Integrated Advanced Oxidation Processes for Decentralized Tap Water and Drinking Water Treatment: From Laboratory Scale to Demonstration Unit

The Scale-Up Challenge: Closing the Loop Between Academia and Industry

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June 11, 2026

Situation of Access to Clean Water in Thailand

Pasak Jolasid Dam, LopBuri

Khwae Noi Bamrung Dan Dam, Phitsanulok

Ubolratana Dam, Khon Kaen

Water Crisis and Drinking Water Quality in Thailand

- 43.7% of household water required further treatment before consumption.
- 15.5% of household water was contaminated with chemicals above recommended limits.
- Overall, 59.2% of household water did not meet required standards.

Urban vs Rural

Bangkok water meets WHO standards, but most people still use bottled or filtered water;
Rural areas face occasional shortages and contamination.

(Thailand's Voluntary National Review 2021)

Situation of Access to Clean Water in Thailand

Industrialization & Urbanization

→ increased turbidity & pollution

Drinking water standard

World Health Organization

Turbidity <1 NTU;
5 NTU is acceptable for effective disinfection.

(WHO, 2022)

Sustainable development

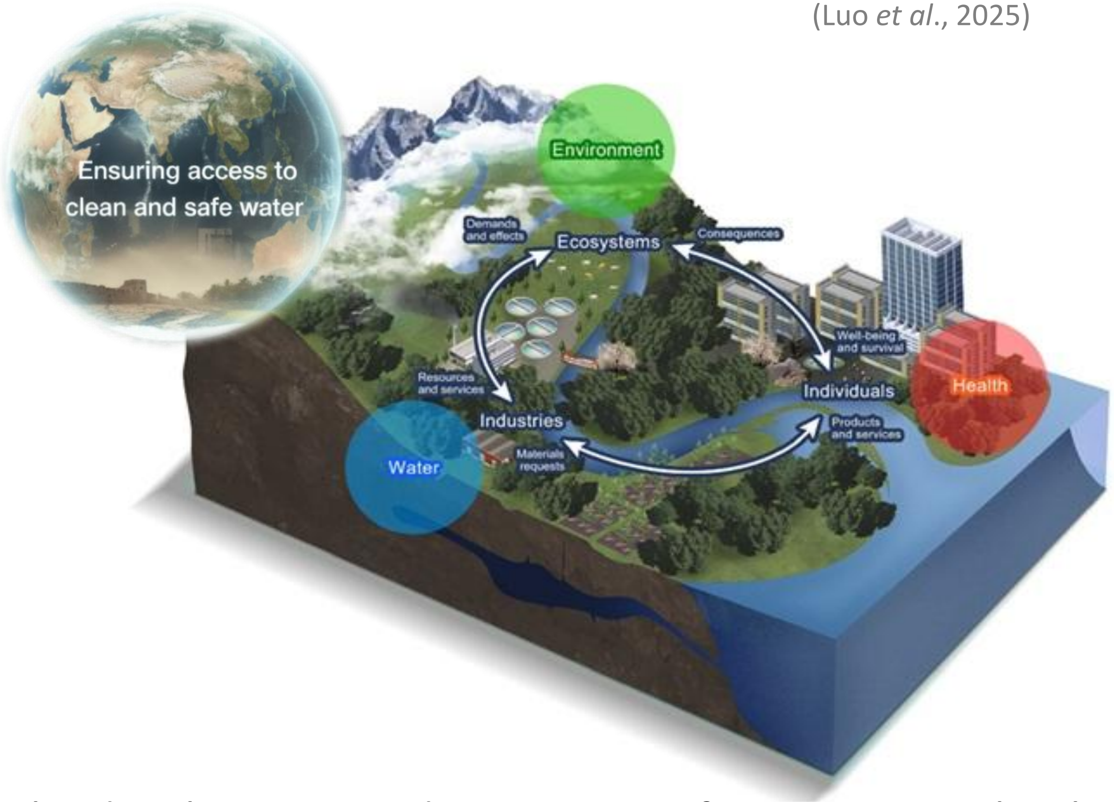
Universal access to clean water and sanitation is a core objective of the United Nations Sustainable Development Goals (SDGs).

(Arora *et al.*, 2023;
Anang *et al.*, 2025)

Foundations of water purification

Advancements in water purification technologies are critical for addressing increasing demands on water quality and securing access to clean and safe water.

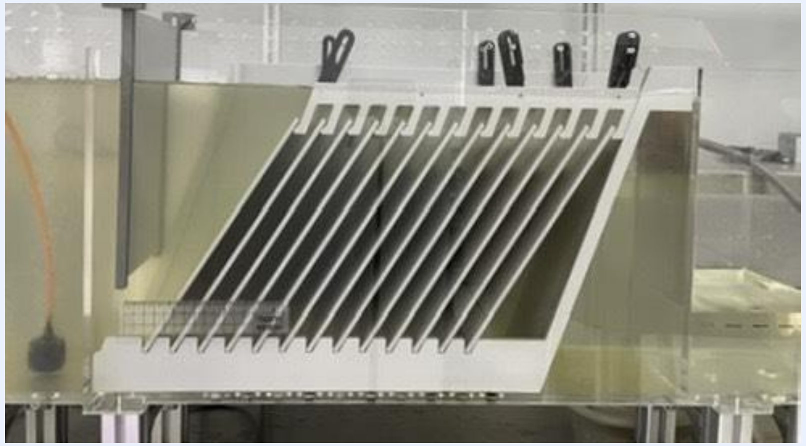
(Luo *et al.*, 2025)



The development and integration of innovative technologies in water purification require rigorous piloting and testing.

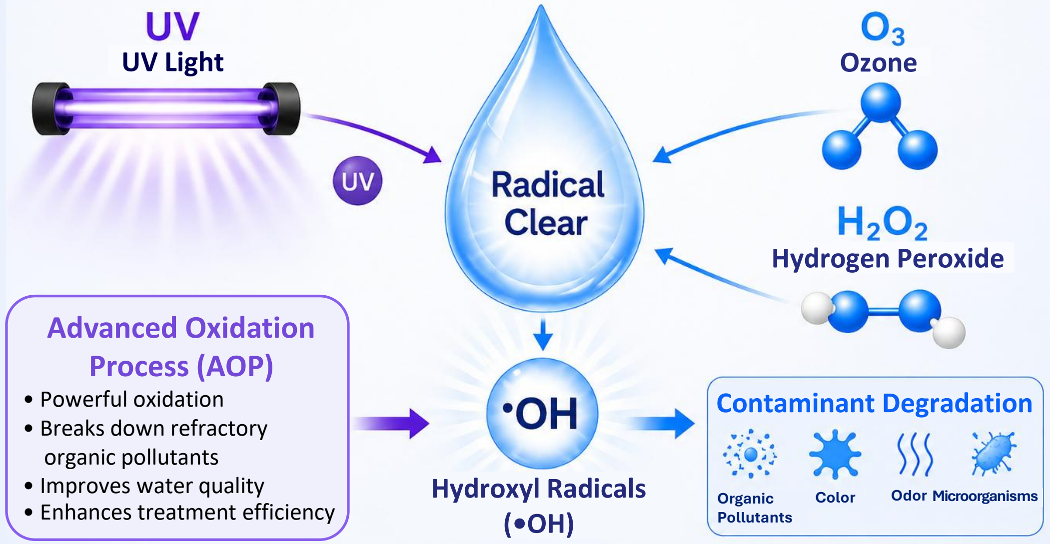
➤ Design and process optimization of an integrated continuous-flow system

▪ Sedimentation Tank



The systems integrate and combine key treatment processes for compact, decentralized water purification.

▪ RadicalClear-Based Advanced Oxidation Process (AOP)



Radical Clear combines UV-assisted O_3 and H_2O_2 to generate highly reactive •OH, enabling effective oxidation and superior water treatment performance.

KNOWLEDGE FROM MAHIDOL → **COORDINATED** BY MICC & iNT → **FUNDED** PSD Road Solutions Co., Ltd.

Uniting industry and academia to create **innovative** and **sustainable impact solutions**.

Proof-of-Concept Lab Demonstration

TRL

DEMONSTRATION IN LABORATORY ENVIRONMENT

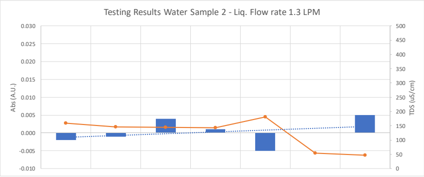
1 2 3 4

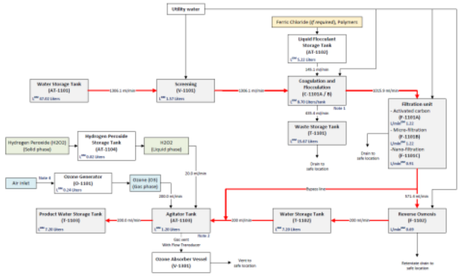
BASIC TECHNOLOGY RESEARCH

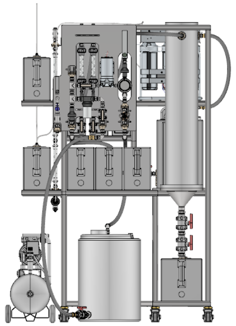
RESEARCH TO PROOF FEASIBILITY

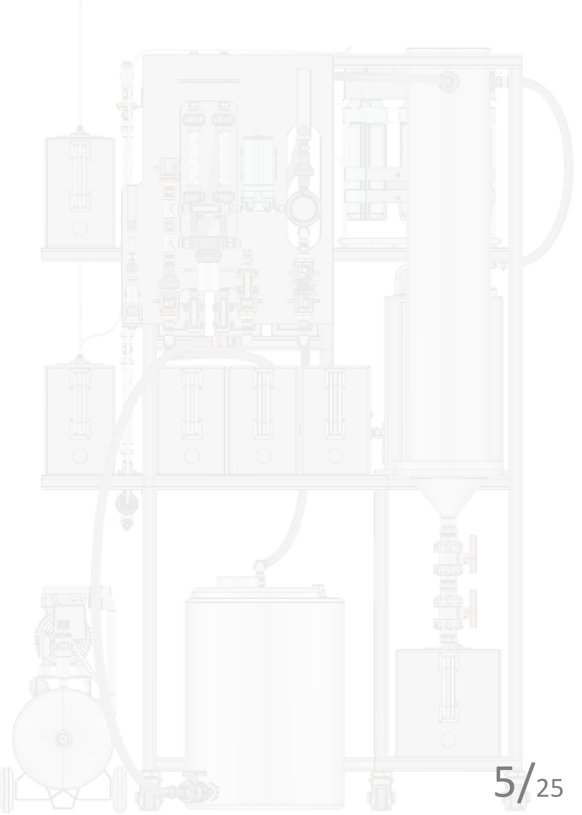
TECHNOLOGY DEVELOPMENT

6 MONTHS









SERVICE ORDER 1

PETTY PATENT 1

- Project Manager
- Project Instructor
- BioInnotech Manager
- Researcher

Development of knowledge and basic research

Laboratory Prototype

Qualified Operational Demonstration

TRL

PROOF OF CONCEPT
DEMONSTRATION IN LABORATORY ENVIRONMENT

1 2 3 4

BASIC TECHNOLOGY RESEARCH — RESEARCH TO PROOF FEASIBILITY — TECHNOLOGY DEVELOPMENT

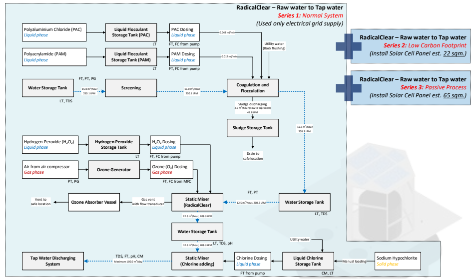
6 MONTHS

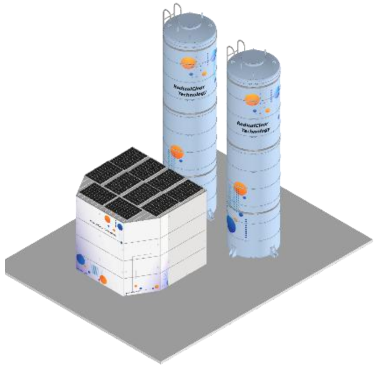
ACTUAL DELIVERABLE QUALIFIED
DEMONSTRATION IN OPERATIONAL ENVIRONMENT

5 6 7 8

TECHNOLOGY DEMONSTRATION — SYSTEM / SUBSYSTEM DEVELOPMENT — SYSTEM TEST, LAUNCH & OPERATIONS

+ 12 MONTHS





SERVICE ORDER 1

PETTY PATENT 1

Development of knowledge and basic research
Laboratory Prototype

SERVICE ORDER 2

THAILAND INNOVATION 2

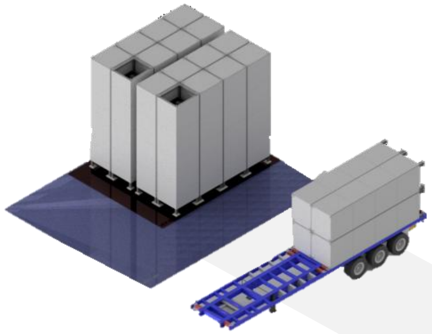
RESEARCH PUBLICATION 1

Project Manager — Project Instructor — Project Instructor — BioInnotech Manager — Researcher — Researcher

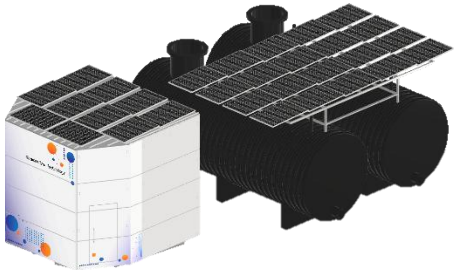
Demonstration at BioInnotech

Project: Radical Clear Technology Phase II (Water Treatment)
Phase: Demonstration Plant

MODULAR SYSTEM INSTALLATION

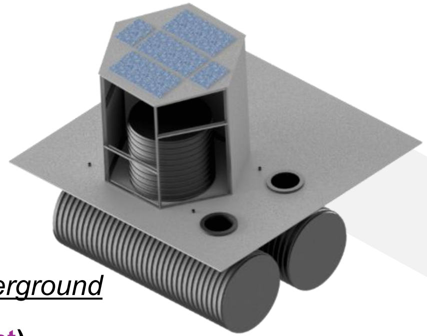


Water Storage Tank ***100.0*** m^3
Estimated area 40.0 m^2



Water Production Module installed *on ground*

RadicalClear (Passive Process)
Solar cell panel 65.0 sqm.
- Est. 22.0 sqm. installed on production skid
- Est. 43.0 sqm. installed on water storage tank



Water Storage Tank installed *underground*

RadicalClear (Low Carbon Footprint)
Solar cell panel 22.0 sqm.
- Est. 22.0 sqm. installed on production skid

TRL

PROOF OF CONCEPT
DEMONSTRATION IN LABORATORY ENVIRONMENT

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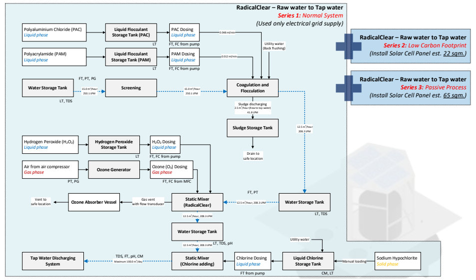
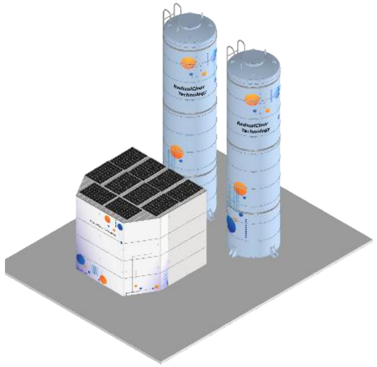




SERVICE ORDER 1

PETTY PATENT 1

Development of knowledge and basic research
Laboratory Prototype

SERVICE ORDER 2

THAILAND INNOVATION 2

RESEARCH PUBLICATION 1

Project Manager | Project Instructor | Project Instructor | BioInnotech Manager | Researcher | Researcher

Demonstration at BioInnotech

Operational Use of Deliverables

TRL

PROOF OF CONCEPT
DEMONSTRATION IN LABORATORY ENVIRONMENT

1 2 3 4

BASIC TECHNOLOGY RESEARCH
RESEARCH TO PROOF FEASIBILITY
TECHNOLOGY DEVELOPMENT

6 MONTHS

ACTUAL DELIVERABLE QUALIFIED
DEMONSTRATION IN OPERATIONAL ENVIRONMENT

5 6 7 8

TECHNOLOGY DEMONSTRATION
SYSTEM / SUBSYSTEM DEVELOPMENT
SYSTEM TEST, LAUNCH & OPERATIONS

+ 12 MONTHS

9

OPERATIONAL USE OF DELIVERABLE

SERVICE ORDER 1
PETTY PATENT 1

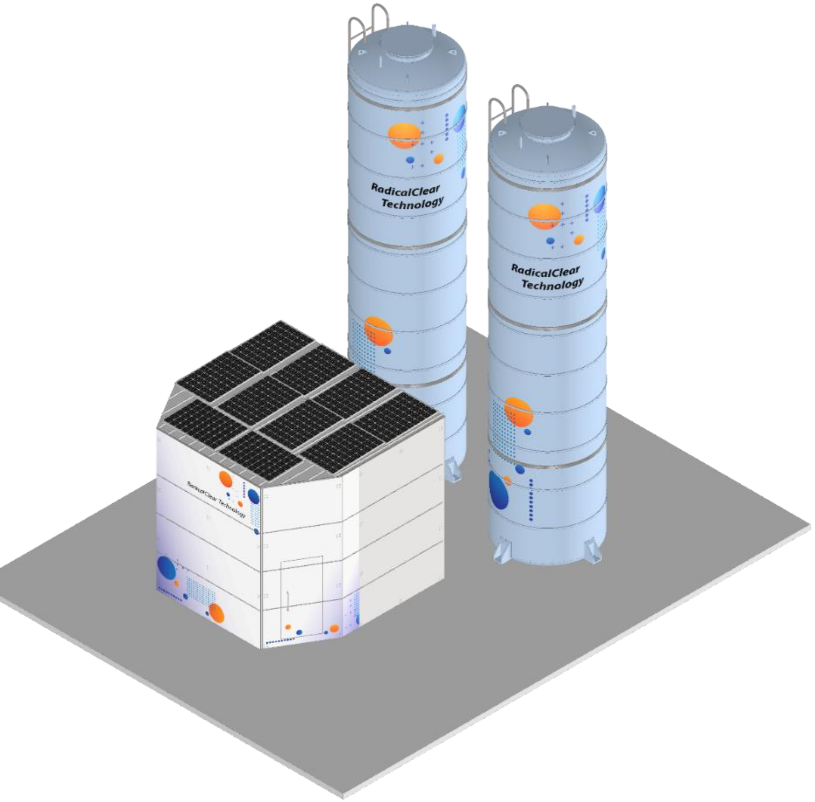
Development of knowledge and basic research
Laboratory Prototype

SERVICE ORDER 2
THAILAND INNOVATION 2
RESEARCH PUBLICATION 1

Demonstration at BioInnotech

Project: Radical Clear Technology Phase I and II
Phase: Laboratory and Demonstration Plant

Research Model and Methodologies



PROOF OF CONCEPT
DEMONSTRATION IN LABORATORY ENVIRONMENT

TRL 1 → 2 → 3 → 4

SERVICE ORDER 1

PETTY PATENT 1

Project Manager, Project Instructor, BioInnotech Manager, Researcher

6 + 12 MONTHS

ACTUAL DELIVERABLE QUALIFIED
DEMONSTRATION IN OPERATIONAL ENVIRONMENT

TRL 5 → 6 → 7 → 8

SERVICE ORDER 2

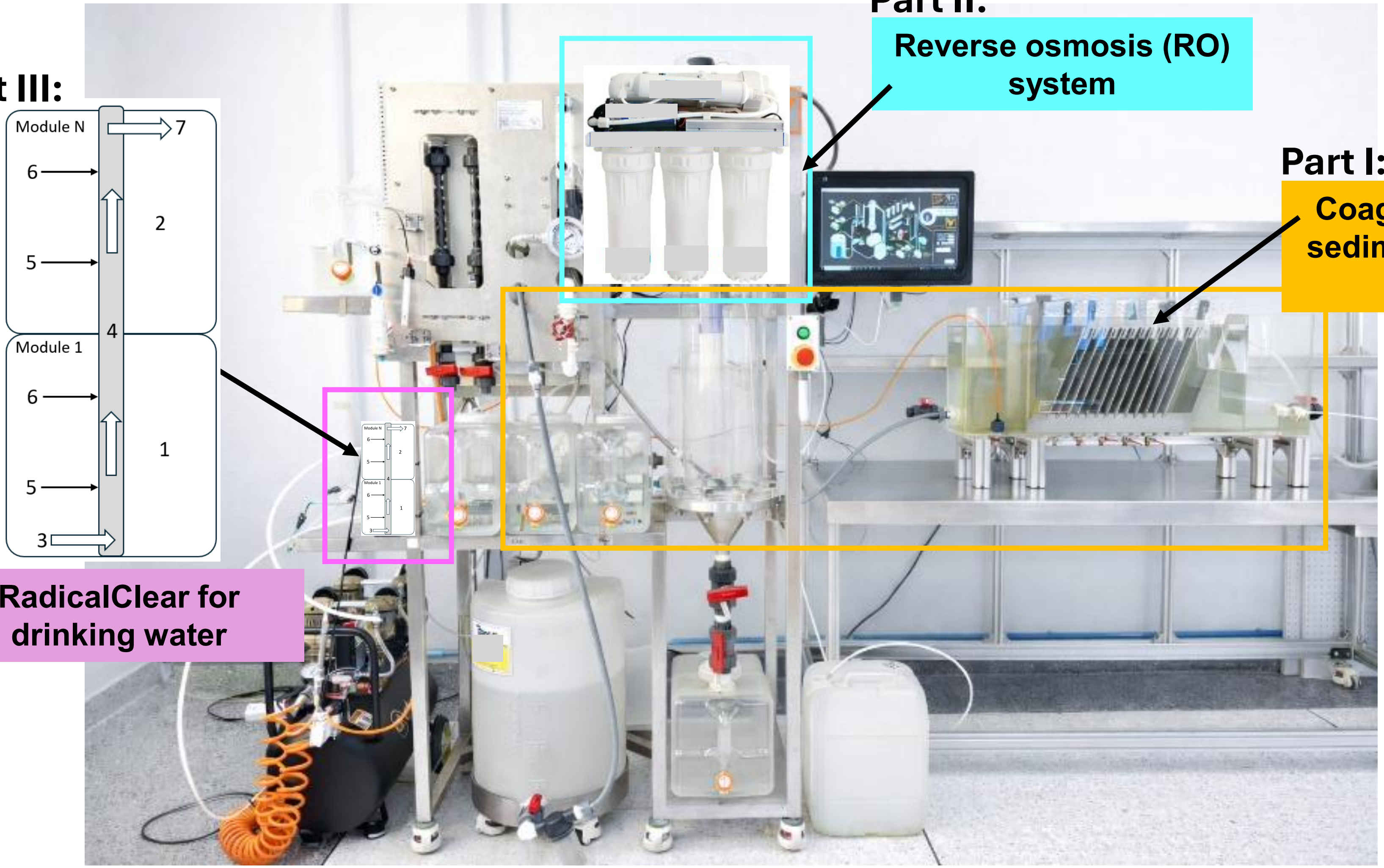
THAILAND INNOVATION 2

RESEARCH PUBLICATION 1

Project Manager, Project Instructor, Project Instructor, BioInnotech Manager, Researcher, Researcher

The Scale-Up Challenge

➢ **Pilot-scale for clean & Drinking water treatment**



Pilot-scale system for clean and safe drinking water treatment.

Improvement of Coagulants and Flocculants

➢ **Integrated turbidity removal unit in a pilot-scale continuous-flow reactor**

1) Coagulation-flocculation concentration optimization

2) Aeration bubble flow: 0, 25, 50, 100, 200, and 300 mL/min

3) Influent flow rates: 0.5, 1.25, and 2.0 L/min

4) Sedimentation tank:

- **Baffle configurations:** 0, 1, 4, 7, and 13 plates
- **Inclination angles:** 57°, 69°, and 75°

5) Filtration system: gravel–sand–anthracite packed bed

The configuration with 13 baffles at a 75° angle.

Hybrid PAC–PAM Coagulation-Flocculation

➢ Hybrid polyaluminium chloride (PAC)–anionic polyacrylamide (PAM) coagulation-flocculation

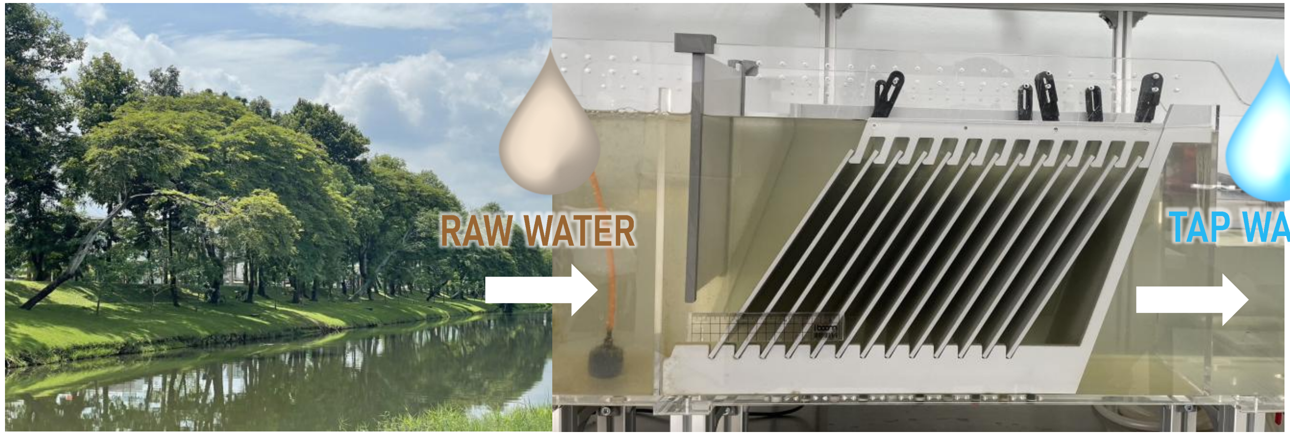
PAC
(Polyaluminum Chloride)

Provides positive charge (Al^{3+}) and neutralizes negatively charged colloidal particles.

+

PAM
(Polyacrylamide)

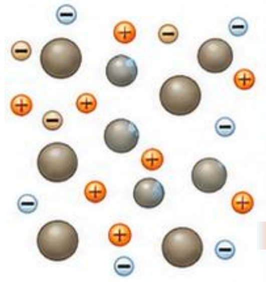
Long-chain polymer that bridges particles together and forms larger, stronger flocs.



Flocculation precipitation, sewage mud

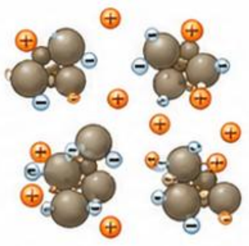
PAC at 45 ppm and PAM at 2 ppm were the optimum concentrations for achieving the highest turbidity removal in this study.

1. CHARGE NEUTRALIZATION



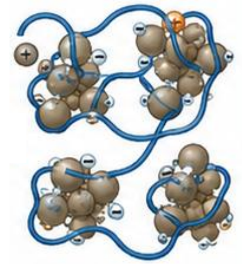
PAC (Al^{3+}) neutralizes the negative charges on colloidal particles.

2. DESTABILIZATION & FLOCCULATION



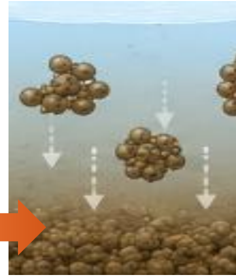
Particles lose repulsion and come closer together.

3. BRIDGING & FLOC FORMATION



PAM polymer chains bridge particles, form larger, stronger flocs.

4. SETTLEMENT & CLARIFICATION



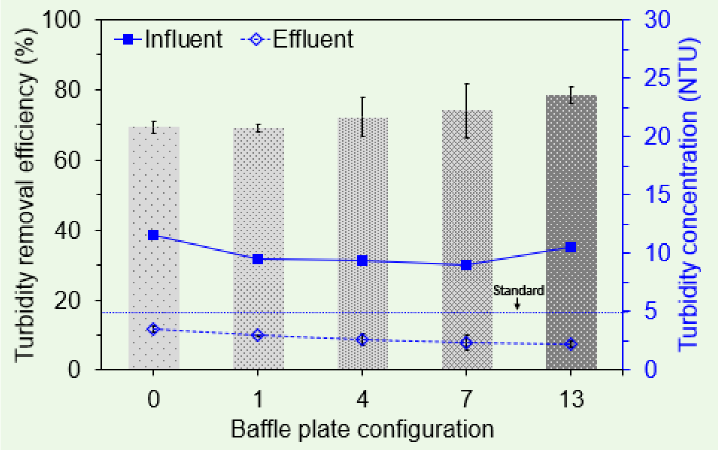
Flocs settle by gravity. Clear water remains on the top.

Colloidal Particle (Negative) | PAC (Al^{3+}) (Positive Charge) | PAM Polymer Chain (Bridging) | Floc (Aggregate)

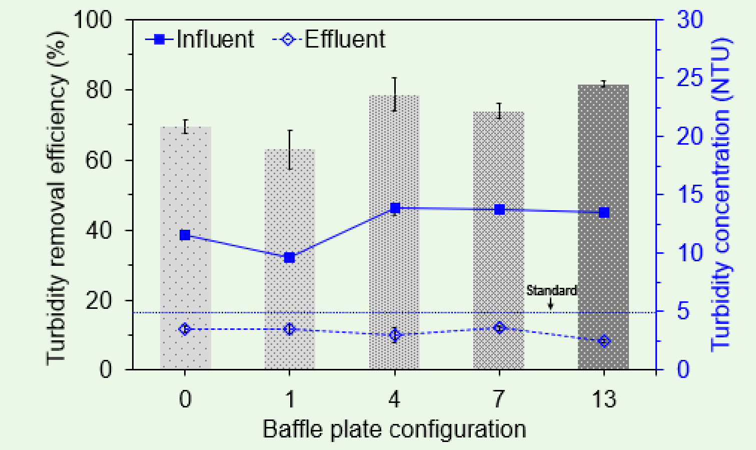
Effect of a Moderate Flow Rate of 1.25 L/min

- **Effect of moderate flow rate; baffle plate configuration: 0, 1, 4, 7, and 13 plates; and inclination angle: 57°, 69°, and 75°.**

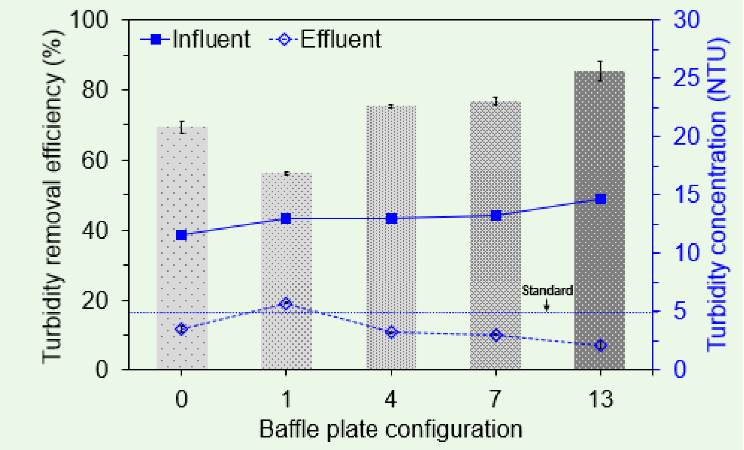
Under optimized hybrid conditions of 45 ppm PAC and 2 ppm PAM.



57° inclination angle

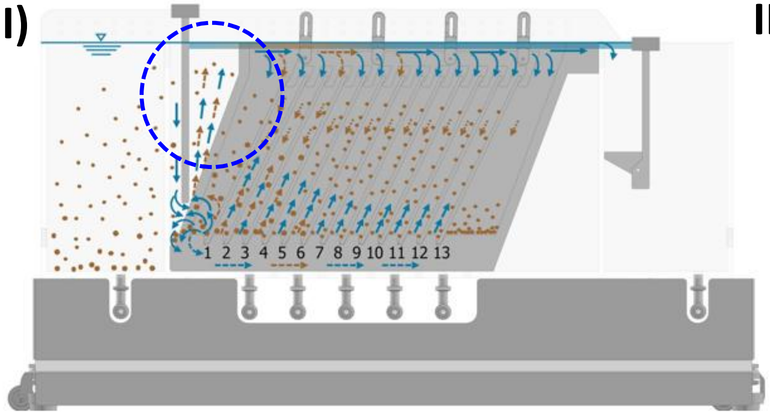


69° inclination angle

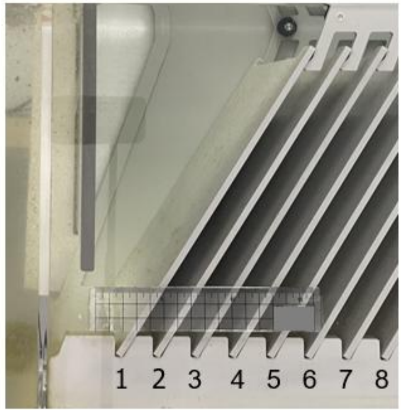


75° inclination angle

I)



II)



Flow behavior: Some fine particles entered the quiescent zone.

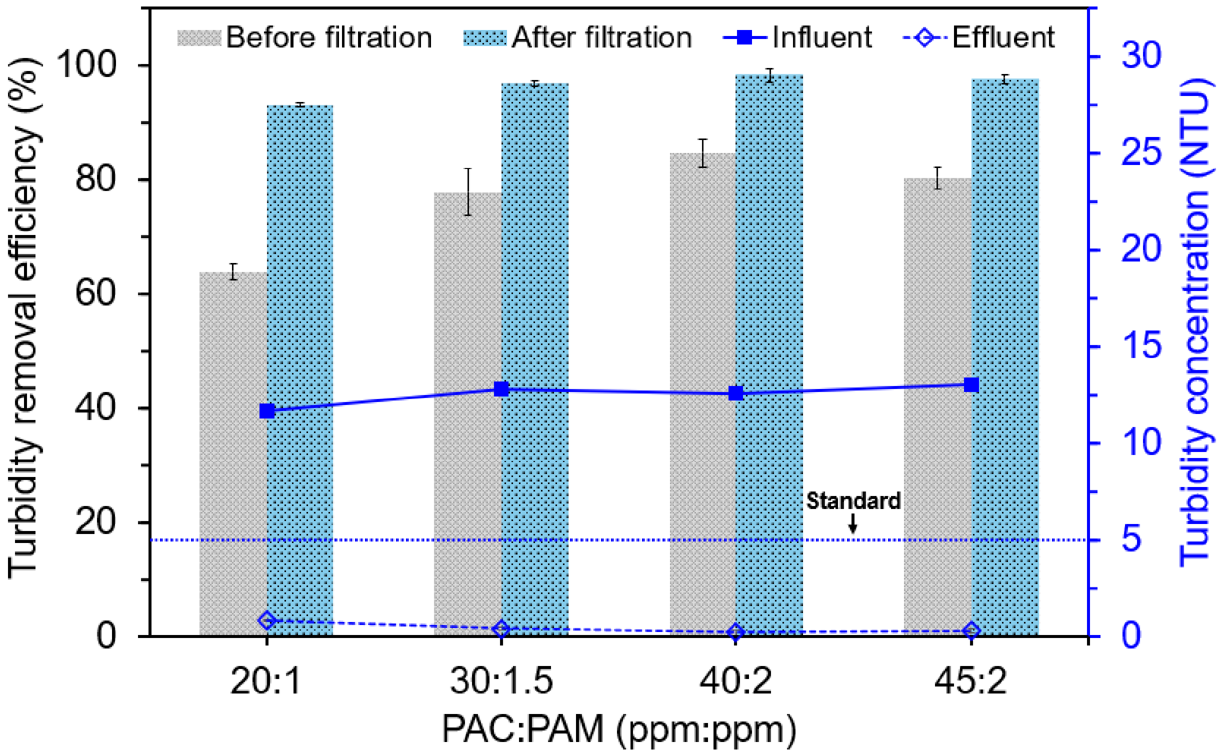
- At 1.25 L/min, turbidity removal ranged from 56–85%, with 13 baffles improving efficiency.
- Increasing the number of baffles improved turbidity removal ($p < 0.05$).
- The 75° angle enhanced gravity effects and mixing. (Lum *et al.*, 2006).

(Chuiprasert *et al.*, 2025)

Integration of Filtration System

- To reduce excess turbidity, various PAC:PAM ratios of 20:1, 30:1.5, 40:2, and 45:2 ppm were evaluated in the **filtration system**. (Fixed flow rate: 1.25 L/min; bubble flow rate: 300 mL/min)

Layer 1: Gravel
Layer 2: Sand
Layer 3: Anthracite



Larger particles were retained by sieving in the upper filter layer.

Finer particles were trapped deeper by adhesion and interception.

(Sutherland and Chase, 2011; Scott, 2008)

In the filtration system, optimized dosages (45 ppm PAC, 2 ppm PAM), turbidity removal improved significantly ($p < 0.05$) from 82% (2.2 NTU) to 97% (0.36 NTU).

(Chuiprasert *et al.*, 2025)

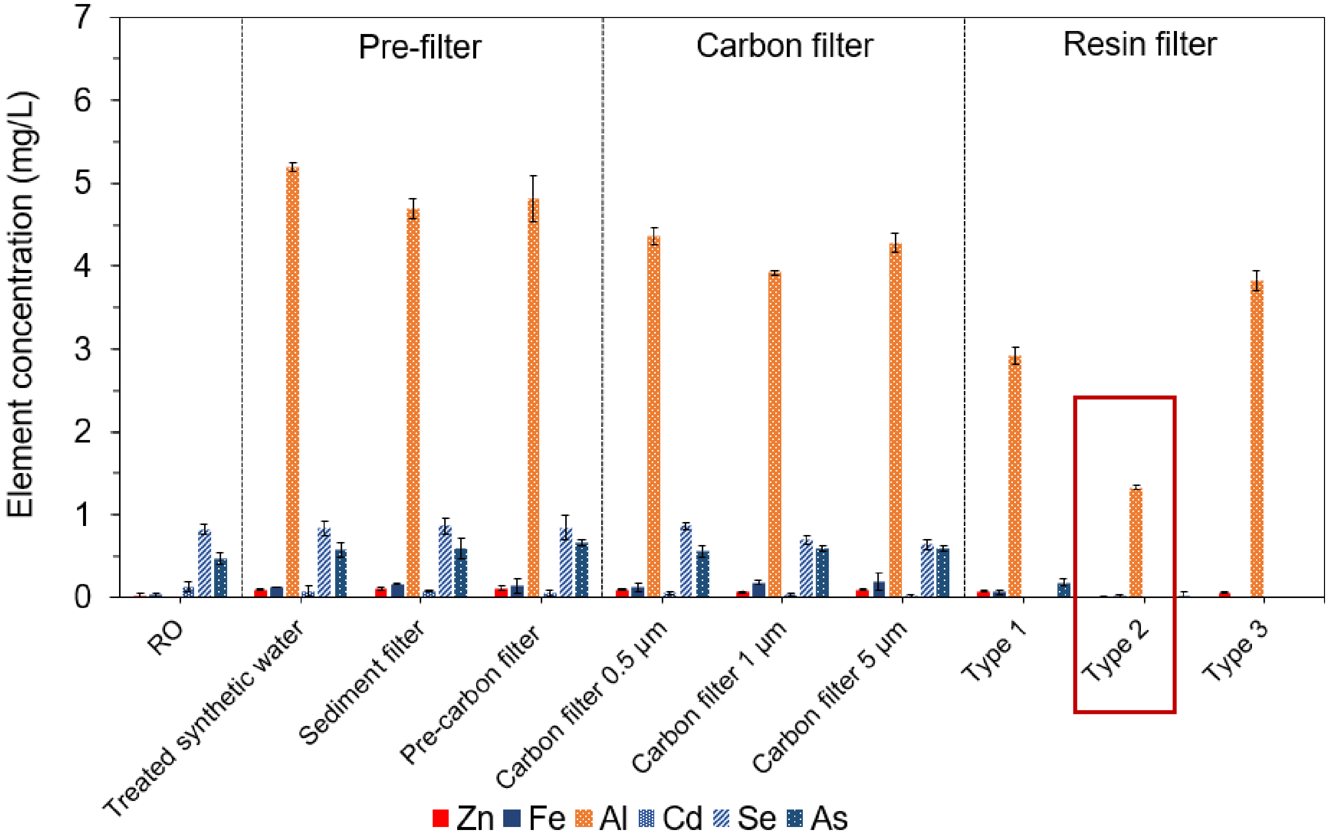
Cartridge Selection for Metal Removal

Comparison of three carbon filters and three ion-exchange resins for metal removal using synthetic (clear) water.

Microwave plasma atomic emission spectroscopy analysis

Influent

3 carbon filters



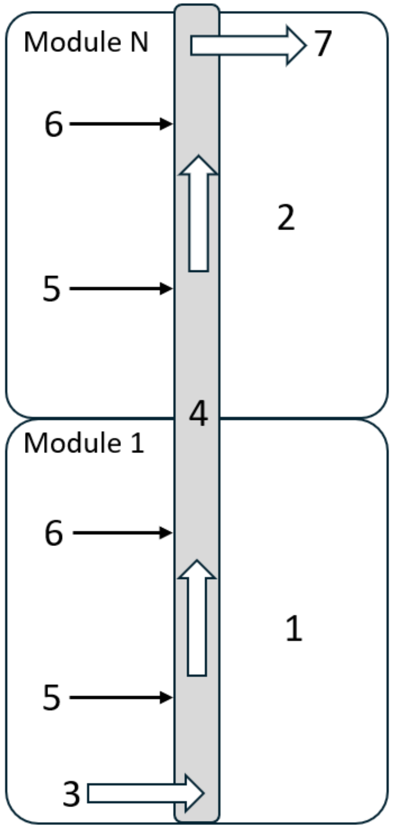
Typical properties of 3 resins

Type	Classification	Total exchange capacity (eq/L)
Type 1	Strong acid cation	≥ 1.70
Type 2	Strong acid cation	≥ 1.90
Type 3	Weakly acidic cation	2.2

Copolymer: Styrene-divinylbenzene
Ionic form as shipped: Na^{+}

Strong acid cation resins were more effective for metal removal than weakly acidic cation resins.

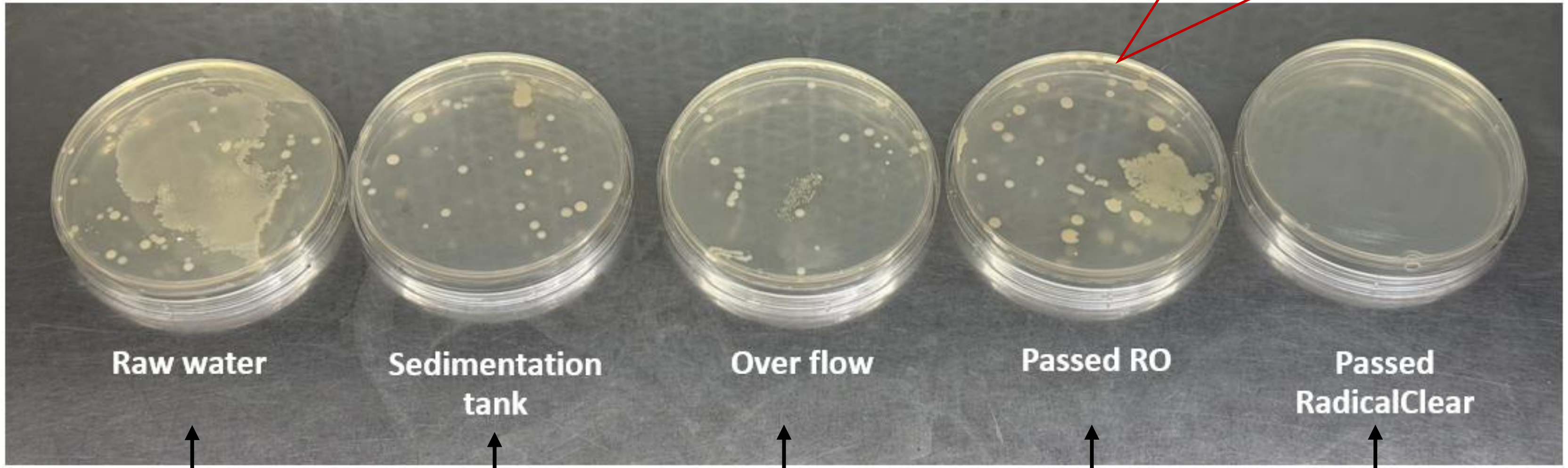
➢ **Bacterial inactivation performance under different AOPs operational conditions.**



UV-C based AOPs (UV-C/O_3/H_2O_2) reactor design

System type: 1) Single: UV, O_3, H_2O_2
2) Double: UV-C/H_2O_2, UV-C/O_3, O_3/H_2O_2
3) Triple: UV-C/O_3/H_2O_2

RO system cannot guarantee potable water free of opportunistic pathogens (Alvarez *et al*., 2012)



- Raw water: High bacterial load with dense colony formation.
- Sedimentation tank: Reduced colony count, indicating partial removal.
- Over flow: Reduction, though residual colonies remain.
- Passed RO: Decrease in bacterial presence.
- Passed RadicalClear: No visible colonies, indicating complete inactivation of *E. coli*.

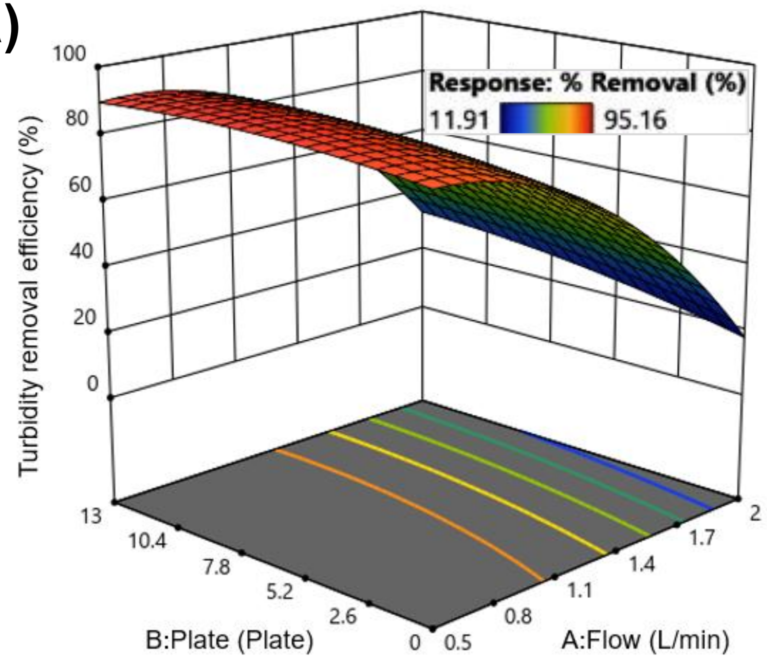
UV/O_3/H_2O_2 reaction: $O_3 + UV \rightarrow O_2 + 2{\bullet}OH$; $O_3 + H_2O_2 \rightarrow {\bullet}OH + O_2 + HO_2{\bullet}$

Diagnostic Validation and Process Optimization

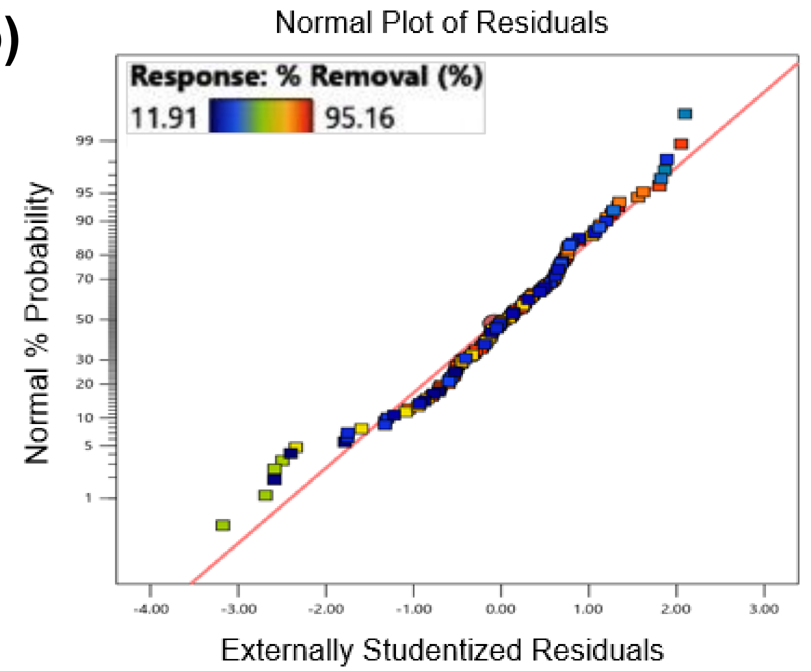
➢ Response Surface Methodology (RSM)-based modeling analysis

The adequacy of the regression model describing turbidity removal in the system was rigorously evaluated using multiple diagnostic analyses.

(a)



(b)



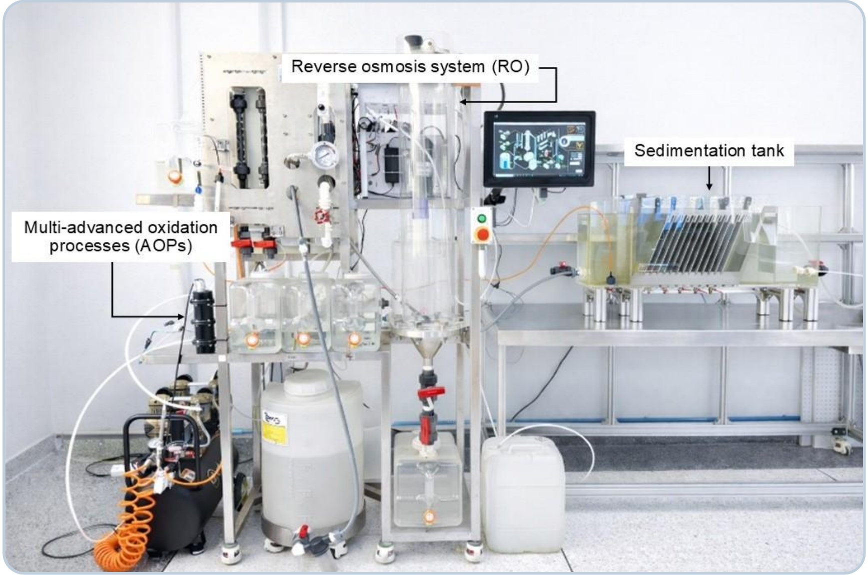
The strongest interaction was observed between flow rate (A) and number of baffle plates (B) (AB) ($p < 0.0001$).

Inclination angle (C^2) and the interaction terms (AC, BC) were not significant ($p > 0.0001$).

The data points closely followed the reference line, indicating homoscedasticity and an approximately normal distribution of the residuals.

From Laboratory Scale to Demonstration Unit

PHASE I: Engineering design of the laboratory-scale system



- Integration of multi-advanced oxidation processes (AOPs)
- sedimentation and reverse osmosis (RO)
- Laboratory-scale system for process optimization and performance evaluation

PHASE II: *RadicalClear demonstration unit*

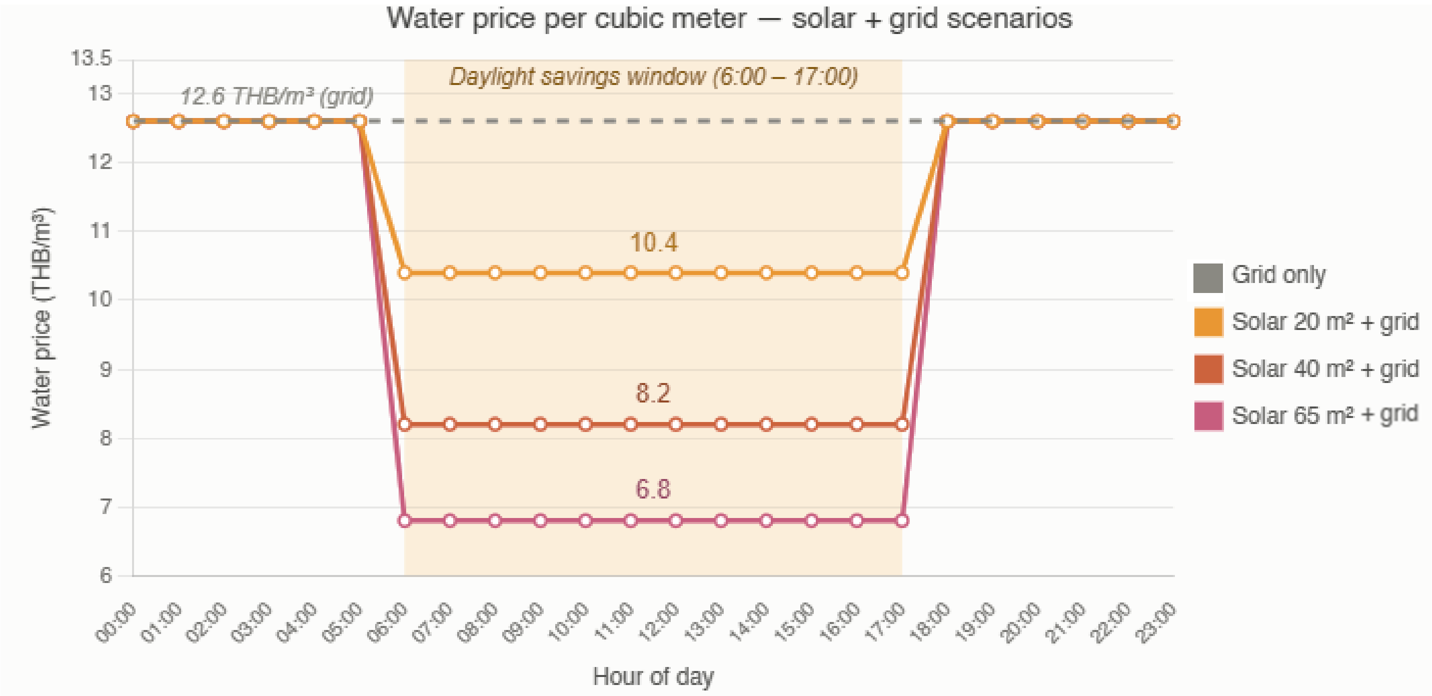
- RadicalClear process in demonstration scale
- Reliable operation for real-world conditions
- Designed for community-level water supply

Production Capacity **100 m^3/day**

Supplies tap water for approximately 300 households

Water Price Prediction with Partial Solar and Grid Support

- **Water price per cubic meter (THB/m³) over a 24-hour period under four energy configurations: Grid Only, Solar 20 m² + Grid, Solar 40 m² + Grid, and Solar 65 m² + Grid.**



Water price prediction (THB/m³) under grid and solar–grid hybrid configurations over a 24-hour operation period.

Grid baseline	Solar 20 m²	Solar 40 m²	Solar 65 m²
12.6	10.4	8.2	6.8
THB/m³	−17%	−35%	−46%

KEY TAKEAWAYS

- **20 m² panel**
  Saves 2.2 THB/m³ during daylight about 17% off grid price.
- **40 m² panel**
  Doubles the daytime savings to 4.4 THB/m³ (35% off).
- **65 m² panel**
  Reaches the deepest cut at 5.8 THB/m³ saved (46% off).
- **Night hours**
  All scenarios match grid price (12.6) when the sun is down.

Petty Patent

- **Petty Patent:** กรรมวิธีเปลี่ยนน้ำดิบเป็นน้ำดื่ม (Process for Converting Surface Water into Drinking Water)

Objectives of the Invention

- To develop a process for converting surface water into safe potable water.
- To enable both stand-alone operation and integration as a plug-in unit within existing drinking water treatment systems.
- To provide a compact, lightweight, durable, and portable treatment system design.

คำขอรับสิทธิบัตร/อนุสิทธิบัตร

- [ ] การประดิษฐ์
- [ ] การออกแบบผลิตภัณฑ์
- [x] อนุสิทธิบัตร

ข้าพเจ้าผู้ลงลายมือชื่อในคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ ขอรับสิทธิบัตร/อนุสิทธิบัตร ตามพระราชบัญญัติสิทธิบัตร พ.ศ. 2522 แก้ไขเพิ่มเติมโดยพระราชบัญญัติสิทธิบัตร (ฉบับที่ 2) พ.ศ. 2535 และ พระราชบัญญัติสิทธิบัตร (ฉบับที่ 3) พ.ศ. 2542

สำหรับเจ้าหน้าที่	
วันรับคำขอ 19/07/2567	เลขที่คำขอ
วันยื่นคำขอ	
สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ	
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วันออกสิทธิบัตร/อนุสิทธิบัตร	เลขที่สิทธิบัตร/อนุสิทธิบัตร
ลายมือชื่อเจ้าหน้าที่	

1. ชื่อที่แสดงถึงการประดิษฐ์/การออกแบบผลิตภัณฑ์ กรรมวิธีเปลี่ยนน้ำดิบเป็นน้ำดื่ม

Petty Patent Claims (10 claims)

Claim 1: A two-stage treatment process consisting of filtration and RadicalClear treatment.

Claims 2–3: Descriptions of the filtration and RadicalClear treatment procedures.

Claims 4–7: Specifications and configurations of the treatment units used in each stage.

Claim 8: Control and regulation of water flow rates throughout the treatment process.

Claim 9: Independent operation of the filtration and RadicalClear units, including applicability to alternative filtration system designs.

Claim 10: Flexible operation of the three treatment tanks, allowing combined or separate usage depending on operational requirements.

Publication/ Conferences

Publication

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ELSEVIER

Design and process optimization of an integrated turbidity removal unit in a pilot-scale continuous-flow system using hybrid coagulants for decentralized water treatment

Jedsada Chuiprasert [a,1], Sutthichai Boonprasop [b,1], Krittawit Sopawanit [b], Tinn Intraluk [a], Natthapong Taithipmathukon [c], Thotsatham Takkawatakarn [d], Weerawut Chaiwat [a,*]

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Conferences

DESIGN AND PERFORMANCE EVALUATION OF A HORIZONTAL-FLOW SEDIMENTATION TANK FOR TURBIDITY AND TOTAL DISSOLVED SOLIDS CONTROL IN SUSTAINABLE WATER TREATMENT

Jedsada Chuiprasert,[1] Sutthichai Boonprasop,[2] Krittawit Sopawanit,[2] Tinn Intraluk,[1] Natthapong Taithipmathukon,[3] Thotsatham Takkawatakarn,[4] and Weerawut Chaiwat,[1,*]

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Best poster award
STT51 International Congress
11–13 November 2025
Chulalongkorn University

The 14th Joint Conference of Renewable Energy and Nanotechnology

Presented:
"Synergistic Coagulation for Compact and Energy-Efficient Water Treatment in Rural and Emergency Applications" and "A Combined Coagulation-Flocculation and Heavy Metal Removal Unit in a Drinking"

October 18–19, 2025,
at National Central University, Taiwan

Conclusions & Applications

Hybrid Coagulation-Sedimentation

- Achieved 97% turbidity removal (0.36 NTU), meeting WHO standard.
- RSM-DOE confirmed flow rate and baffle number as key variables ($p < 0.0001$).

RO & RadicalClear (UV-C/O_3/H_2O_2)

- Strong acid cation resin provided superior heavy metal removal
- Complete *E. coli* inactivation achieved using triple AOP system

Demonstration Unit

- Capacity: 100 m^3/day tap water and 2.8 m^3/day drinking water for 300 households
- Solar-powered (22–65 m^2) reduces energy costs and grid dependency

The system is well-suited for:

✓ Rural communities lacking infrastructure

✓ Emergency response during floods and disasters

✓ Resource-limited settings with financial constraints

- This framework provides a pathway for scalable, decentralized treatment systems, supporting sustainable water access in alignment with UN SDG 6 and SDG 14.

“Closing the Gap Between Research and Real-World Application”

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Water researcher project team

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Thank you for your kind attention

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