Oct. 14, 2020

３Ｄ（バイオ排水処理）
スマートバイオ社会を実現するバイオプロセス最適化技術の開発

Development of Novel Technology for Bioprocess Optimization in Smart Bio-Industry

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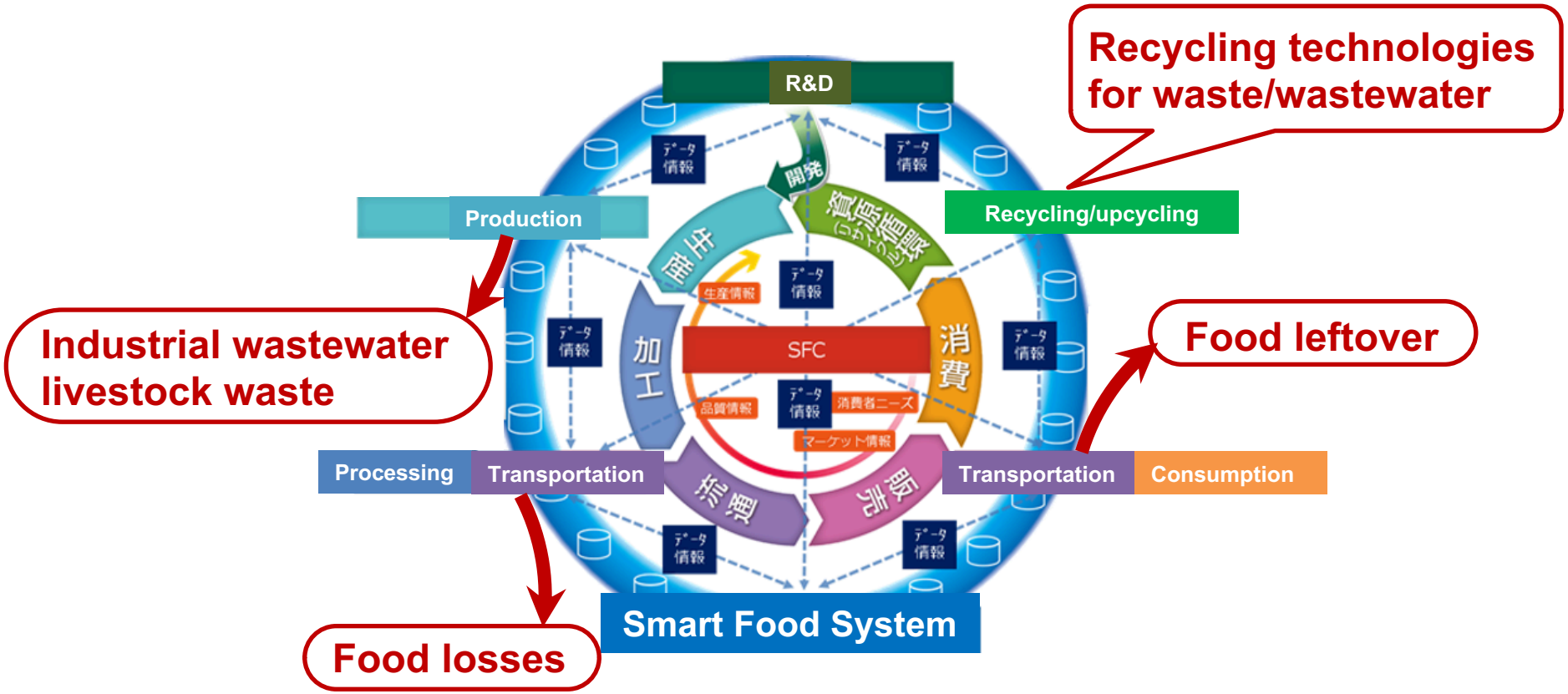
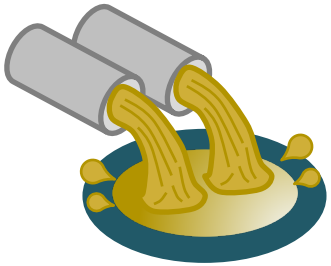
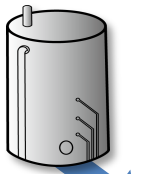
Importance of waste/wastewater treatment in smart food system

A large amount of organic waste/wastewater is generated in the production, processing, distribution, transportation, and consumption processes in the Smart Food System (SFS). Since the cost of waste/wastewater treatment is enormous, it is necessary to develop the novel technologies to optimaze the SFS.



Fasts of waste/wastewater treatment in Japan



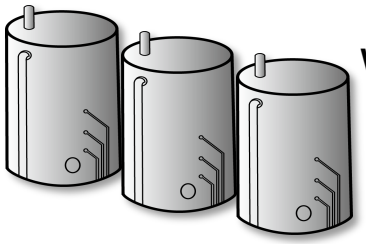


- The estimated annual amount of water used in the food and beverage manufacturing industry in Japan is approximately 750 million m^3, accounting for 11.5% of the total manufacturing industry. [1)]
- Treatment cost of industrial wastewater per cubic meter is 6 times higher than sewage treatment. [2)]
- 25.5 million tons of food-derived waste are discharged annually in Japan, of which 6.12 million tons are "food loss." [3)]
- Some of these organic wastes are treated by biogas plant to produce methane as a source of electric power generation; however, the treatment of digestate is an issue.
- The number of food/beverages producing factories are >3,300.[4)] Wastewater is commonly treated by the conventional activated sludge (CAS) process.

1) Ministry of Economy, Trade and Industry, Japan, 2019; 2) Ohkuma, 2016;
3) Ministry of the Environment, Japan, 2017; 4) Ministry of the Environment, Japan, 2019

Current situations of waste/wastewater treatment in bio-industry

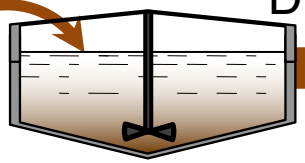
Food/beverages producing factories



Wastewater

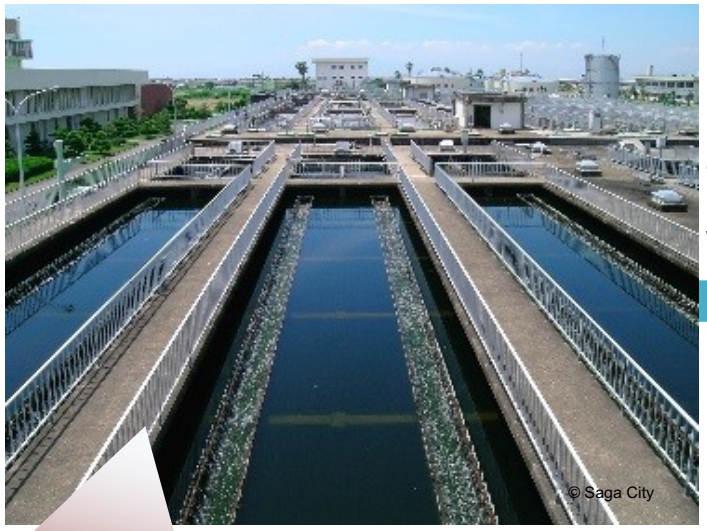
"Food loss"

Digestate



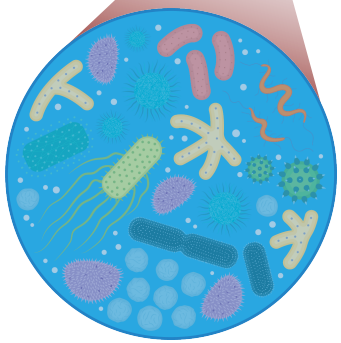
Anaerobic digestion process

Biological wastewater treatment process
e.g., conventional activated sludge (CAS)



Treated water

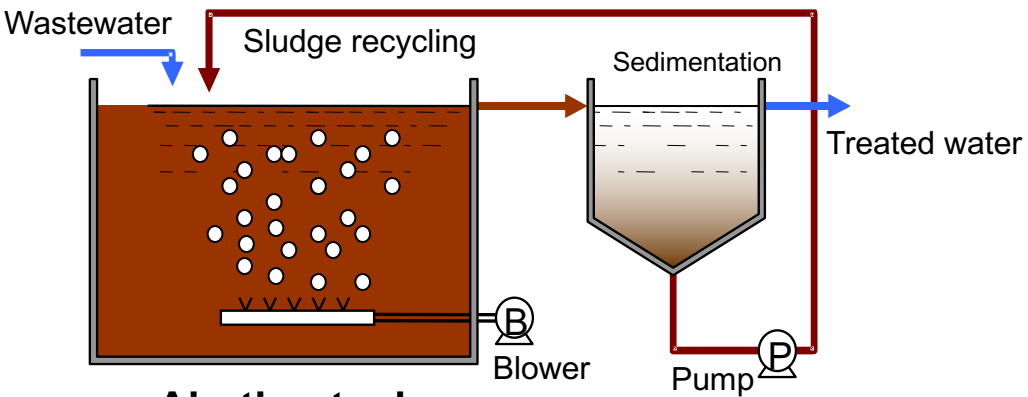
River, ocean



Phylogenetically and functionally diverse microorganisms decompose and remove organic matter and nitrogen components contained in wastewater.

Current situations of waste/wastewater treatment in bio-industry

Conventional activated sludge (CAS)



Airation tank

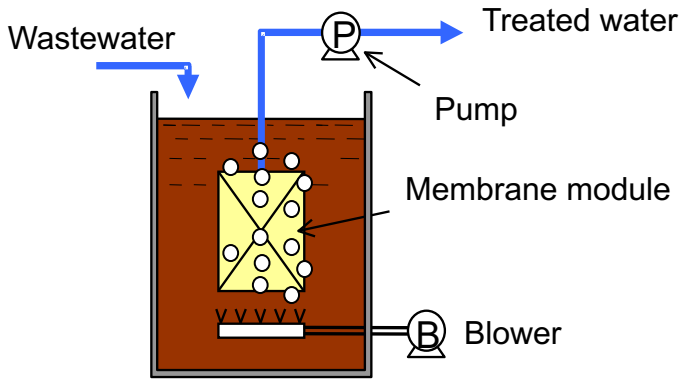
◆**Huge energy for airation**

⇒ Due to excess aeration, the annual electricity cost for industrial wastewater treatment is up to 141 billion yen in Japan.[1)]

◆**Unexpected failure**

⇒ It is impossible to predict and control based on water quality data, etc., and so the operation is handled based on individual experiences.

Membrane BioReacter (MBR)



Airation/filtration tank

◆**Huge energy for airation**

⇒ In some cases, it is twice as much as the CAS.

◆**Fouling and clogging**

⇒ It is impossible to predict or avoid by commonlly monitored parameters,e.g., differential pressure of the membrane, pH, etc.

Advantages: Space-saving, relatively low CAPEX, useful for high strength organic wastewater, and enabling add-on to CAS.

1) Ohkuma, doi:10.14989:doctor.k19678, 2016.

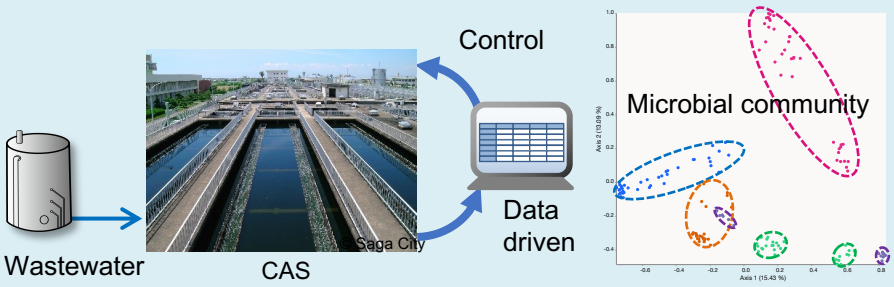
From the viewpoint of "Bio & Digital", we are developing predictive control technologies for:

- degradation efficiency in CAS and anaerobic digestion processes
- fouling/clogging in MBR

To reduce wastewater treatment costs by optimizing the aeration rate and saving labor.

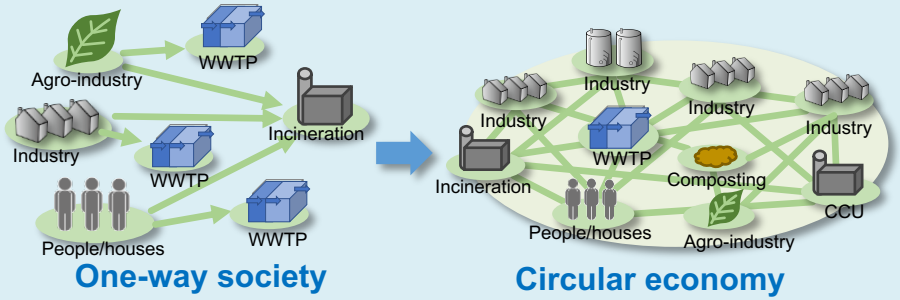
Novel Technologies for Bioprocess Optimization in Smart Bio-Industry

Data-driven predictive control technology for wastewater treatment process



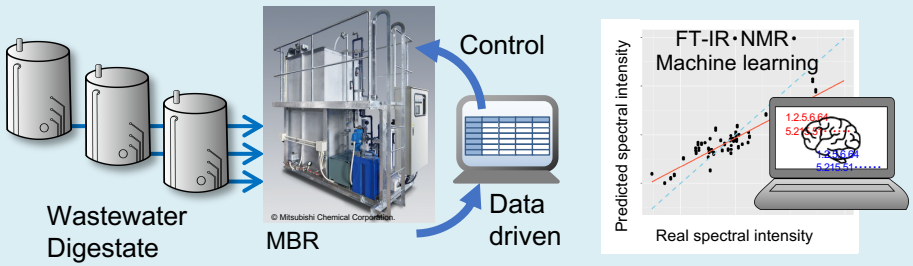
520 : 16S rRNA gene amplicon sequence data
90 : Shotgun metagenome sequence data
~1,000 : Draft genomes of microorganisms

Simulation tool for the design of bioeconomy-based society



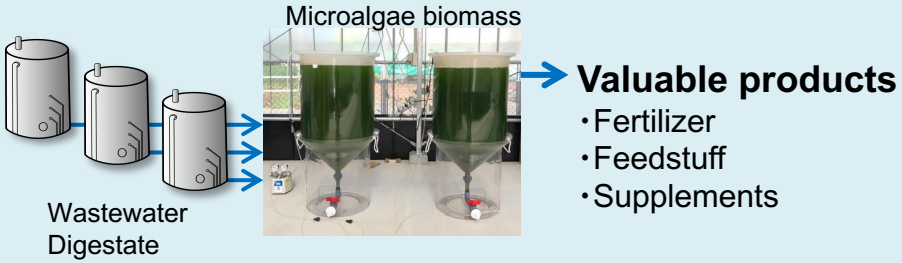
Development of α-version of the simulation tool installing wooden board manufacturing process using lignocellulose waste as raw material

Advanced MBR with predictive control technology for fouling/clogging



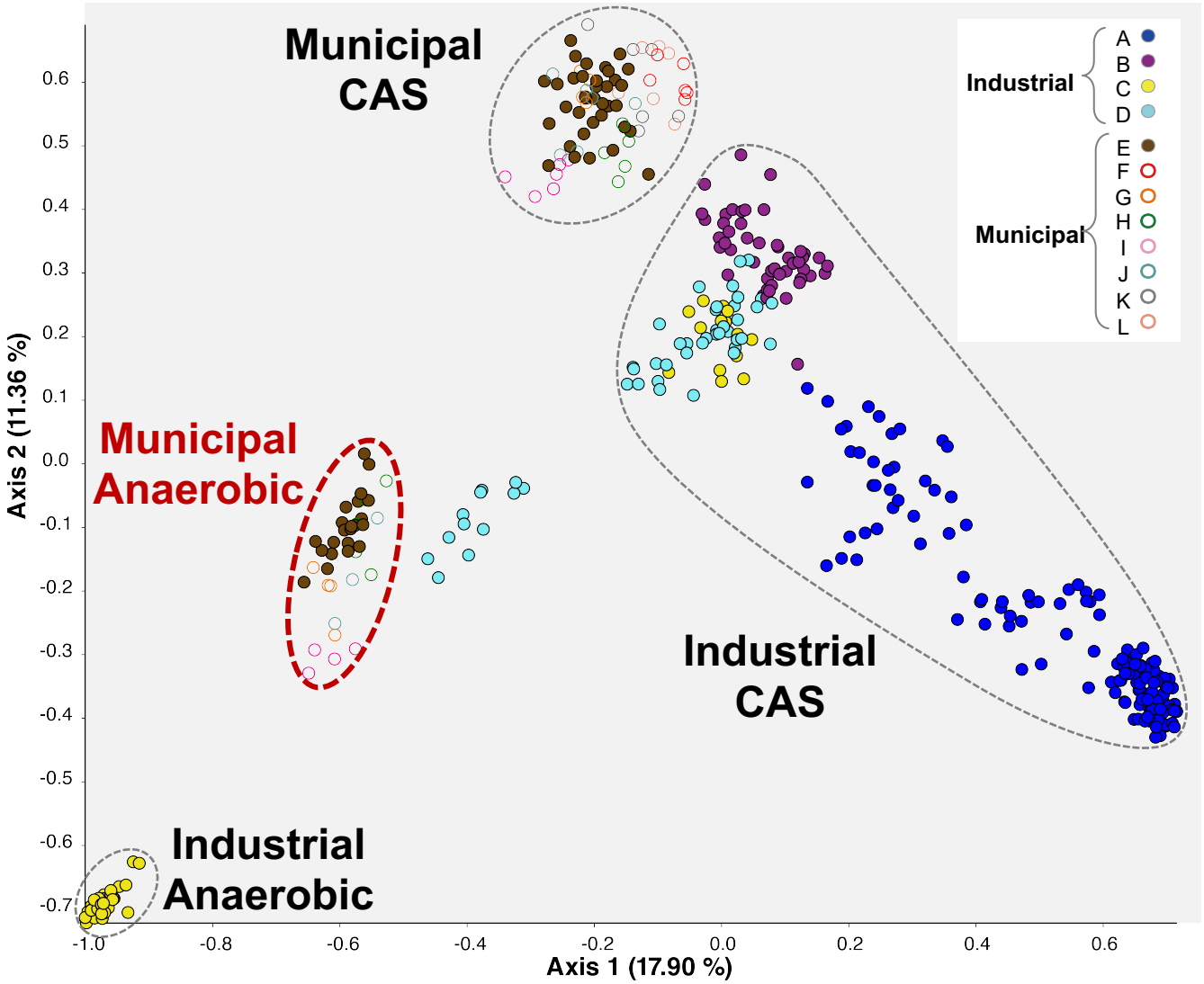
Development of prediction model for fouling by using machine learning approach

Microalgae cultivation system using industrial wastewater



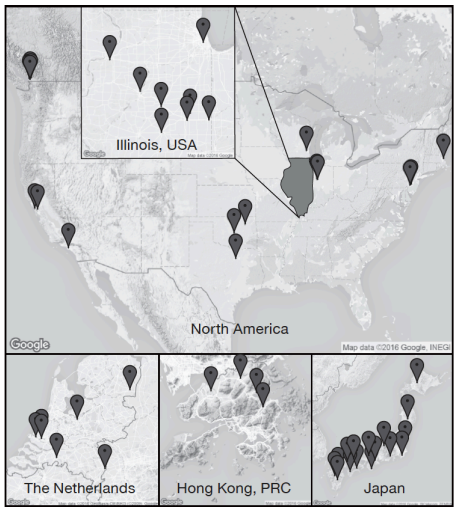
Development of 100L-scale cultivation system of microalgae using digestate as substrate

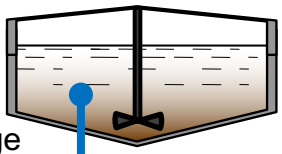
16S rRNA gene amplicon sequence data of 520 sludge samples to evaluate microbial community structures of industrial and municipal WWTPs



International research projects: Anaerobic Digester Microbiome

- 51 grobal WWTPs
- 90 anaerobic digesters

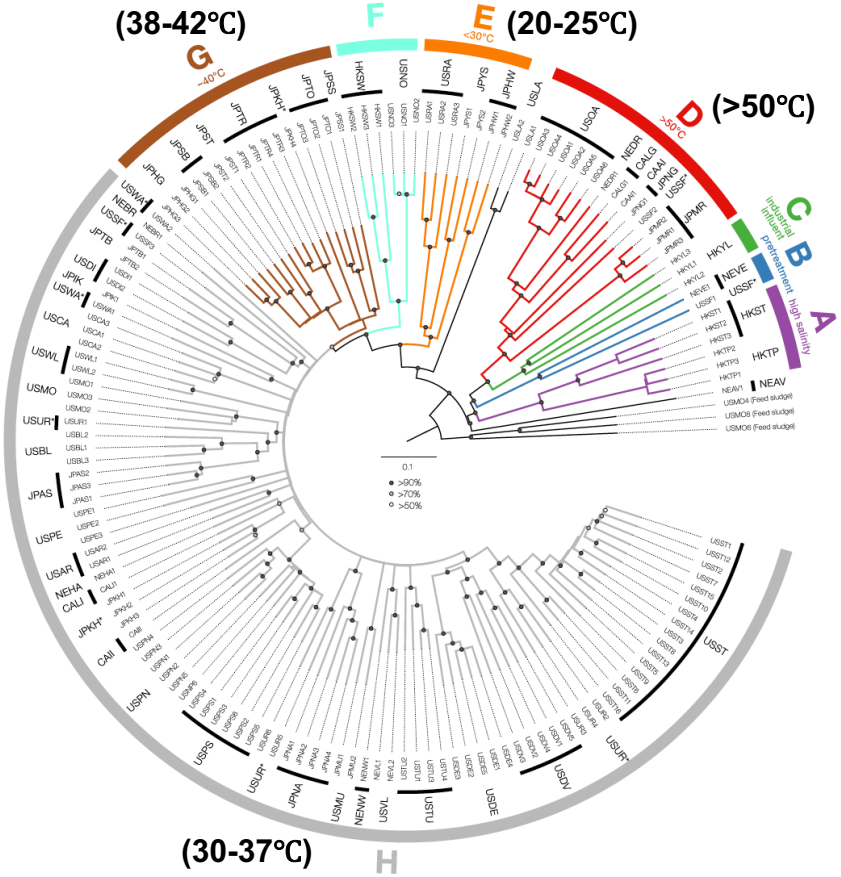




Sludge sampling

Microbial community analysis
Metagenomic analysis

- What factors shape the microbial composition of the anaerobic digester sludge?
- What is the ecological role of individual microorganisms?

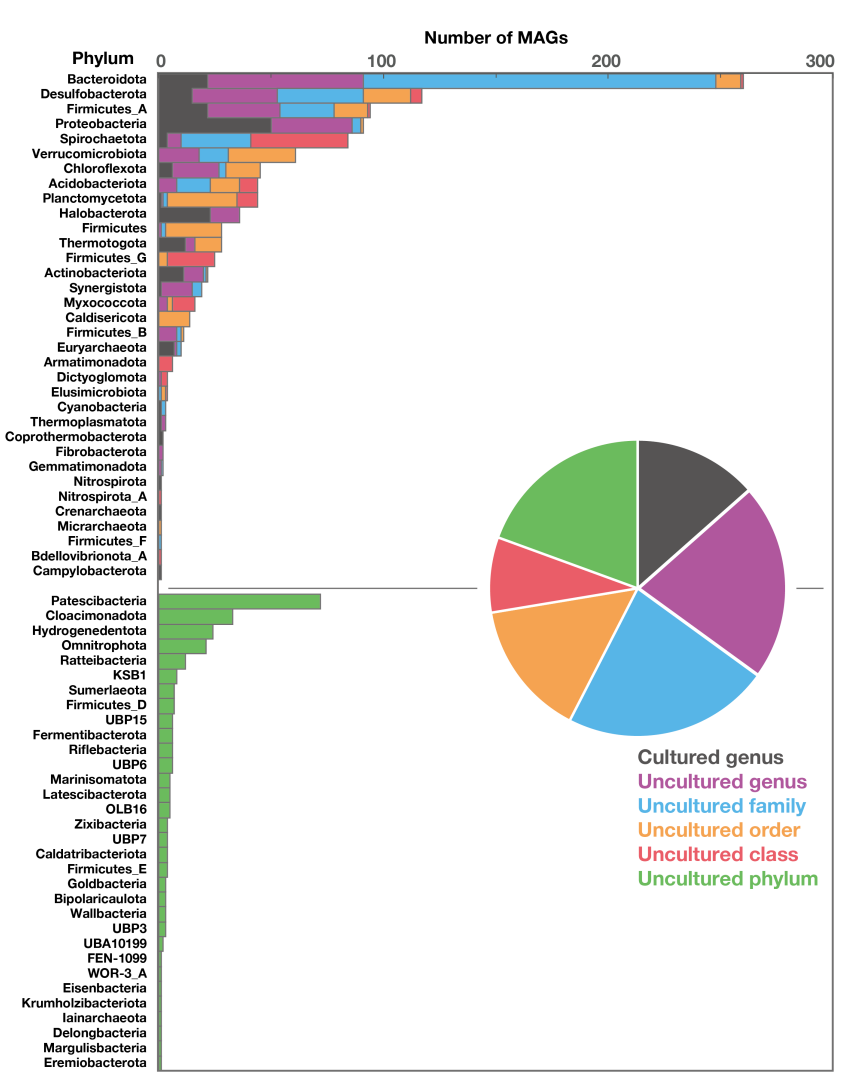


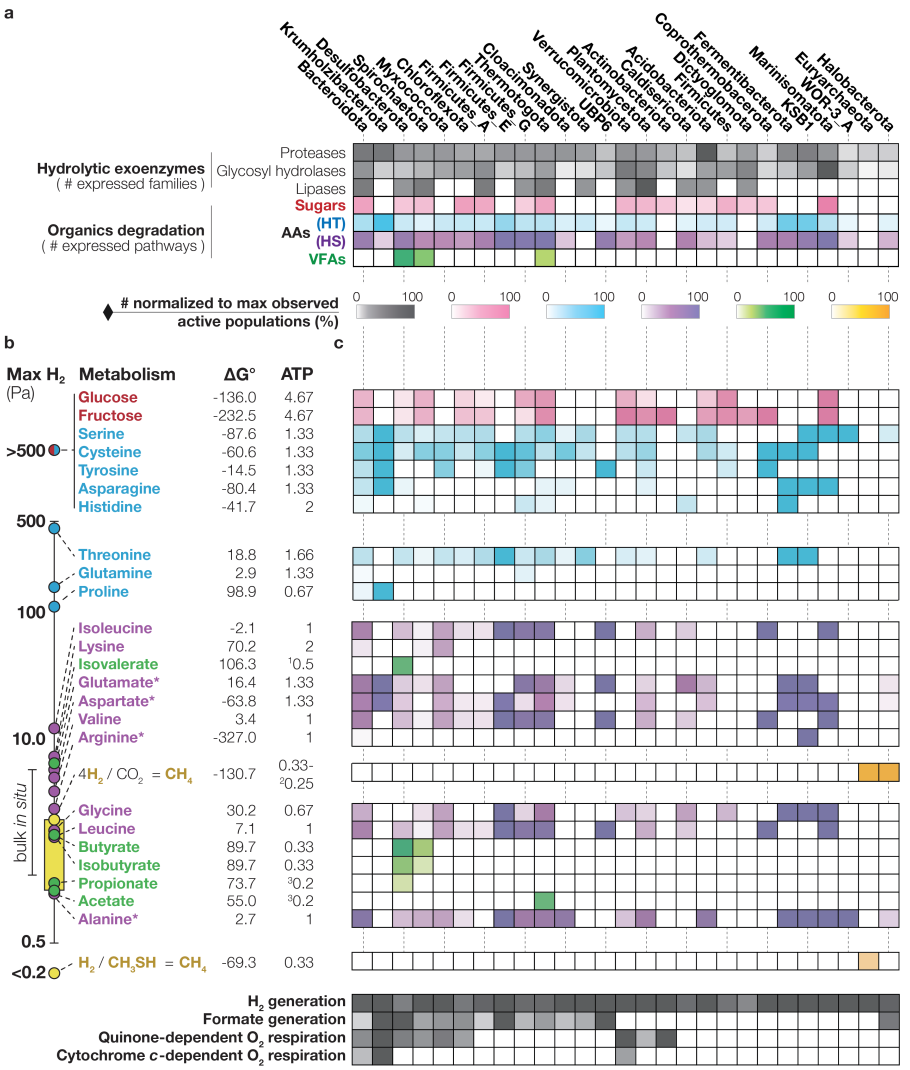
Operation temperature and wastewater types affect the microbial composition of digester sludge.

Mei, et al., Water Research 124:77-84, 2017

International research projects: Anaerobic Digester Microbiome

- **Recovered >1,000 microbial draft genomes including uncultured species.**
- **Identified active species/metabolic pathway according to RNA expression .**

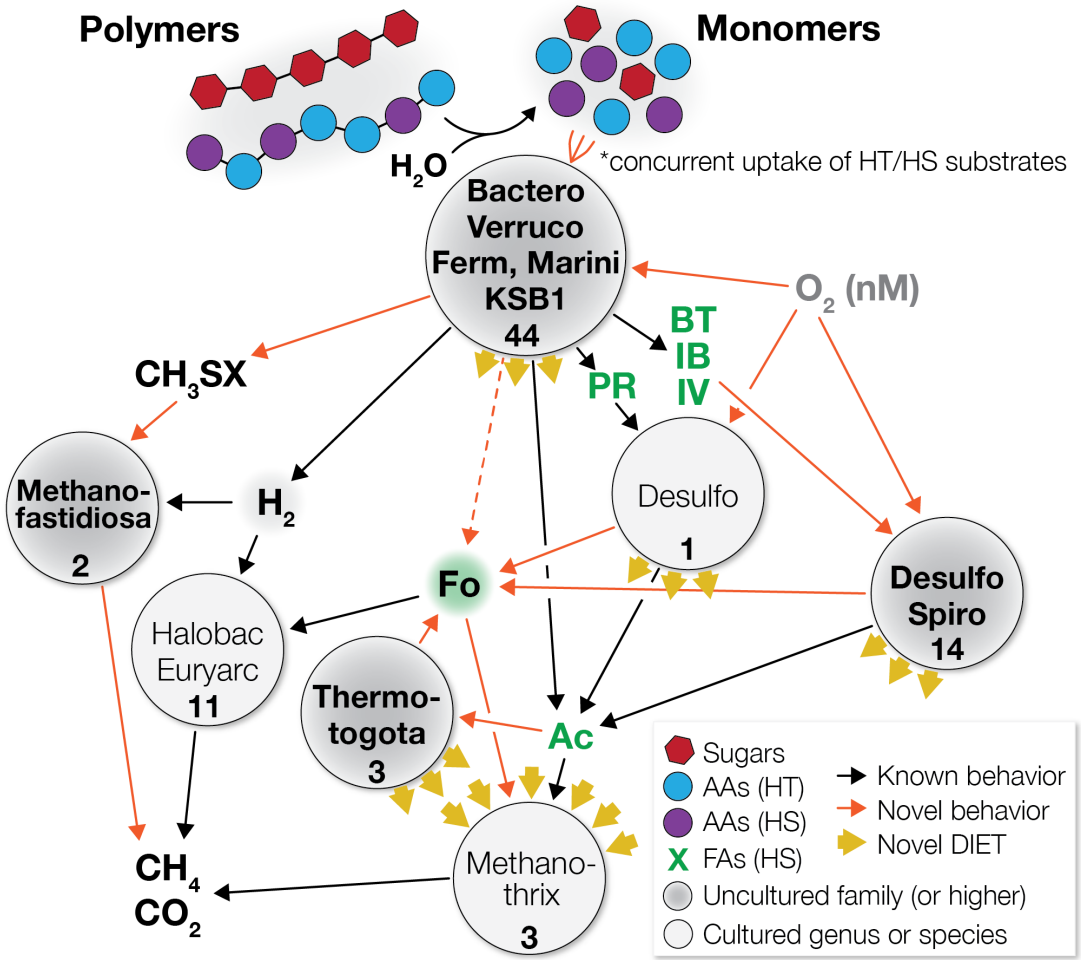




Nobu, Narihiro et al., Microbiome 8: 111 (2020)

International research projects: Anaerobic Digester Microbiome

Uncover of hidden flow of organic matter decomposition in anaerobic sludge digestion ecosystem



PR: propionate
BT: butyrate
IB: isobutyrate
IV: isovalerate
Ac: acetate
Fo: formate
CH_3SX: methanethiol

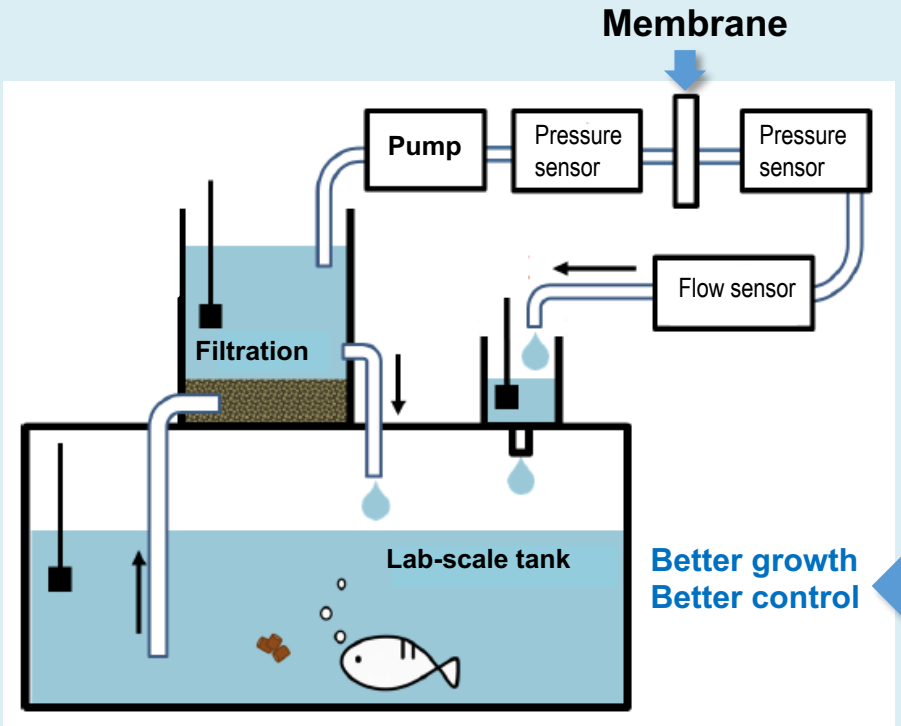
The SIP project will employ these microbial community and metagenomic information as "big data" for the upgrading of wastewater treatment technology.

Nobu, Narihiro et al., Microbiome 8: 111 (2020)

Data-driven predictive control technology for MBR

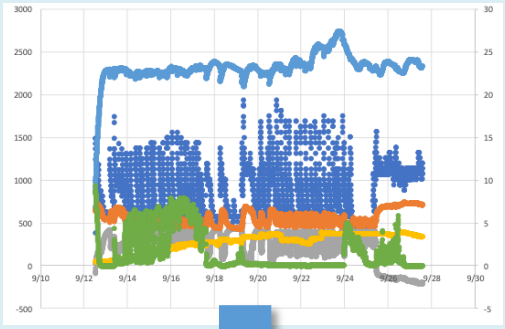
We have constructed a prediction model for differential pressure of membrane by machine learning approach in a lab-scale model system for aquaculture wastewater treatment.

Model system

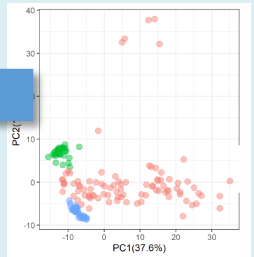


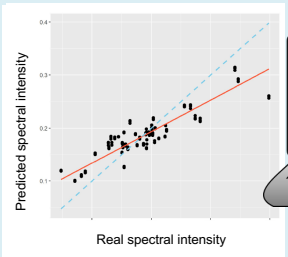
Better growth
Better control

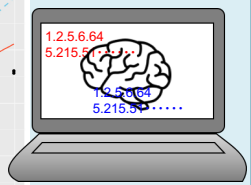
Data aquisition



Model calculation



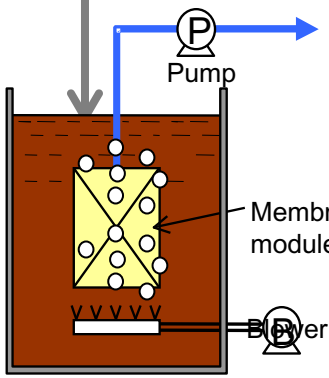




Proof-of-concept for the Data-driven MBR system

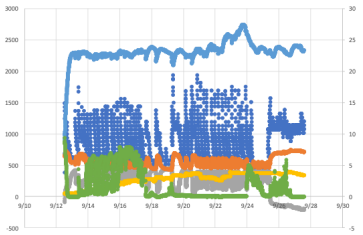
Anaerobic digesters treating food loss wastes in Nagaoka City, Japan

Digestate

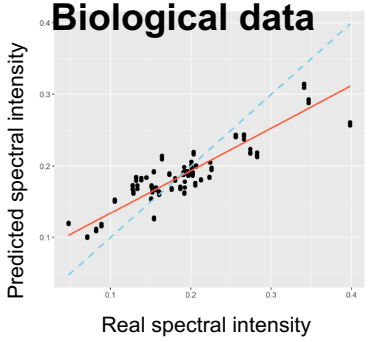


Pilot-scale MBR

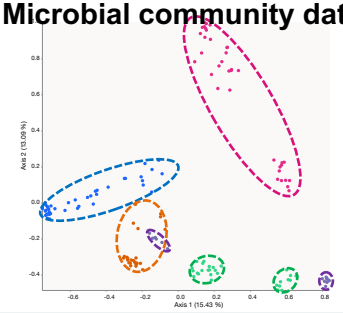
Data aquisition

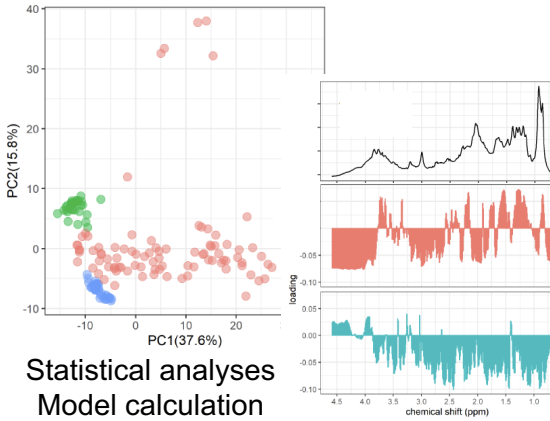


Biological data



Microbial community data

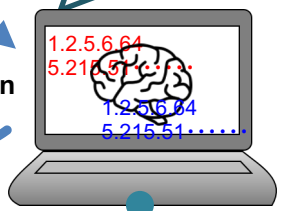




Statistical analyses
Model calculation

DB

Data driven

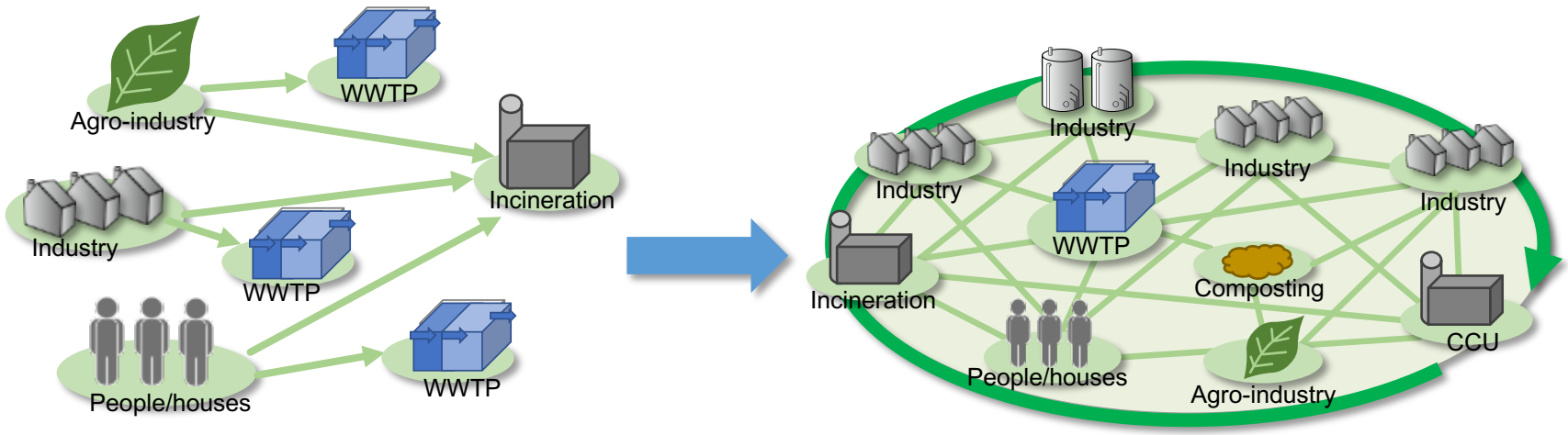


Better airation condition, etc.

Data-driven, cost-cut solutions for MBR operation

Simulation tool for the design of bioeconomy-based society

Verification for the environmental and economic impacts on the regional circular economy in Saga City as a model districts.



Concepts of the bioeconomy simulation tool:

- Harvesting the data of waste/wastewater held by local governments.
- Hearing survey of the bottlenecks of production process and waste generation for companies.
- Making the simulation scheme of certain production process using unused and abundant biomass waste as a raw material.
- Evaluation of the business feasibility based on the environmental and economic impacts.

Simulation tool for the design of bioeconomy-based society

ECOR Enabling
co-Creation
co-Operation
co-Responsibility

A company with new technology that produces earth-friendly materials from waste and unused resources

佐賀市 SAGA

Morodomi Furniture Promotion Cooperative

The Morodomi area in Saga City is a center of furniture manufacturing industry adjacent to the Okawa area, whrere the largest furniture producing area in Japan.

Tech.

Manufacture wooden panels from wasted cellulose fiber.

Info.

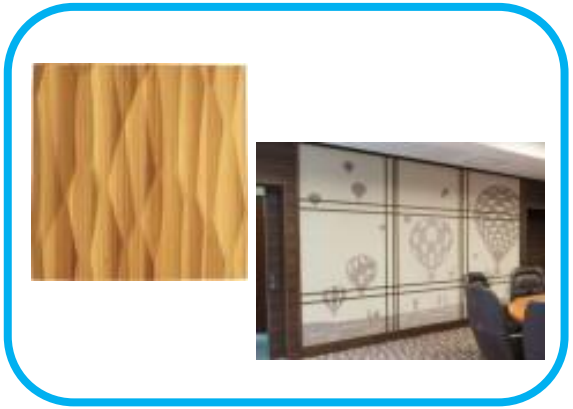
Information about the amount of cellulose-based biowastes in Saga City, such as straw, rice husks, used paper, and seaweed residue.

Tech.

Veneer technique for laminating wood materials.

+

+



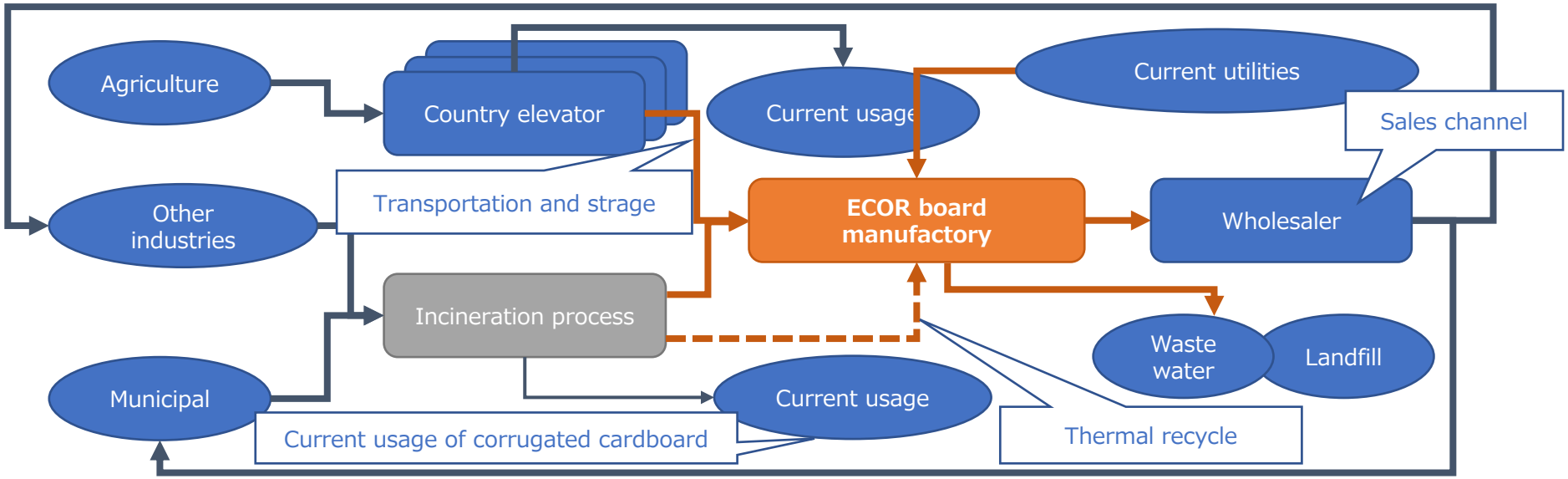
Cradle To Cradle certified + FSC certified

→Expanded to domestic and overseas furniture markets with environmental performance

Cradle to Cradle Certified website, https://www.c2ccertified.org/
Forest Stewardship Council Japan website, https://jp.fsc.org/

Simulation tool for the design of bioeconomy-based society

Development an α-version simulation tool to upcycling the wasted cellulosic biomass, which has a large amount in Saga City.

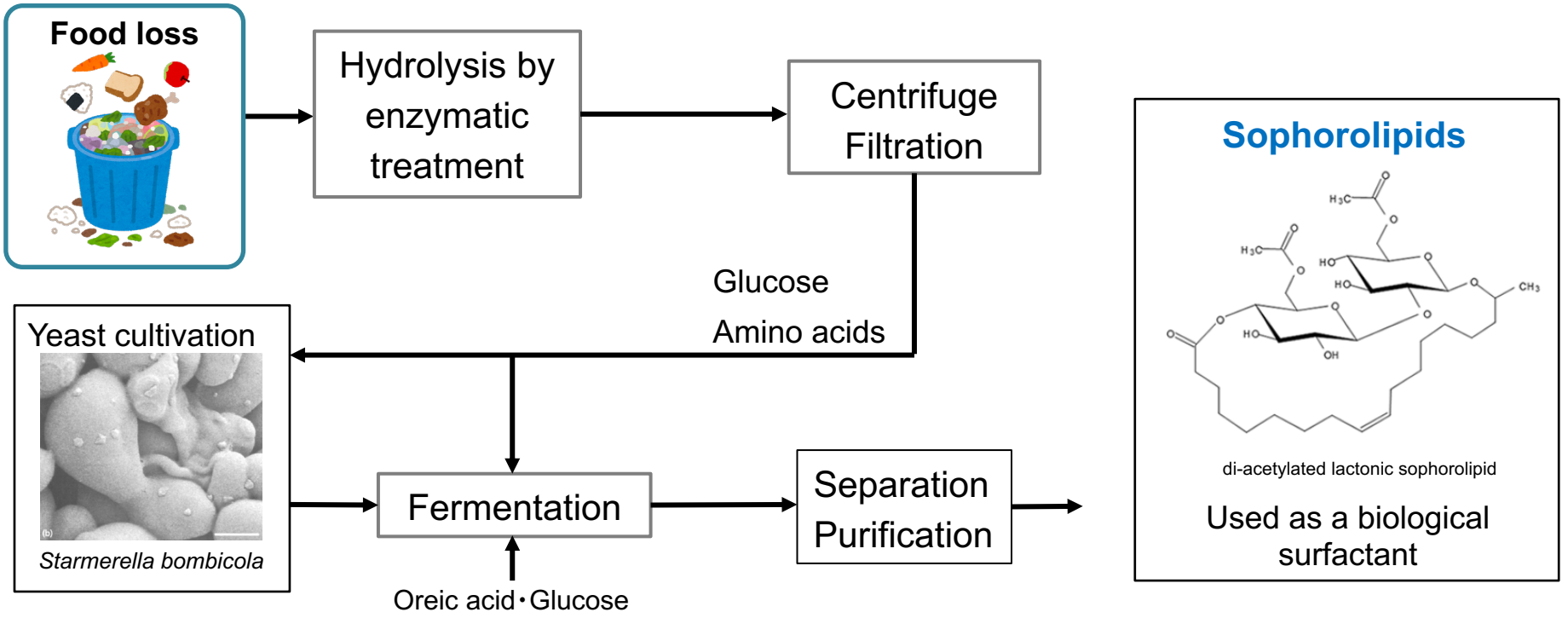


Case study	Energy consumption [GJ/ton]	GHG emission [t-CO_2eq/ton]
ECOR board	◎	◎
Conventional board	△	△

By comparing the ECOR board with the conventional wooden board, the environmental and economic superiority of the ECOR board manufacturing factory was verified.

Simulation tool for the design of bioeconomy-based society

Simulation of sophorolipid production process by fermentation with yeast using food-derived waste and food loss as raw materials.



- Integration the sophorolipid production process to simulation tool.
- Evaluation of the business feasibility based on the environmental (e.g., CO_2 emission) and economic (e.g., sohololipid manufacturing cost) impacts in Saga City.

Rosa & Lachance, Int J Syst Bacteriol., 1998; De Graeve et al., FEMS Yeast Research, 2018

Bio-economy-related initiatives in Saga City

Carbon Capture Utilization (CCU)

CO_2

Production of astaxanthin, a high-value-added ingredient, from the microalga *Haematococcus*.

Waste incineration

Production of herb and cucumber in greenhouse.

Anaerobic digestion

Electric power generation using biogas

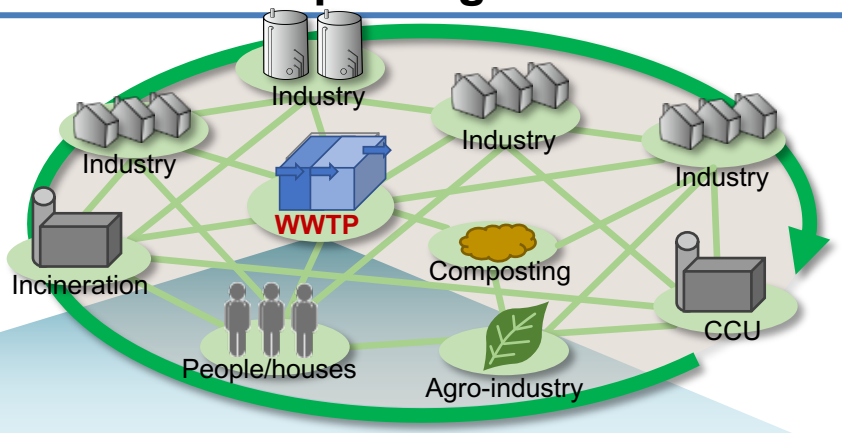
Digestate

Algal biomass

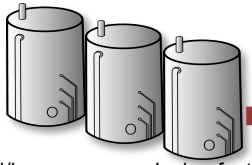
- Low-cost cultivation of native microalgae population using digestate containing N, P, etc., as substrate.
- Obtained algal biomass will be used for fertilizer, feedstuff, food supplements.

Novel waste/wastewater treatment tech. underpinning circular bioeconomy

We will implement the sophistication of wastewater treatment processes to optimize the regional circular economy from both simulation and technological development.



Waste, Wastewater



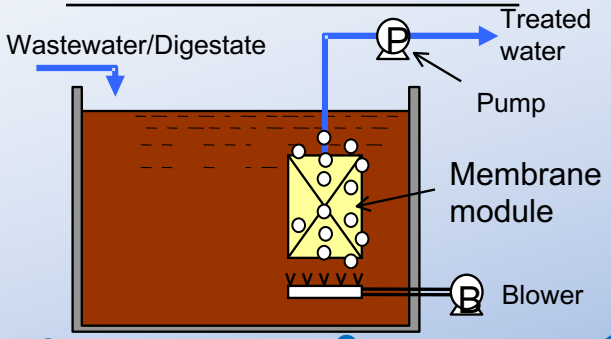
Wastewater

Food/beverages producing factories

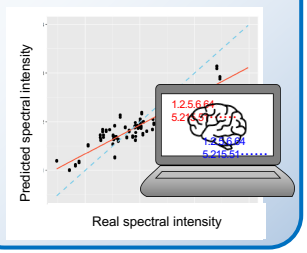
Digestate

Anaerobic digestion process

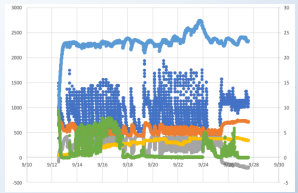
MBR added-on to CAS



Data-driven control



Data aquisition



Microalgae cultivation using wastewater

Extruction by super-critical CO_2

Separation/purification by inorganic menbrane

Each technologies (e.g., advanced MBR, data-driven control, multi-sensing, algae cultivation, etc.) will be commercialized and installed based on individual situations.

３Ｄ（バイオ排水処理）
スマートバイオ社会を実現するバイオプロセス最適化技術の開発

Smart Bio-process Consortium

9 members:

National Institute of Advanced Industrial Science and Technology, AIST
RIKEN
Mitsubishi Chemical Corporation
Chitose Laboratory Corporation
Ajinomoto Co., Inc.
Saga City
Nagaoka City
Saga University
Nagaoka University of Technology

We have been collaborated with 3 public organizations and 8 private companies.

３Ｄ（バイオ排水処理）
スマートバイオ社会を実現するバイオプロセス最適化技術の開発

Smart Bio-process Consortium

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