Advanced treatment of domestic wastewater using a combination of Johkasou and simple BGF ditch

- Examination of production and safety of vegetables and fruits -

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Dr. Yasuo Ozaki

Professor Emeritus, Akita Prefectural University

1. Purpose of the Research

The presenters developed a BGF ditch (Biogeofilter ditch) that combines useful plants and natural mineral filter media in order to recycle fertilizer components in Johkasou effluent. We have conducted research on combination of useful plants etc., to obtain stable treated domestic wastewater quality throughout the year.[1)]

After retiring, I installed a simple BGF ditch at my home in Tsukuba City in November 2016 using materials that could be purchased at DIY store in order to spread the utilization of BGF ditch, and conducting advanced treatment tests for Johkasou effluent using vegetables, fruits, flowers, etc. We are considering for vegetables and fruits that are suitable for this system, and considering annual cultivation management methods.[2),3)]

I investigated the results of surveys of 2018 and 2023, the safety of harvested vegetables and fruits by referring to the International Organization for Standardization's Guidelines for Irrigation Use of Treated Wastewater[4)] (ISO Guidelines). In this presentation, I will report the summary of the results.

2. The prototype of BGF ditch and its feature

Picture. 1

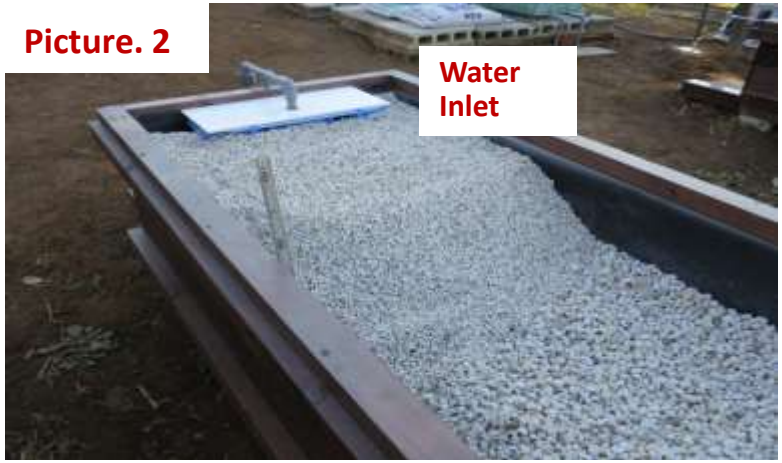
W；59cm, L；5.46m, H；31.5cm

Prototype simple BGF ditch

①Prototype simple BGF ditch：Create a ditch using waterproof plywood and rubber sheet. Filled with pumice to a height of 28 cm.

④Feature：The inflowing effluent from a Johkasou flows down through the pumice stone and flows from the outlet through the PVC pipe into the biotope pond. Therefore, effluent does not rise to the surface layer of the ditch.

Picture. 2



② Effluent inlet；The waterway was filled with pumice to a height of 28 cm.（upper part；Particle size 2～6m, bottom part；Particle size 6～11mm)

Picture. 3

③Water outlet：The water depth was set to 17cm. Runoff water passes through PVC pipes and flows into the biotope pond.

3. Method of the research

☆ Advanced treatment type Johkasou (CENeco-5 type) installed in October 2016.

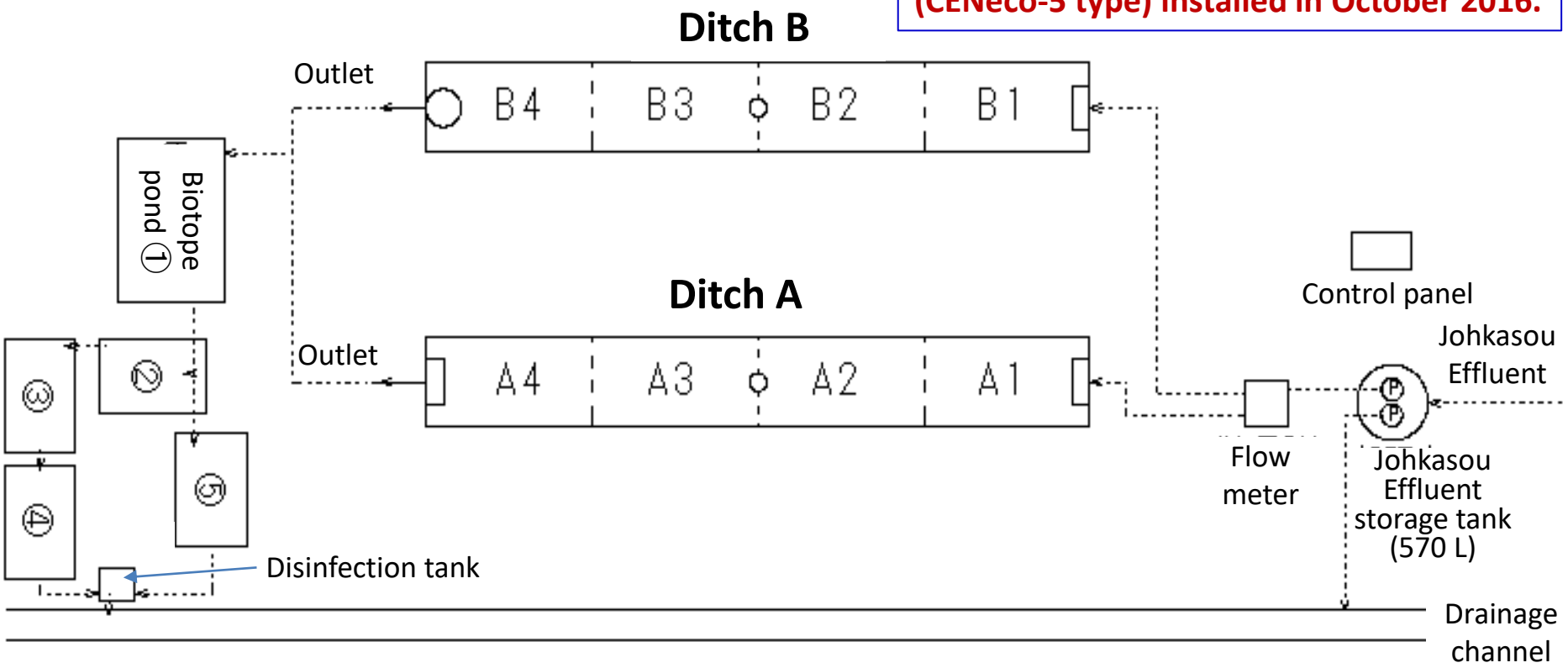


Figure. 1 An advanced treatment system for domestic wastewater that combines a Johkasou, a simple BGF ditch, and a biotope pond.

- Simple BGF ditch : W ; 59 cm, L ; 5.46 m, H ; 31.5 cm, water depth 17 cm, capacity of retention water: approx. 302 L
- Pumice filling height : 28 cm. Fill 450 L of small grains (2 to 6 mm) on top of 450 L of medium grains (6 to 11 mm).
- Biotope pond water capacity: approx. 570 L, water area: approx. 2.5 m^2

○ Operation and Maintenance of Johkasou and simple BGF ditch

A fixed amount of Johkasou effluent (see Table 1) is supplied to two lines of simple BGF ditch by a submersible pump every day under timer control (e.g., supplied for 10 minutes, stopped for 50 minutes).

Table. 1 Johkasou operation management method in 2018 and average supply amount of Johkasou effluent (L/day)

survey period	Ditch A (Flowers/ Conifer)	Ditch B (vegetables/ fruits)	Johkasou operation management method
9 April to 17 April	161	160	5-June：Reduce circulating water volume (6.5Q→2.5Q)
18 April to 17 July	258	268	17-July：Continuous aeration → changed to intermittent aeration
18 July to 27 September	238	343	12-September： Intermittent aeration → return to continuous aeration
28 September to 18 March	236	238	2-October：Increase circulating water volume (2.5Q →6.5Q)

survey period ：9-April, 2018 to 18-March, 2019, Q: Inlet water of Johkasou (L/day)

○ Water sampling and Analyzing

- Water sampling was conducted at six points: the treated water storage tank, the midpoint and outlet of both A&B ditches, and biotope pond ②.
- Sampling was conducted 2-3 times a month. Analysis items include COD, SS, nitrogen, and phosphorus. Water sampling will be postponed if rainfall exceeds 10 mm in the three days before water sampling.

Ditch B (vegetable)

Outlet

Water convolvulus (4 plants)	Asparagus bean (5 plants)	Leaf lettuce	Passion fruit (2 plants)
Molokheiya (4 plants) Taro	Leaf lettuce	Basil (3plants) Tomato (1 plant)	Basil (5 plants)
Water convolvulus (4 plants)	Tomato (3 plants)	Tomato (3 plants)	Melon (2 plants) Edible chrysanthemum
B4	B3	B2	B1

Inlet

Ditch A (Flowers/Conifer)

Outlet

Zinnia (2 plants)	Torenia (1 plant)	Petunia (4 plant)	Zinnia (2 plants)
Sunpatience (1 plant)	Gazania (2 plants)	Kochia (3 plants)	Lobelia (4 plants)
Bidens (1 plant)	Marigold (6 plants)	Dwarf sunflower (6 plants)	Bidens (1 plant)
A4	A3	A2	A1

Inlet

Figure. 2 An example of planting vegetables and flowers in Ditch A and B (mid-June to September 2018)

Conifer planting location : AI; Red star, A2; Gold crest, A3,A4; Elegante sima

☆After harvesting the vegetables and flowers planted in each plot, the next vegetables and flowers were immediately transplanted.

4. Research Results in FY 2018

○ Growth status and harvested melons on July 9th

Ditch A

Ditch B

Melon (section B1)

Leaf lettuce, Tomato (section B3)

Asparagus bean, Water convolvulus (Section B3 and B4)

○ Growth status and harvested passion fruit on September 12th

Ditch A

Ditch B

Harvested passion fruit（section B1）

Passion fruit and Basil (Section B1)

Water convolvulus, Taro, Asparagus bean (section B3, B4)

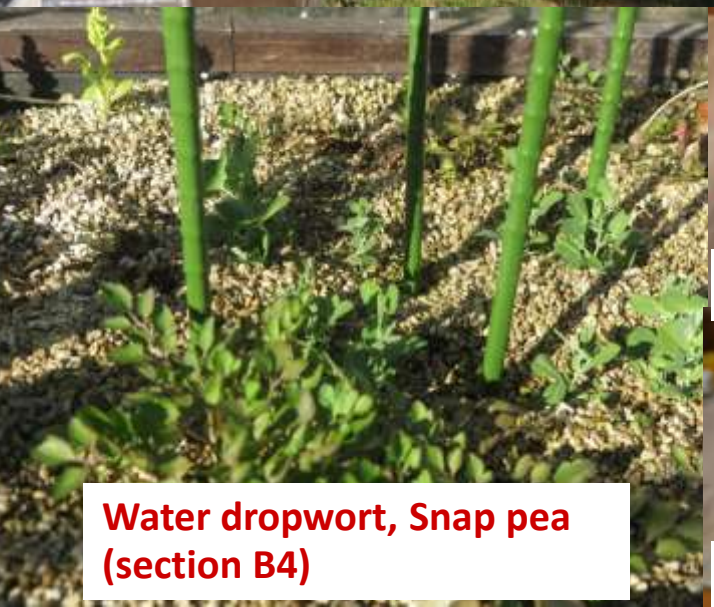
○ Growth status as of January 17, 2019 and harvested bok choy and sunny lettuce

Ditch A

Ditch B

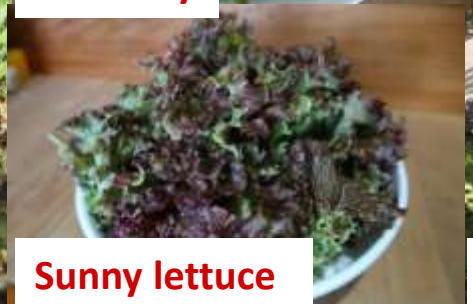
Broccoli, strawberry (Section B1)

Garland chrysanthemum, Bok choy, Sunny lettuce (section B2, B3)



Water dropwort, Snap pea (section B4)

Bok choy



Sunny lettuce

Sunny lettuce (section B3)

○ Growth status of Flowers/Conifer (Ditch A)

24-May, 2018

9-July, 2018

12-September, 2018

17-January, 2019 (view from the back side of the Ditch)

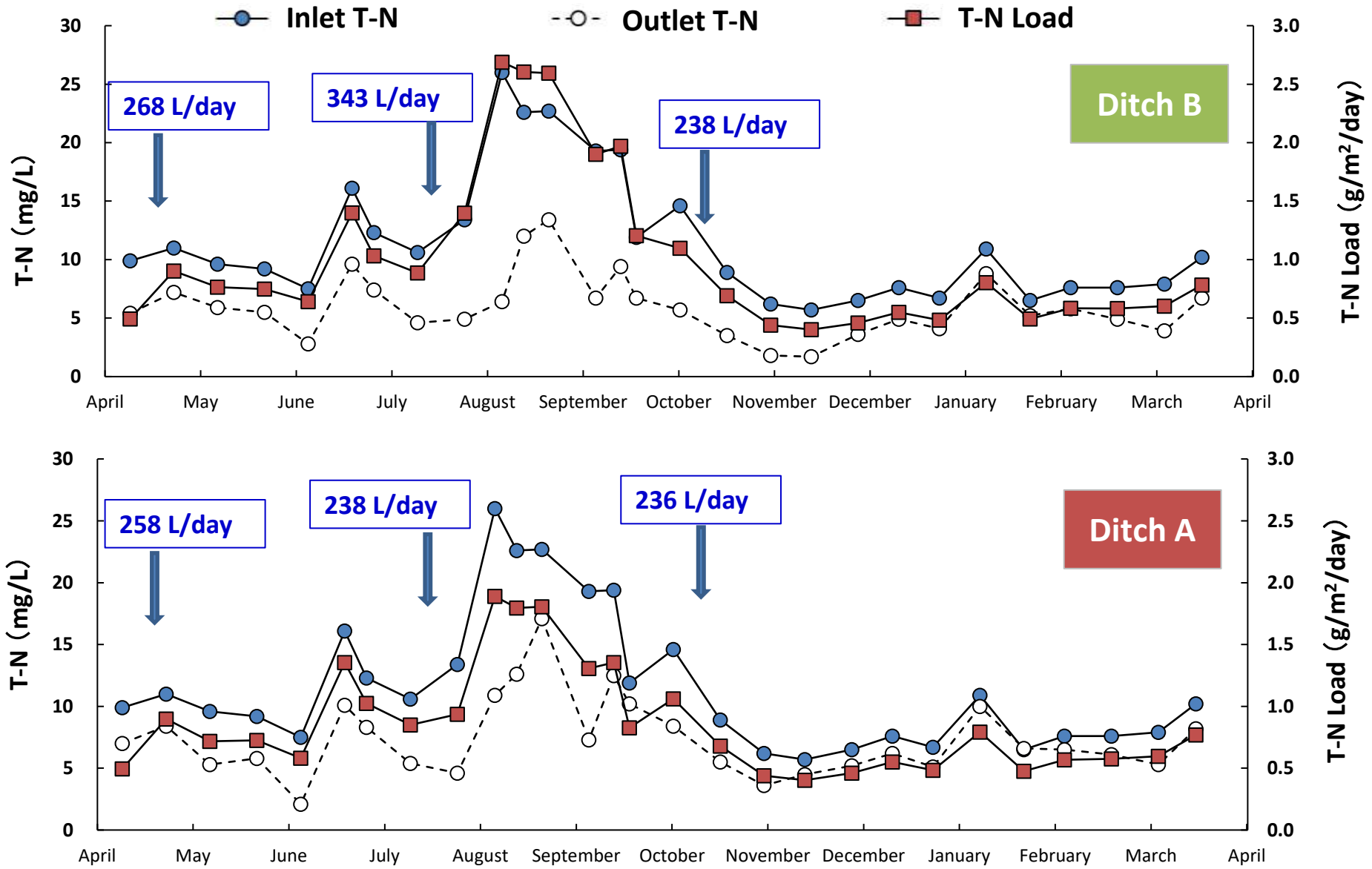


Figure 3. Changes in nitrogen removal function of Ditch B and Ditch A (April 2018 to March 2019)

Table. 2 Nitrogen removal results of simple BGF Ditch (April 9, 2018 to March 18, 2019)

Ditch	survey period	Average nitrogen load ($g/m^2 \cdot day$)	Average T-N concentration of Inlet water (mg/L)	Average T-N concentration of Outlet water (mg/L)	Average nitrogen removal rate ($g/m^2 \cdot day$)	Removal ratio (%)
Vegetables/ Fruits (Ditch B)	Spring(9-April to 22-May)	0.73	9.9	6.0	0.28	38.4
	Early summer (5-June to 10-July)	0.99	11.6	6.1	0.47	47.5
	Summer (25-July to 13-September)	2.35	22.0	9.6	1.31	55.7
	Autumn (18-September to 13-November)	0.66	8.9	3.2	0.42	63.6
	Winter (28-November to 19-February)	0.58	7.9	5.4	0.19	32.8
	Early spring (6-March to 18-March	0.69	9.1	5.3	0.29	42.0
Flowers/ Conifer (Ditch A)	Spring(9-April to 22-May)	0.71	9.9	6.6	0.24	33.8
	Early summer (5-June to 10-July)	0.95	11.6	6.5	0.42	44.2
	Summer (25-July to 13-September)	1.63	22.0	12.1	0.73	44.8
	Autumn (18-September to 13-November)	0.65	8.9	5.5	0.24	36.9
	Winter (28-November to 19-February)	0.58	7.9	6.6	0.10	17.2
	Early spring (6-March to 18-March	0.68	9.1	6.8	0.17	25.0

Water sampling and analysis were conducted 2 to 3 times a month, 28 samples in total.

Table. 3 Average concentration and removal ratio of COD, SS, nitrogen, phosphorus, etc. in inlet and outlet water during the survey period

Items	Inlet water (Johkasou effluent,mg/L)	Outlet water (mg/L)	
		Vegetables/ Fruits (Ditch B)	Flowers/ Conifer (Ditch A)
COD_{Mn}	10.2	6.3 （38.2）	5.9 （42.2）
SS	0.5	0.0 （100）	0.0 （100）
T-N	11.7	6.0 （48.7）	7.5 （35.9）
NO_3-N	10.3	5.5 （46.6）	6.9 （33.0）
T-P	4.8	3.7 （22.9）	3.9 （18.8）
PO_4-P	4.8	3.7 （22.9）	3.9 （18.8）
K	13.9	10.1 （27.3）	12.2 (12.2)
Ca	12.3	11.0 （10.6）	11.7 （4.9）
Mg	6.3	5.8 （7.9）	6.1 （3.2）

- Survey period: April 9, 2018 to March 18, 2019, average value of 28 samples in total
- (　　) is the annual average removal ratio

5. Research Results in FY 2023

○ Growth status and harvested sunny lettuce on June 5th

Ditch A

Ditch B

Tomato and Passion fruit (section A1)

Calla and Manchurian wild rice (biotope pond)

forward

backward

The grass is taller towards the forward of the ditch.

Corn (section A2 & A3)

Kidney bean and sunny lettuce (section B3)

Harvested sunny lettuce (234 g, section B3)

○Growth status on July 25th and harvested Molokheiya, Asparagus bean, and tomatoes

Backward of Ditch A
（Water convolvulus ）

Backward of Ditch B
(Asparagus bean)

Tomato (section A1)

Molokheiya ：181 g
Asparagus bean ：625 g

Tomato（A1：3150 g, B1：580 g)

6. Safety consideration based on ISO guidelines

Table 4. Water quality of treated wastewater and crops that can be used as irrigation water (ISO guidelines)

category (Quality of effluent)	BOD (mg/L)		SS (mg/L)		fecal coliform bacteria (N/100mL)		available crops
	Ave.	Max.	Ave.	Max.	95% ile.	Max.	
A (Very high quality)	≦5	10	≦5	10	≦10 or below the detection limit	100	vagetables consumed raw
B (High quality)	≦10	20	≦10	25	≦200	1,000	processed food crops
C (Good quality)	≦20	35	≦30	50	≦1000	10,000	non-food crops
D (Medium quality)	≦60	100	≦90	140	-	-	industrial and seeded crops

Excerpt from ISO 16075-2, Table 1 (2020)

Table 5. Water quality classification of treated wastewater and number of barrier points required for irrigation of each crop

Crop type	Category of treated wastewater			
	A	B	C	D
Vegetables consumed raw	0	1	3	Prohibit to use
Processing crops, pasture	0	0	2	Prohibit to use
fruit trees, garden crops	0	0	1	3
seeded crops, feed crops	0	0	0	1

Excerpt from ISO 16075-2, Table 3 (2020)

Table 6. Barriers that help improve safety and their scores (example)

Type of barriers	Number of barriers
(1) Drip irrigation using a protective sheet to prevent irrigation water from adhering to crops	1
(2) Cleaning crops with potable water before sale	1
(3) Irrigation cessation or interruption before harvest	1 to 2
(4) Underground drip irrigation at a depth where irrigation water does not rise to the ground surface due to capillary action	3

Excerpt from ISO 16075-2, Table 2 (2020)

In the BGF Ditch, pumice is filled to a height of 28 cm and the water level is maintained at 17 cm, so the effluent from the Johkasou (inlet water) does not rise to the surface of the pumice. For this reason, BGF Ditches are considered to correspond to the 3 points of the barrier similar to underground drip irrigation in the ISO guidelines. Therefore, it is suggested that even vegetables produced in the BGF Ditch into which Category C treated wastewater flows can be used for raw consumption.

At my house, an advanced treatment type Johkasou has been installed so that keeps the BDD and SS concentrations of effluent below than 10 mg/L (performance evaluation value). For this reason, it is thought that effluent with a quality close to Category B is being supplied to the simple BGF Ditch, which is presumed to bring safer.

In addition, in order to safely eat the vegetables and fruits we harvest, our family is reviewing our lifestyle, including refraining from using chemical substances that may have a negative impact on the environment.[2)] For this reason, food poisoning caused by harvested raw vegetables such as sunny lettuce, tomatoes, and strawberries has never occurred.

7. Summary

1. By supplying Johkasou effluent to the simple BGF Ditch, it was able to produce a wide variety of vegetables and fruits, including sunny lettuce, tomatoes, Asparagus bean , passion fruit, and strawberries.
2. The nitrogen removal rate from Ditch B (Vegetables/Fruits) during the summer when biomass is actively growing was 1.31 $g/m^2/day$, approximately 1.8 times higher than that of Ditch A (flower/conifer).
3. According to the ISO guidelines, it was suggested that raw vegetables and fruits such as sunny lettuce, tomatoes, and strawberries produced using simple BGF Ditch can be safely consumed.
4. This purification system is an energy-saving and resource-recycling purification system for domestic wastewater that complies with the SDGs, so we would like you to plant crops that suit the characteristics of each region and use it to conserve the water environment and resource recycling.
5. In order to safely eat harvested vegetables and fruits, it is important to review our lifestyles, such as refraining from using chemical substances that may have a negative impact on the environment.

Acknowledgment

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References

1) Y. Ozaki: Japan Agricultural Research Quarterly, 33(4), 243-249 (1999)
2) Yasuo Ozaki: Journal of Johkasou, October 2019 issue, No. 522, 32-38
3) Yasuo Ozaki: Johkaasou Research, 32 (1), 1-8 (2022)
4) International Standard, ISO 16075-2(2020-11)

Thank you for your attention !

passion fruit

strawberry

Animals and plants that live in the biotope pond (August 24, 2017)

Potamogeton malaianus, Myriophyllum spicatum

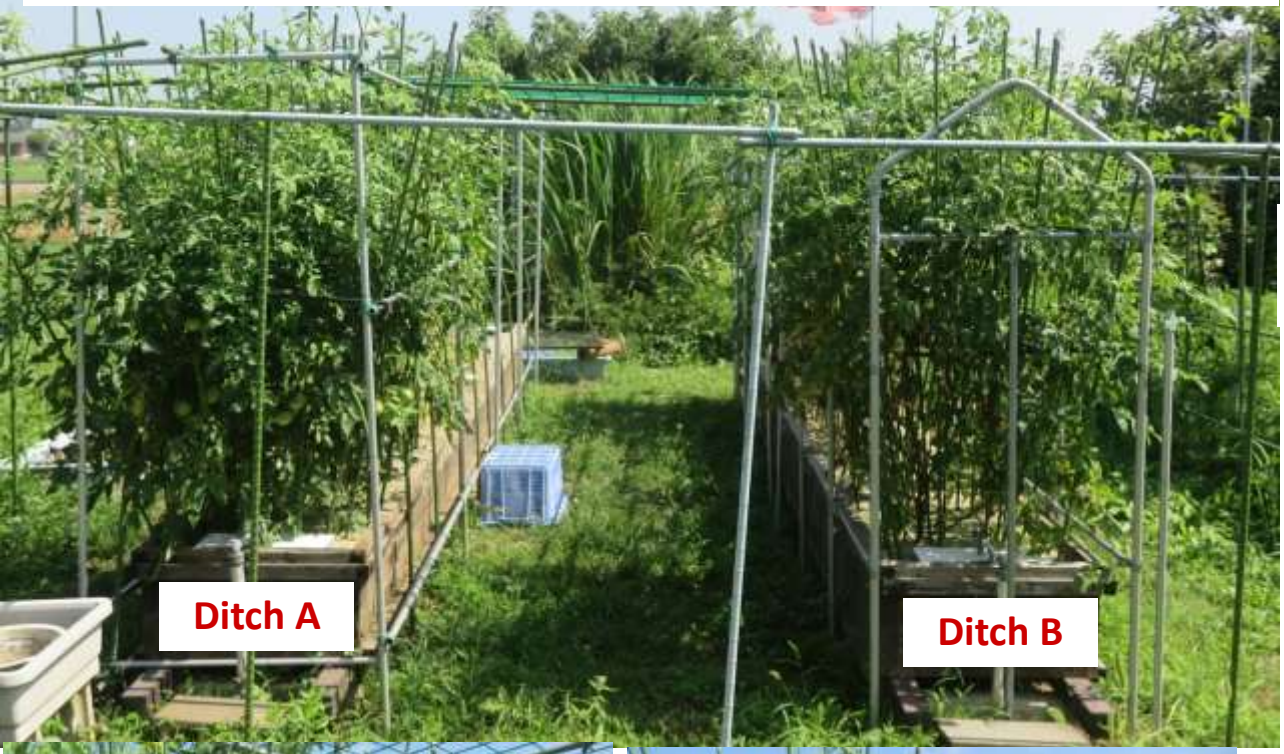
American bullfrog, black-spotted pond frog

Japanese killfish, Tadpole

Cybister japonicus

dragonfly larva

○ Growth status and harvested corn on July 9, 2023



Transplanted Asparagus bean (section A2 & A3)

Transplanted Corn (section B3)

Ditch A (Tomato, Passion fruit, etc.)

Ditch B (Tomato, Passion fruit, etc.)

Corn (A2: 1,500 g, A3: 1,170 g)

Growth status of tomatoes, passion fruits, etc. (7/17)

Growth status of sunny lettuce, kidney beans, etc. (May 28)

Examples of vegetables and fruits harvested using a simple BGF Ditch (FY 2021, Tsukuba City, Ibaraki Prefecture)

Snap peas（7-April）

Strawberry（23-April）

Leaf lettuce (18-May）

Garland chrysanthemum(18-May）

Sunny lettuce (20-May)

Kidney bean (19-June)

Tomato and Asparagus bean (24-July)

Passion fruit (18-August）