11, 2005	32	OFF	0.25	3	180
VIII	Nov.22, 2005	32.04	50	2	3	180
IX	Dec.3, 2005	56.34	50	2	3	180
X	Dec.27, 2005		50	2	3	360
XI	Jan.11, 2006	56.34	50	2	3	180
XII	Feb.20, 2006	56.34	50	2	3	360

Effect of ventilation air flow rate

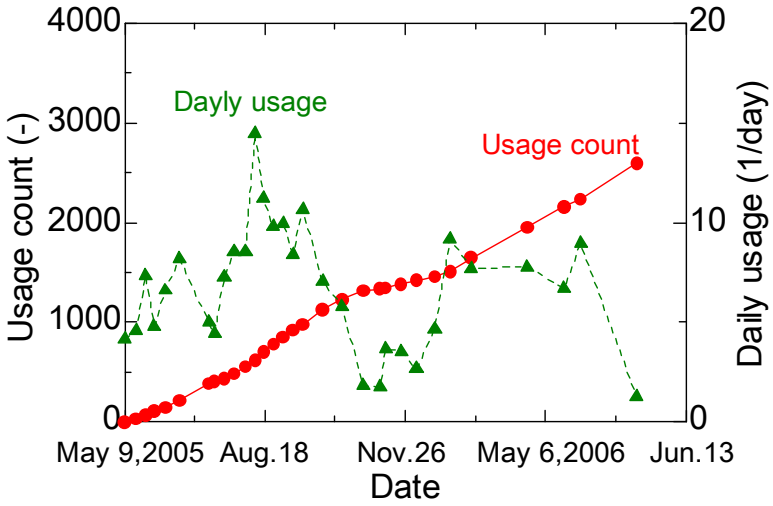
Effect of heater temperature

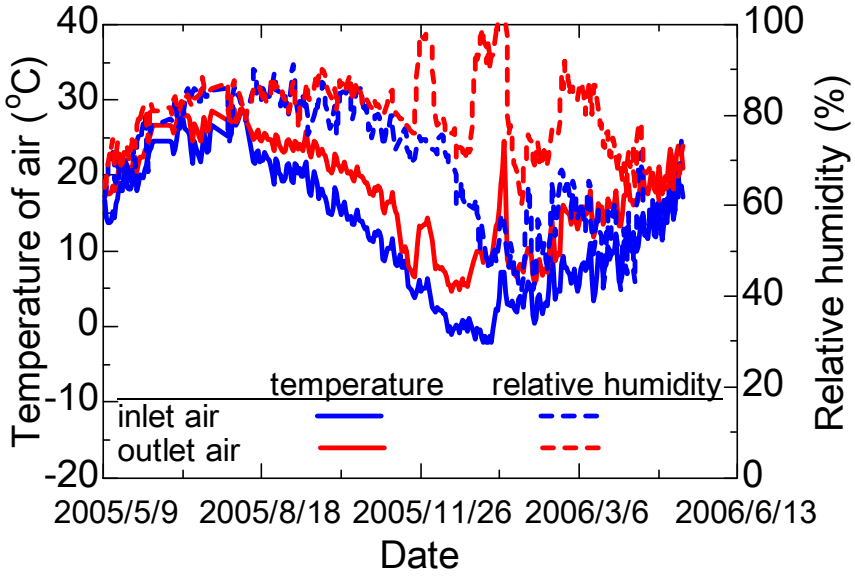
Heater off

Effect of heater

* Period from Jul.17, 2005 to Aug.3, 2005 is out of service

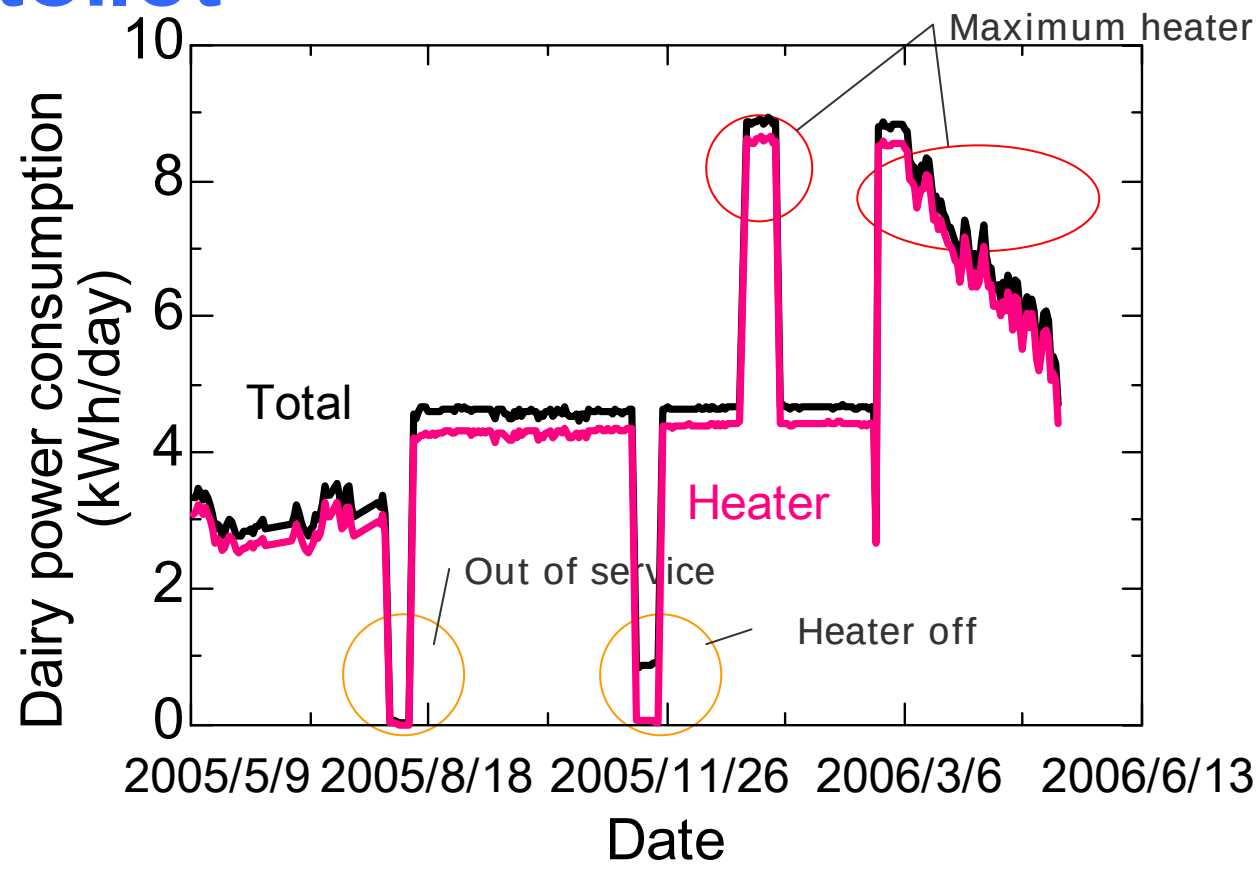
Usage time and annual changes of air conditions





The facility was constantly used around 7-8 times per day.
<- 1.2L of water (urine) is evacuated from one person per day.
<- 150ml and 50 ml of water respectively estimated for hand wash and bowl washing.
= Approximately 4L of water was charged into the toilet.
The average temperature of inlet air was changed from freezing temperature to 30°C.
The temperature and relative humidity was always higher than inlet one.
-> The air was heated up and water was evaporated.

Energy consumption of the toilet

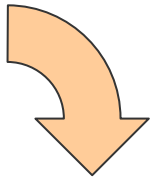


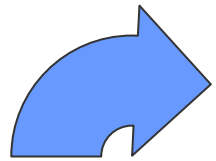
The electricity was consumed 3-9kWh/day (90-270kWh/month).
Over 90% of it was used for heater.

=>This toilet consumes huge amount of energy by heater.
= Structure of energy consumption must be cleared for energy saving.

Energy flow model in the composting toilet system

Energy input with materials:
- Inlet air
- Urine
- Feaces
- Other organic matter
- Hand washing water
- Toilet bowl washing water





Energy output with materials:
- Outlet air

Energy consumption:
- Vaporization of water
- Heat up air

Energy generation from organic matter

Other route for output:
- Heat conduction

Accumulation:
- Compost
- Moisture

Energy input from heater:
- Power supply

Energy balance:
Accumulation = Input – Output + Heater + Reaction

Equations for estimation of energy balance

Energy balance equation:

$$d\Delta H_{accum}/dt = q_{air,in} - q_{air,out} + q_{heater} + q_{react} - q_{loss}$$

Energy flow rate of air

$$q_{air} = \left(Cp_{dryair} T_{air} + \left(Cp_{vapor} T_{air} + \Delta H_{vap} \right) H_{air} \right) F$$

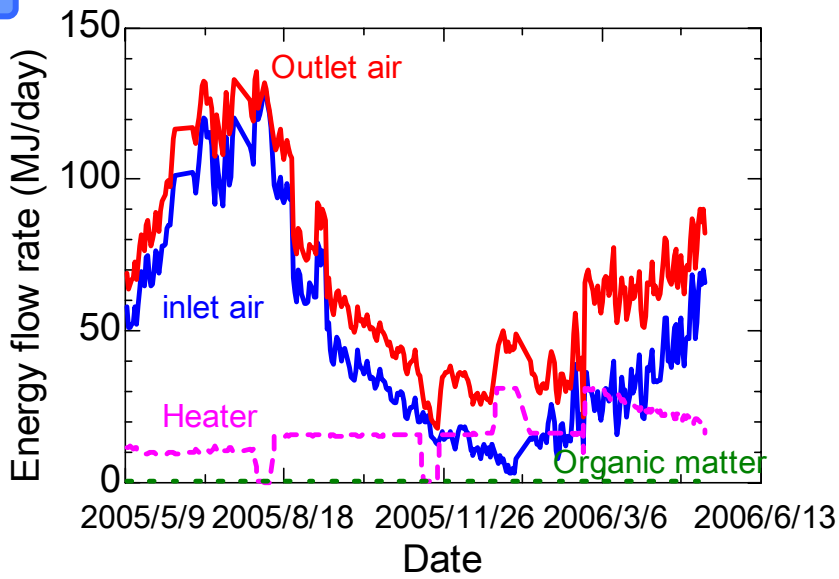
Energy from heater

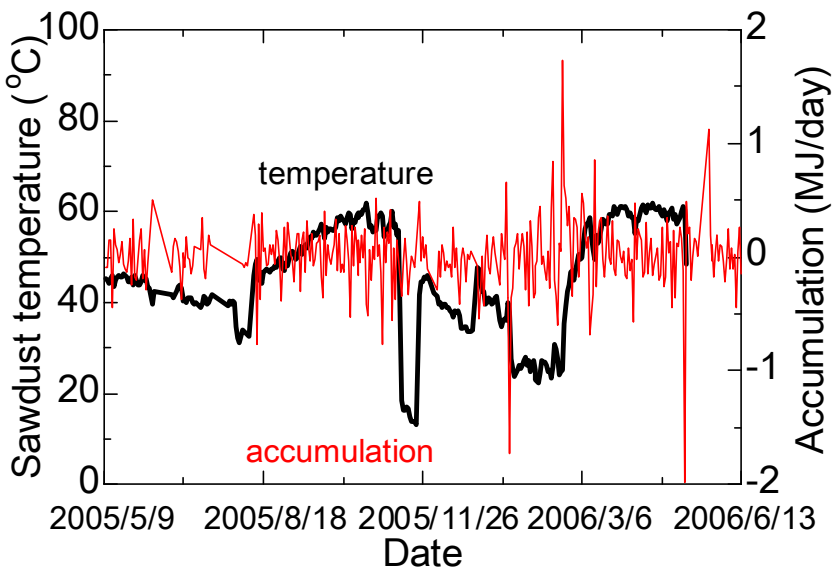
$$q_{heat} = Q_{heater}$$

Energy generation by oxidation of organic matter

$$q_{react} = \Delta H_{organicmatter} M_{organicmatter}$$

Heat balance





*The data just after condition changed was removed

The energy inflow to the toilet agrees with outflow by outlet air.
⇒Little accumulation?

Energy accumulation into sawdust

$$d\Delta H_{accum}/dt = \frac{d\left(Cp_{sawdust} M_{sawdust} T_{sawdust}\right)}{dt}$$

Energy supply from heater: 10-20MJ/day

Energy accumulation: 0.5MJ/day-> ignored

Calculation of drying rate

Water amount in unit volume of air

$$W_{water} = \frac{P_{water}}{R\left(T_{air} + 273.15\right)} Mw_{water}, \; P_{water} = P_{water,saturated} RH$$

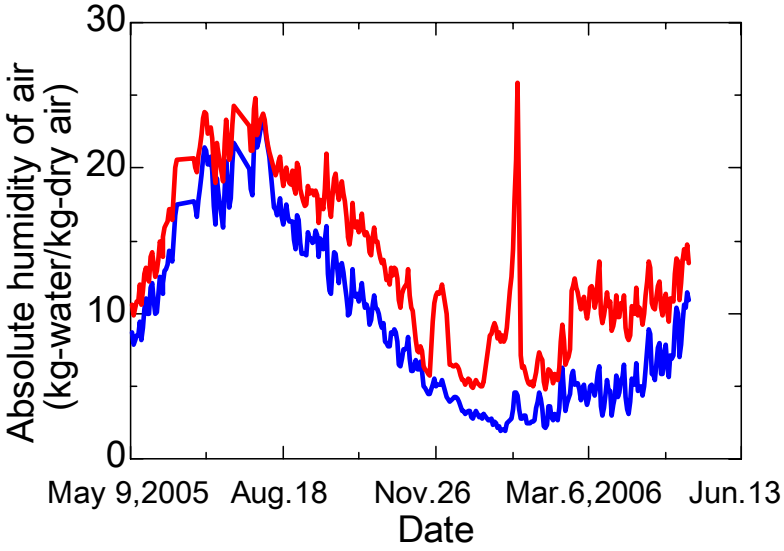
Drying rate

$$DR = \left(W_{water,out} - W_{water,in}\right) F$$

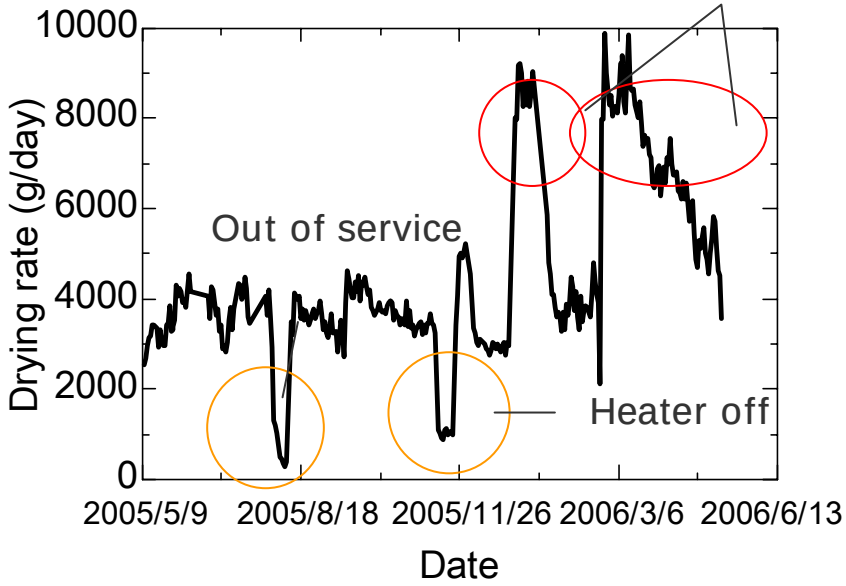
Water evaporation heat

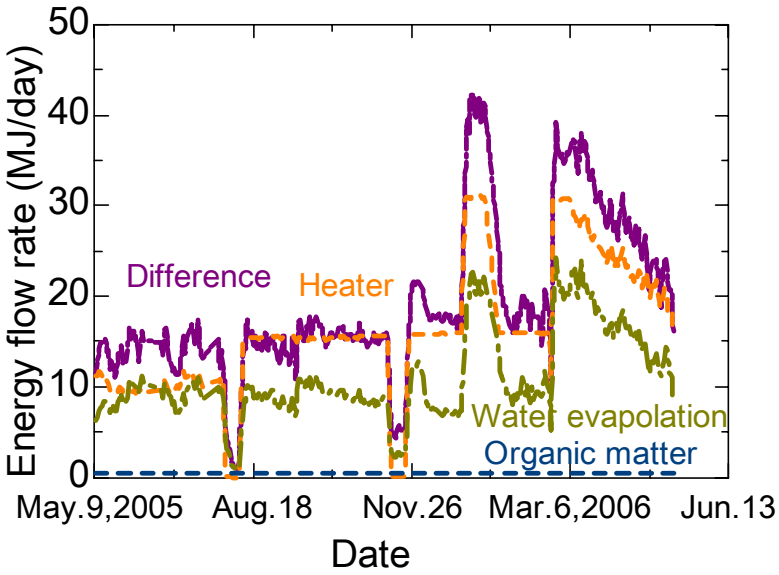
$$q_{evaporation} = \Delta H_{vap} DR$$

Energy consuming structure



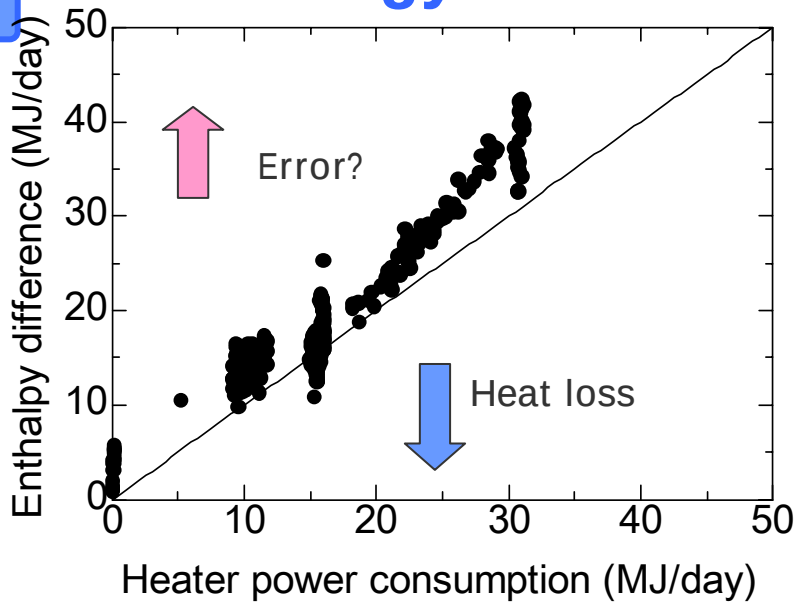
Maximum heater power: 360W

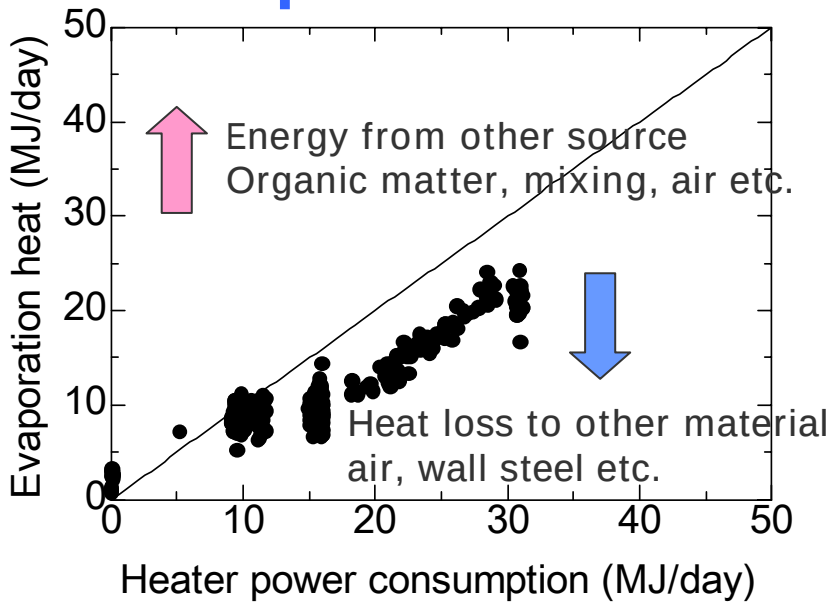




Drying rate: 4kg/day
Organic matter: very small
Difference between inlet and outlet air agrees with heater

Influence of heater power consumption on energy difference of air and evaporation heat





There is strong correlation between heater power consumption and energy difference.

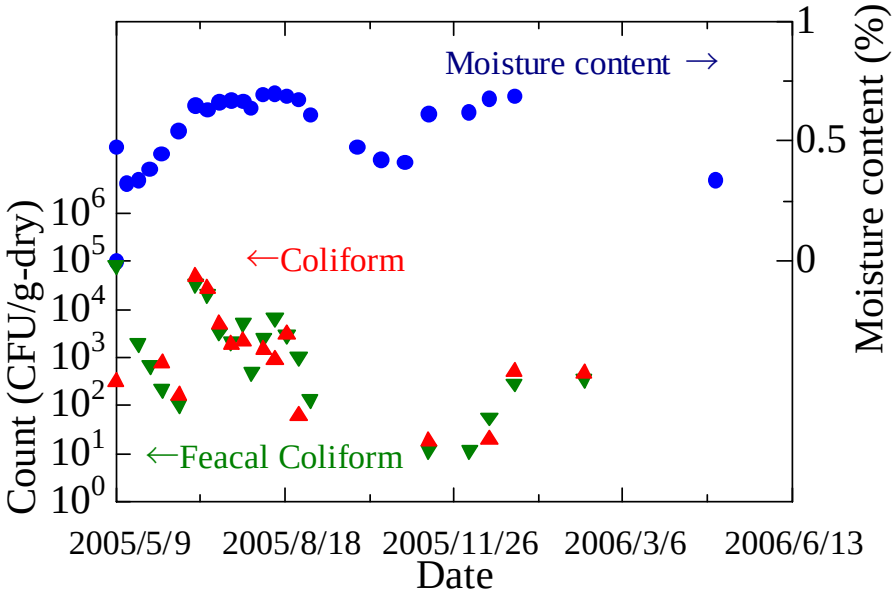
->Supplied energy from heater transferred to ventilation air, including water evaporation heat

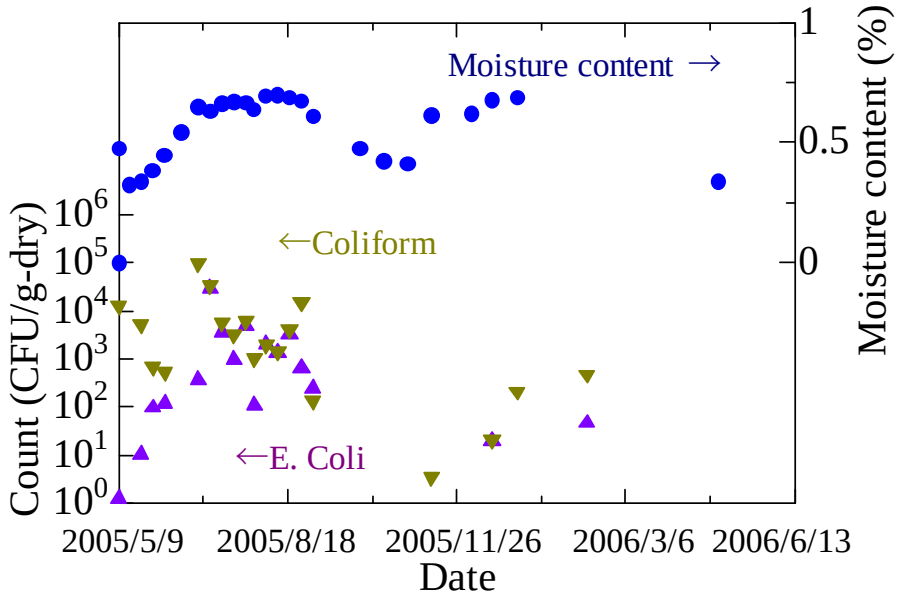
Water evaporation heat was smaller than supplied energy,
and strong correlation between them.

->Strong correlation between drying rate and heat power consumption

->How about the ratio?

Pathogens in compost

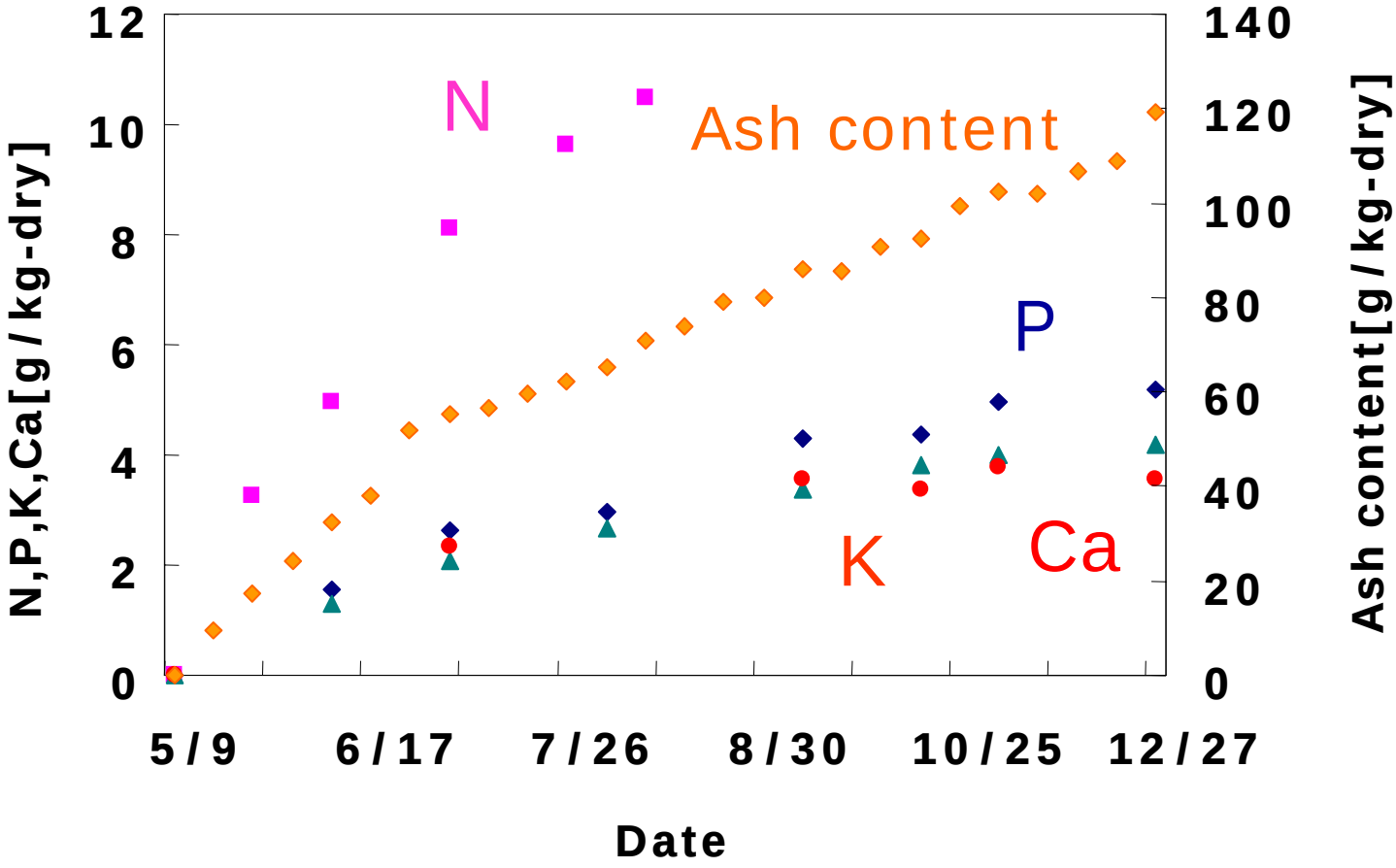




Coliform count -> less than 10^5 CFU/g-dry compost
-> risk assessment – next trial

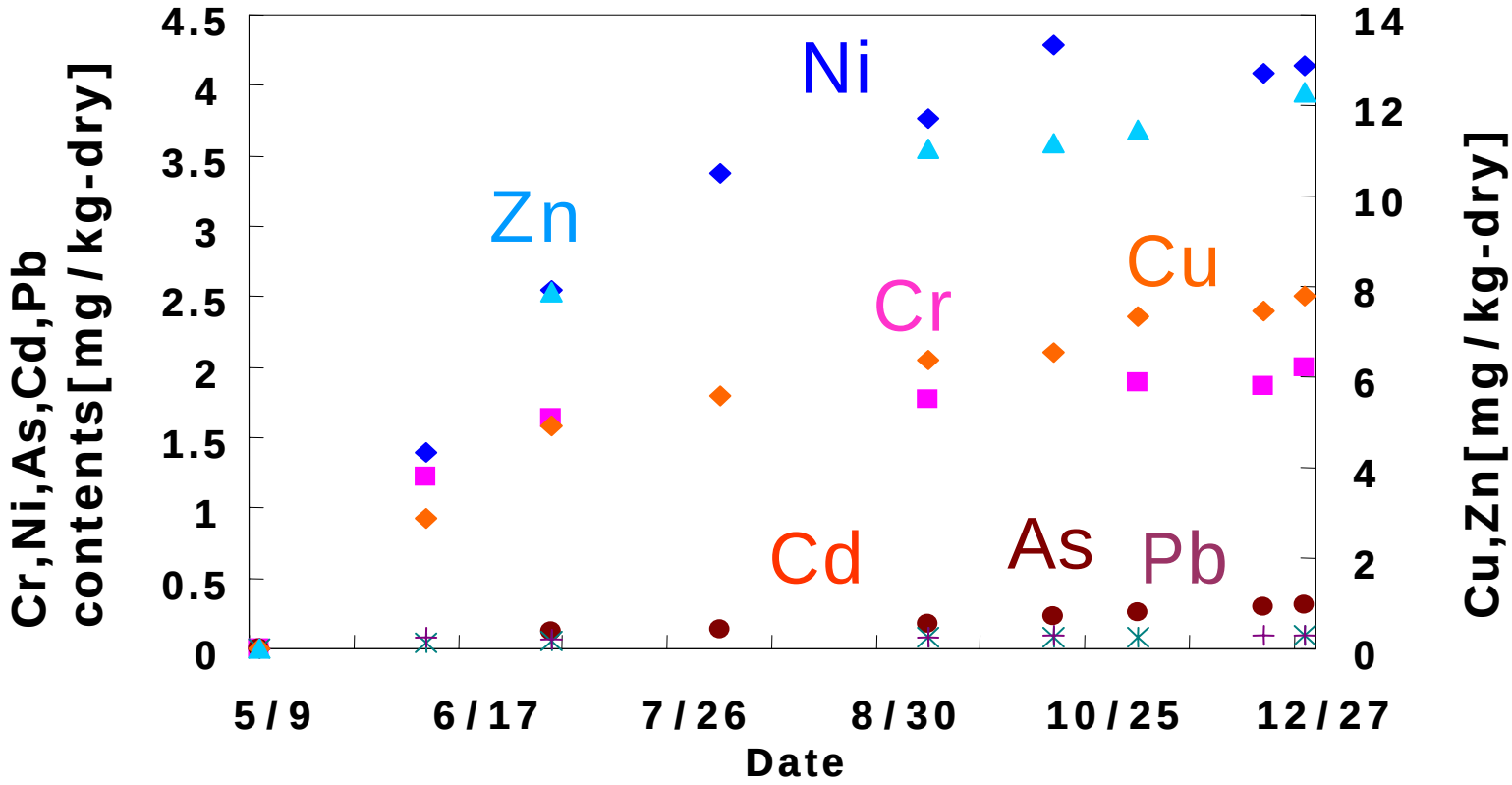
Measured by Prof. Otaki

Materials in compost



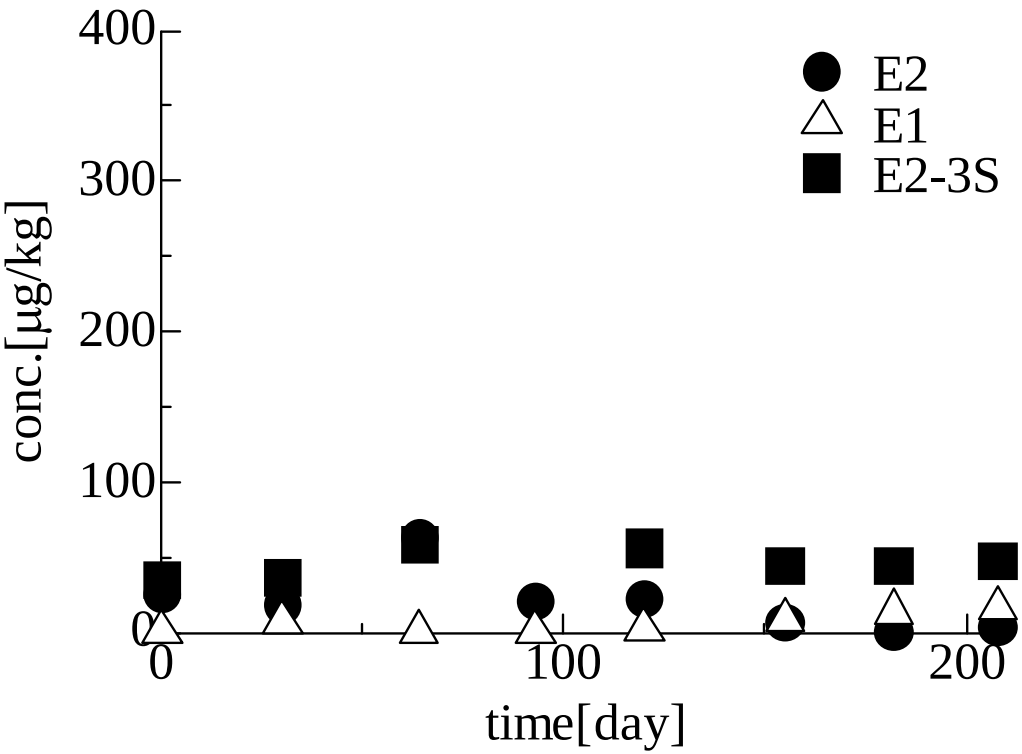
Prepared by Miss. Fukuda

Materials in compost



Prepared by Miss. Fukuda

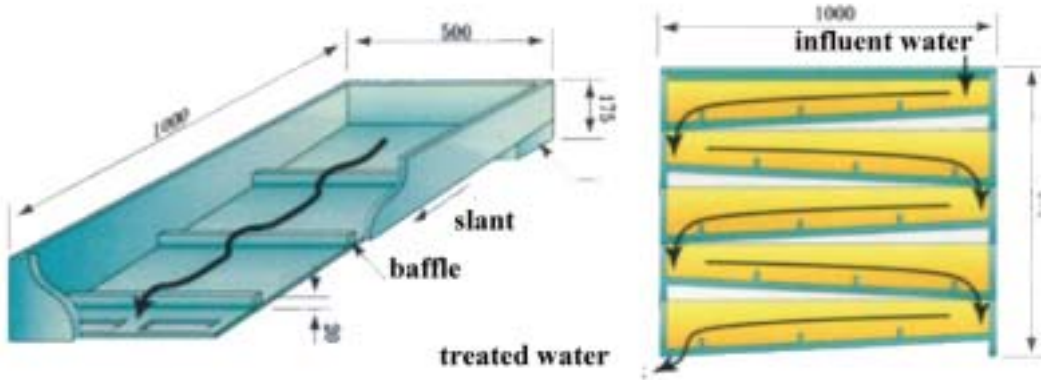
Accumulation of estrogenic compounds into compost



Gray water treatment

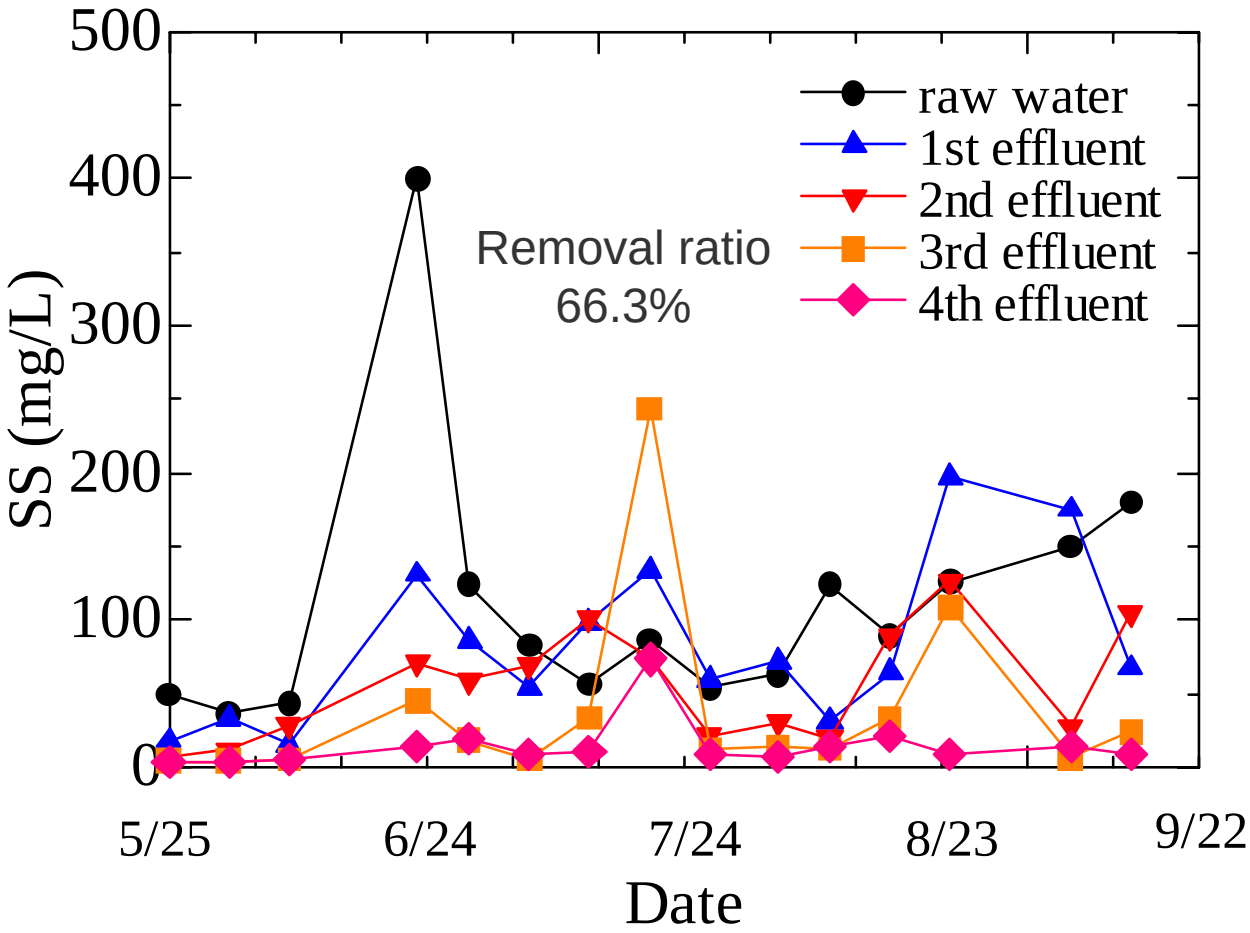
SLANTED SOIL TREATMENT SYSTEM ON CHICHIBU SITE

Kanuma Soil
soft and porus soil

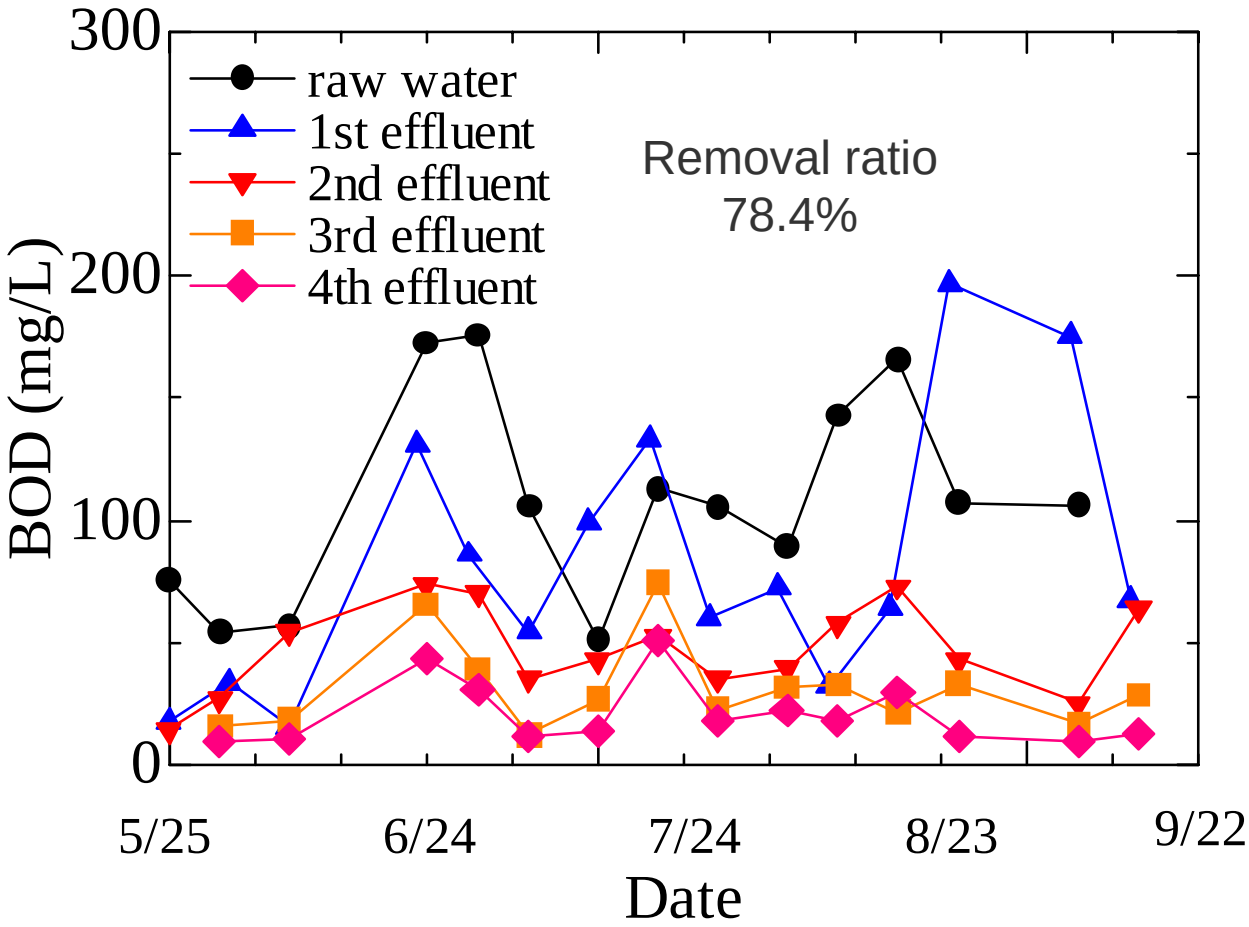


Slanted soil treatment system

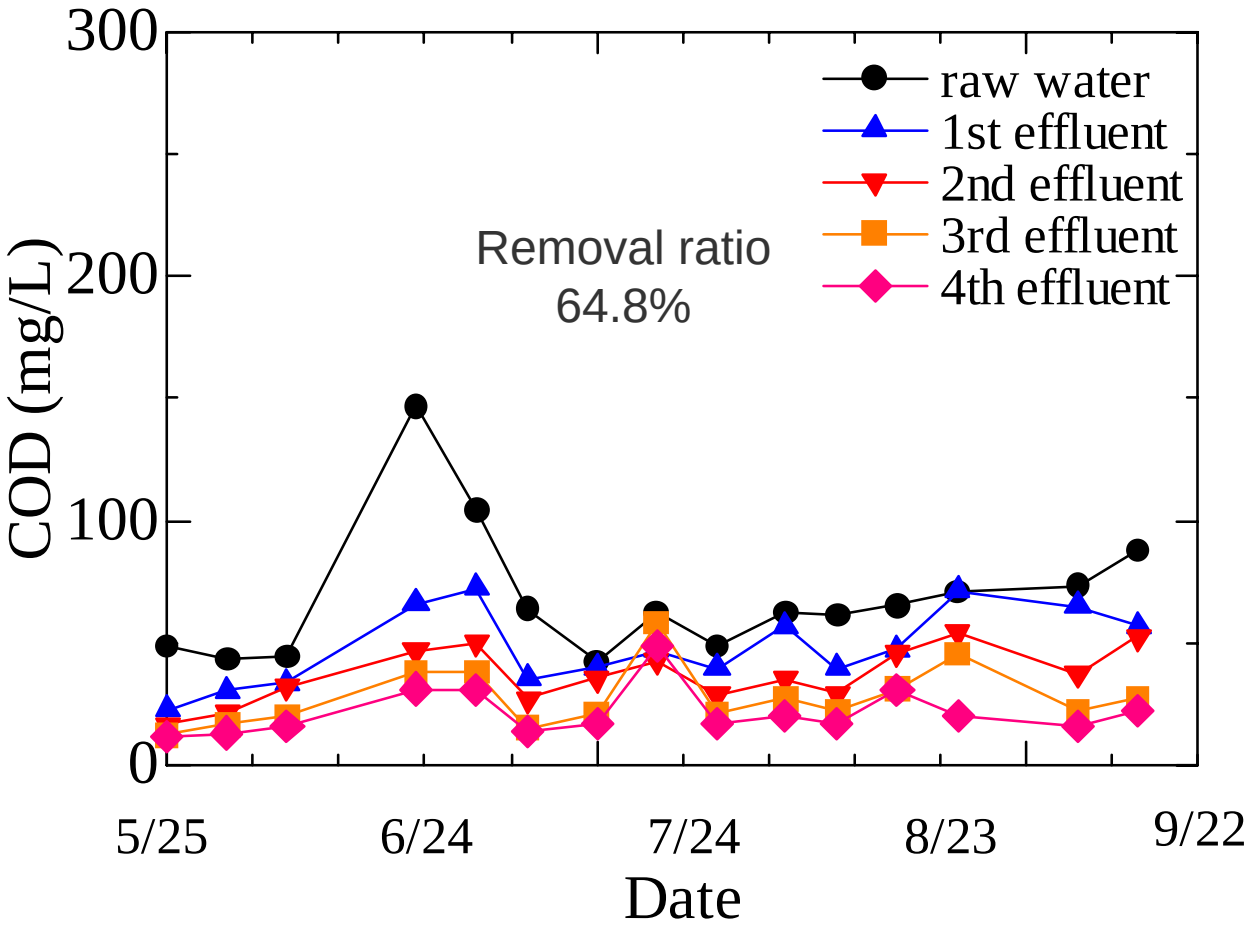
Operation result (SS)



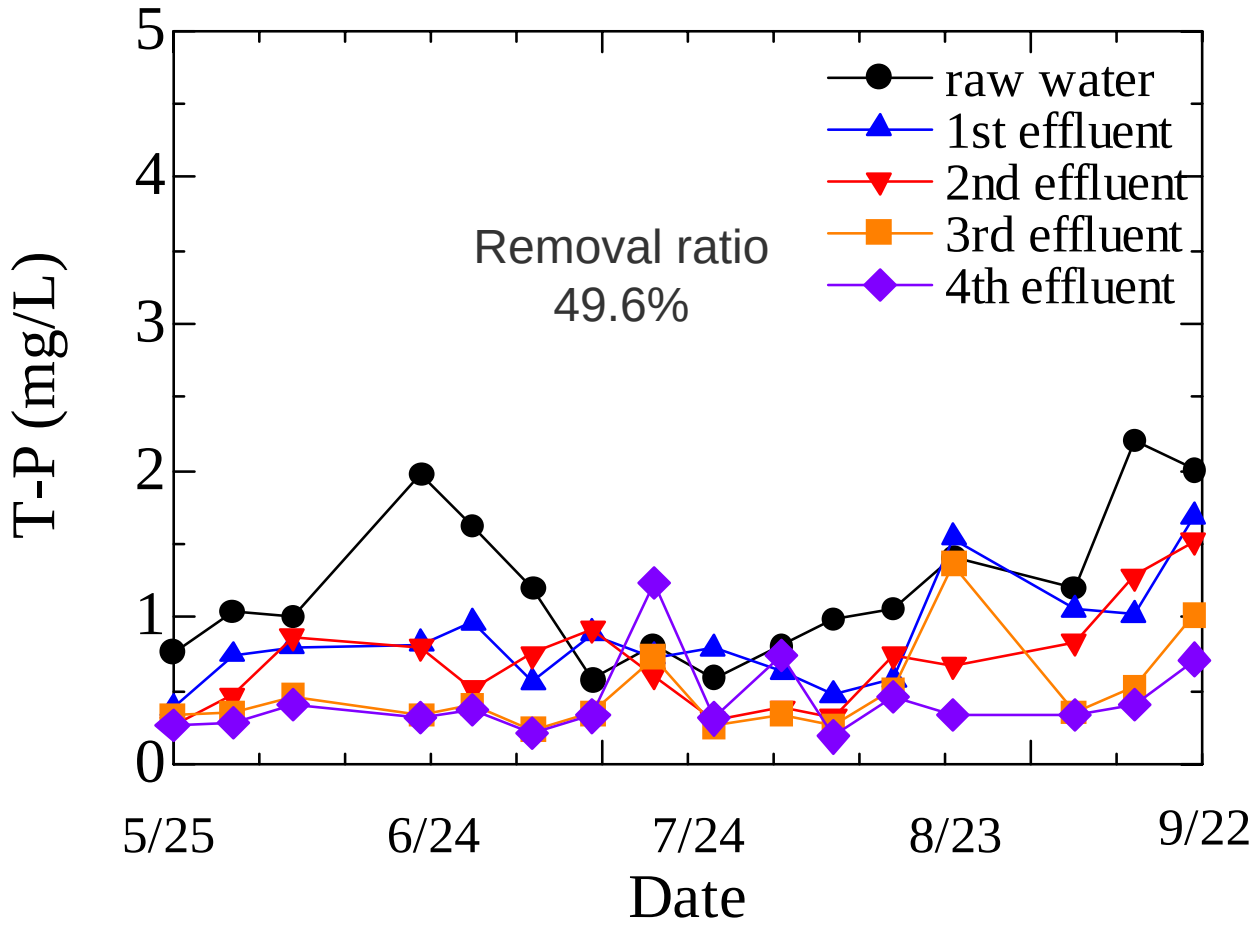
Operation result (BOD)



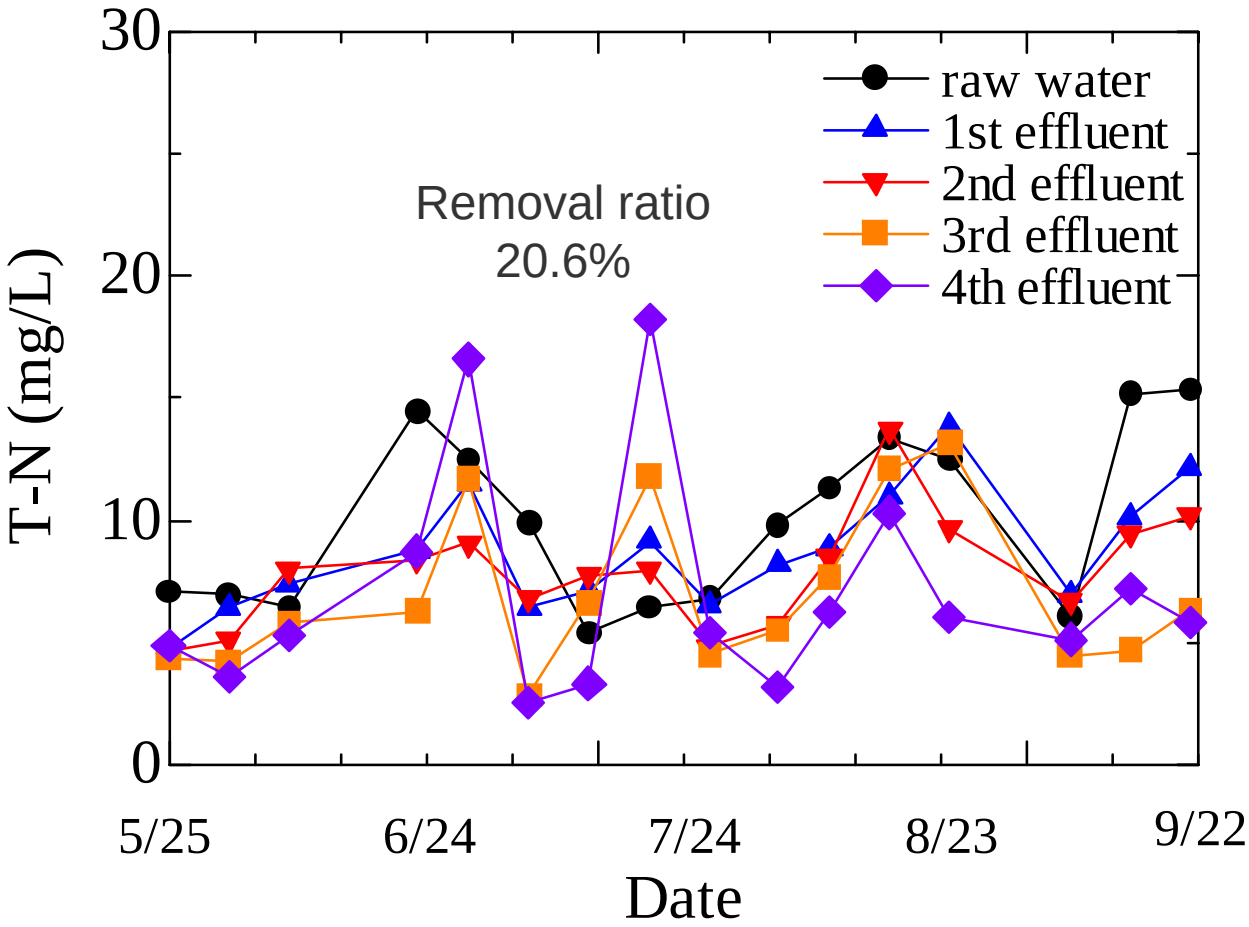
Operation result (COD)



Operation result (Total Phosphor)

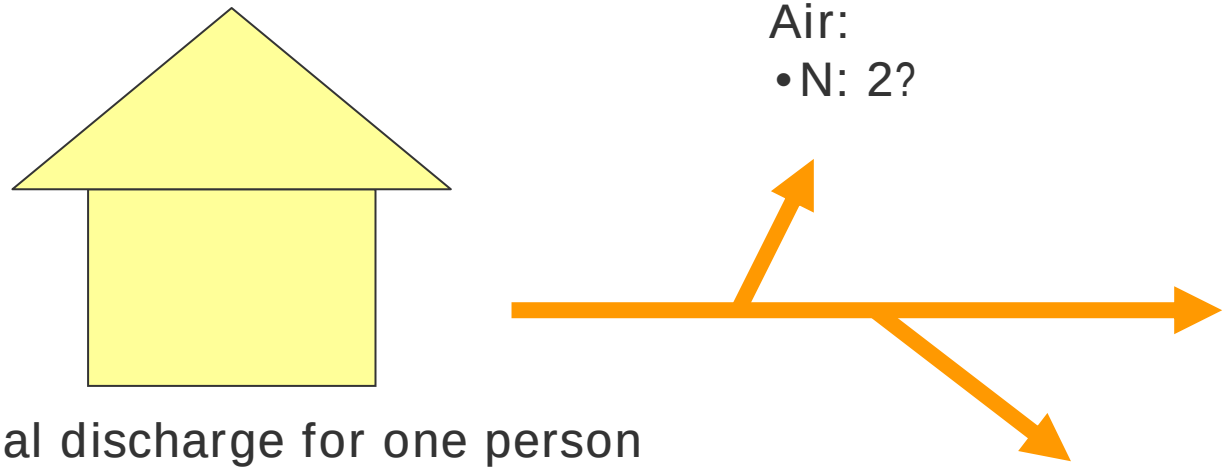


Operation result (Total Nitrogen)



Material flow through the OWDTS

Unit: kg/year



Air:
- N: 2?

Effluent:
- N: 0.095-0.12
- P: 0.036
- COD: 4.2

Annual discharge for one person

Generation as gray water
- N: 0.12-0.15
- P: 0.07
- COD: 12

Generation as black water
- N: 4-5
- P: 0.68
- CDO: 18

Total generation
- N: 4.12-5.15
- P: 0.75
- COD: 30

Accumulation into compost
- N: 1.6-3?
- P: 0.7
- COD: ?

Recovery ratio
- N: 50%?
- P: 95%

Removal ratio from effluent
- N: 95%
- P: 95%
- COD: 85%

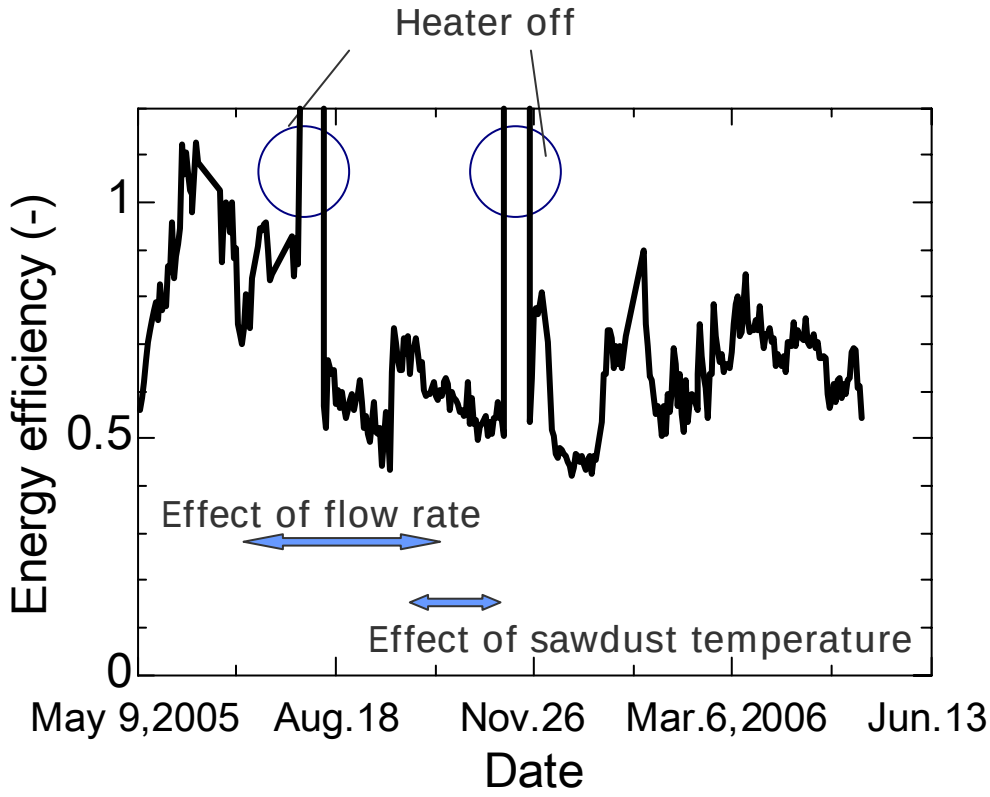
Summary

- Pilot plants for OWDTS worked well and are still under operation.
- Monitoring systems were developed on all sites.

- Composting toilet
  - Structure of energy consumption was analyzed.
  - Water evaporation occupied more than half of whole energy consumption.
  - Accumulation of materials and pathogens were measured.
  - The compost satisfied environmental regulation in Japan.
- Slanted soil treatment system
  - Removed 60% of COD.
  - Poorly removed nitrogen.

- Material circulation
  - The compost was reused into farmland.

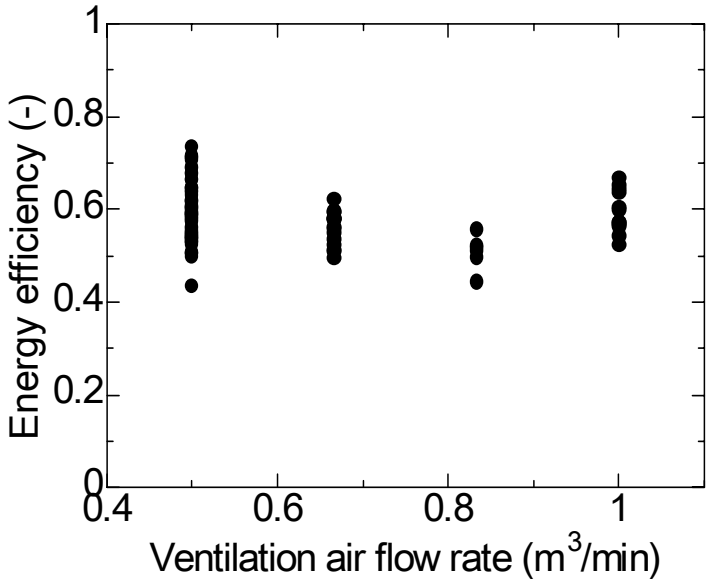
Heat efficiency

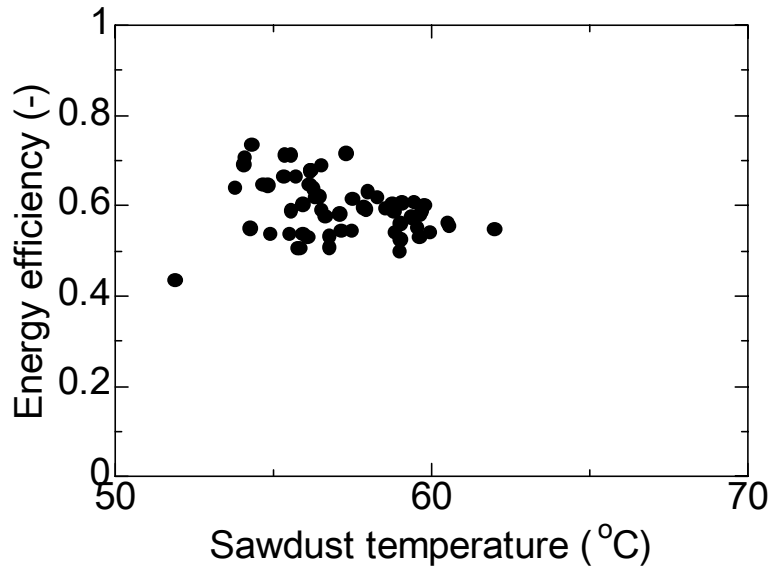


definition

$$\text{Energy efficiency (-)} = \frac{\text{Evaporation heat (kJ/day)}}{\text{Power consumption (kJ/day)}}$$

Effect of ventilation air flow rate and sawdust temperature

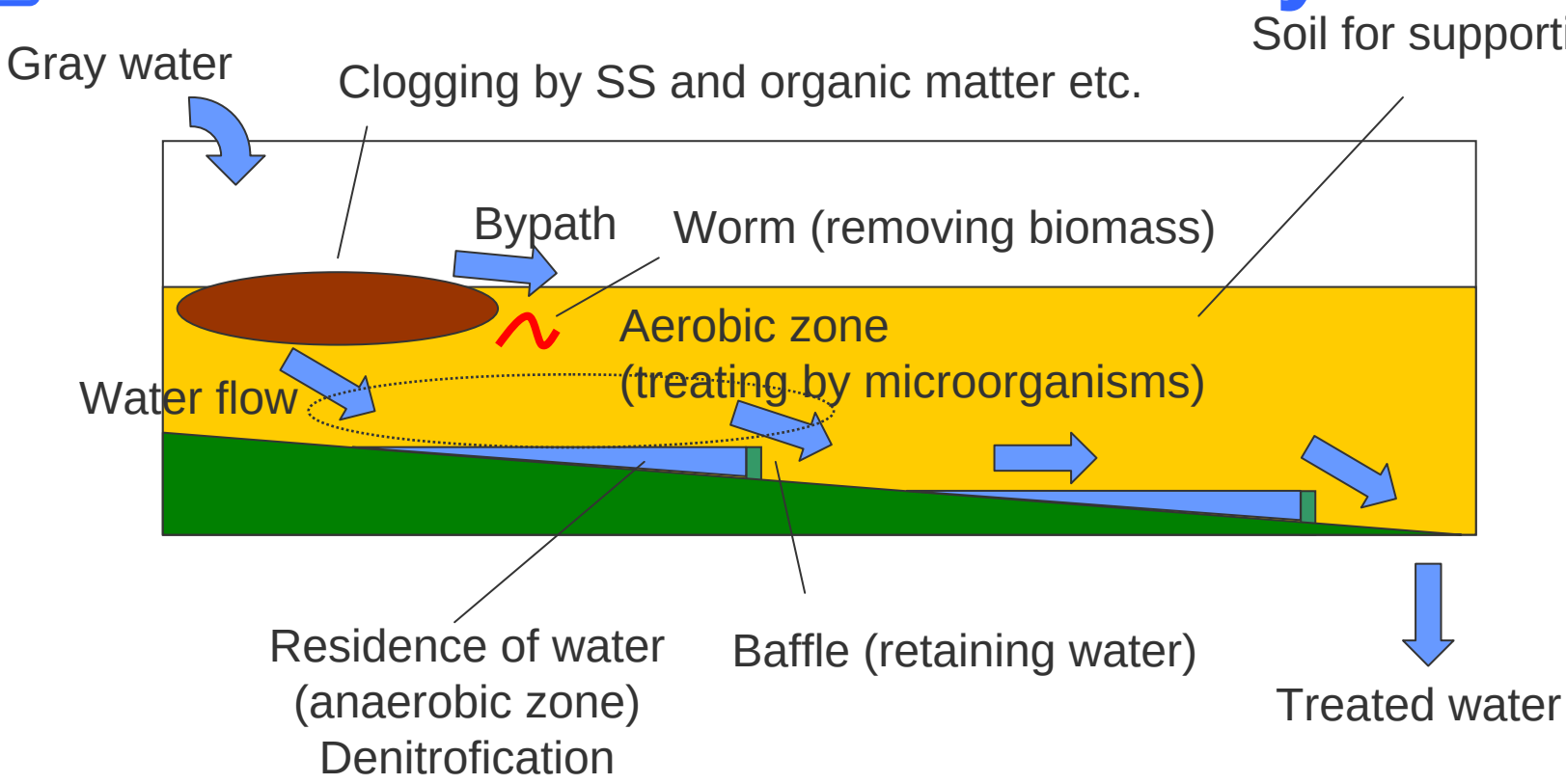




- Slight effect of ventilation air flow rate and sawdust temperature

<- other drying process limits drying rate and energy transfer rate?

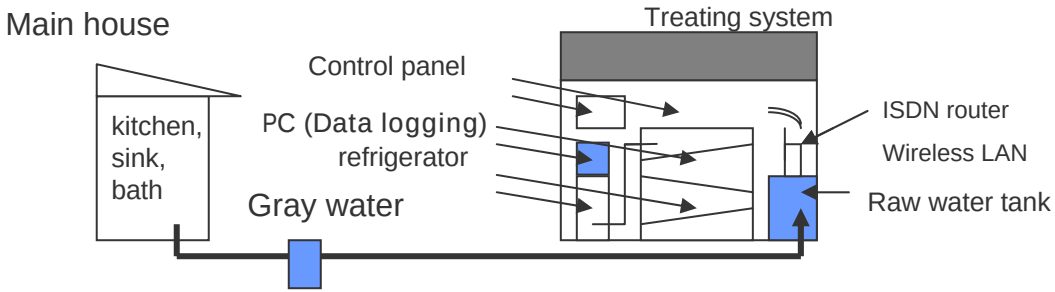
Mechanism of slanted soil treatment system



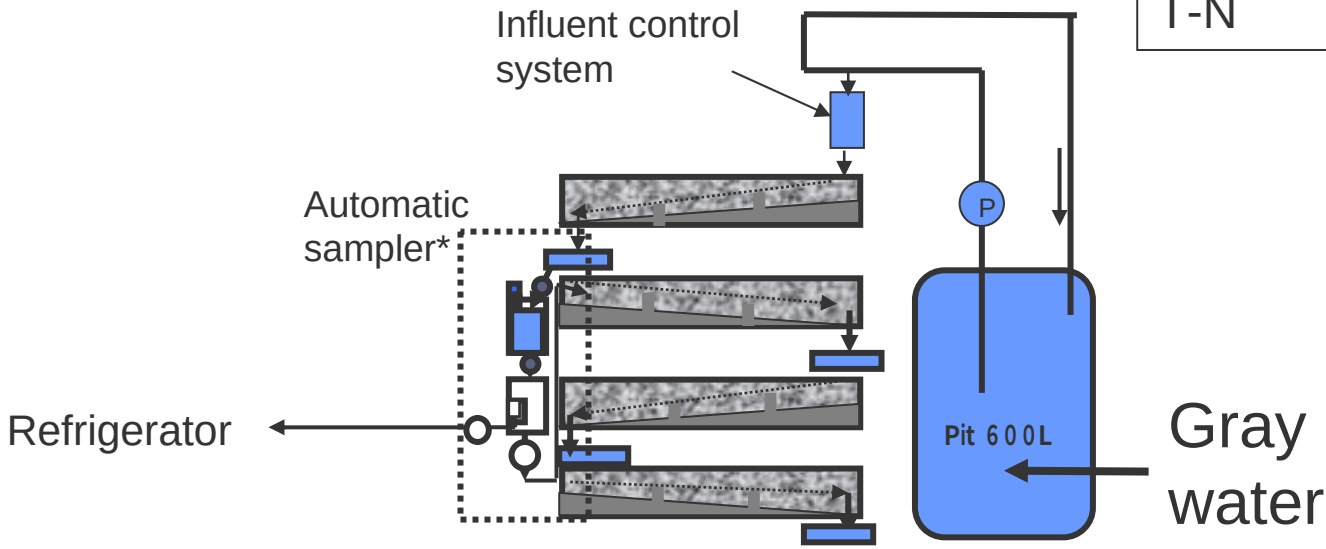
Features

- Operation with small water head
- Large capacity for clogging SS
- Thin layer thickness for stacking

Experimental facility (gray water treatment)



Measured items
SS
COD
BOD
T-P
T-N



∗Automatic sampler: This device makes composites for all effluent.