Sustainable Sanitation System based on the concept: “don’t collect” and “don’t mix” wastewater

NAOYUKI FUNAMIZU
My topic today is

- Why do we have to develop a new sanitation system?
- Our interdisciplinary research project supported by Japan Science and Technology Agency
> 1.2 million tons of fresh excreta deposited in the environment and water sources each day
To achieve the Millennium Development Goals
Water Supply and Sanitation 2000

Up to 5.5 billion people will be without sanitation by the year 2035, if sanitation provisions continue to be installed based on the current standards.

Sanitary means for excreta disposal
Sanitation Issues in Asia

Distribution of the global population not served with improved sanitation (WHO, 2001)

- Asia: 80%
- Africa: 13%
- Latin America: 5%
- Europe: 2%

Economical Issues
*(Peter Wildere, 2002).*

- It becomes evident that the capacity of the global money market would not be sufficient to cover the need for investment capital for centralized system.

- The rehabilitation cost for the piping system in Germany is estimated to be in the range of 100 billion euros.

- The cost of the installation of the pipe system is almost one order of magnitude higher than the cost of building the treatment facilities.
Watershed Management
Don’t collect

- Taking water from a discrete location and discharging it to a distant surface water body may have negative effect on the water cycle in that area.
- Sewers and water mains are leaking
Water Resource

Don’t collect

- A significant amount of the drinking water is used as a means to transport the pollutants
- Reuse wastewater by retaining water near the point of origin
Managing raw wastewater quality to recycle nutrients and to use simple treatment process

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Volume</th>
<th>COD</th>
<th>NH$_4$-N</th>
<th>NO$_3$-N</th>
<th>PO$_4$-P</th>
<th>TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC</td>
<td>31%</td>
<td>44%</td>
<td>97%</td>
<td>3.8%</td>
<td>80%</td>
<td>77%</td>
</tr>
<tr>
<td>Kitchen sink</td>
<td>13%</td>
<td>23%</td>
<td>0.3%</td>
<td>38%</td>
<td>9.4%</td>
<td>10%</td>
</tr>
<tr>
<td>Wash Basin</td>
<td>13%</td>
<td>11%</td>
<td>0.1%</td>
<td>11%</td>
<td>1.3%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Bath</td>
<td>16%</td>
<td>2.5%</td>
<td>0.6%</td>
<td>15%</td>
<td>1.1%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Shower</td>
<td>12%</td>
<td>6.4%</td>
<td>0.7%</td>
<td>25%</td>
<td>4.1%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Washing machine</td>
<td>16%</td>
<td>22%</td>
<td>1.2%</td>
<td>7.6%</td>
<td>4.3%</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

Don’t Mix
Controlling micro-pollutants
Feces Philia Culture vs Feces Phobia Culture

This figure is modified from Professor Kada’s original by Funamizu.
ONSITE WASTEWATER DIFFERENTIABLE TREATMENT SYSTEM

House

Feces, Urine, Garbage

Bio-Toilet

Compost

Treatment

Agriculture

Ground and/or Surface water

Soil System

Bath & WB

KS & WM

Rain Water
Benefits

- Separating black water gives
  - Recovery and recycle of nutrients
  - Elimination of micro-pollutants in urine
  - Elimination of sources of pathogens
  - Reduction of wastewater flow
  - Conservation of water resources

- On-site treatment gives
  - No requirement of pipes

- The system creates
  - Material cycle (organic matter and nutrients)
  - New social system such as M&O NPO or company.
Composting Toilet

Air circulation

Exhaust pipe

Fan

Exhausted air

Mixing mechanism

Mixing Device

Sawdust Matrix
SAWDUST MATRIX: Key element of the composting reactor

Sawdust properties:

- High porosity
- High water and air retention
- High drainage
- High bacterial tolerance
- Low apparent density
- Biodegradability

Aerobic biodegradation (without odor)

Use of sawdust for long time

Energy saving when mixing

Reuse as a fertilizer or soil conditioner
BIODEGRADATION OF ORGANIC MATTER

130 g feces/day (wet basis)

23.5 g feces/day (dry basis)

Bio-degradation
Remaining TS: 44%

Design and operation
Accumulation: 15 kg TS/year

10.3 g TS/day

Accumulation: 7.6 kg TS/6 months

Health Risk: Mixing frequency • reaction time and infection risk

![Graph showing health risk over time for different mixing frequencies and infection levels.](image)

(a) Salmonella

Mixing Frequency:
- 2 times/d
- 5 times/d
- 10 times/d
- 15 times/d
- 20 times/d
- 30 times/d

Infection Risk

Time (h)
Compost is safe-1:
Fate of pharmaceuticals (F/S=20%)

Kakimoto and Funamizu: Chemospher (submitted)
Compost is safe-2: Basal Cytotoxicity of compost from Bio-toilet Bio-assay by human

No toxicity was observed

Gray water Treatment-1

Slanted soil treatment system

by Dr. Itayama National Institute for Environmental Studies

A kitchen sink

A slanted soil treatment system of 3 stacks

These figures are prepared by Dr. Itayama
Gray water Treatment-2
MBR without high pressure for kitchen Sink wastewater

- influent
- pump
- reactor
- Water Level sensor
- UF membrane (PAN-100kDa MWCO)

0.5 m
Urine Treatment -1: Concentration of Source-Separated Urine by Electrodialysis

- Max. consumption: 0.1W
- Voltage: 3.4V
- Required membrane area: 400cm$^2$ (for treating 4L of urine in 24 hours)
Electro-oxidation of pharmaceuticals in urine

Possibility of treatment by electro-oxidation process
- : Possible
- : Difficult

Kow

-2

0

3

2 7 12

Neutral

pKa

- Tetracycline
- Oxytetracycline
- Amoxicillin
- Diclofenac sodium
- Aspirin
- Amoxicillin
- Atenolol
- Metoprolol
- Paracetamol
- Iopamidol
- Carbamazepine
- Simvastatin
- Bezafibrate
- Pravastatin
- Ibuprofen
- Naproxen
- Indomethacin
- Caffeine
- Imipramine

Kakimoto, Ohsawa, Funamizu: Proceedings of Annual Meeting of Society of Civil Engineer, 2007
Pilot project
Mitsumasa Yokota, as an Innovation Partner, produced Community Innovation Platform to design the optimized concepts of sustainable sanitation model, including circulation of biomass, harmonized with the nature of Chichibu City. Sharing of a vision with the residents, community and local government, which has inherited the "culture to water" and life style harmonized with nature serves as a starting point of the sustainable system creation.
Human friendly design

Quality: Functional, comfortable, safety and sustainable
Creation of Sustainable Sanitation model by emergent evolution which shall bring the best out of the wisdom harmonized with nature, culture and lifestyle of rural area.

2005年11月：地域の自然・文化・伝統を調和し、「生命」や「感性」を豊かにするイノベーションに関するものがあると主張し、橋本と共に小麦の種を詰めました。

In November 2005, Mr.Hashimoto planted wheat with compost.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>項目</th>
<th>穂長</th>
<th>穗重</th>
<th>穂数</th>
<th>2005年</th>
<th>2006年</th>
<th>2007年</th>
<th>2008年</th>
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<tbody>
<tr>
<td>Control</td>
<td>種別</td>
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<td>8.2</td>
<td>723</td>
<td>69.1</td>
<td>40.2</td>
<td>38.4</td>
<td>38.4</td>
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<tr>
<td></td>
<td>全重</td>
<td>0.6</td>
<td>0.4</td>
<td>0.7</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

We harvested wheat in June 2006.

2006年6月26日 小麦収穫
Slum in Bandung

Kiaracondong

- Water flush toilet (87%)
- Septic tank
- No treatment

Result of interview (62 households)

- Bathing: 30%
- Urination: 29%
- Washing: 13%
- Kitchen: 12%
- Plant: 4%
- Defecation: 12%

Interview Survey

Bandung City

RW02, SUKAPURA village

Kiaracondong district

Population: 1,477

Household: 410

Area: 0.03 km²

Shift the social system

Urban area (slum)

- Toilet
- Kitchen
- Interface
- Garbage

Rural Area

- Water resource area
- Farmland

Collection & Transportation

- Composting Toilet
- Compost
- Water supply

Utilization

Products

River

USHIJIMA Ken (WEC) : 3rd South-East Asia Water Forum: 22nd Oct. 2007
Low cost composting toilet
Compost Collection System

Compost Collector 1 person
Collector works 3 times in a week
Urine collection: once in 2 weeks
Compost collection: once in 4 months

Urine Collector 2 persons

Managed by local community (Each residents pay the cost)

Managed by Bandung City (Each residents pay the cost)

Urine
19 m³/day

Compost
8 m³/day

Middle Station

Collected amount
27 m³/day

To Suburbs

4 m³ → 5 times

8 m³ → 1 time

USHIJIMA Ken (WEC) : 3rd South-East Asia Water Forum: 22nd Oct. 2007
Summary

- Sustainable sanitation system
  - “Don’t mix!”, “Don’t collect”
- Onsite Wastewater Differentiable Treatment System
  - We have developed and analyzed several technologies for on-site differentiable wastewater treatment system
  - The new system for rural area in Japan: Pilot plant in Chichibu, Japan
  - The system for developing countries: Pilot project in Indonesia
CREST team

• Hokkaido University, Graduate School of Engineering: Prof. Funamizu, Prof. Takahashi
• Hokkaido University, Graduate School of Agriculture: Prof. Terasawa
• Tokyo Institute of Technology: Prof. Ishikawa
• Industrial Innovation Partners Inc. Ex-Prsident, Advisor of Chichibu City: Mr. Yokota
• University of Tokyo: Prof. Aramaki
• Ochanomizu University: Prof. Ohtaki
• Tsukuba University: Prof. Isoda
• Nagasaki University: Prof. Tanabe
• Waseda University: Prof. Sakakibara
CREST team

- Indonesian Institute of Science: Dr. Neni
- Xi’an University of Architecture & Technology: Prof. Wang
- Nanjing University: Prof. Xin Qian
- Tsinghua University: Prof. Guangheng Ni
- Northeast Normal University: Prof. Linaxi Sheng
- Water Resources Environment Technology Center: Mr. Kumagai
- IDEA Consultants, Inc.: Mr. Itoh
- Okinawa National College of Technology: Dr. Tada
- National Institute for Environmental Studies: Dr. Jo
- NPO Kokaigawa Project: Mr. Kitamura