# Outline of Water Project of AIST

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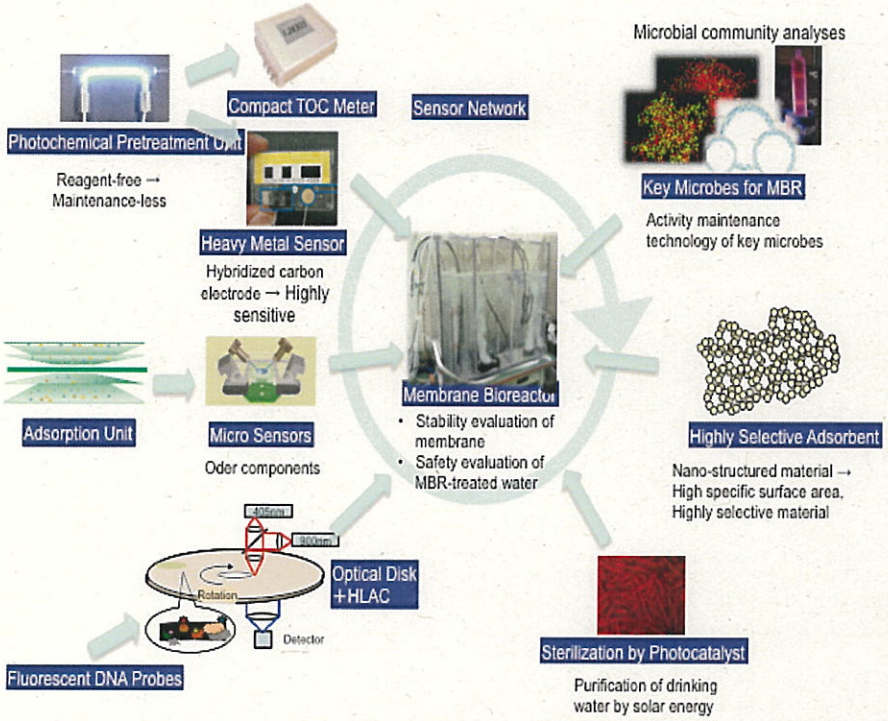
# AIST Water Project

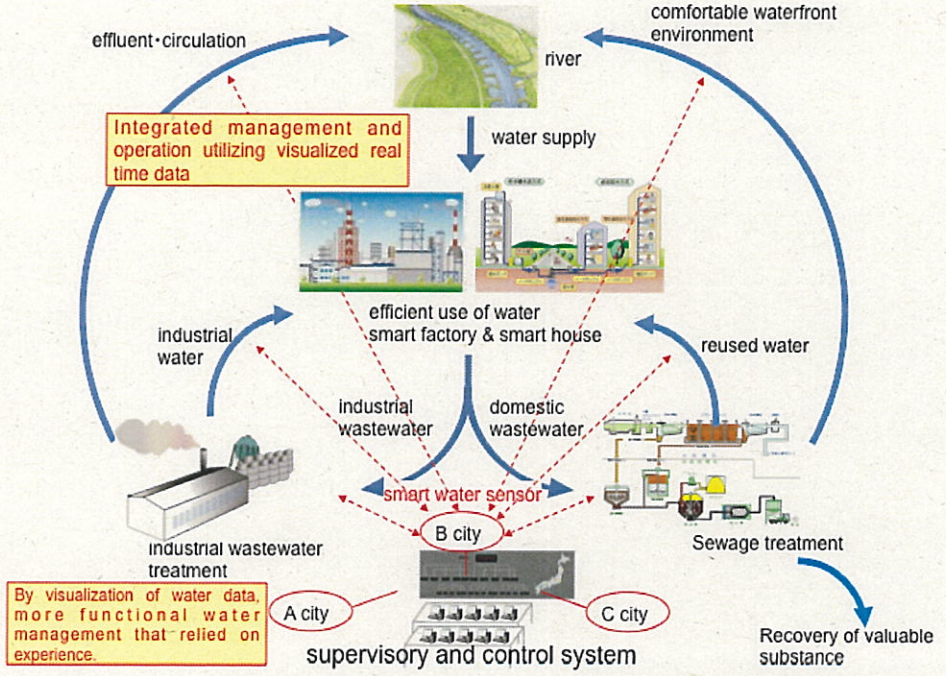

## Objective

This project aims to develop water measurement, treatment and information processing technologies for efficient and safe utilization of water resources, and to promote international collaboration for addressing global water issues, especially in Asian areas.

## Energy saving of water treatment




## Smart management of water in community



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Ryoji Chubachi,
President of AIST

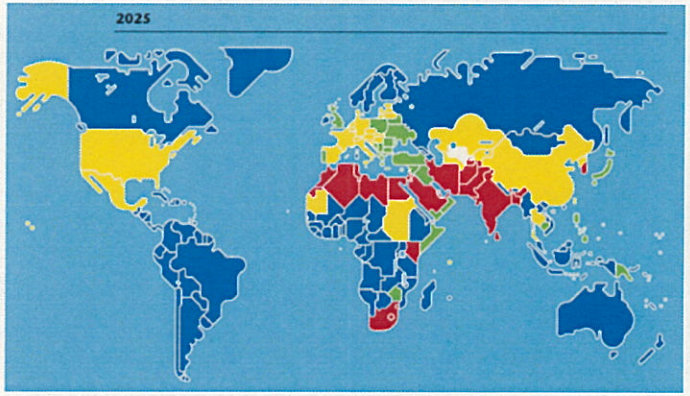
# AIST Water Project


Environment and Energy | Life Science and Biotechnology | Information Technology and Electronics | Nanotechnology, Materials and Manufacturing | Metrology and Measurement Science | Geological Survey and Applied Geoscience

- Research Institute for Environmental Management Technology
- Research Institute for Innovation in Sustainable Chemistry
- Bioproduction Research Institute
- Biomedical Research Institute
- Electronics and Photonics Research Institute
- Information Technology Research Institute

Dr. Masaki Torimura
Principal Research of EMTech

Over 30 researchers of 6 Research Institutes participate in this AIST Water Project




Global water stress
* WBCSD Water Scenarios to 2025

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# AIST Water Project


## AIST Technologies

Overcome the water problems by integrating AIST owned technologies listed below.

- Online water quality monitoring technology
- Highly sensitive heavy metals detection technology
- High-speed microbial image acquisition and processing technology
- Microbial separation & identification technology
- Membrane bioreactor (MBR)
- Decomposition & sterilization technology by photocatalyst
- Various materials for adsorption film
- Water data transfer and processing using cloud technology

## Global Collaboration

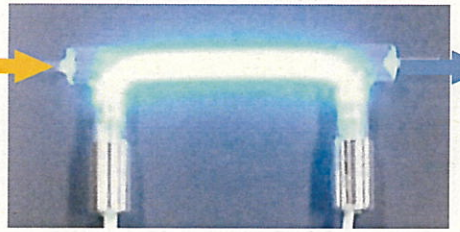
- Promotion of personnel exchanges and joint researches with the National Institutes and universities in Asia
- International cooperation for standardization of water technologies

# Maintenance-free TOC monitor using photochemical reaction

- Generation of oxidative species, ·OH, with UV irradiation (<190 nm)
- Persistent substances, humic acid, water is decomposed to $CO_2$ in less than 1 min
- No hazardous reagent and heating device

## Principle

Lamp-pass-through reactor



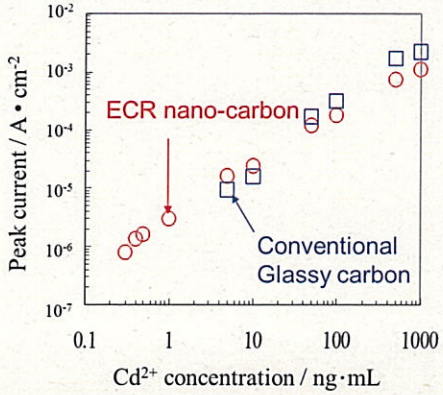

$H_2O + h\nu\ (<190\ nm) \rightarrow H\cdot + OH\cdot$

$OH\cdot$ + Organic matter $\rightarrow$ $CO_2$

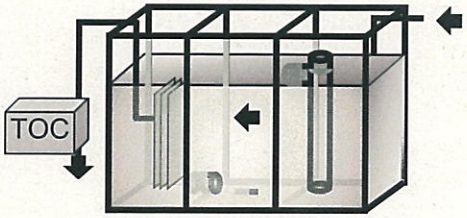
## Prototype

TOC, heavy metals

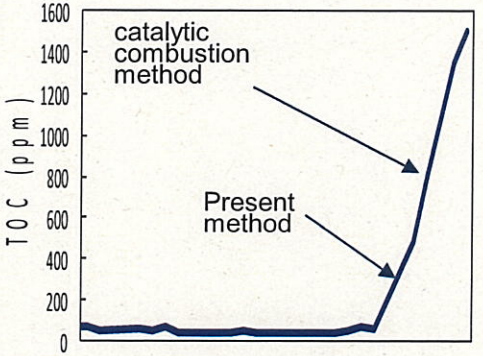
stripping voltammetry using ECR nano-carbon electrode




## Continuous Monitoring of MBR




MBR




Period: 1 month
Precision :1.8% for 12 h
Good comparability with catalytic combustion method

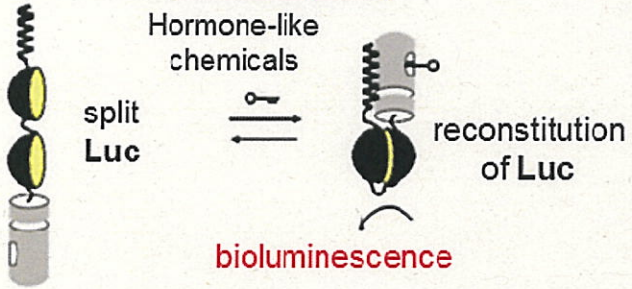
## Comparison with other methods

| | present | catalytic combustion method | UV oxidation with $K_2S_2O_8$ |
|---|---|---|---|
| reagent | none | Pt catalyst | $K_2S_2O_8$ |
| heater | none | >600°C | ~100°C |
| Detection limit | 6.2 μgC/L | 48 μgC/L | - |
| Mainte-nance | no need | exchange of catalyst, cleaning of heater | supply of reagent |

# Bioluminescent assay for endocrine-disrupting chemicals

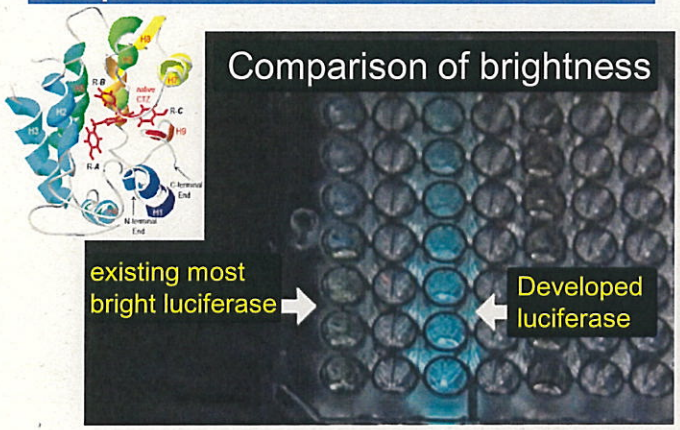
- Hormone receptor-mimicking bioluminescent probes for endocrine-disrupting chemicals (EDCs)
- High-throughput illumination of the activities of EDCs in wastewater and living subjects
- Superluminescent luciferases for supporting a high-sensitive analysis of EDCs of the probes

## Principle



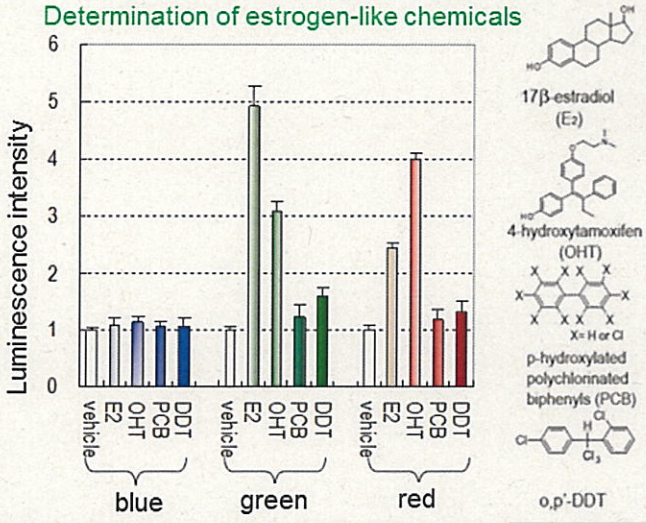

single-chain bioluminescent probe mimicking hormone receptors, which sense hormones and change the conformation. This change exerts reconstitution of the fragments of a luciferase and specific light emission.

## Superluminescent luciferase




- 100 times brighter than ever existing luciferases
- half-life period of luminescence is long (20 min)

## Determination of estrogen-like activities of chemicals

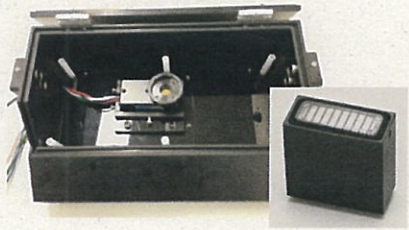



A multicolor imaging probe set. Green and red colors indicate genomic and nongenomic activities of chemicals, respectively.

## Step toward the practical use

Cooperation with several companies

## Prototype



## Ongoing research

- Application to PPCPs (pharmaceutical & personal care products)
- On-site monitoring
- Evaluation of efficiency of water treatment

# Whole cell biosensor for ecotoxicity testing using human iPS cells

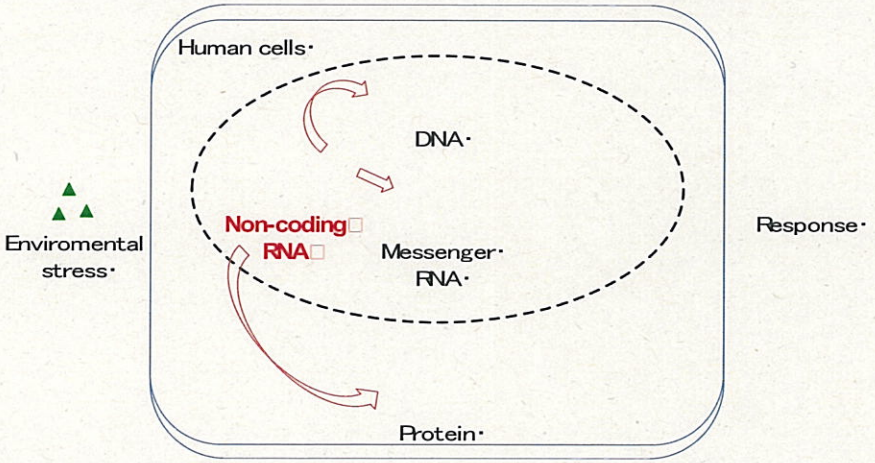
- Whole cell biosensor with broad substrate responses using human iPS cells
- Highly-responsive cell-based assay utilizing non-coding RNAs
- Rapid and cost-effective method for toxicity testing using microdevices

Non-coding RNAs are RNA molecules that are not translated into proteins. Recent transcriptomic and bioinformatic studies indicate that the thousands of non-coding RNAs exist, and newly identified non-coding RNAs dynamically regulate the gene expression in mammalian cells.

We hypothesized that non-coding RNAs highly respond to environmental stresses, such as ecotoxicological substrates. We have developed a highly susceptible cells that died by environmental stresses faster than normal cells. This technique is capable of rapid and sensitive method for toxicity testing.

We focus on the human iPS cells that can differentiate into various cells and tissues. In the future, we will assess the ecotoxicity of environmental samples to each human tissue using human iPS cells. Moreover, we will developed a rapid and cost-effective devices for ecotoxicity testing.

## Importance of non-coding RNA in human cells




## New sensor devices using human iPS cells

| | Normal cells | Genetically Modified | This study |
|---|---|---|---|
| Specific toxicity | △ | ○ | — |
| Whole toxicity | △ | — | ◎ |

# Detection of microorganisms using optical disk and image recognition technologies

- Early detection without culturing microorganisms
- Rapid scanning and low cost system using optical disk
- Identification of the organisms by image recognition and DNA probe hybridization techniques

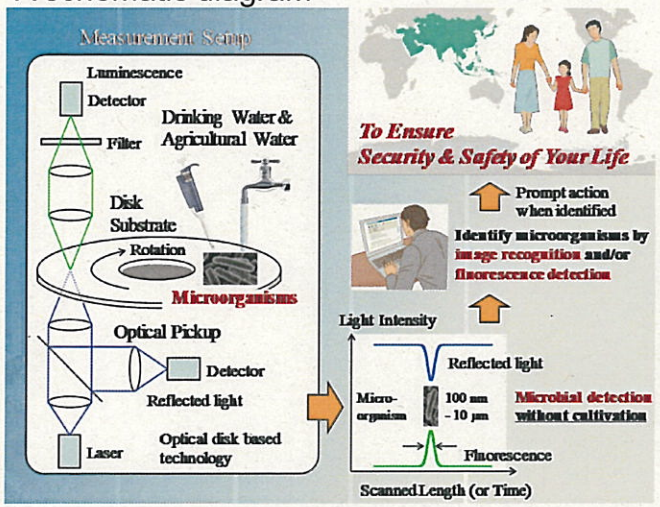
## Research target

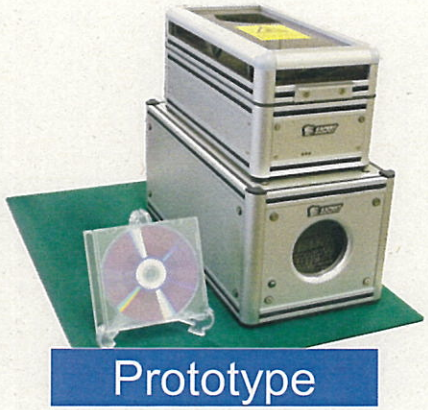
Detection and identification of pathogenic microorganisms such as *Escherichia coli* within several hours without cultivation by combined use of our original technologies including optical disk techniques and image recognition based on HLAC (Higher-order Local Auto Correlation).

## Research content

We measure the light intensity from an optical disk when microorganisms are attached and rebuild an image of the microorganisms by scanning many grooves and aligning the results properly. We roughly identify microorganisms from the cell shapes by pattern recognition techniques based on HLAC. We also use DNA probe hybridization technique for more accurate identification of microorganisms based on the fluorescently-labeled probe.

A schematic diagram



Prototype

Comparison with other techniques (Advantages are shown in red.)

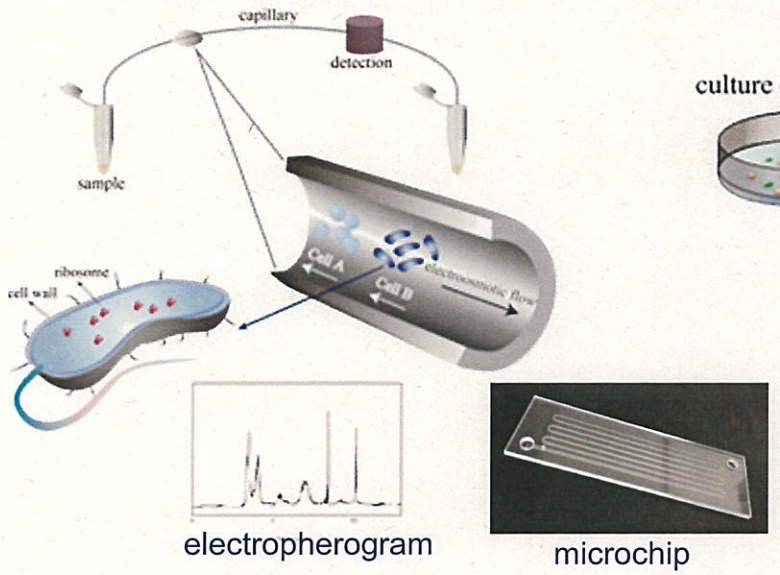
| | Optical Microscope | Optical Disk | Cultivation (e.g., *E. coli*) |
|---|---|---|---|
| Recognition of the attachment | Just after the measurement | | Cultivation time: > 1 day |
| Identification | Simple test within several hrs | | # 1-3 days for simple test<br># 5 days for definitive test |
| Scanning time (Area: 100 cm²) | 22 hrs (2 s /img. @40x†) | 0.2 hrs (@DVD 6X) | ——— |
| Expertise | High | Low | Extremely high |
| Apparatus cost | $10k - $50k | $50k (initial stage)<br>$100 (as of DVD) | $30k - $50k |
| Inspection cost | $1 - $2 (Glass sub.) | $1 - $2 (Polycarbonate sub.) | $20 - $50‡ |

$: in US dollars, †: an assumption with no automatic-scanning stage,
‡: depending on with or w/o the employment costs

# Rapid separation and identification of microorganisms

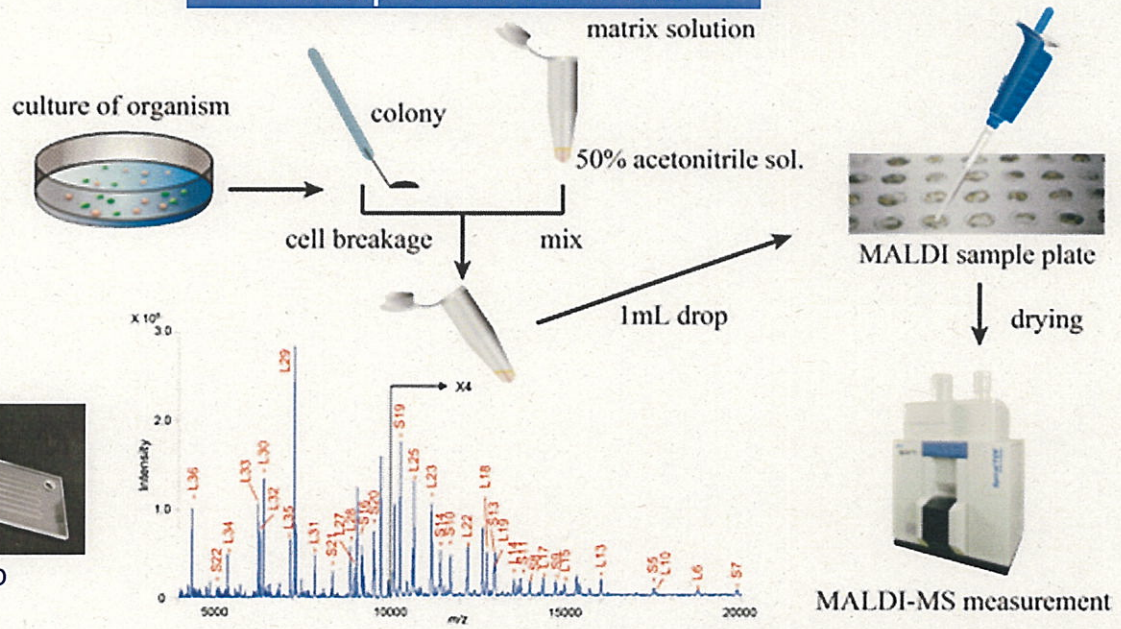
- Rapid separation of microorganisms in a micro-tube by electrophoretic technique.
- Rapid identification of microorganisms by Laser Desorption / Ionization MS.

## Principle: CE




Schematic diagram of cell migration in micro-scaled tube, and practical example of electropherogram.

## Principle: MALDI-MS




Microorganism-identification by MALDI-MS, and practical example of MS spectra of E coli.

Surfaces of most microorganisms have a negative charge, thus they migrate to a positive electrode in electrical field. Rapid separation of microorganisms on the second time scale is possible in a microchip electrophoresis.

Ribosomal proteins, which are attributed to each DNA, can be used for identification of microorganisms. These proteins in the cells can be extracted and analyzed by matrix assisted laser desorption/ionization mass spectrometry within an hour. It enables us to differentiate between similar strains of microorganisms.

in practical use by Shimadzu Co., Ltd.

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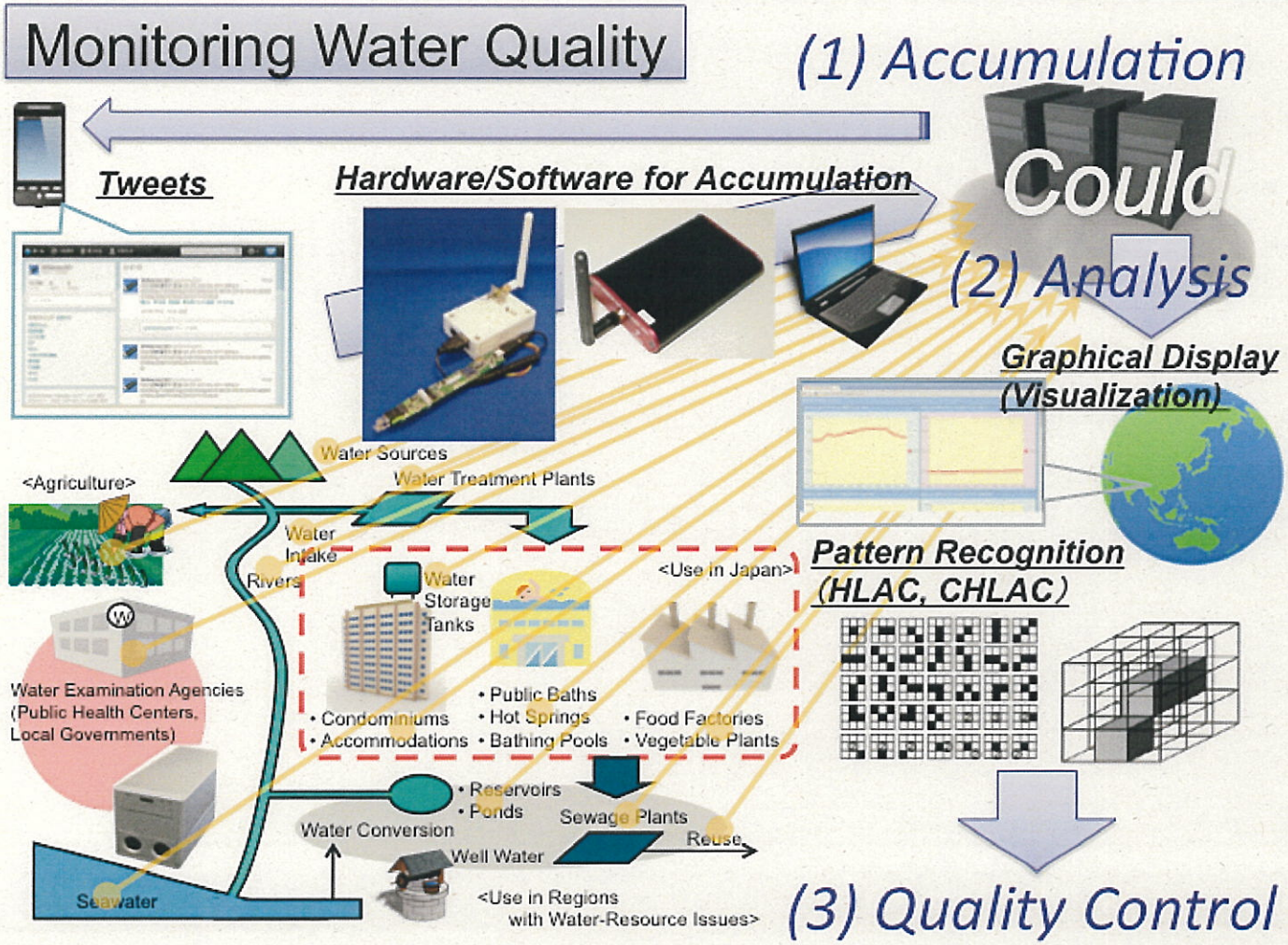
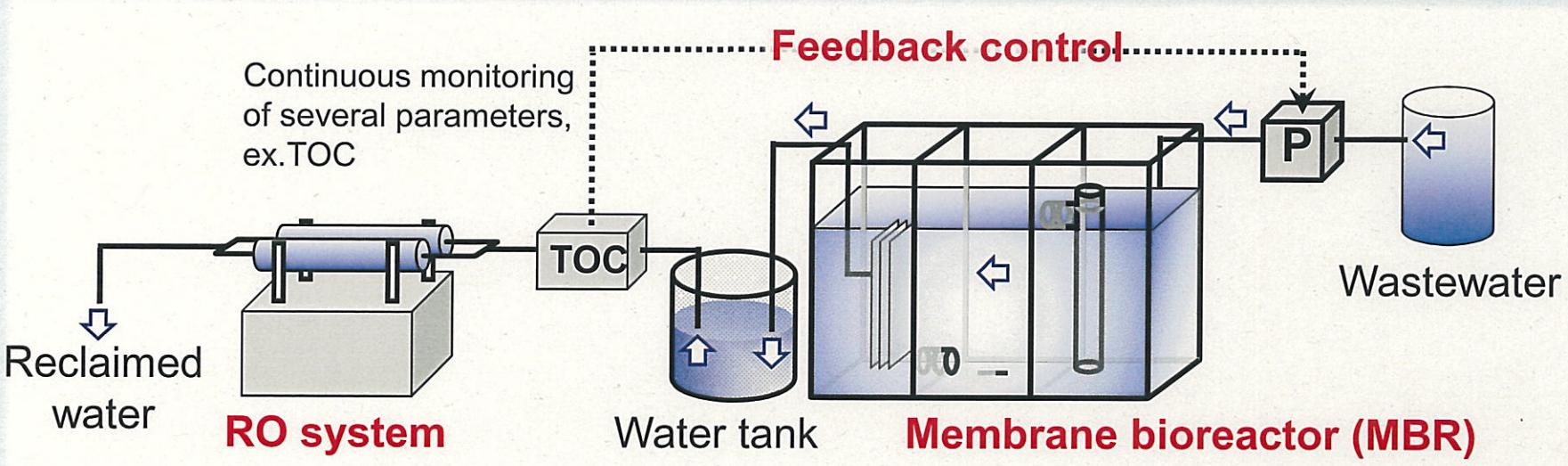
# Smart Sensor Network for Environmental Management

- Cloud-based water quality monitoring & controlling sensor network system
- Both simple measurement using SNSs and large-scale analysis using cloud are possible
- Also applicable to power consumption management and home security system

The water management system is a large-scale distributed system which monitors and controls water resource, and its key to high reliability and low cost is utilization of the cloud computing. We have developed several hardware and software combining various sensors and the cloud systems, and have realized both simple and easy monitoring using social network services such as Twitter® and large-scale information accumulation and analysis using cloud services such as Google App Engine®.

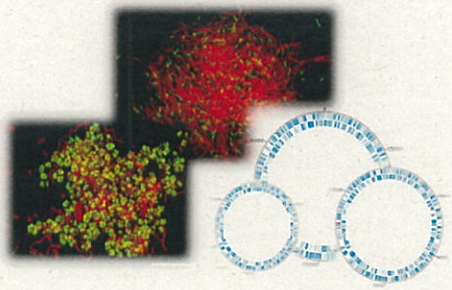


# Management of MBR/RO system at high organic loading rate




MBR and RO systems

Key microbes



**Problem**
(Operating information)

**Mechanism**
(Microbiology)

**Optimization**

Operation management

→ Pilot-scale MBR/RO systems

→ Artificial induction of the functional states (e.g., deterioration)

Microbial community analyses

→ Next-generation DNA sequencer

→ Stable isotope probing (SIP)

# Next-generation DNA sequencer

MiSeq version 3 (illumina)

- Read: 50 million
- Sequencing length: 300 bp × 2
- Data amount: 15 Gb

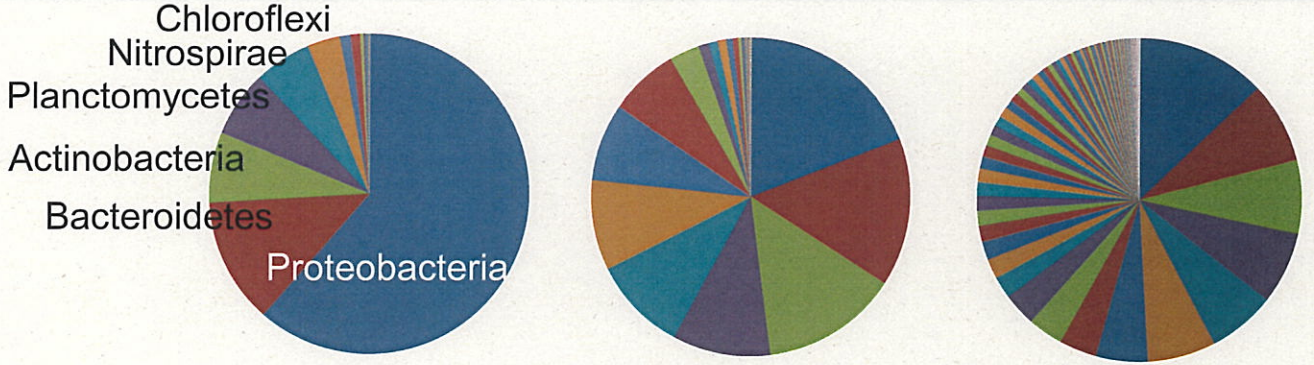
❖ The development of next-generation DNA sequencers allows for obtaining the large-scale gene information

→ Deep sequencing of the 16S rRNA amplicons phylogenetically identifies 10 million species of microbes by ONE RUN of MiSeq

## Microbial community of seed culture for the MBR operation

DNA

12,510 reads

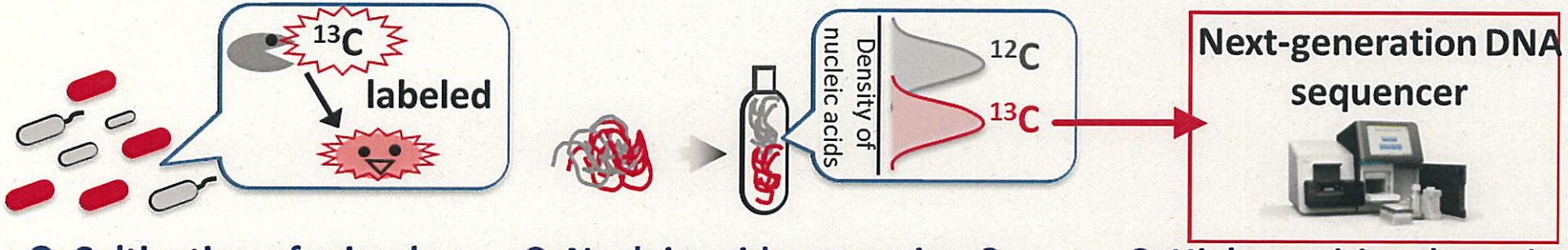



Phylum: 18 Class: 31 Family: 122

→ Which microbes are the key players in the MBR process ?

# Stable isotope probing (SIP):

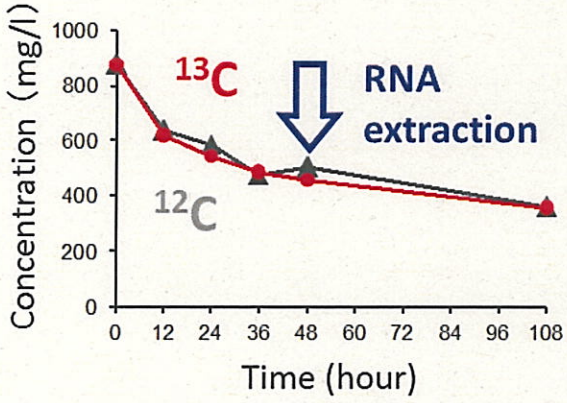
## *A powerful tool to identify the function of uncultured microbes*



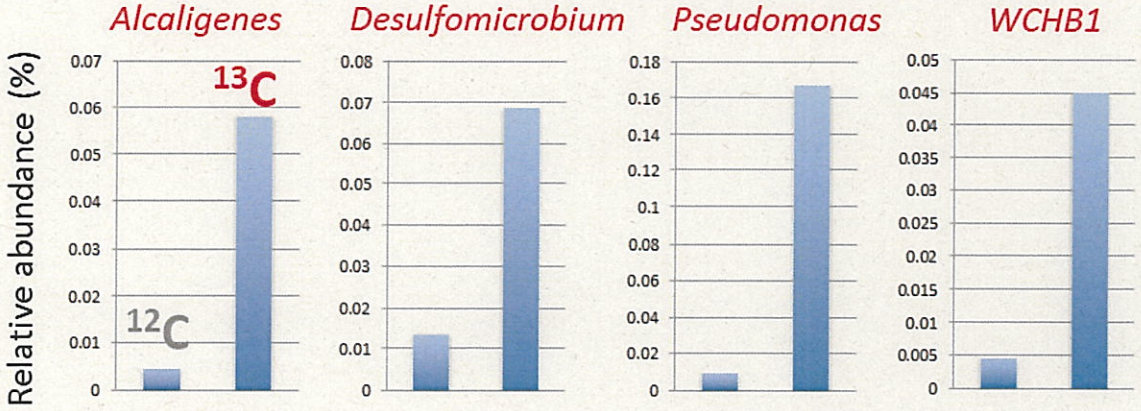

- Cultivation of microbes with stable isotopes
- Nucleic acids extraction & density gradient centrifugation
- High sensitive detection of the labeled microbes

## Key microbes involved in the degradation of palmitic acid

### *Palmitic acid*




### *Microbes enriched in the heavy fraction of RNA*




**SIP combined with deep sequencing has a high sensitivity for identifying the key microbes**

# Nanocomposite for Cleaning Environmental Pollutants

Novel hybrid nanostrucutres of carbon nanosheets (1 to tens graphene layers) and metal / metal oxide nanoparticles achieving synergy of adsorption and catalysis

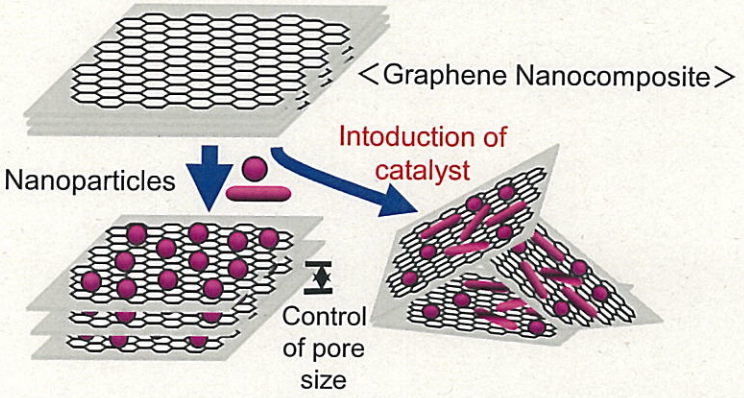
## Research target

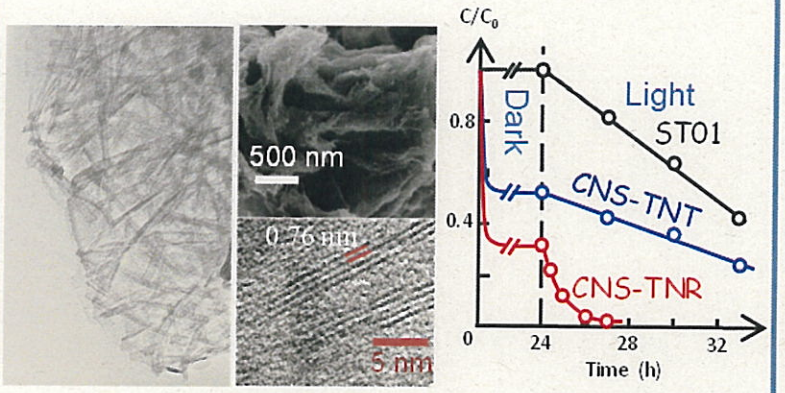
Aiming at efficient removal of trace chemicals (POPs, PPCPs, etc.) which have potential impacts on human beings and ecosystem, we are developing technology for nanostructured composition of graphene (G) and metal/metal oxides. Nanocomposite from titania and G demonstrates a high efficient adsorption concentration-induced photocatalysis.

## Research content

By combining intercalation and hydrothermal methods, a synthesis technique which utilizes carbon nanosheets (CNS) as a template for 2D deposition of 1D titanate nanotube (TNT) or nanorod (TNR) was developed. Through adsorption concentration of the substrate CNS, photoactivity of the composite was promoted by 5 to 6 times as compared to the pure titania.

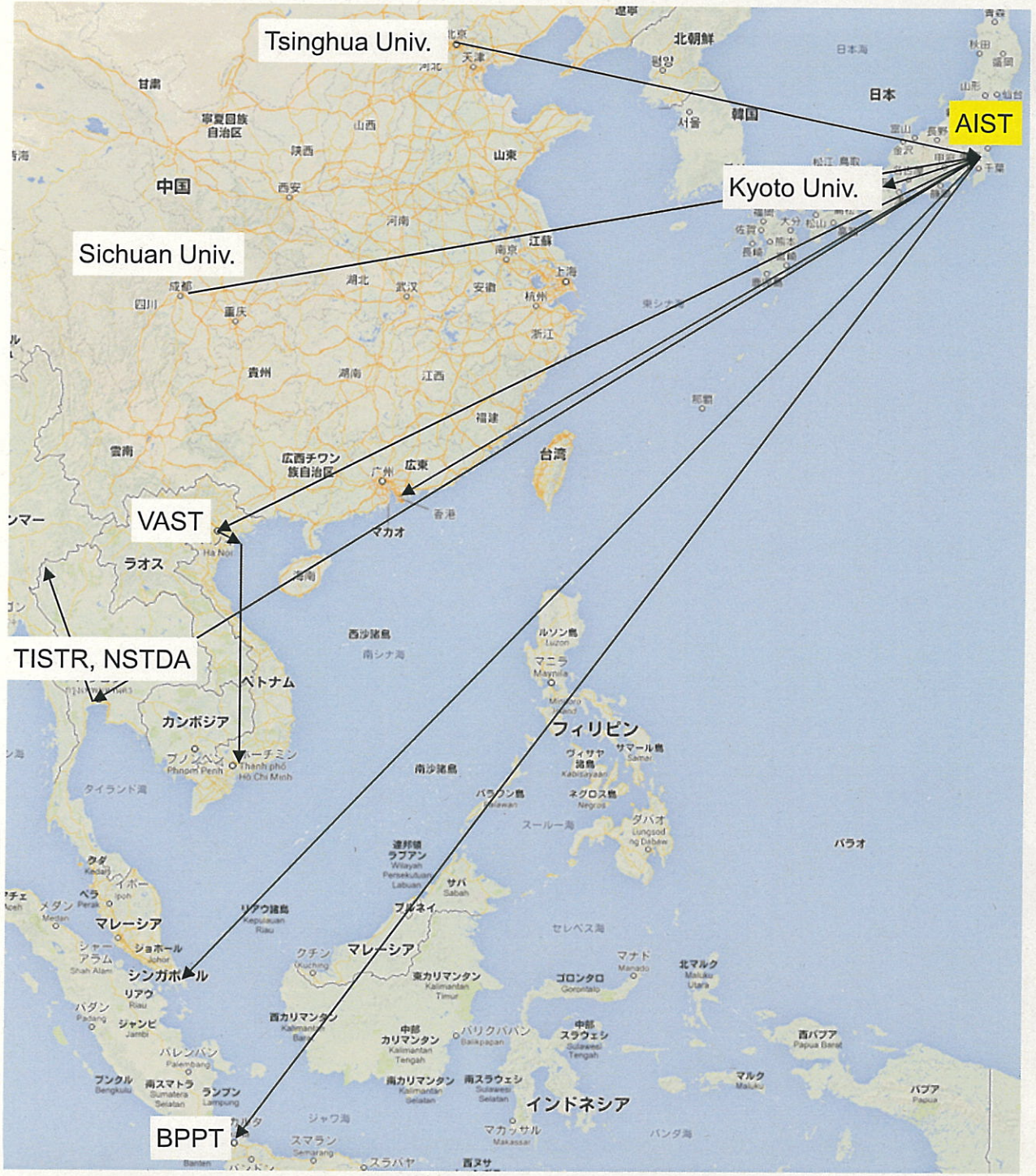
Nanocomposite achieving synergy of adsorption and catalysis




CNS-TNT

Adsorption and decomposition of methyl orange




# Current Collaboration

**Vietnam**
VAST
JSPS Bilateral Programs
MBR, Photocatalyst

**Thailand**
TISTR, NSTDA (NANOTEC)
Field Experiment for Sterilization of Drinking Water

**China**
Research exchange
Tsinghua Univ., Sichuan Univ.
Nano-materials for Water Treatment

Joint Research Proposal
Tsinghua Univ., CAS
Efficient and Safe Water Re-use

# Future Collaboration

**Indonesia (national institutes companies and universities)**
**Singapore**
**India**