Workshop at Hanoi, Vietnam, Nov. 30, 2017

Introduction of Multistage Hybrid Wetland Systems for Livestock Wastewater Treatment in Japan and Vietnam

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NARO 農研機構 National Agriculture and Food Research Organization

TUSK 株式会社 TUSK Co.,Ltd

北海道大学 HOKKAIDO UNIVERSITY

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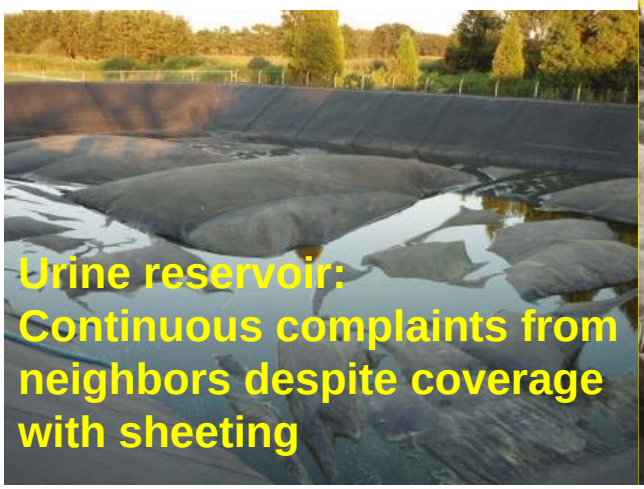
Problems of wastewater from dairy milking parlors

The presence of milk, excreta and detergents in milking parlor wastewater makes its treatment difficult. Such a mixture can contaminate parts of the water system, including underground water and rivers.

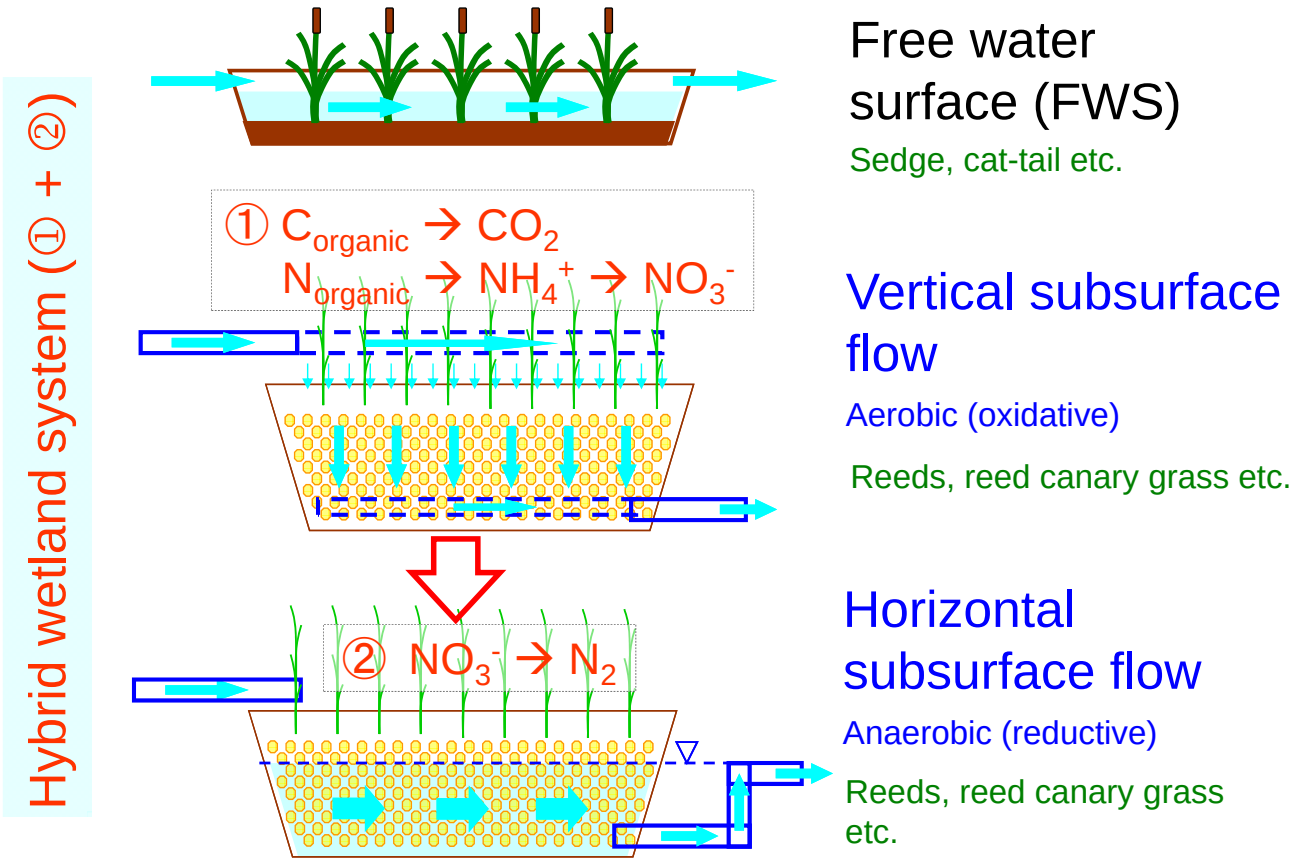
The mixture may contain water used to wash milking lines and floors as well as excreta, detergent and disinfectants.

Pig farm urine issues



Conventional method: high cost

What is a hybrid constructed wetland system ?

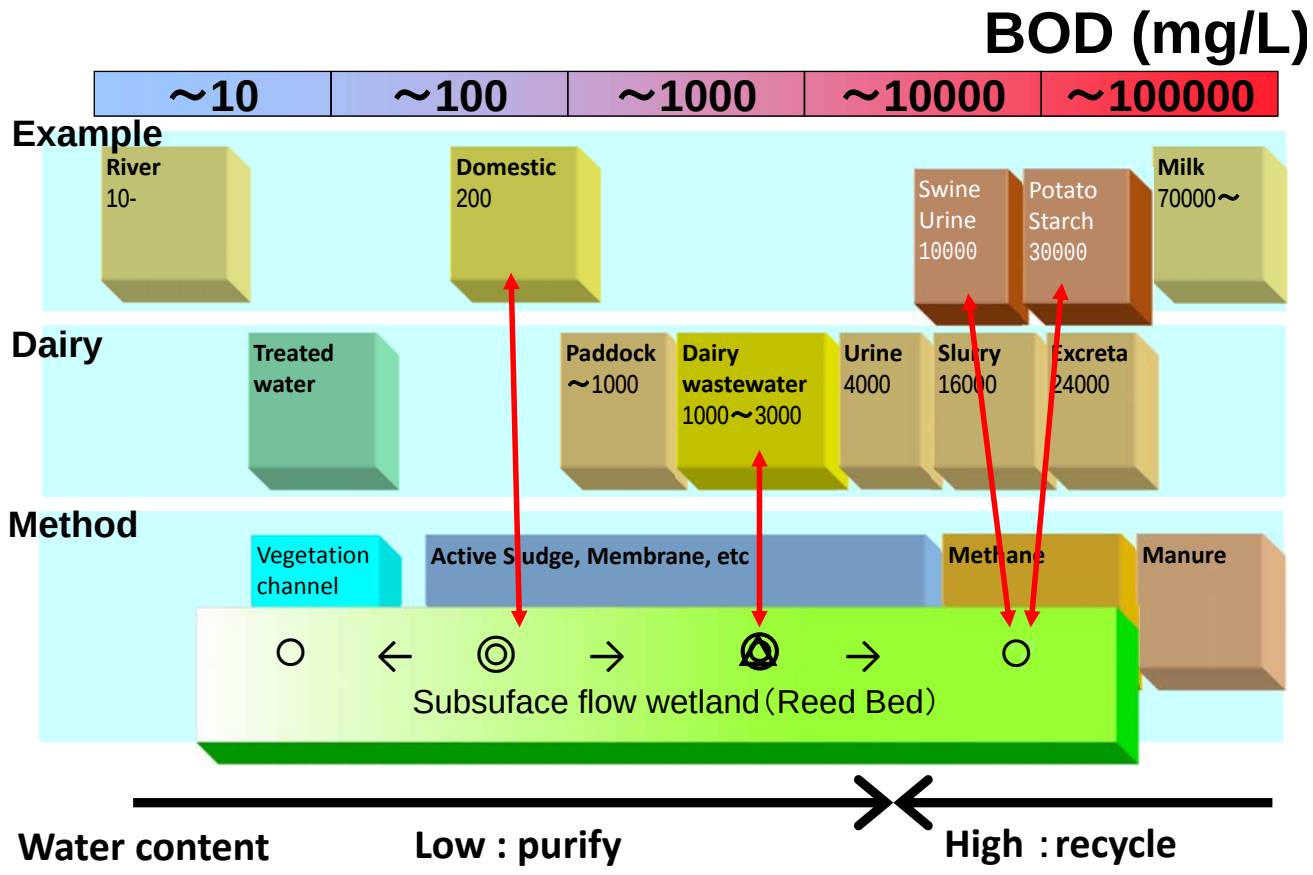


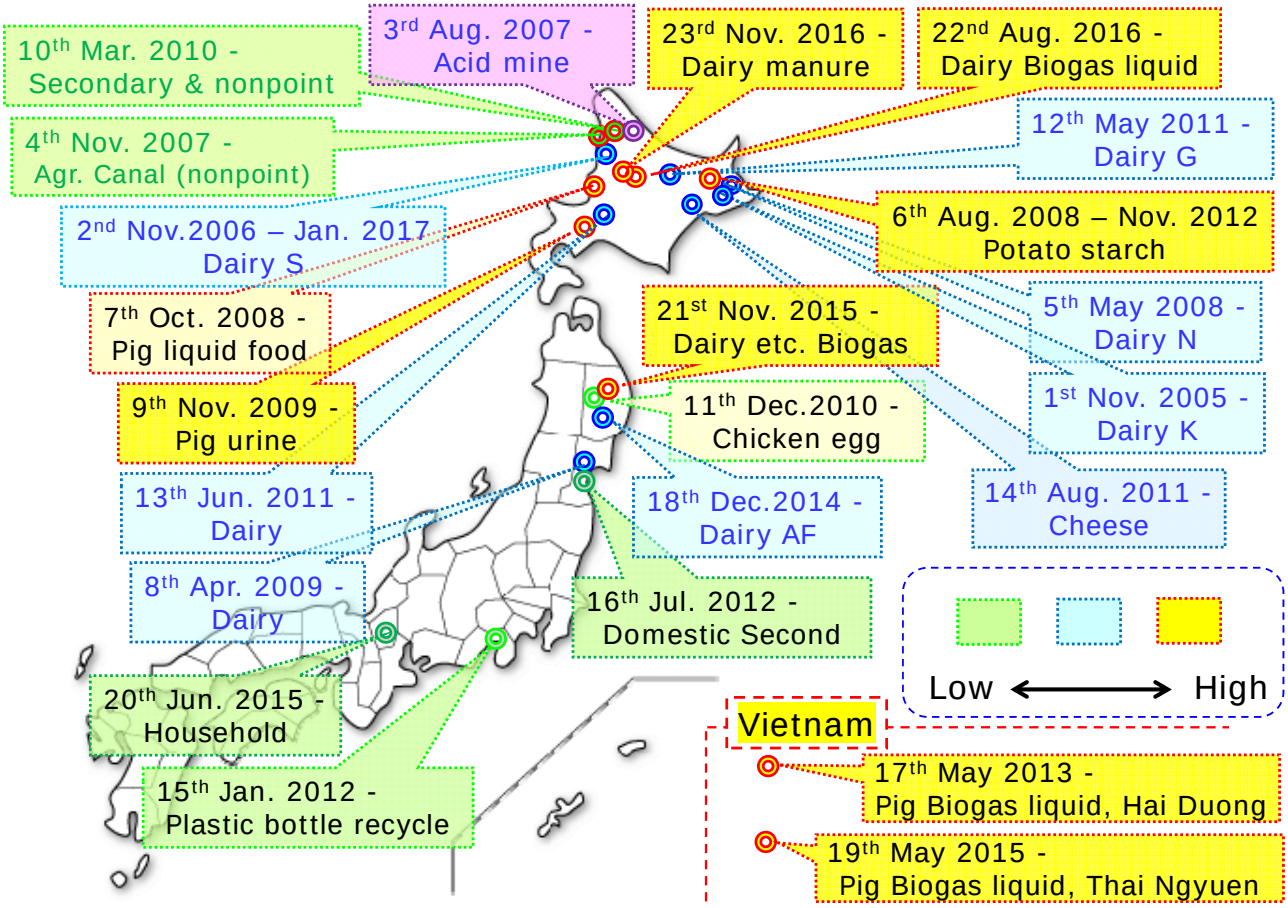
Types of constructed wetlands for wastewater treatment

Merits of multistage wetland system for wastewater treatment

- Low-priced (initial and running costs)
- Electricity-saving and Labor-saving
- Need small space compared from free water surface wetland system
- Prevent the spread of harmful insects as mosquito and horsefly
- Usable throughout years even in cold climates

Range of density treating organic wastewater

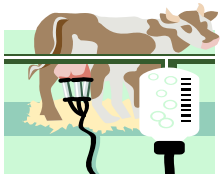




Our constructed wetlands in Japan and Vietnam Jan. 2017

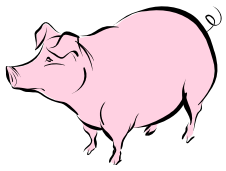
Main issue to treat dense wastewater in cold climates.

Clogging and Freezing



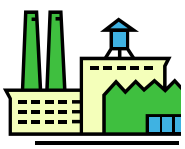
Dairy farm

Milking parlor
2,000 – 5,000 mg COD/L
40 – 80 mg NH_4-N/L



Pig farm

swine urine
10,000 mg COD/L
1,800 mg NH_4-N/L



Potato starch factory

Starch processing decanter
24,000 – 54,000 mg COD/L
1,000 – 1,300 mg NH_4-N/L

A cattle shed (capacity: 400 cows) under construction, Sep. 16, 2005

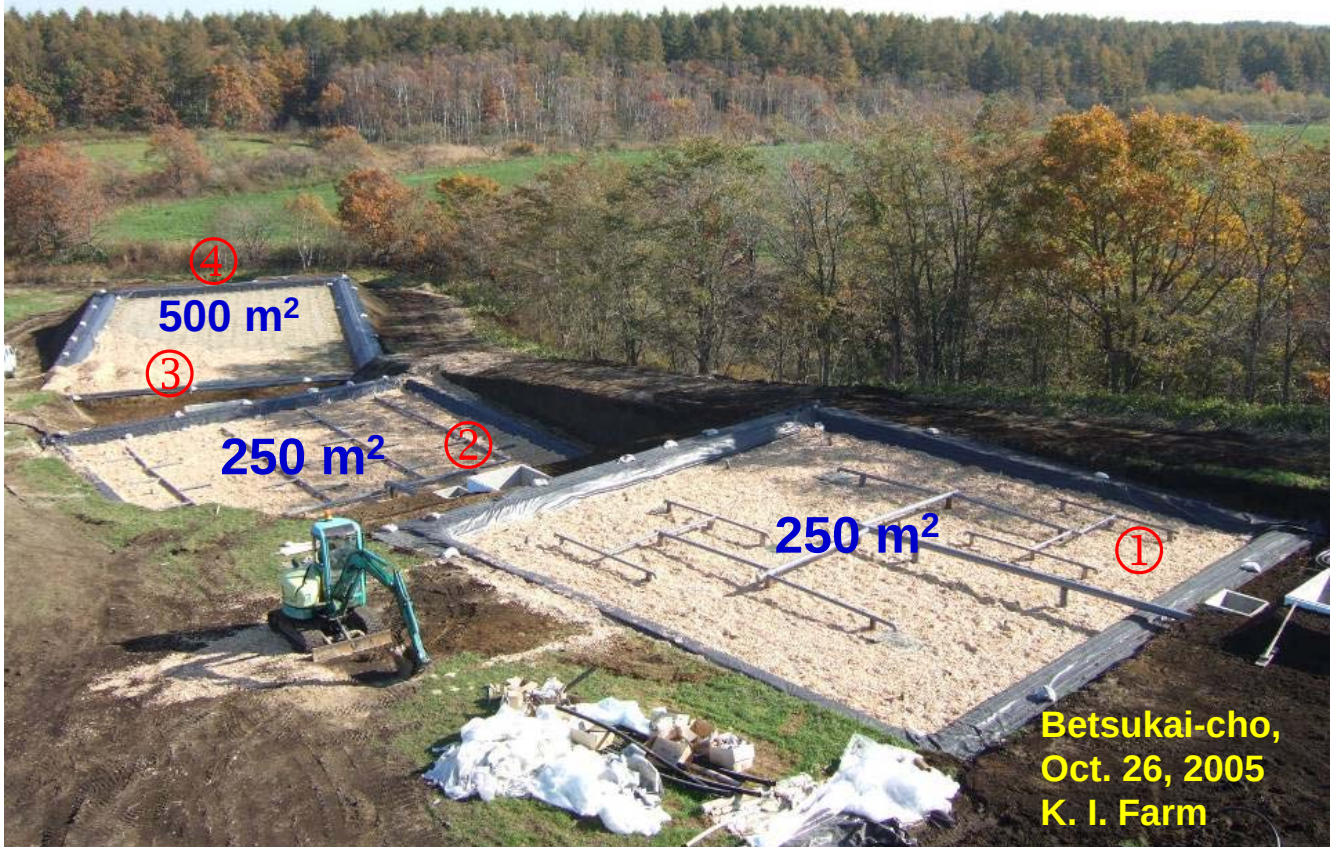
Start construction (digging): Sep. 27, 2005

Siphon installation: Oct. 10, 2005

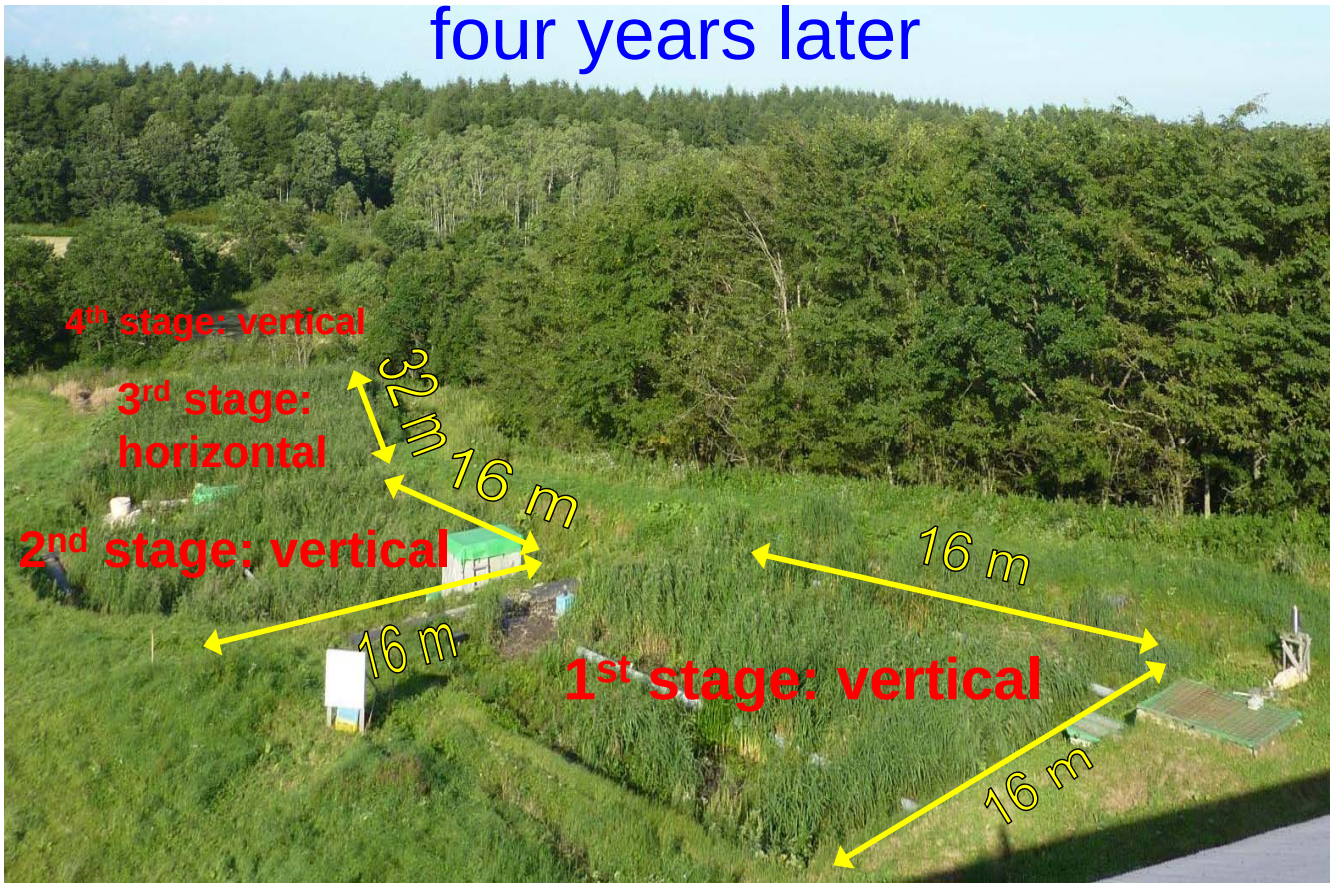
Impermeable sheet installation: Oct. 10, 2005

Filling with materials: Oct. 10, 2005

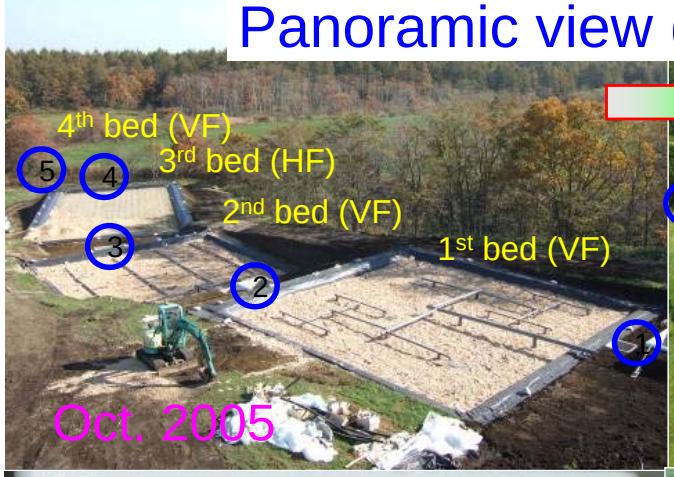
The first subsurface flow hybrid wetland system for dairy wastewater treatment in Betsukai-cho, constructed in fall 2005. Treatment start : Nov. 2017

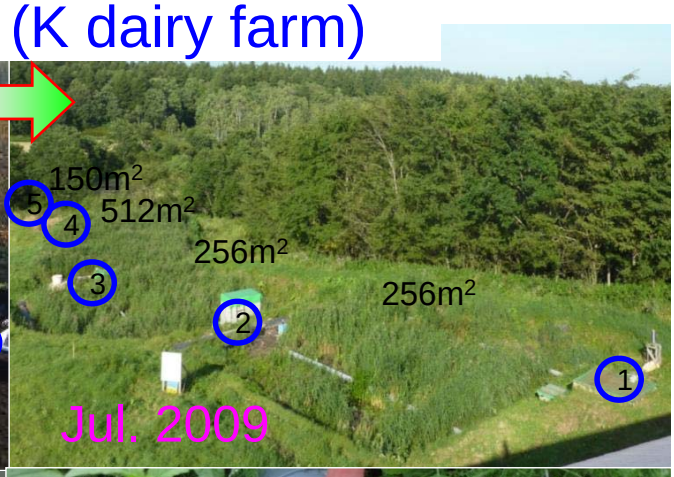


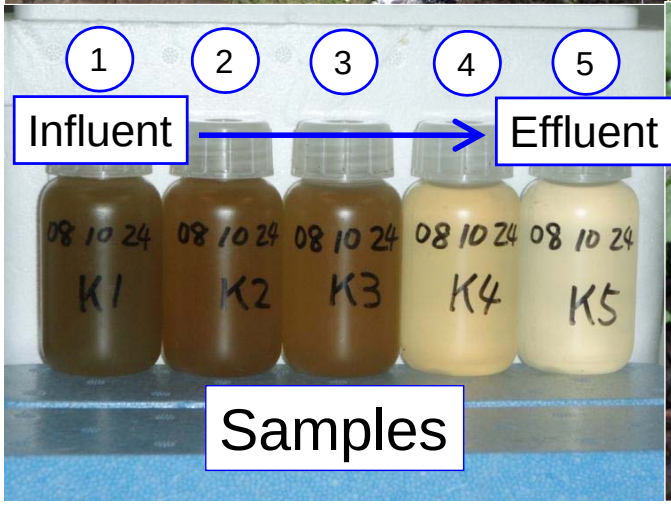
First system in Betsukai-cho: four years later

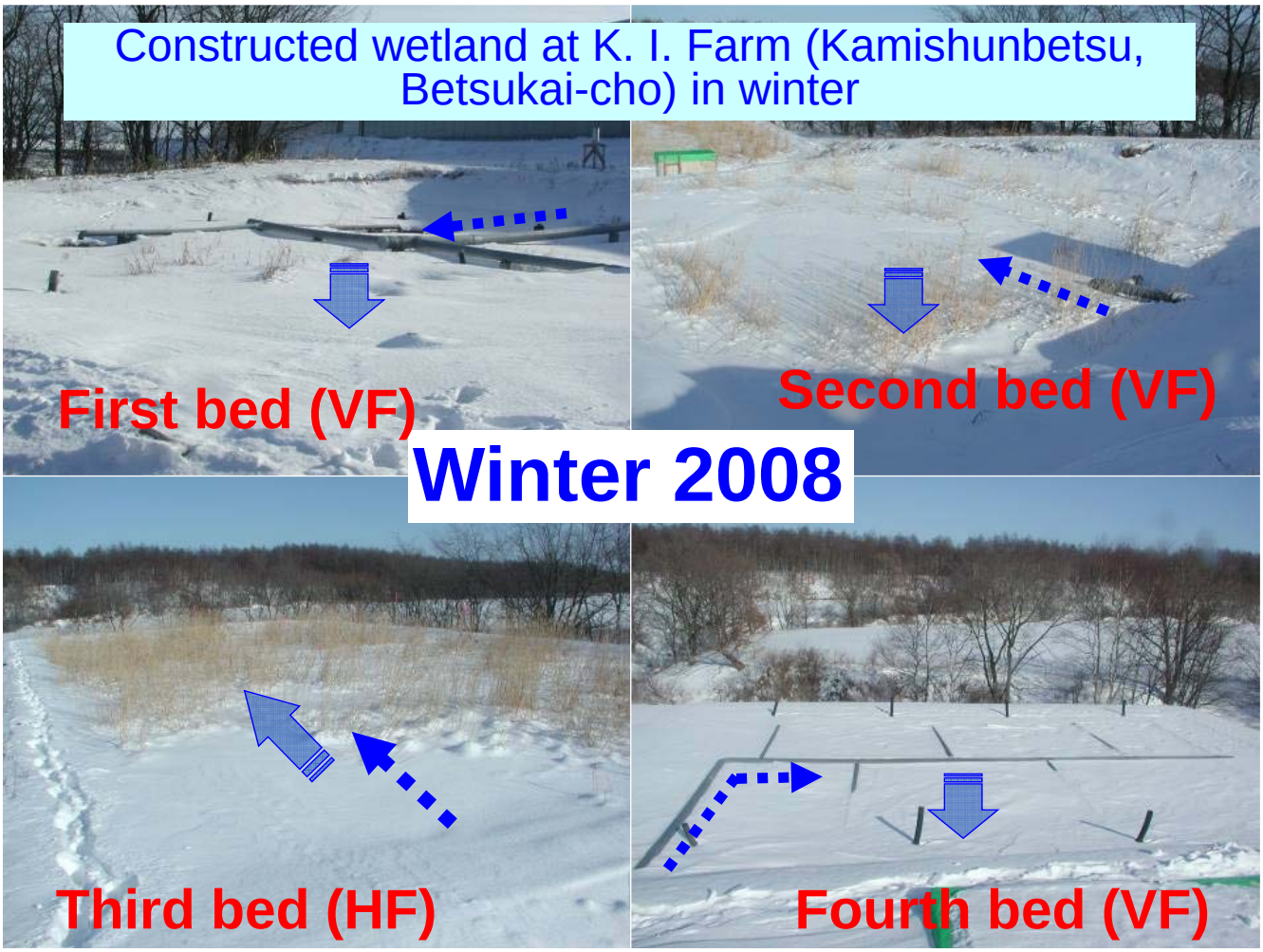


Panoramic view (K dairy farm)



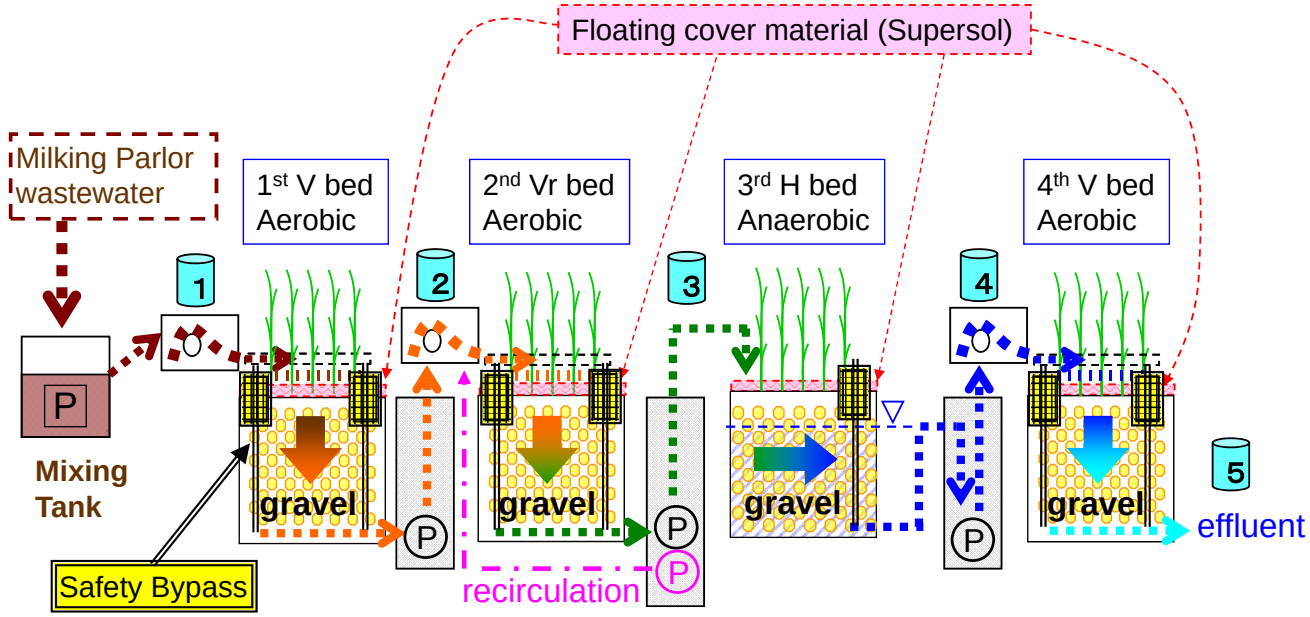






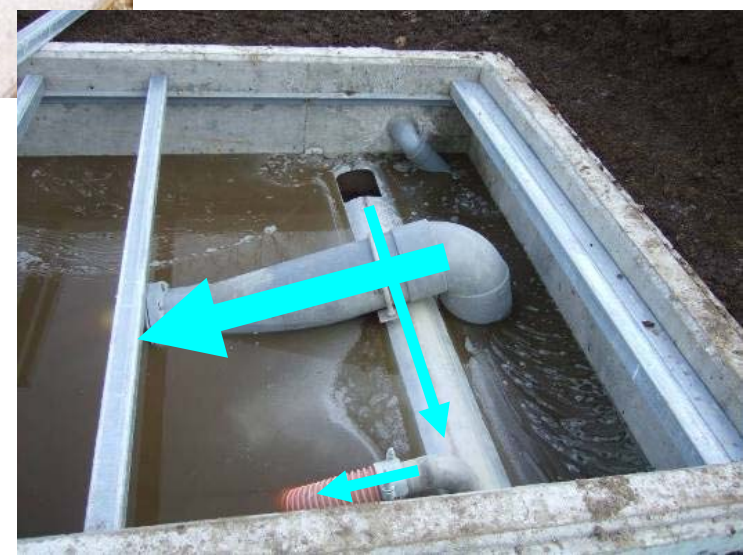
A constructed wetland system developed for dense wastewater treatment in cold climates

- Design
- Mechanism
- Performance
- Cost



A schematic diagram of a multi-stage hybrid wetland system (Example; Dairy farm N)

Miner change of French type self-priming siphon



Every inlet and outlet hole and pipe is single and every flow is one way. So, diameter of each pipe is about 1.4 times thicker for same amount of flow.

Self-priming-siphon operation

Example of KI Farm in Bekkai-cho (Since 2005)

Photo courtesy of Hidehiro Ietsugu, Tusk Co., Ltd.

Main design innovation

- Bypass structure for safety treatment
- Floating cover material on the bed surface

Advantage

- It's able to increase organic load per area without clogging
- Available just after construction while growing reed and earthworm

Minimize the area and cost !

Floating material to insulate cold and to avoid clogging.
Super Sol®
Recycled glass
Density is 0.4 g cm-3
Reinforced safety bypass
Pig farm O
Oct. 2009

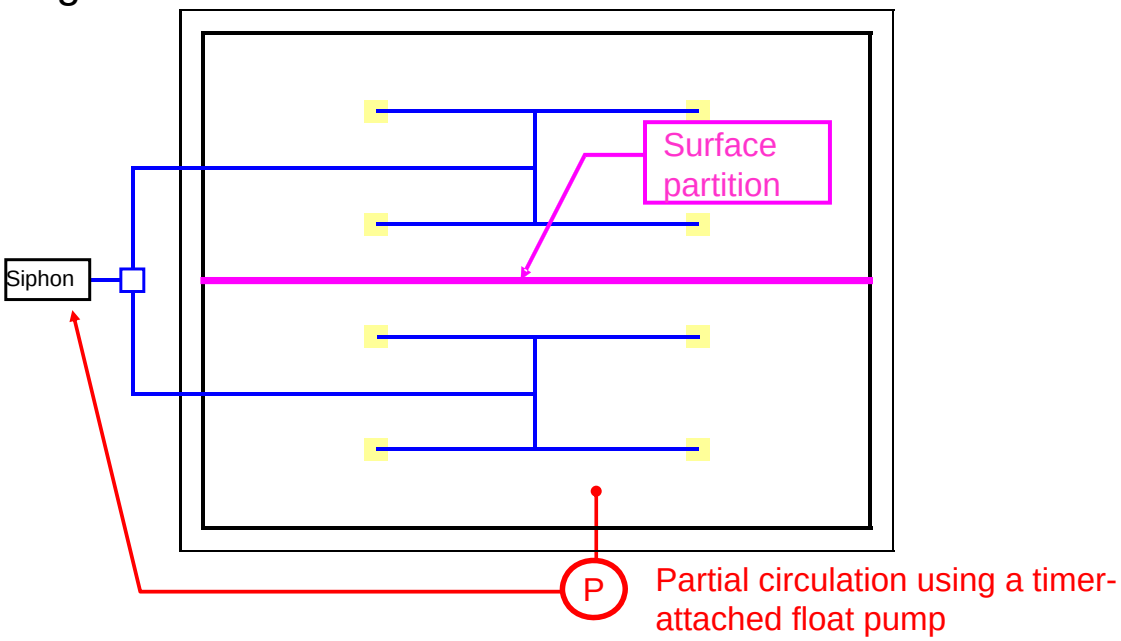
Alternate drying in the growing season
1st summer, Pig farm O
July 2010

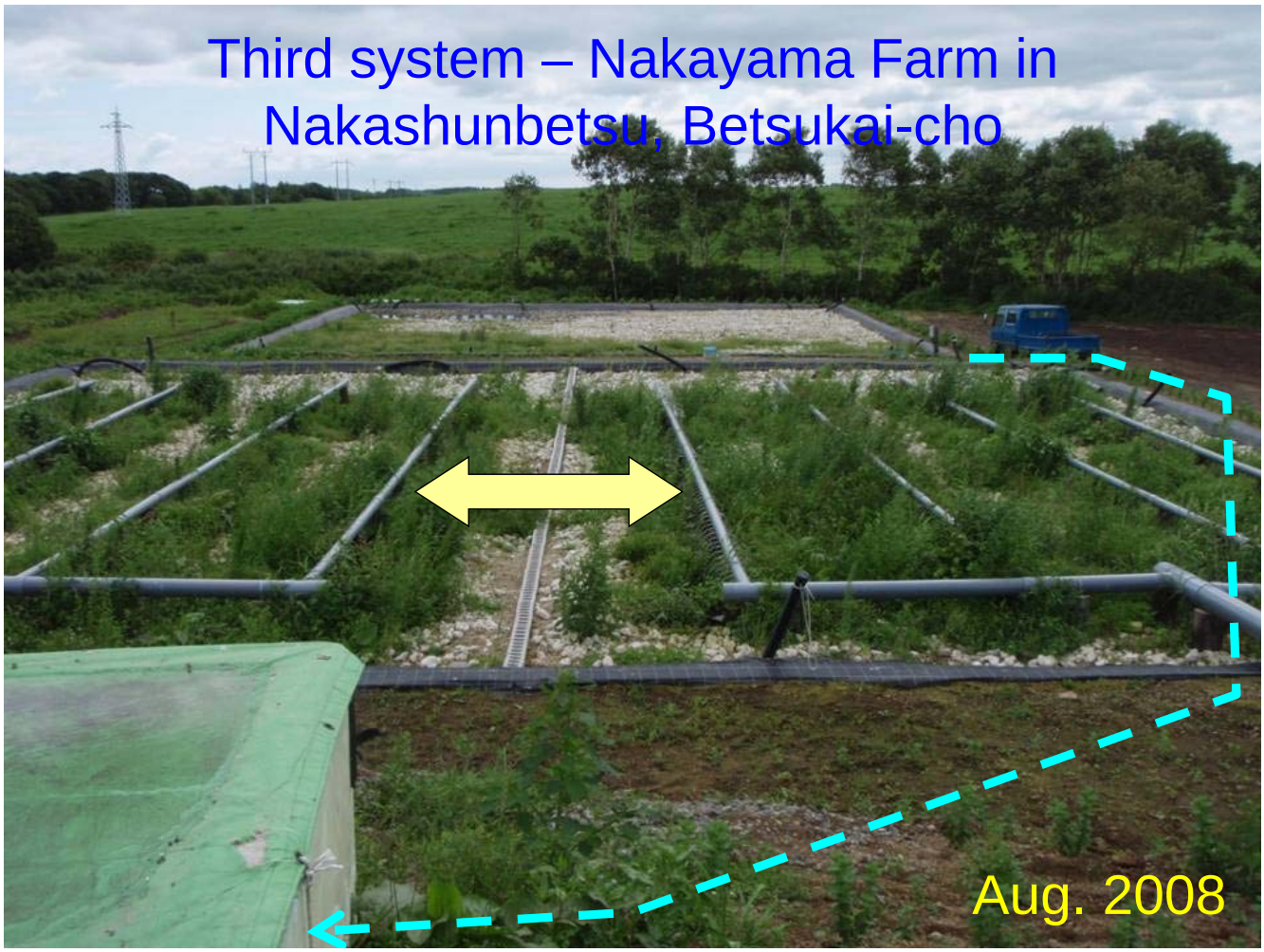
2nd summer, Pig farm O July 2011

2nd winter, Pig O, 1st Vr bed Feb 2011

Combination of alternate drying and recirculation

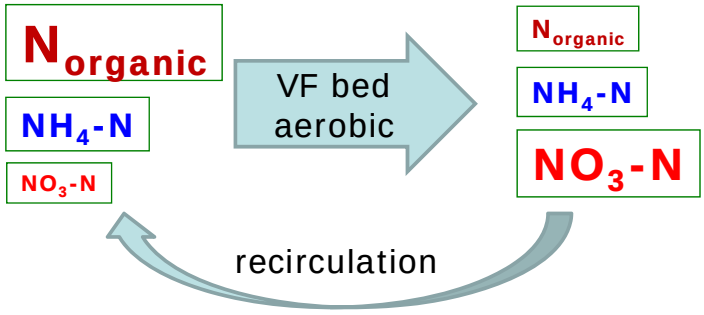
- Drying promotion through surface division and alternate drying of filter beds
- Improvement of the treatment water purification rate through recirculation





$N_{organic} \rightarrow NH_4^+\text{-}N$ (Ammonification)

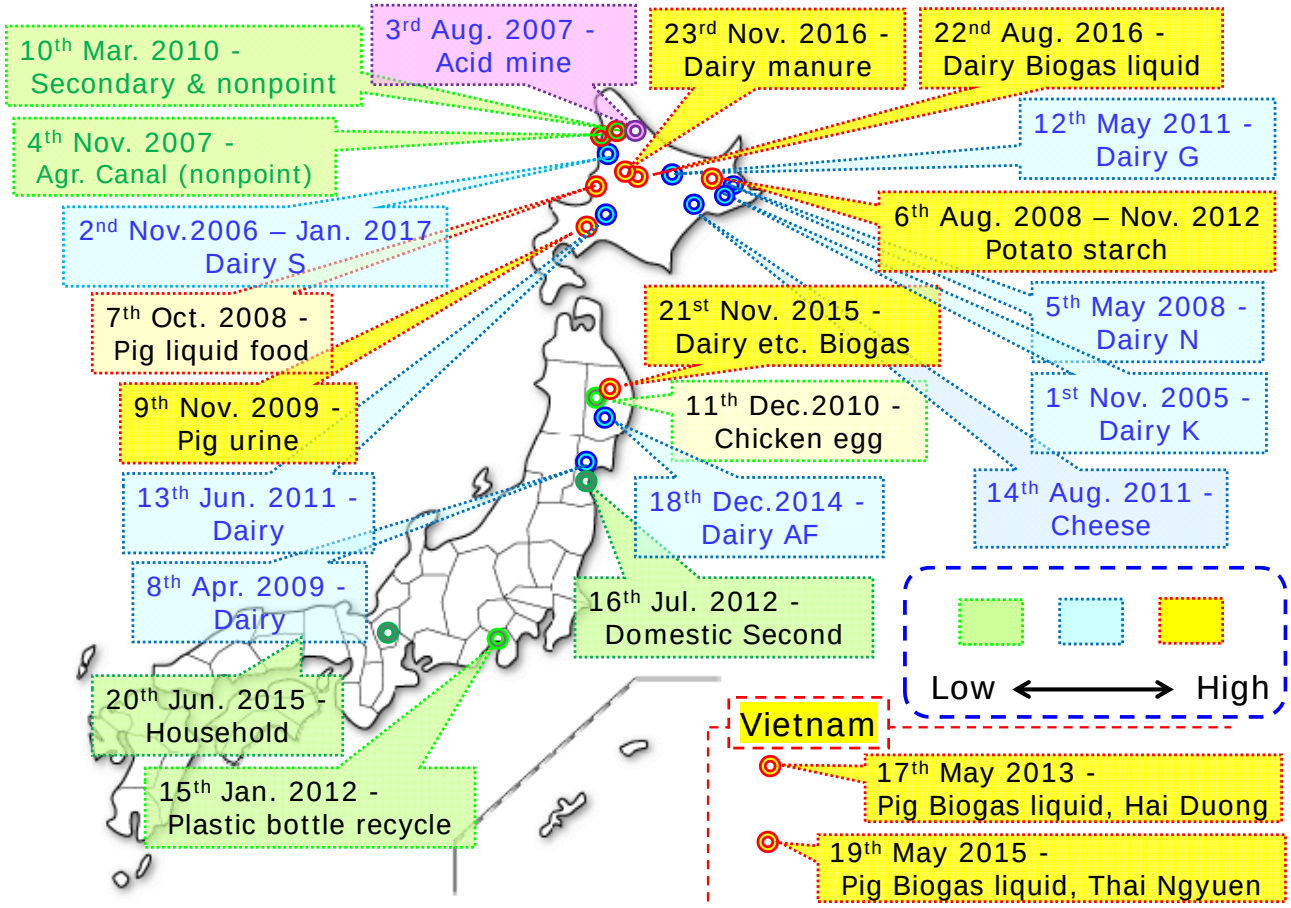
$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$ (Nitrification)



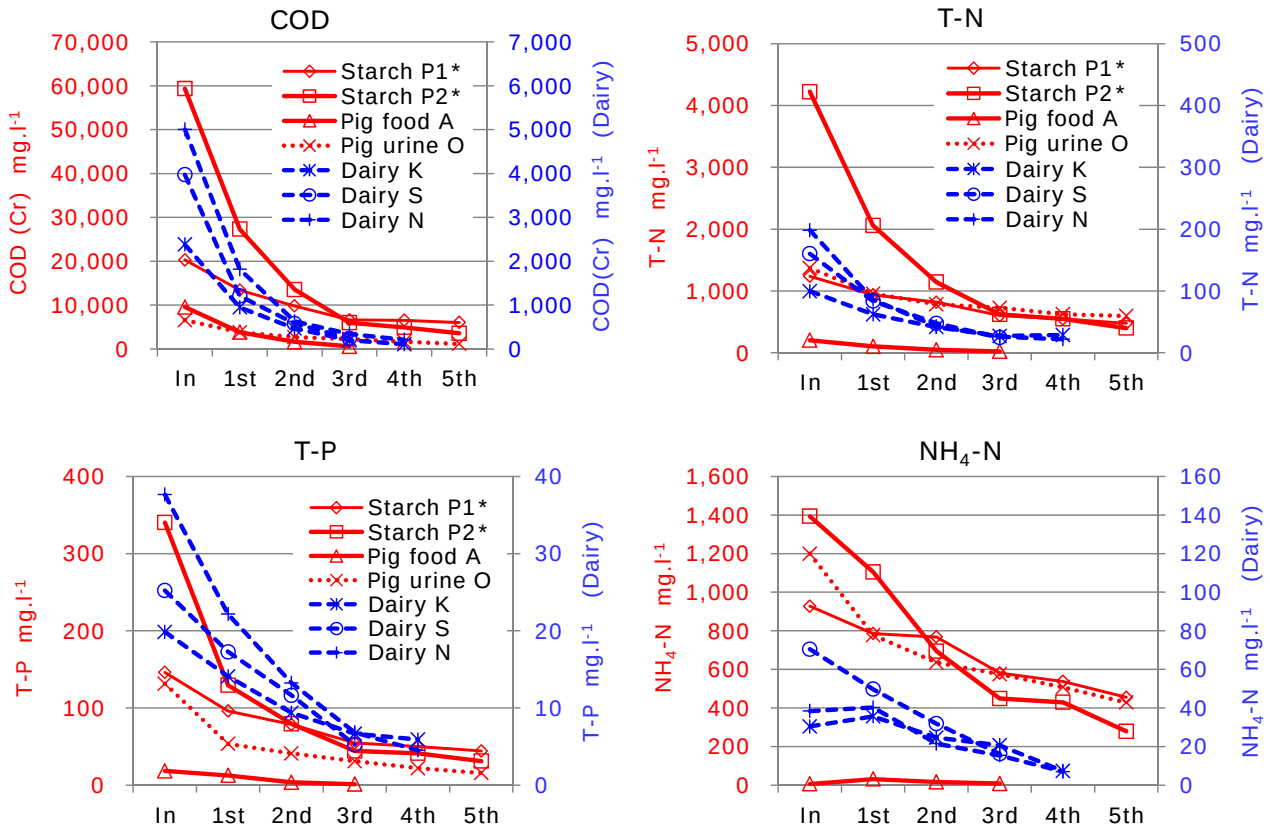
$6(CH_2O) + 4NO_3^- \rightarrow 6CO_2^- + 2N_2\uparrow + 6H_2O$ (Denitrification)

Reduction of nitrogen by recirculation

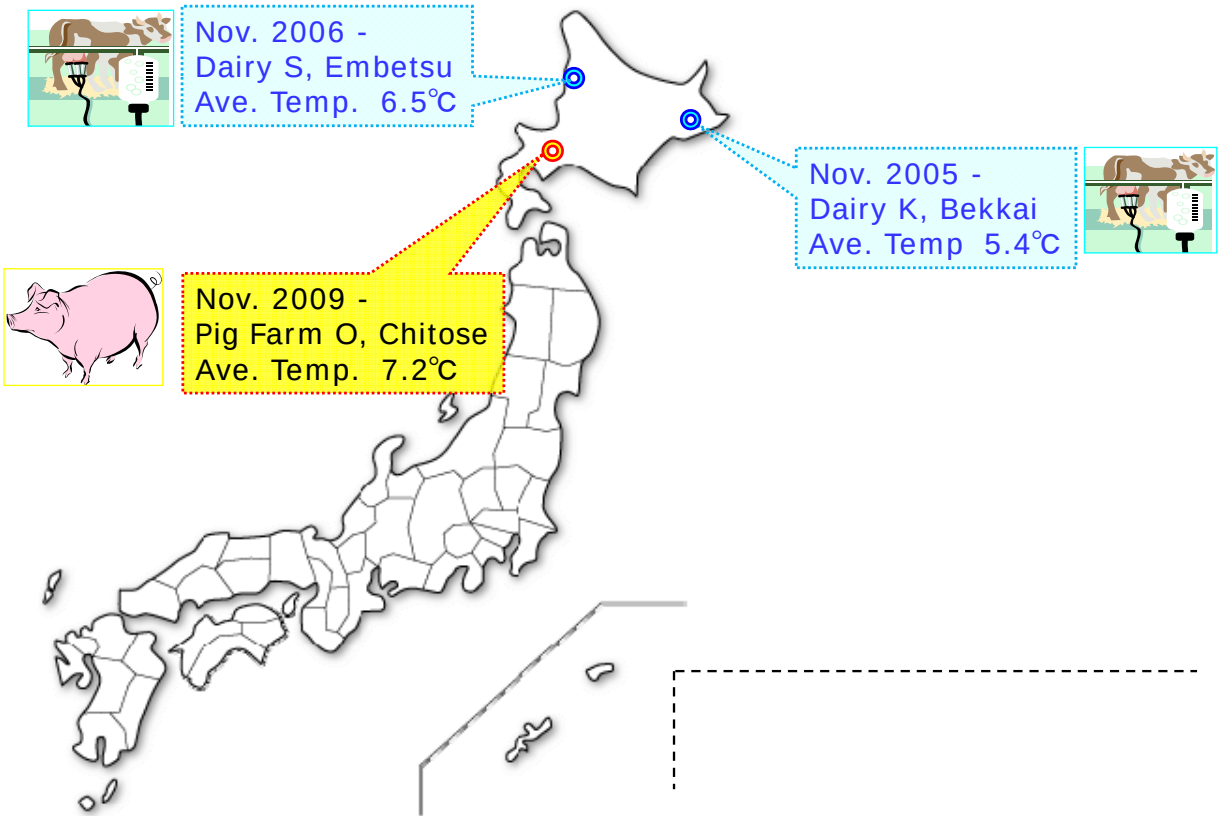
Reed and earthworm in the bed



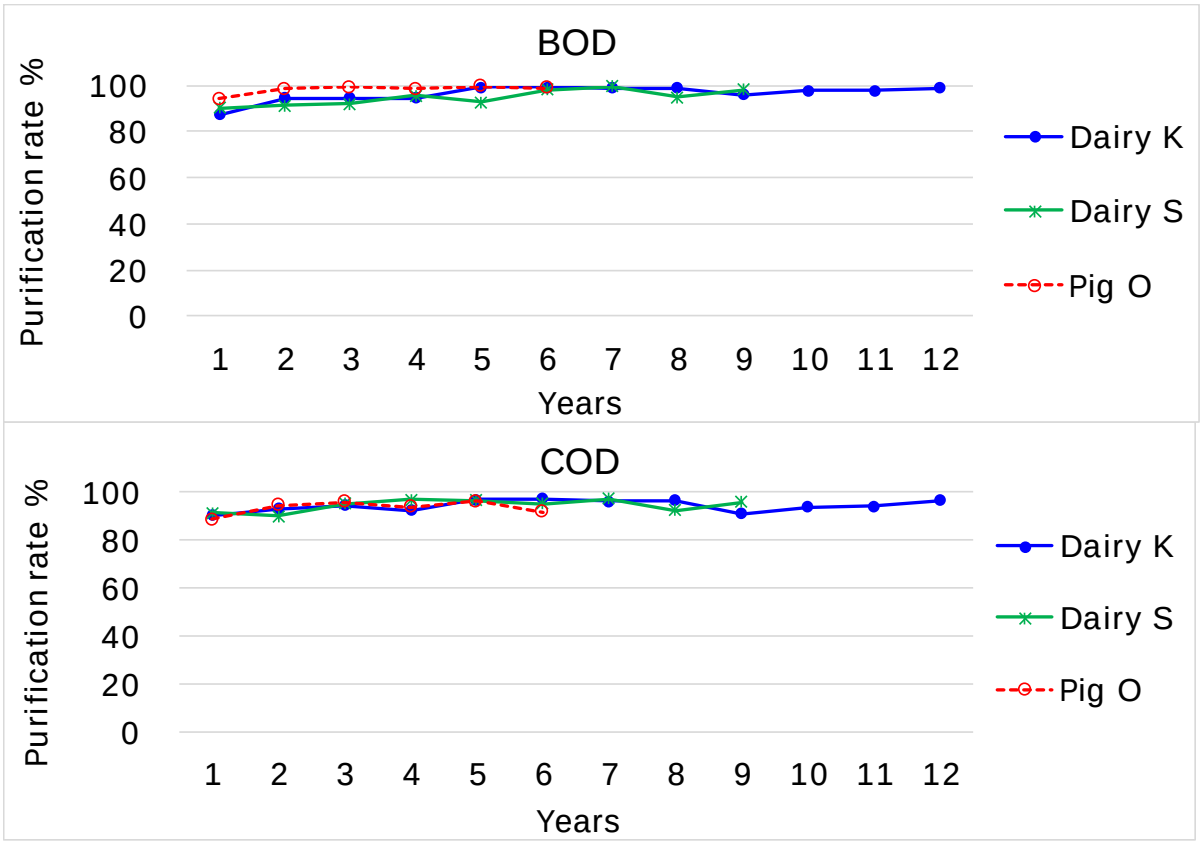
Our constructed wetlands in Japan and Vietnam Aug. 2017



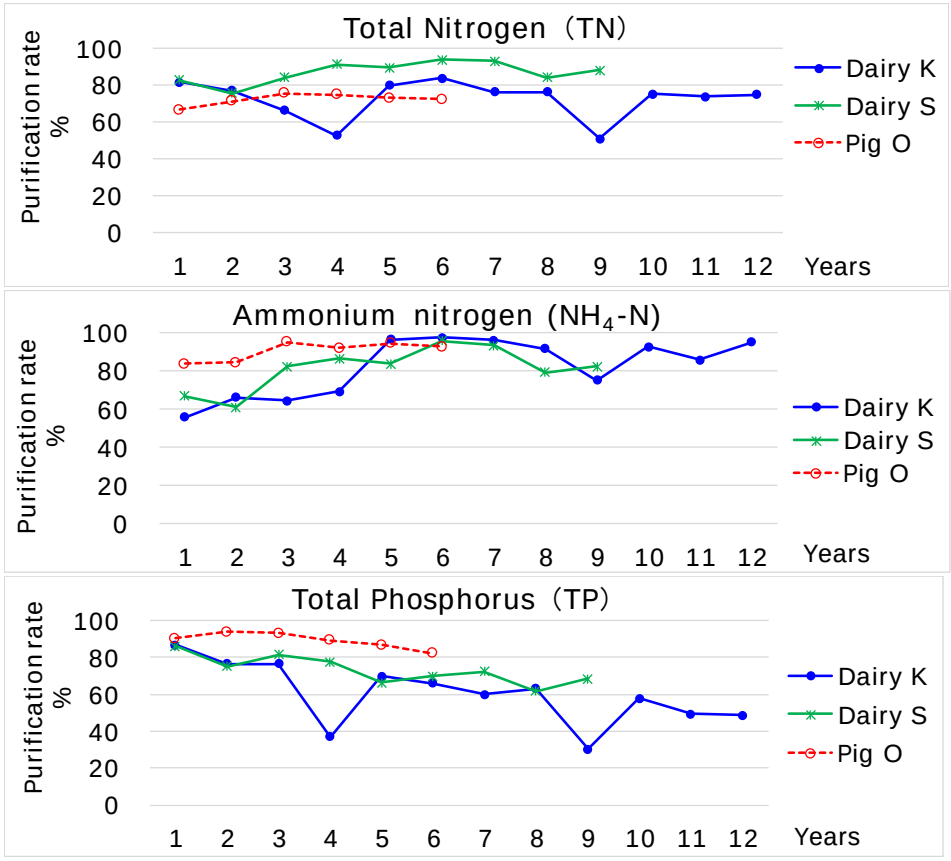
Average pollutant concentrations in the inter-stage data



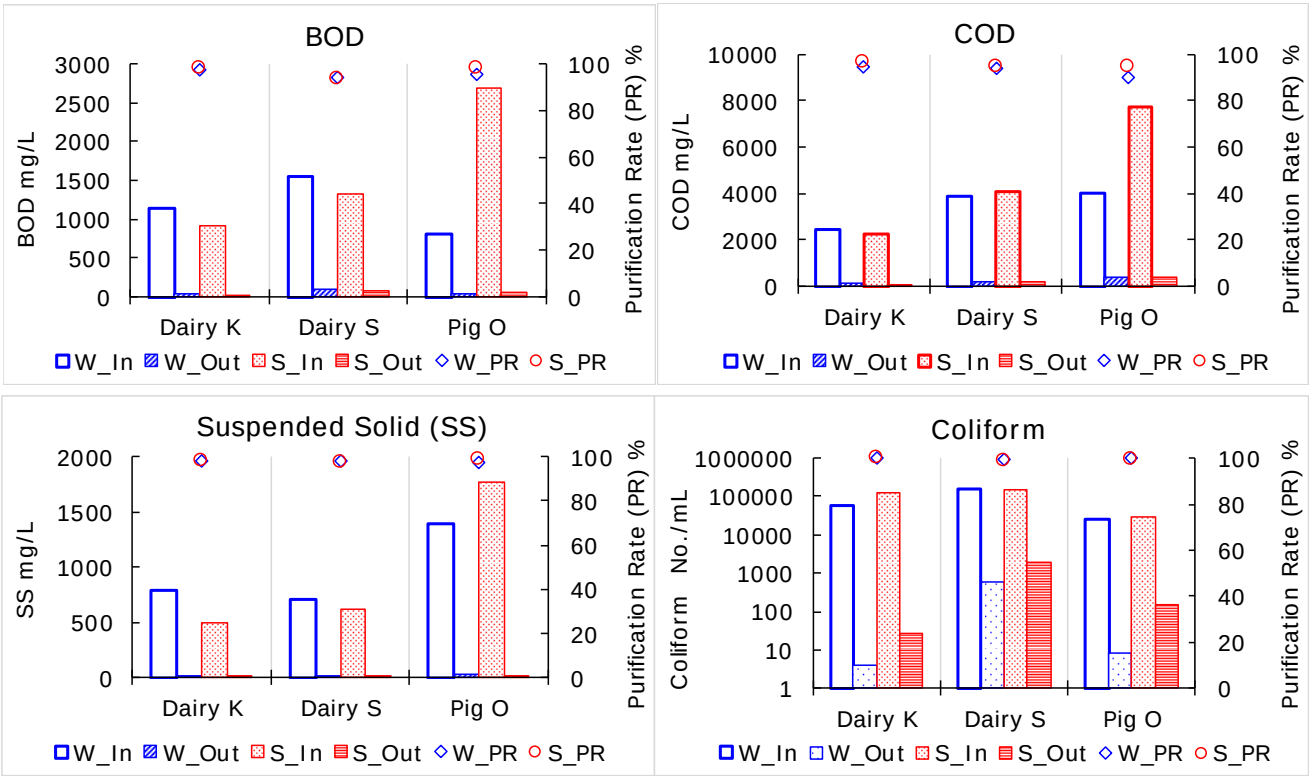
Three wetland systems evaluated during 6 to 12 years



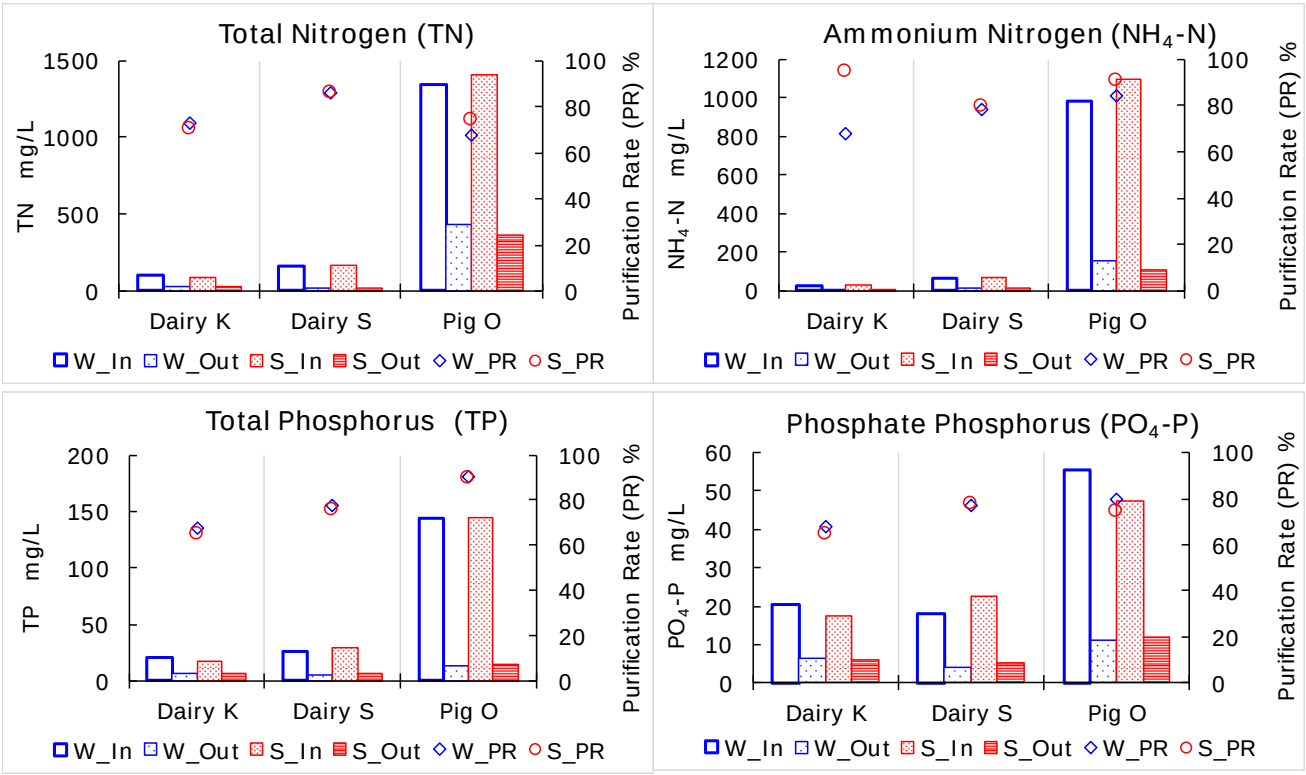
Change of purification rate over the years (BOD, COD)



Change of purification rate over the years (TN, NH_4-N, TP)



Purification in Winter (May – Oct.) and Summer (Nov. – Apr.)



Purification in Winter (May – Oct.) and Summer (Nov. – Apr.)

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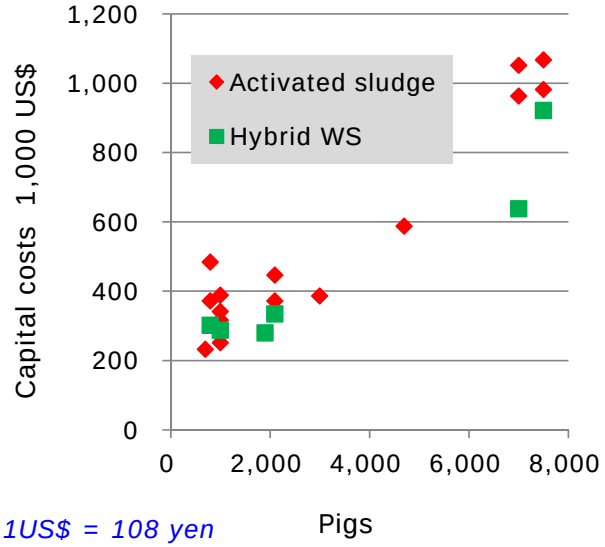
Capital costs



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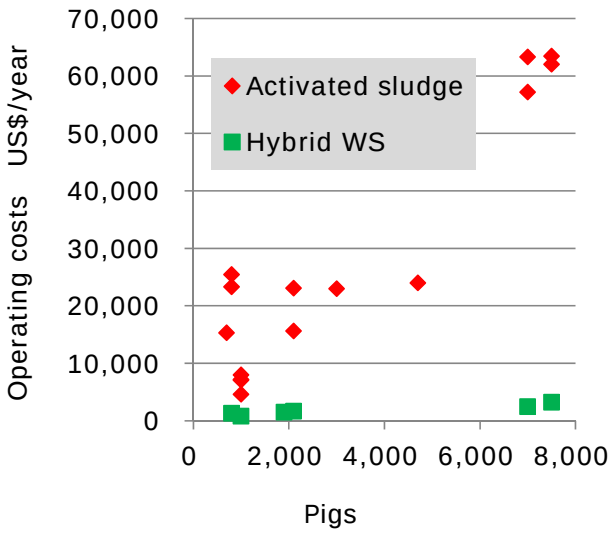
Operating costs



1US$ = 108 yen

Cost comparison between activated sludge* and hybrid wetland system for swine wastewater treatment (under the condition that the influent and effluent BOD conc. is same)

**From the open database of Livestock Indusrtry's Environmental Improvement Organization (LEIO), Japan*

Introduction of Multistage Hybrid Wetland Systems in Vietnam

Multistage Hybrid Wetland Systems in Vietnam

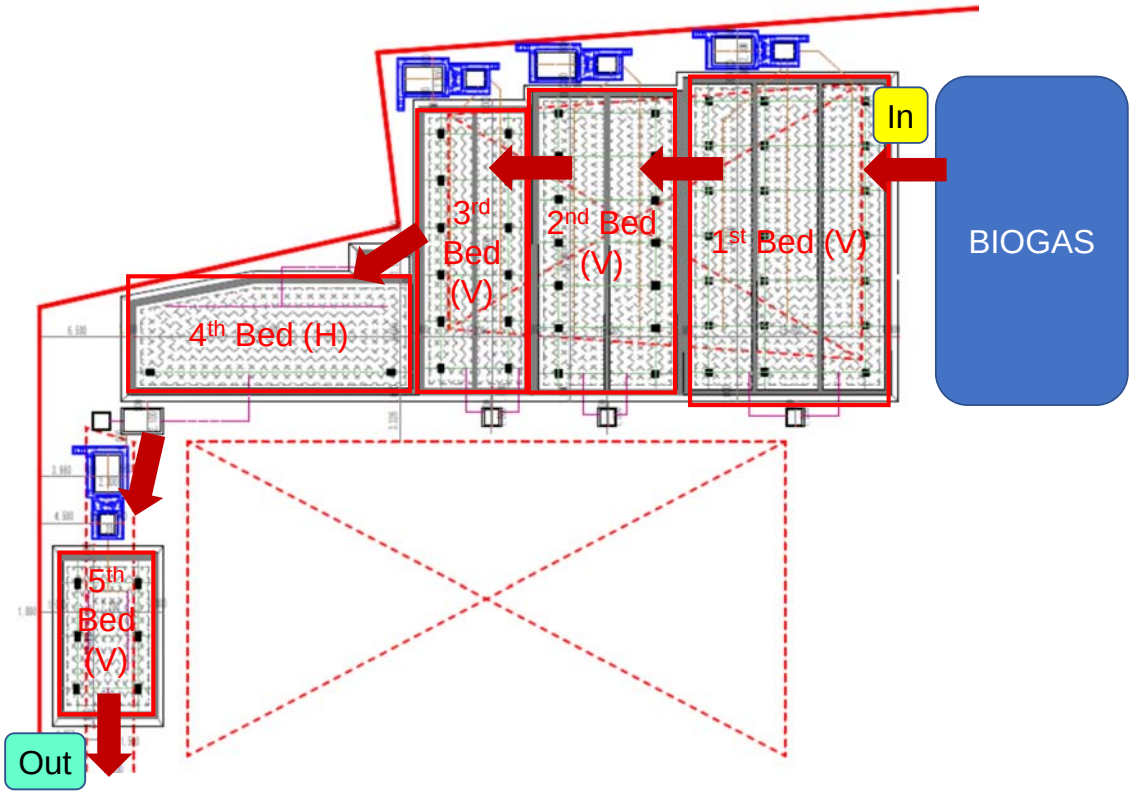
Thai Nguyen Province/ May 2015～

Hai Duong Province/ May 2013～

Bui Huy Hanh Pig Farm in Hai Duong Province

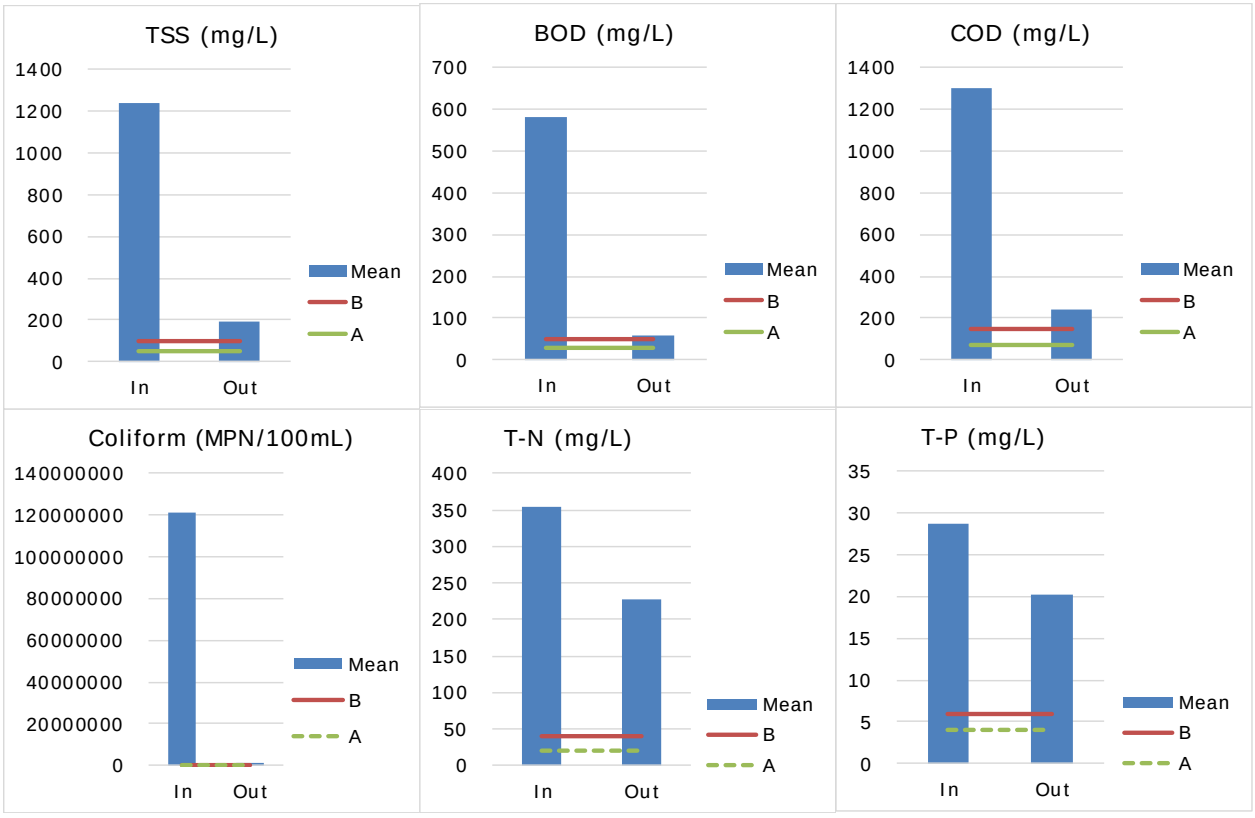
Total bed area : 1,220m^2 Inflow rate : 80 m^3/d	1,400 sows (2,700 pigs equivalent)	Since 2013

Layout of MSHWS at Bui Huy Hanh Pig Farm in Hai Duong



Bui Huy Hanh Pig Farm in Hai Duong Province

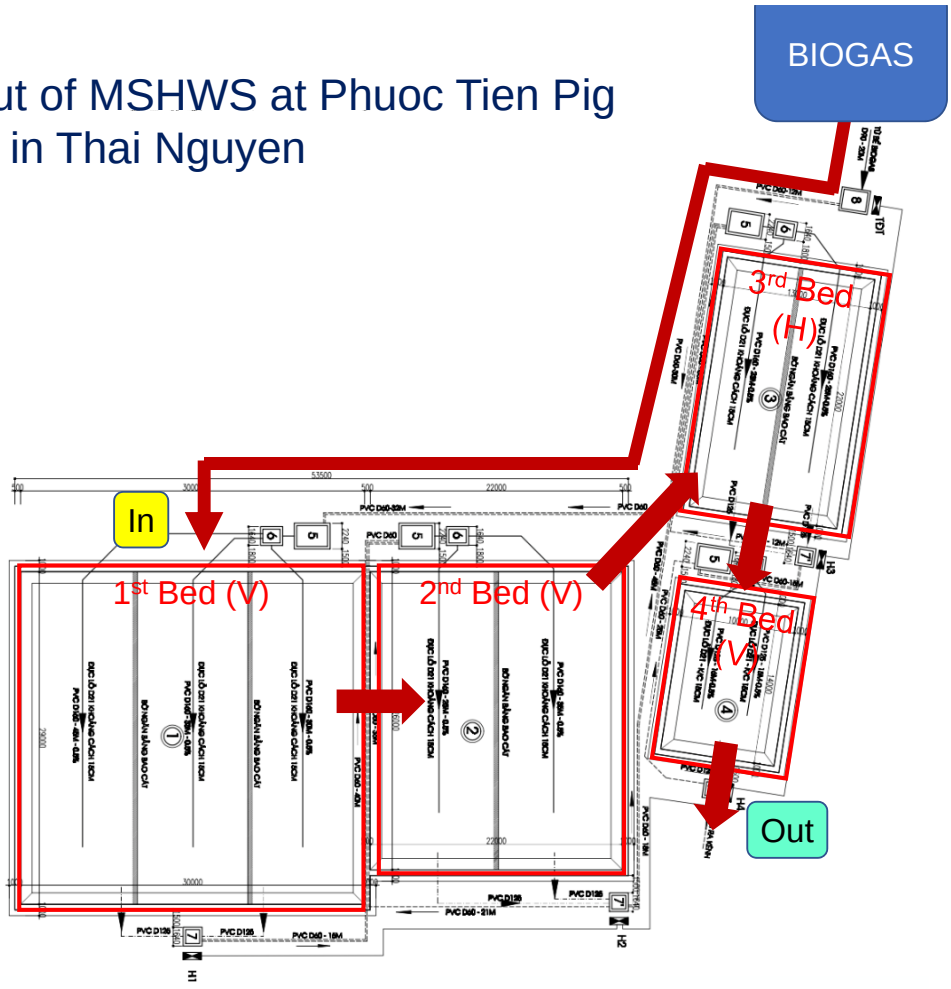
Inflow and Outflow Water Quality sampled at Bui Huy Hanh Pig Farm in Hai Duong Province (from 2013 to 2017)



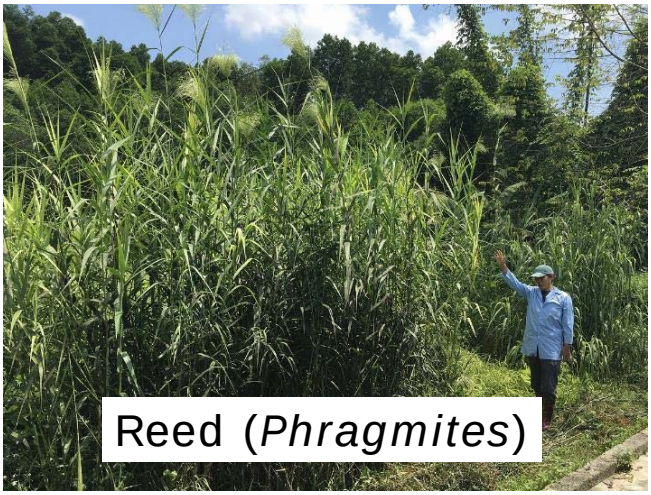
Phuoc Tien Pig Farm in Thai Nguyen Province

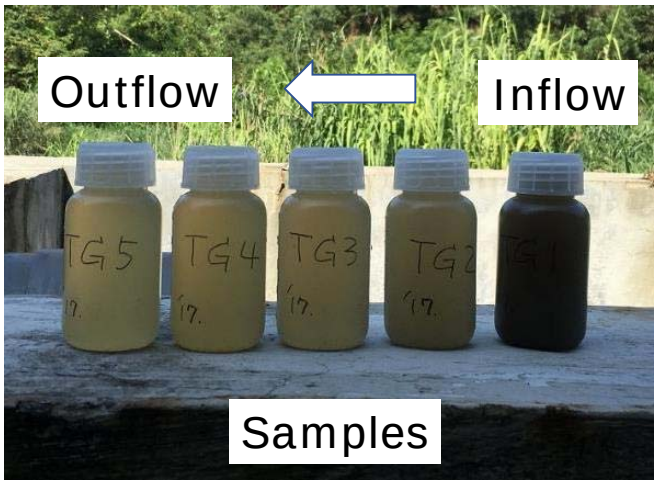
Total bed area : 1,868m^2 Inflow rate : 180 m^3/d	4,000 pigs	Since 2015

Layout of MSHWS at Phuoc Tien Pig Farm in Thai Nguyen

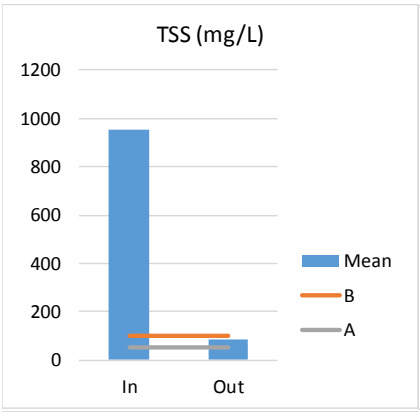


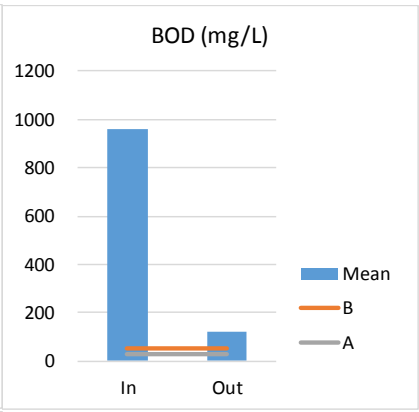
Phuoc Tien Pig Farm in Thai Nguyen Province

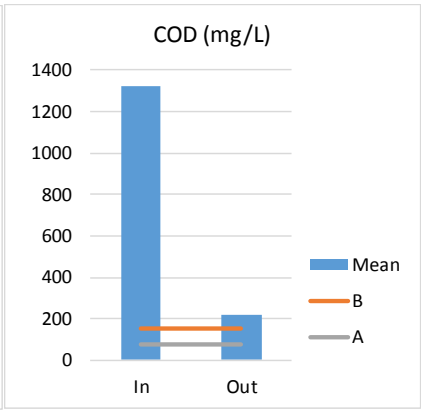


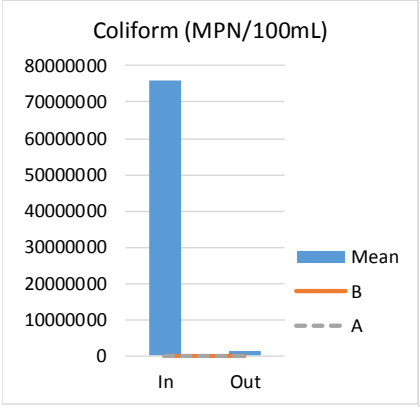


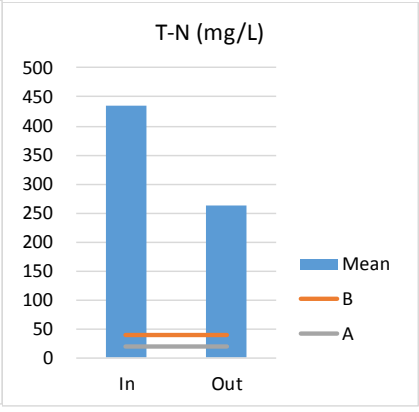
Influent and Effluent sampled at Phuoc Tien Pig Farm in Thai Nguyen Province

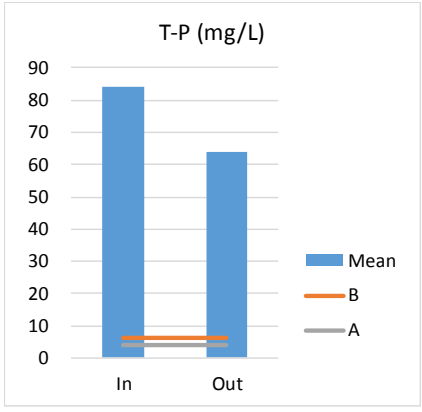




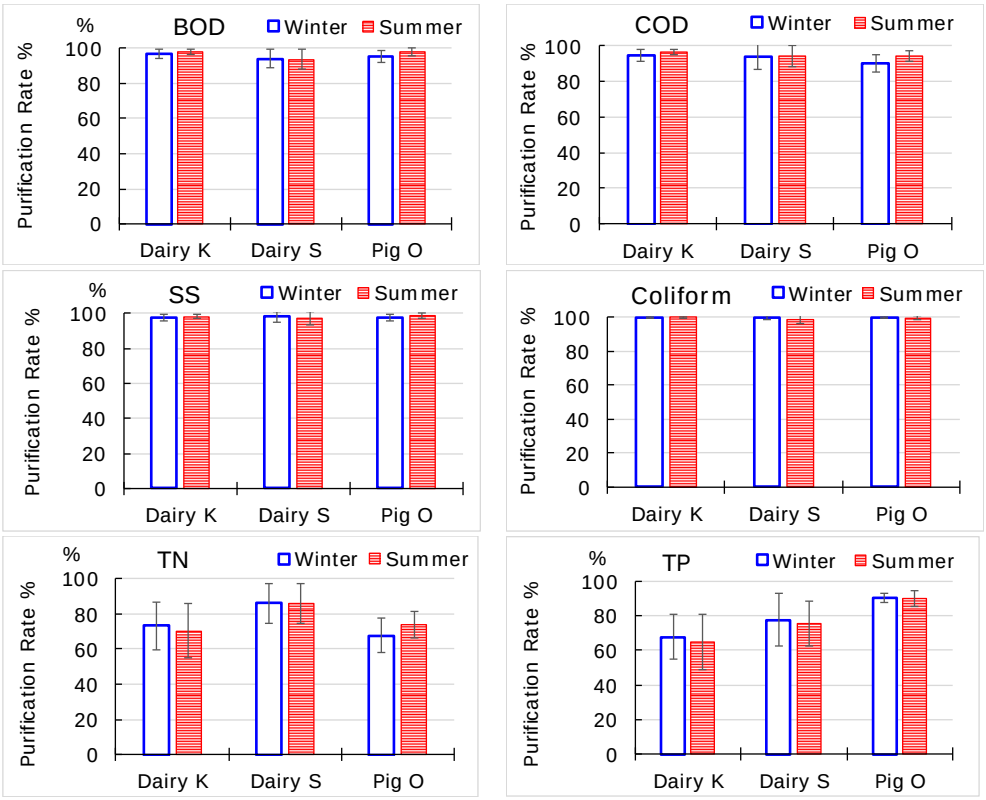








complement



※ Purification rate is the average of all research period in winter and in summer.
Error bars are standard deviations.

Purification rate in Winter (May – Oct.) and in Summer (Nov. – Apr.)

1st hybrid system evaluated
Dairy K (Bekkai Hokkaido)
Milking wastewater treatment
Milked cows : 200 → 400
Parlor : 20×2 parallel

Running : Aug. 2005 -
4 stages : V – Vr – H – V
Total bed area : 1686 m^2
Water volume : 28.5 m^3/d
Inf. content : BOD 1200mg/L

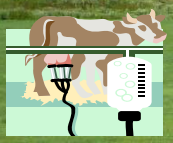
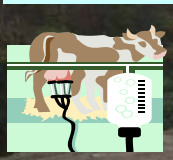


Photo by Ietsugu H. (Aug. 2010)

2nd Hybrid system evaluated
Dairy S (Embetsu Hokkaido)
Milking wastewater treatment
Milked cows : 120
Parlor : 8×2 parallel

Running : Nov. 2006
3stages : V – Vr – H
Total bed area : 656 m^2
Water volume : 4.8 m^3/d
Inf. content : BOD 1,431mg/L



Surface 5cm is covered with Supersol ®
Recycled from glass
Porous and light
Float on water

Main bed material
0-25cm : gravel (5-15mm)
25–75cm : gravel (5-25mm)

6th Hybrid system
Pig O (Chitose Hokkaido)
Swine urine
150 -180 sows
2000 – 3000 pigs

Running : Nov. 2009
5 stages : Vr – Vr – V – H – V
Total bed area : 1472 m^2
Water volume : 12.0 m^3/d
Inf. content : NH_4-N 1184 mg/L

Nov. 2009

Performance of a Multi-Stage Hybrid Constructed Wetland System for Swine Wastewater Treatment in a Cold Climate

PO.115

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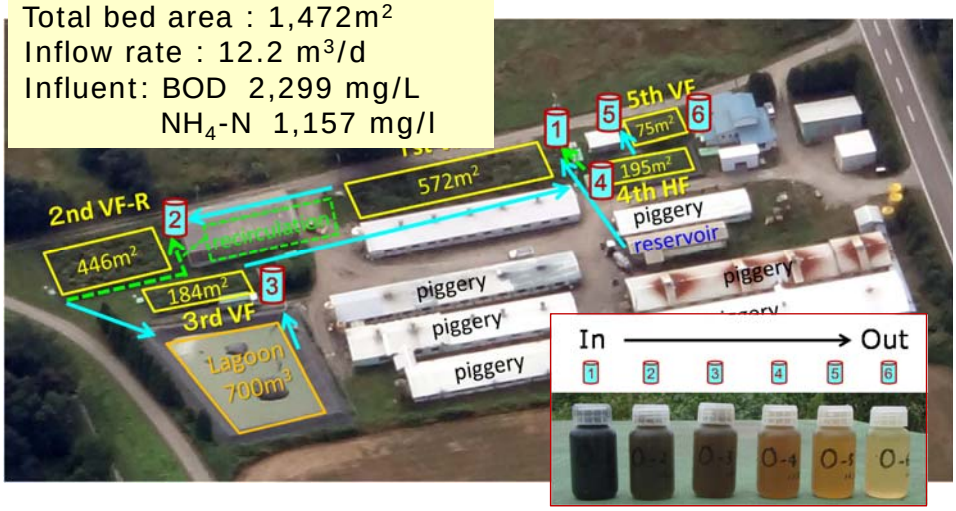
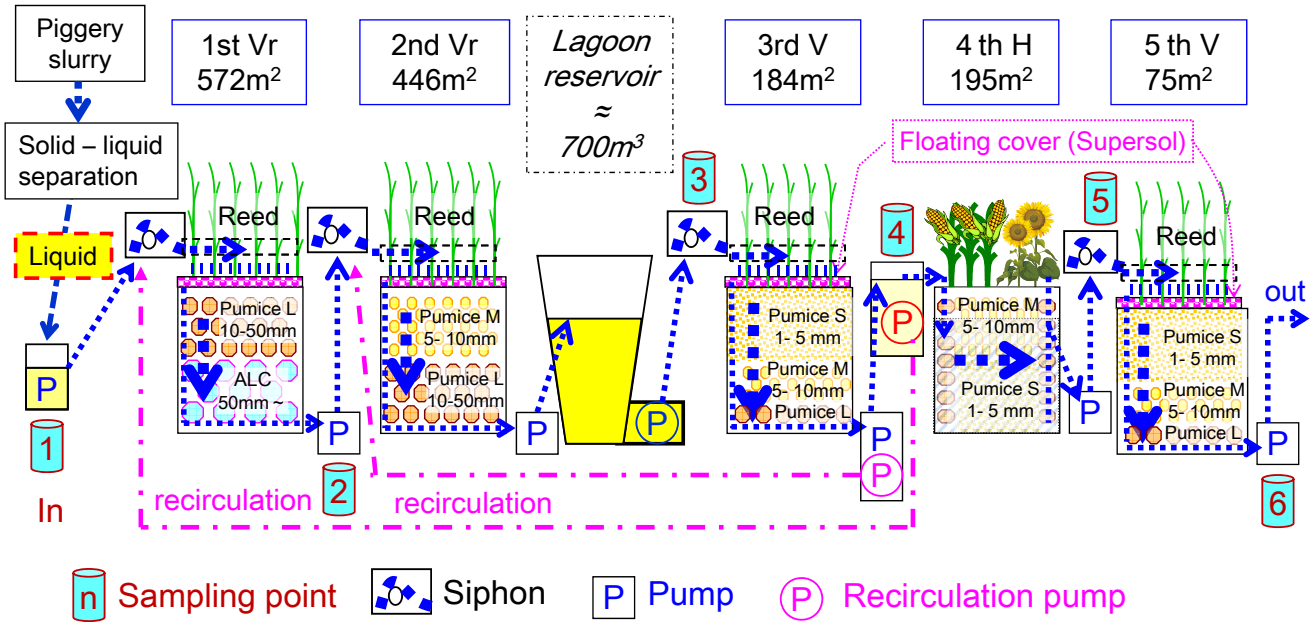
[b] Hokkaido University, [c] TUSK Co., Ltd.

150 - 180 sows
2,000 - 2,500 pigs
Mean temp. 7.3°C
Coldest month mean temp. -5.7°C

Total bed area : 1,472m²
Inflow rate : 12.2 m³/d
Influent: BOD 2,299 mg/L
NH_4-N 1,157 mg/l





Vr: Vertical flow with recirculation, V: Vertical flow, H: Horizontal flow

Fig.1 Schematic diagram of the system (Pig Farm O)

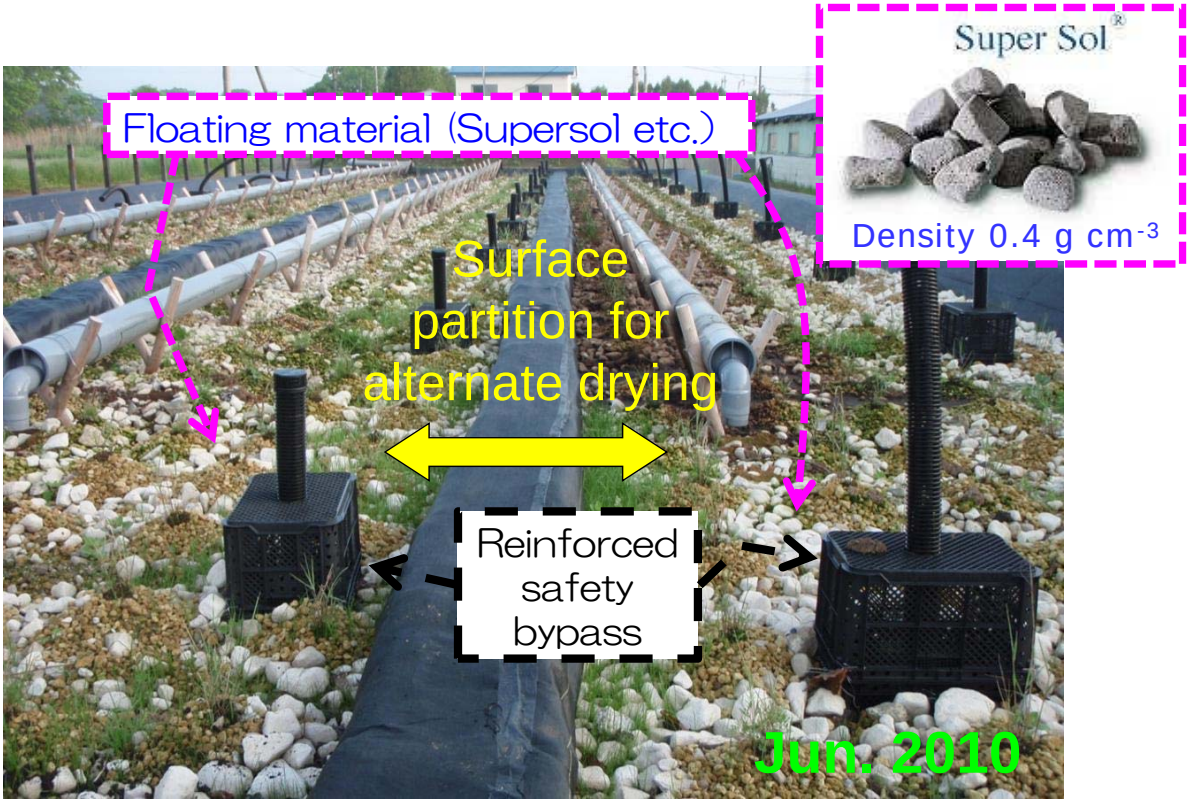


Fig.2. Safety bypass and floating material (Super Sol®) to avoid clogging

Minimize the area and cost !

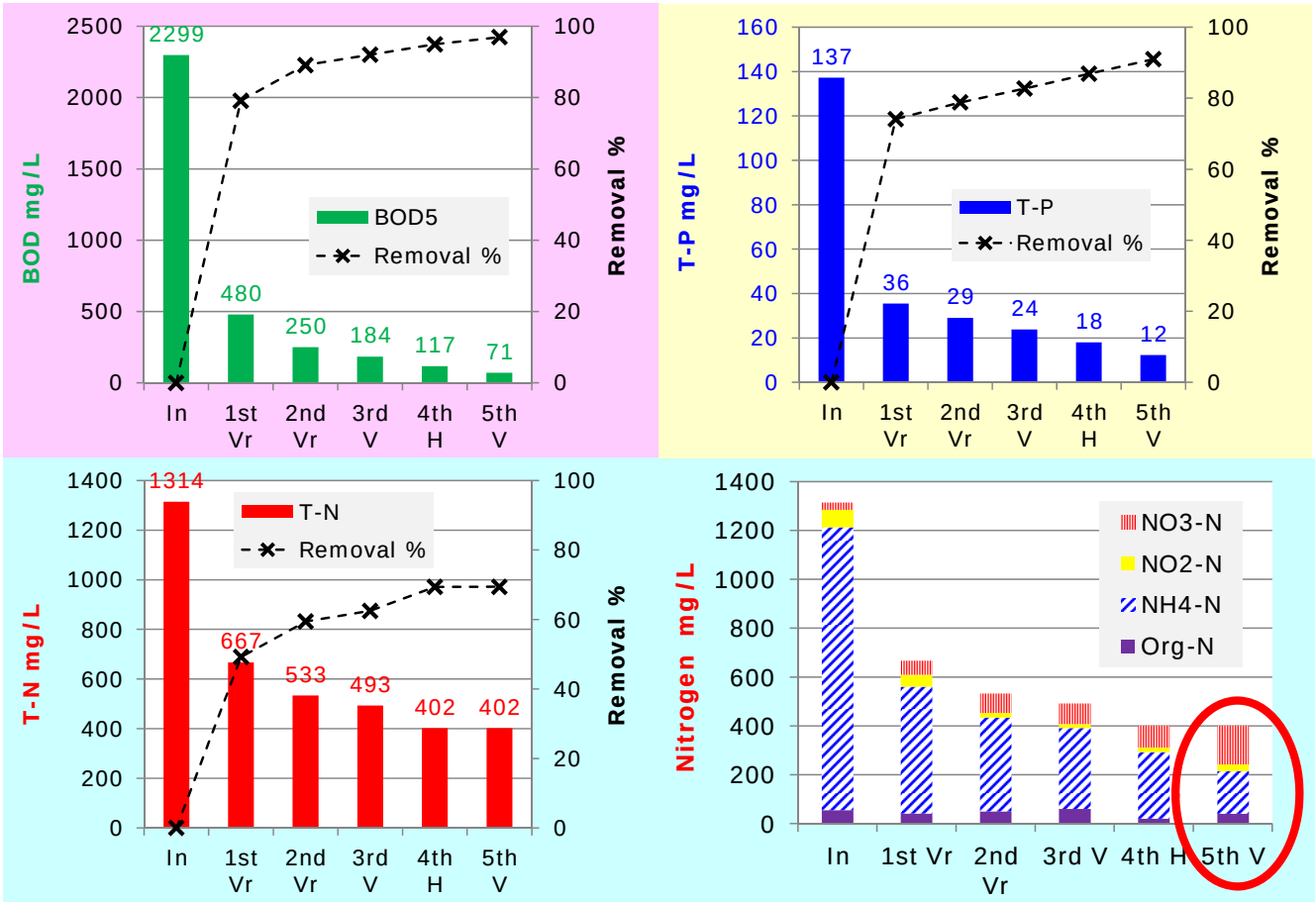


Fig.3. Mean pollutant concentration (Aug. 2010 - Dec. 2012)

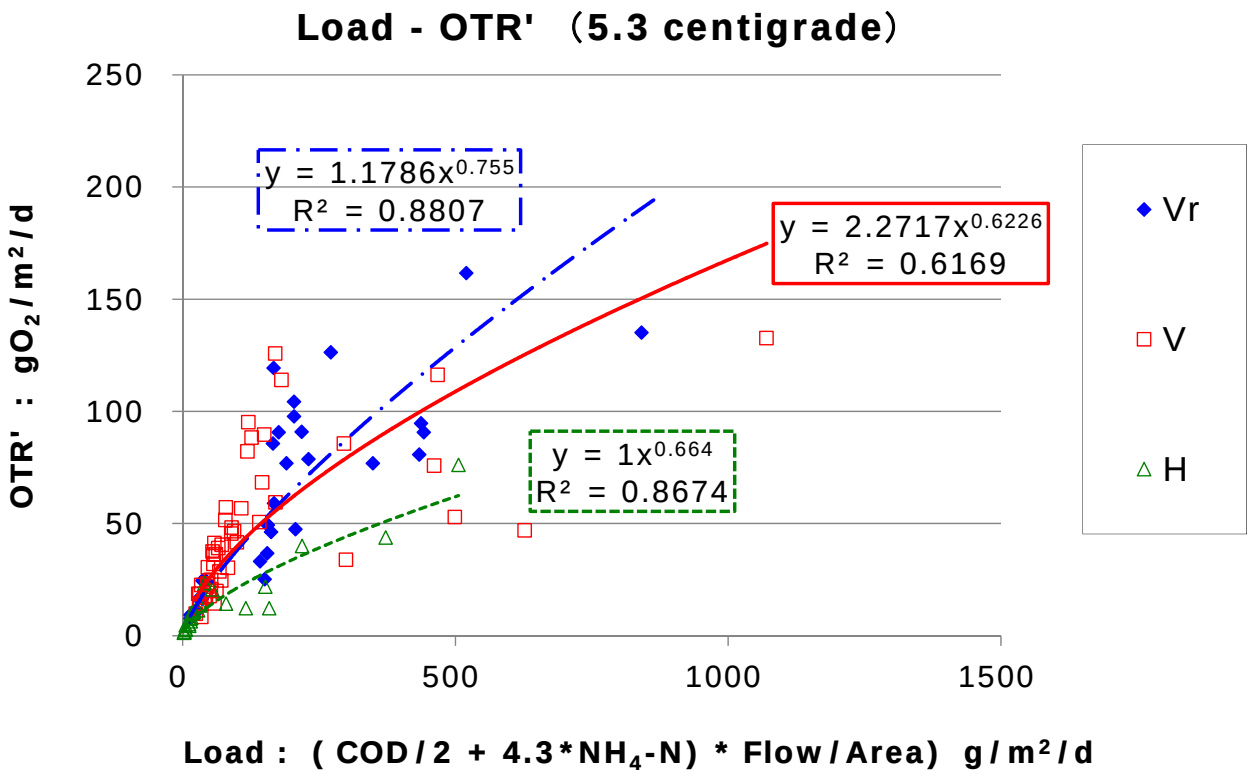
Performance estimation using OTR (Oxygen Transfer Rate)

(Cooper 2005)

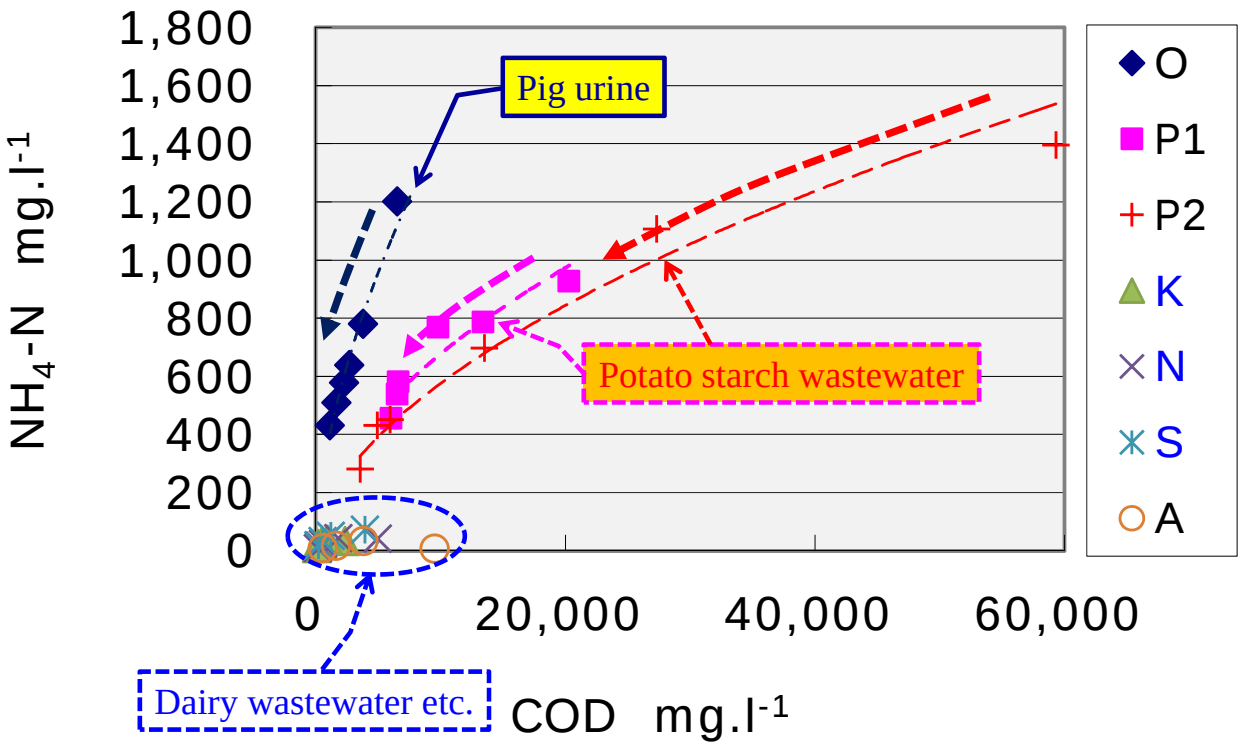
OTR = flow rate {(BOD in – BOD out) + 4.3 (NH_4-N in – NH_4-N out)} / bed area

BOD ≒ COD/2

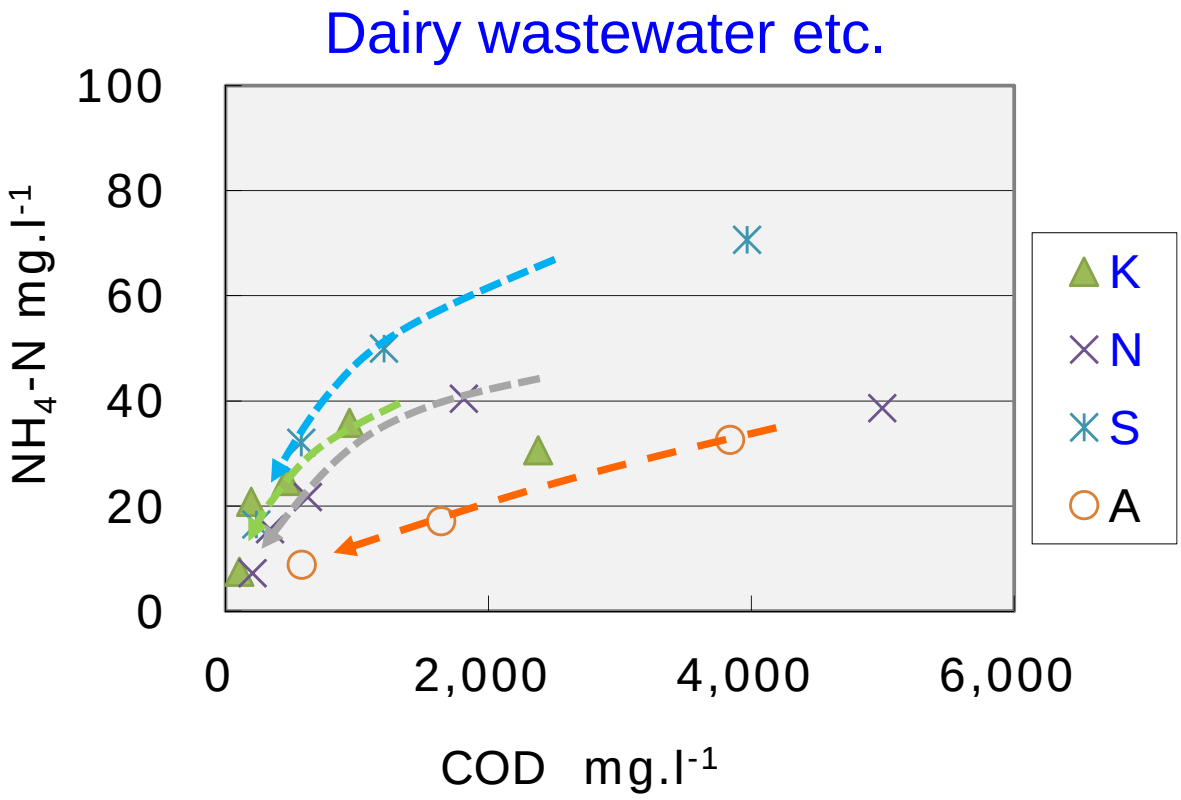
OTR = flow rate {0.5 (COD in – COD out) + 4.3 (NH_4-N in – NH_4-N out)} / bed area



Relation between load and oxygen transfer rate (OTR') values adjusted with annual average air temperature



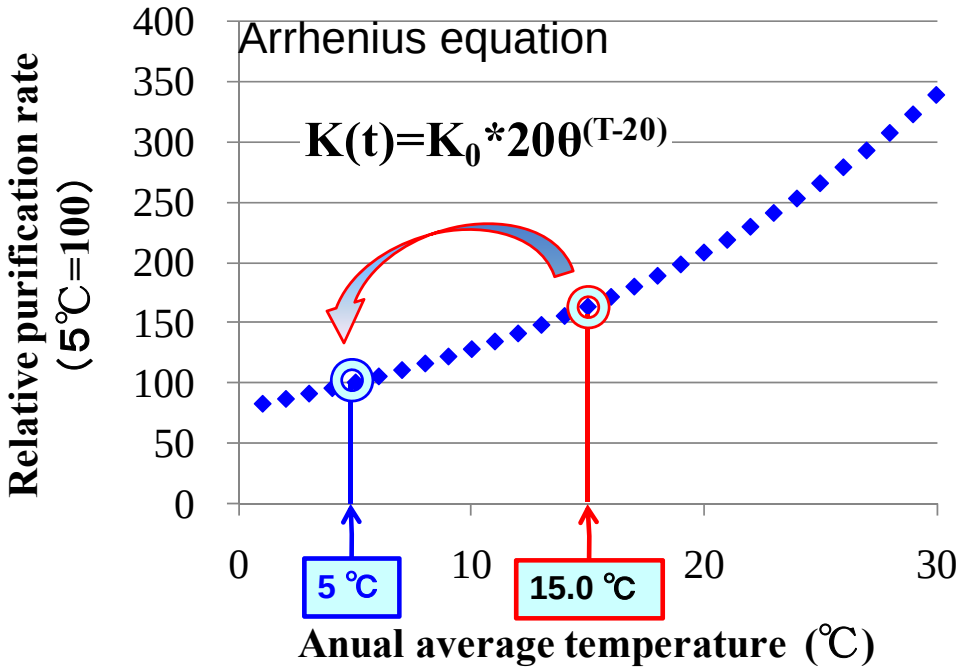
Relation between average COD and NH_4-N through the system



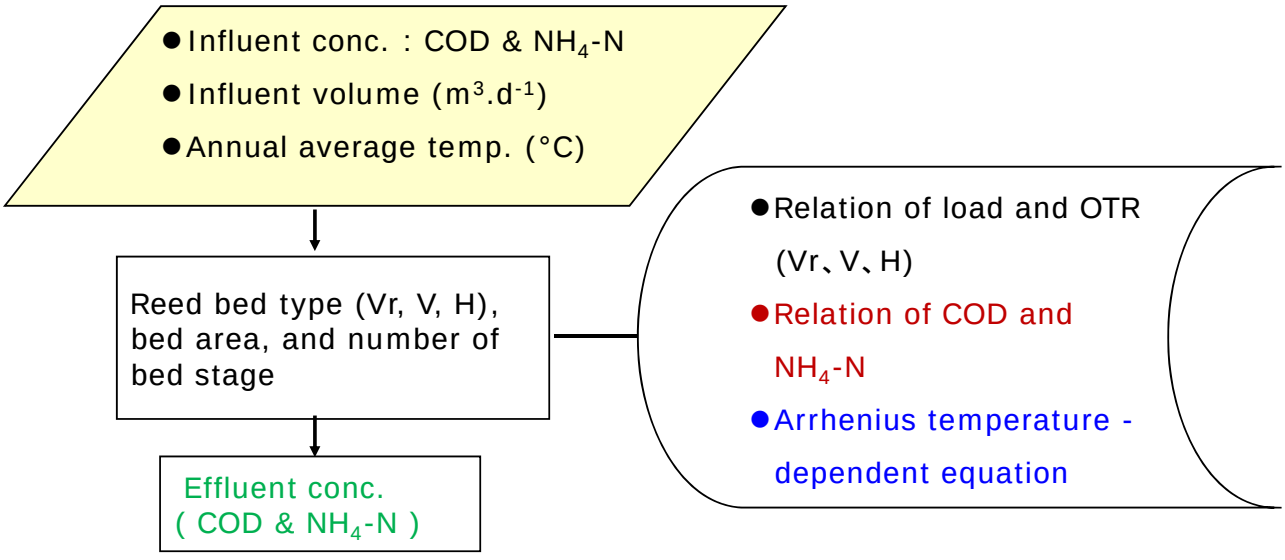
Relation between average COD and NH_4-N through the system

$OTR' / OTR = \theta^{(T'-20)} / \theta^{(T-20)}$

$\theta = 1.05$ (Kadlec and Reddy, 2001)

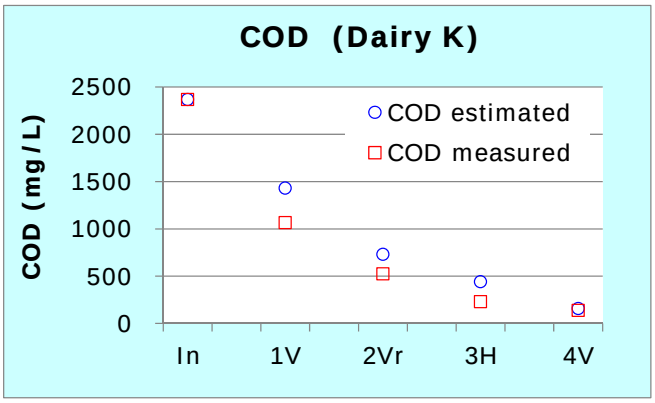


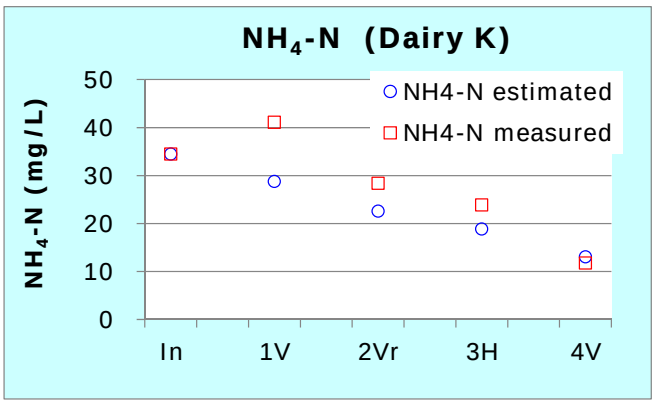
Temperature correction of OTR

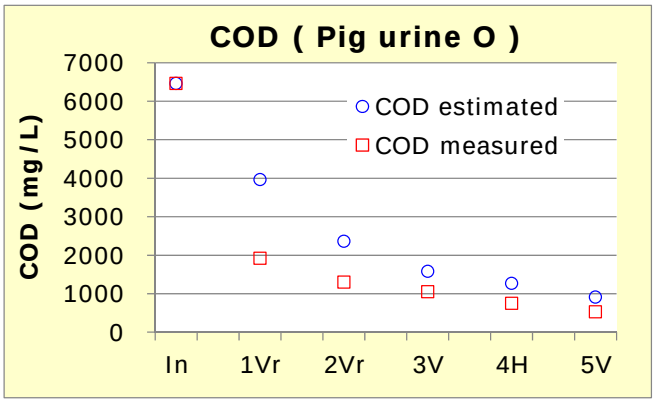


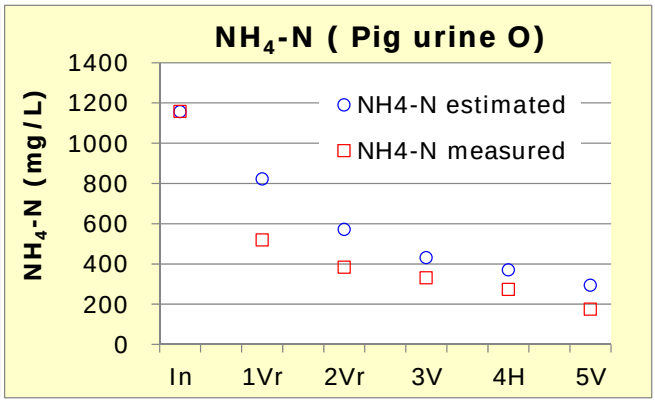
(Kato et al. 2013 *Water Science and Technology* 68(7), 1468-1476)

Procedure to estimate effluent water quality









Estimated and measured COD and NH_4-N of treated wastewater (Dairy K and Pig urine O)