# Demonstration Test Results and Future Prospects for the Rapid Fiber Filtration System for High-Turbidity Water in Cambodia

Reliable water infrastructure remains a challenge in Southeast Asia's regional cities and rural areas. Kanadevia developed a " Rapid Fiber Filtration System " to treat high-turbidity raw water, and tested it in Cambodia. The system successfully treated water with very high turbidity levels of up to 547 NTU, generating treated water that met local quality standards. Although changes in raw water quality temporarily affected performance, these issues were effectively resolved through appropriate adjustments.

Kanadevia plans to improve system responsiveness, optimize operations, and standardize equipment to reduce costs. These efforts are designed to ensure safe water supply and support sustainable development in the region.

**Key Words**

Rapid Fiber Filtration System, fiber filtration unit, water treatment equipment,
high-turbidity raw water treatment

## 1. Introduction

For Southeast Asian nations, economic growth and urbanization means that ensuring access to safe water is becoming an increasingly pressing issue. While waterworks infrastructure is increasingly common in urban areas, many regional cities and rural areas remain unconnected to waterworks, and there are numerous cases where people use river water or well water directly in their daily lives. A steady supply of safe water for these areas is a key issue directly connected with the health and sustained development of regional societies.[1] In addition, unlike in Japan, raw water in Southeast Asia is affected by the monsoon climate, making it extremely turbid, and moreover, the water quality can vary rapidly depending on the amount of rainfall. Water treatment technologies suited for these natural conditions are needed, but applying conventional technologies is often difficult.[2]

This is why Kanadevia developed our Rapid Fiber Filtration System (RFFS) for treating highly turbid water. The rapid filtration technology in the RFFS uses high-performance fiber filters that ensure compact size and footprint. In addition, due to its easily distributed structure, it is suited for introduction to small villages and remote areas, and the system can be easily run and managed by local operators.

In FY2023, we installed test equipment in the Bangkhen Water Treatment Plant in the outskirts of Bangkok, Thailand, and conducted a demonstration test under raw-water turbidity conditions of up to 239 NTU. The results showed the turbidity of the treated water was consistently maintained at not more than 1 NTU, confirming the high treatment performance of the RFFS. However, as there are areas in Southeast Asia where the raw water turbidity exceeds 500 NTU or even 1000 NTU, we conducted further demonstration testing in Cambodia's Pursat province to verify performance under even harsher conditions. This was done in FY2024, with the support of the SDGs Business Supporting Surveys of the Japan International Cooperation Agency (JICA). In this test, we collaborated with the local water utility to assess the equipment's ability to adapt to changing water qualities and its operational stability from a range of angles and over the long term, covering both the rainy season and the dry season.

This paper presents an outline of the RFFS, the results of our demonstration testing in Cambodia, and future prospects.

## 2. Outline of RFFS

### 2.1 Equipment configuration and treatment flow

The RFFS is a packaged system that integrates the entire process from taking in raw water to generating treated water. It is water treatment equipment aimed mainly for treating highly turbid river water or lake water.

The equipment configuration of the RFFS is shown in **Figure 1**. First, raw water is taken into the Receiving Tank installed in the Pre-treatment Unit. Next, chemicals such as flocculants are added to the Mixing Tank.

Through gentle stirring in the Flocculation Tank, a coagulation process takes place in which fine suspended solids are grown into flocs. Next, in the Sedimentation and Filtration Tank, some of the formed flocs sink due to gravity, while the remaining flocs are captured by fiber filters arranged at the top of the tank. In this way, we can efficiently reduce turbidity through integrated pre-treatment that combines sedimentation and filtration.

The water pre-treated in the Pre-treatment Unit is temporarily stored in the Filtration Raw Water Tank, then sent to the Filtration Unit. Here, the water is passed through a higher-performance fiber filter, removing any remaining minute flocs, and finally treated water is generated.

In addition, one of the features of this system is how it regularly backwashes to maintain filtration performance. Using air backwashes in the Pre-treatment Unit and combined pre-treated water/air backwashes in the Filtration Unit is designed to efficiently remove suspended matter trapped in the filters.

### 2.2 Superiority over existing technologies

A comparison between the RFFS and conventional methods is shown in **Table 1**. The main feature of the RFFS is that it offers high-speed filtration using fiber filters.

**Table 1 Comparison between RFFS and conventional methods**

| | | RFFS | Conventional methods |
|---|---|---|---|
| Pre-treatment | Method | Sedimentation + fiber filtration | Sedimentation |
| | Surface loading | 100 - 200 m/day | Cross-flow: 15 - 30 m/day<br>Lamella clarifier: 40 - 100 m/day |
| Filtration | Method | Fiber filtration | Sand filtration |
| | Filtration speed | 500 - 1000 m/day | 100 - 150 m/day |

The Sedimentation and Filtration Tank, which is incorporated in the Pre-treatment Unit, effectively integrates the two functions of sedimentation and fiber filtration. This integration makes it possible to eliminate the individual sedimentation basins and grit chambers that were previously required. The result is that it is possible to set a large surface loading, allowing for a high treatment capacity even in a limited space.

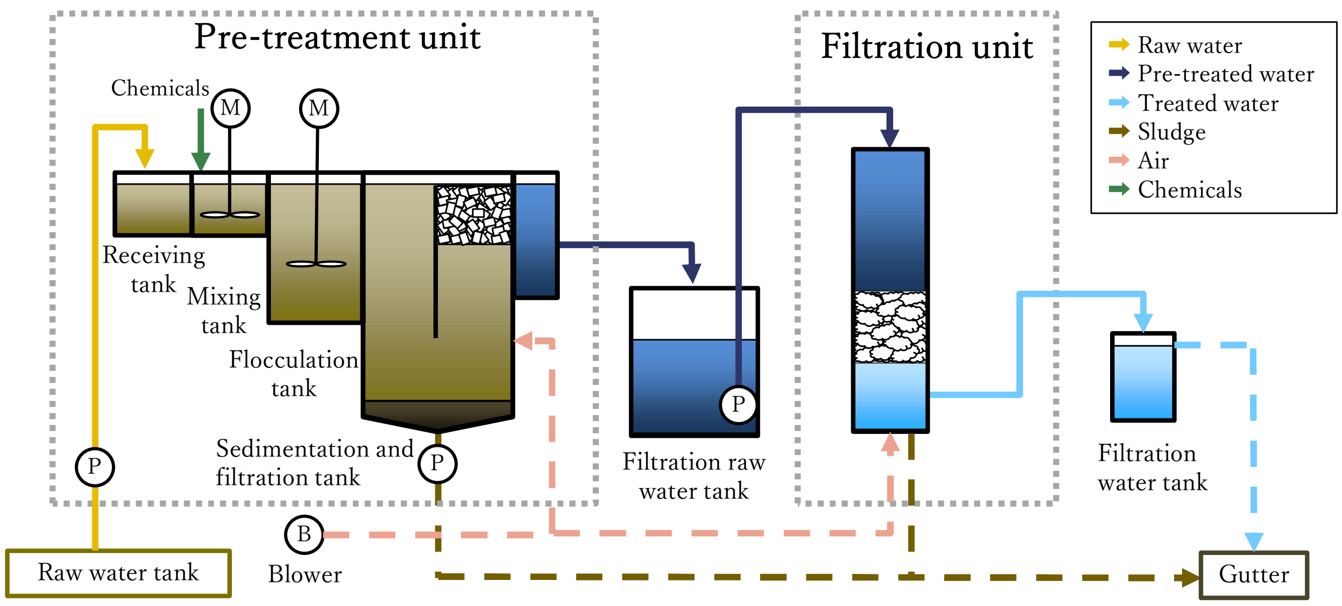


**Figure 1 Configuration of RFFS demonstration equipment installation**

Moreover, the fiber filter used in the Filtration Unit has the advantage of lower filtration differential pressure compared to conventional sand filtration methods. This allows water to pass through at over five times the speed of conventional systems, making it possible for the equipment to be more compact and take up less space.

Note that the fiber filters (**Figures 2, 3**) used in the RFFS have been developed entirely in-house by Kanadevia, building on our track record and wealth of experience in water treatment in the fields of water supply, sewerage, and wastewater treatment.

**Figure 2 Fiber filter material (Pre-treatment Unit)**

**Figure 3 Fiber filter material (Filtration Unit)**

## 3. Demonstration Test Operation Conditions and Methods

### 3.1 Demonstration test site

The demonstration tests were planned in accordance with the results of hearings conducted locally and with the cooperation of the Cambodian Ministry of Industry, Science, Technology and Innovation (MISTI). The tests were carried out in verification facilities on the Pursat Water Utility (PSWU) site, in Cambodia's Pursat Province. The raw water used in these tests was river water drawn from the Pursat River, which was pumped into the Raw Water Tank managed by PSWU. In addition, the treated water and waste cleansing water were expelled appropriately in accordance with PSWU directives.

### 3.2 Demonstration test schedule

These tests were conducted in two phases to obtain data from both the wet and dry seasons: from July 1st to September 26th, 2024, for the wet season, and from October 18th to December 19th for the dry season. Note that demonstration data for the period from August 11th to 16th, 2024, is excluded due to an error in setting the amount of flocculant added.

### 3.3 Operation conditions and control management

The demonstration facility was operated 24 hours a day, so data was obtained during normal operations, including at night. The main operating parameters were as follows.

- Treatment flow rate: 4.1 m3/hour
- Pre-processing surface loading rate: 100 m/day
- Filtration speed: 500 m/day
- Backwash frequency: 1 time/day

The amount of chemicals injected was adjusted appropriately based on the raw water turbidity, pH, alkalinity, and so on, so regular jar tests were done to determine the amount to inject.

### 3.4 Chemicals used

The chemicals used in these demonstration tests are shown in **Table 2**. These demonstration tests used chemicals that were already in use at PSWU in order to use chemicals that were able to be obtained locally, and in consideration of the future expansion of the project within Cambodia. Note that flocculant was used throughout the test periods, while alkaline agents were used from September 5th and chlorine agents were used from September 9th, as needed.

**Table 2 Chemicals Used**

| Type | Name | Purpose |
|---|---|---|
| Flocculant | PAC (Polyaluminum chloride) | Causes coagulation and sedimentation of the fine water-suspended particles (colloids) that cause turbidity. |
| Alkaline agent (from Sept. 5) | Slaked lime (Calcium hydroxide) | Adjusts the pH to the appropriate range to maximize the flocculant effectiveness. |
| Chlorine agent (from Sept. 9) | Bleaching powder (Calcium hypochlorite) | Breaks down organic matter like algae that inhibits coagulation to promote the formation of coagulated flocs. |

### 3.5 Third-party water quality analysis

Evaluation of the treated water quality was carried out by the Science, Technology and Innovation National Laboratory (STINL), an official third-party analysis institute, based on the waterworks license acquisition conditions within Cambodia. Samples of raw and treated water were taken on September 26th, and analyzed in all criteria in accordance with the Cambodian tap water quality standards. This analysis confirmed that the treated water met the standards, and assessed the reliability and suitability of the system.

## 4. Demonstration Test Results

### 4.1 Turbidity of raw and treated water

Changes in the daily average turbidity of the raw and treated water are shown in **Figure 4**, while the raw water samples during operation are shown in **Figure 5**, and the treated water samples in **Figure 6**.

There were major changes in raw water turbidity during the test periods. During July to September in particular, the rainy season, inflow of suspended matter from upstream had an impact, raising the average turbidity of the raw water to 120 NTU, with the highest turbidity being a day average of 441 NTU recorded on July 20th. On the other hand, from October to December, the dry season, turbidity was lower than the rainy season and more stable, with an average of 78 NTU.

The turbidity of the treated water averaged 4.4 NTU during the rainy season and 3.9 NTU during the dry season. In particular, the 54 days from October 27th to the end of the test on December 19th showed a sustained turbidity of not more than 5 NTU, the Cambodian tap water quality standard. The average turbidity during this period was 0.9 NTU, maintaining good water quality, and showing the performance and stability of the equipment. However, there were also temporary spikes in treated water turbidity, when the treatment process did not function adequately. The specific causes for this defective treatment and its countermeasures are detailed in **4.3** and **4.4**.

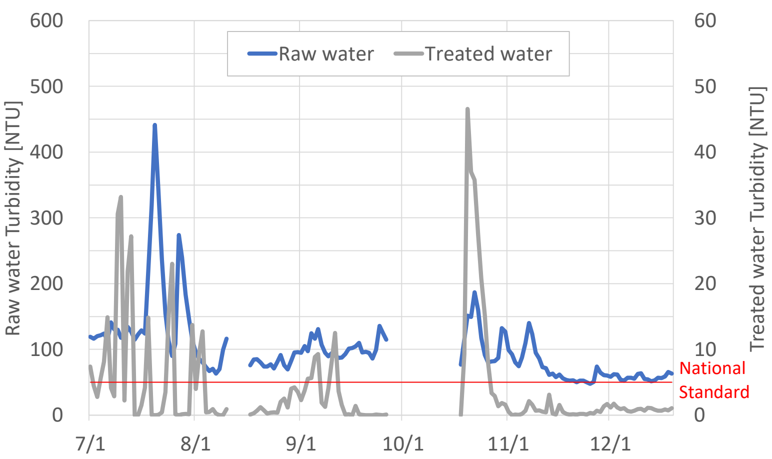


**Figure 4 Daily average turbidity of raw and treated water**

**Figure 5 Raw water samples**

**Figure 6 Treated water samples**

### 4.2 Results of continuous operation using high-turbidity raw water

From early to mid July, Cambodia experienced heavy rainfalls, which caused silt to be washed into the river from upstream, spiking turbidity levels in the raw water. The changes in measured levels of turbidity levels of the raw water and the treated water from July 19th to 21st when this high-turbidity raw water lasted are shown in **Figure 7**.

During this period, the raw water turbidity exceeded 200 NTU, reaching a maximum of 547 NTU. On the other hand, the treated water turbidity remained level at 0 NTU over the bulk of this period, and while there was a spike, it topped out at 1.2 NTU, and never exceeded the standard for treated water turbidity. In addition, the normal once per day backwashing in the Pre-treatment Unit and Filtration Unit was still possible. From these results, it was confirmed that the RFFS has the water treatment capacity to stably handle raw water at 200 NTU or more, and even high turbidity levels of over 500 NTU. However, a rise in treated water turbidity was confirmed later, showing that at this point there are still issues remaining for stable operation.

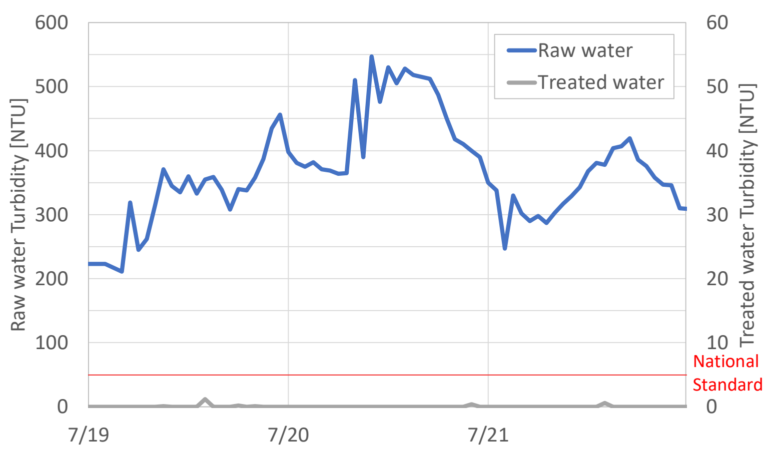


**Figure 7 Measured turbidity values for raw water and treated water during high turbidity**

### 4.3 Treatment issue and cause analysis

As shown in **Figure 4**, it was confirmed that treated water turbidity for the period July to October exceeded the threshold of 5 NTU for an extended period, showing a drop in treatment performance. As a result of investigating the cause, it was believed to be the effects of multiple factors working together.

First, it was found that the alkalinity of the raw water was varying greatly over a short period, and as a result, it was hypothesized there was a period when the flocculant coagulating effect was not fully working. When alkalinity is low, the flocculant cannot function effectively, and it hampers the formation of coagulated flocs. Therefore, this is thought to be one of the factors behind the drop in treatment performance[3)].

Moreover, algae and other organic matter in the raw water are also believed to be a factor hampering the formation of flocs. The existence of organic matter interferes with the flocculant effects, meaning that the floc size and strength are inadequate. As a result, it is hypothesized that this caused a drop in sedimentation and separation efficiency[4)].

In addition, as the amount of chemicals injected was adjusted manually, it was not possible to adjust the amount quickly enough to cope with the rapid changes in the raw water. This means that appropriate coagulation did not take place, and the treatment efficiency dropped. Furthermore, communication delays with the local operator meant that it took longer to respond to the problem after it occurred, resulting in a prolonged decline in treatment performance.

### 4.4 Measures for treatment issues

As measures to counter these issues, first, the jar test frequency was increased starting from September 2nd. This enabled the development of a system that could handle rapid changes in the raw water, and the amount of chemicals added was adjusted appropriately. This measure made it possible to understand flocculation conditions both promptly and accurately, leading to increased processing efficiency.

Moreover, an alkaline agent (slaked lime) to increase the raw water alkalinity was added starting on September 5th, and a chlorine agent (bleaching powder) to oxidize organic matter was added starting from September 9th. The injection of these chemicals was not done on a permanent basis, but when the jar test showed they were needed, and their amounts adjusted as appropriate. As a result, floc formation was encouraged and improved treatment performance was confirmed.

In addition, along with maintaining close contact with the operator when a treatment issue arises, inexperienced operators were able to improve their skills in dealing with changes in raw water conditions through practical experience. As a result, it became possible to respond immediately and appropriately when a treatment issue arose, contributing to increased stability of the overall treatment performance.

These measures have made it possible to overcome drops in treatment performance and ensure stable water quality.

### 4.5 Third-party water quality analysis results

Samples of raw and treated water were taken on September 26th, and analyzed at STINL. The results are shown in **Table 3**. The raw water turbidity when sampled was 150 NTU, and the treated water turbidity was 0 NTU. In addition, the treated water was confirmed to meet the

**Table 3 STINL water quality analysis results**

| Content | unit | Raw water | Treated water | National Standard Treated Water |
|---|---|---|---|---|
| pH | - | 7.26 | 7.00 | 6.5-8.5 |
| Turbidity | NTU | 150 | 0 | ≦5 |
| TDS | mg/L | 29 | 39 | ≦800 |
| Total hardness | mg/L | 36.70 | 34.72 | ≦5300 |
| As | μg/L | 0 | 0 | ≦50 |
| Fe | mg/L | 1.88 | 0.00 | ≦0.3 |
| SO4- | mg/L | 0.0 | 0.0 | ≦250 |
| Na | mg/L | 3.429 | 3.578 | ≦250 |
| NO3 | mg/L | 1.14 | 1.11 | ≦50 |
| NO2 | mg/L | 0.01 | 0.05 | ≦3.0 |
| Al | μg/L | 449 | 13 | ≦200 |
| Color | TCU | 28 | 0 | ≦5 |
| Conductivity | μs/cm | 57 | 78 | ≦1,600 |
| Ba | μg/L | 14 | 20 | ≦700 |
| Mn | mg/L | 0.021 | 0.011 | ≦0.1 |
| Hg | μg/L | 0.156 | 0.121 | ≦1.00 |
| F | mg/L | 0.17 | 0.20 | ≦1.5 |
| NH4 | mg/L | 0.2 | 0.01 | ≦1.5 |
| Cd | μg/L | ND | ND | ≦3.0 |
| Pb | mg/L | ND | ND | ≦10 |
| Zn | mg/L | ND | ND | ≦3.0 |
| Cu | mg/L | ND | ND | ≦1.0 |

threshold for all criteria in the Cambodian tap water standards. These results show that the treatment process functions extremely effectively, and it is clear that this treatment system has sufficient adaptability to comply with local water quality standards.

## 5. Outcome of the Demonstration Tests, Future Issues and Prospects

### 5.1 Demonstration test outcomes

#### 5.1.1 Adaptability to turbidity

The RFFS can maintain a treated water turbidity of almost 0 NTU through normal operations and one backwash per day if flocculation effects can be obtained through appropriate chemical injection for turbid raw water that is normally 200 NTU or more, and even when turbidity levels reach a maximum of 547 NTU. The conventional sand filtration method leads to filter blockages or rapid drops in filtration speed during highly turbid conditions, and requires frequent backwashing, meaning that declines in water production become a major issue. In contrast, the RFFS, which uses a fiber filter, demonstrates superior characteristics in terms of high filtration rates and ability to treat highly turbid raw water, showing that it is clearly superior to the conventional method.

#### 5.1.2 Operation flexibility and reproducibility

Even when an issue arises in treatment, appropriately adjusting the amount of injected chemicals or revising the operation conditions have allowed prompt restoration of functions. This demonstrates the flexibility and reproducibility of this system. Moreover, using appropriate operation management, for a period of 54 days in a row treated water reached the water quality standards with an average turbidity of 0.9 NTU. This result shows that stable operation is possible if the operator has some degree of experience, even over short-term changes in water quality.

#### 5.1.3 Knowledge regarding selection of injected chemicals

In the demonstration test conducted in Thailand in FY2023, it was possible to stably maintain treated water turbidity at not more than 1 NTU simply by injecting a flocculant (PAC) alone. In contrast, in this test, it was confirmed that there was a drop in treatment performance despite using the same operating conditions. As a result of investigating the cause, it was hypothesized that, in addition to the raw water turbidity, the low alkaline levels and the presence of organic matter such as algae hampered the effects of flocculation. To deal with these factors, the appropriate injection of an alkaline agent and a chlorine agent stabilized treated water quality, and subsequent operations still maintained good treatment performance. These results show that it is essential to optimize chemical selection and injection conditions based on the characteristics of the raw water. This knowledge provides a useful guideline for future design and operation.

#### 5.1.4 Operation and ease of maintenance

The RFFS does not require excessive maintenance or complex operations, as even if run 24 hours a day, all it requires is one backwash per day and the injected chemicals are, in general, set based on jar test results. This is a major point in its favor for small-scale waterworks companies, and it is suited for wide use in regions where there are personnel issues.

#### 5.1.5 Cleared all criteria in the tap water standards

The treated water was confirmed to meet the threshold for all criteria in the Cambodian tap water standards, and to satisfy the water quality requirements needed to obtain a waterworks license. This clearly shows that the RFFS possesses a performance that complies with water quality standards within Cambodia.

#### 5.1.6 PR activities through workshop

With the cooperation of JICA, MISTI, and PSWU, we held a workshop aimed at presenting the RFFS and showing people around the demonstration equipment. (**Figures 8, 9**) A total of 59 people took part in this workshop, including from JICA's Cambodia Office, MISTI, the Cambodia Water Supply Association (CWA), public waterworks utilities, and Private Water Operators (PWO). Participants were extremely interested in this system, and this workshop allowed us to build a network with local waterworks-related parties. This initiative is expected to form a key foundation for future business expansion.

**Figure 8 View of the workshop**

**Figure 9 Viewing the demonstration equipment**

### 5.2 Future issues

#### 5.2.1 Dealing with raw water changes

In these demonstration tests, there was a temporary issue with treatment where the equipment could not keep up with a rapid change in the raw water quality. We believe there are two ways to handle this: mechanical response and human response.

A mechanical response would be to introduce a feedback system that measures the raw water quality in real time and automatically controls the amount of chemicals injected. While this is expected to be highly responsive and reduce human error, it comes with high initial setup costs and maintenance burdens, so may be difficult for small-scale waterworks companies.

The human response is to work to improve responsiveness through training local operators and preparing an operation manual. While there are benefits in terms of cost, the reliance on experience means that operational misses are a possibility. For this reason, it will be needed to prepare a practical manual and response steps based on demonstration data.

It is important to select or combine these approaches appropriately in light of the local technical and economic conditions.

#### 5.2.2 Lowering costs

In Southeast Asia there is a tendency to prioritize lower construction costs even if there is a shortage of technical verification. This means that the initial introduction costs of the RFFS may be relatively high, so measures to reduce costs will be needed.

One measure could be moving towards standardization or modularization, which could reduce design manhours and construction costs. Another could be enhancing the local procurement of devices or parts, which could reduce shipping and purchasing costs. Additionally, carrying out economic assessments based on life cycle costs (LCC) and presenting the long-term cost-effectiveness will allow the value of bringing in the RFFS to be shown quantitatively.

Through these efforts, we will need to balance both the economic and practical aspects of the RFFS so it can be developed as a sustainable water treatment technology adapted to local needs.

### 5.3 Future prospects

In the February 2024 water purification facility enhancement project in Baribour District, Kampong Chhnang Province, Cambodia, we received our first commercial order for an RFFS from Isza Trade Sdn Bhd, which operates the local water purification plants. The treatment capacity of this project is 30 m3/hour, and it can provide around 1,600 households with safe water.

Successful completion of this project will underpin the reliability and practicality of the RFFS, and is extremely important in terms of building a foundation for future business expansion. In addition, we expect to see further spread of the RFFS and market expansion through these initiatives.

## 6. Conclusion

This paper has presented an outline of the RFFS treatment system for high turbidity water and the results of demonstration tests in Cambodia, as well as the direction of future developments.

The results of the demonstration testing confirmed that the RFFS is able to treat water stably even at a maximum turbidity level of 547 NTU, and the treated water thus generated meets the tap water standards of Cambodia. On the other hand, we also confirmed a temporary drop in treatment performance due to changes in the raw water quality and delays in adjusting operating conditions. However, as a result of taking appropriate measures, system performance was recovered and it was possible to maintain stable treatment performance for 54 days in succession using appropriate operation management. These tests provided useful knowledge related to optimization of operating conditions in the future.

Henceforth, based on the knowledge we gained through the demonstration tests, we will work to develop human responses and systems that can immediately adapt to changing raw water quality, along with promoting equipment standardization and modularization with the goal of reducing costs. In addition, using our success at getting an order in Cambodia as a springboard, we will move ahead with a full-scale rollout to the Southeast Asian market.

Through these initiatives, the spread of RFFS sites can be expected to contribute to a safe, reliable waterworks infrastructure throughout Southeast Asia, helping improve the living standards of local residents and bring about a sustainable society.

## Acknowledgments

This demonstration test was selected and carried out by the Japan International Cooperation Agency (JICA) as part of its "SDGs Business Supporting Surveys" (contract period: March 1st, 2024 to March 31st, 2026).

In addition, we would like to thank MISTI, PSWU, and all the local operators from whom we received so much support.

## References

1) Toru WATANABE, Takayuki MIURA, Tsukasa SASAKI, et al.：Risk Evaluation for Waterborne Infectious Diseases in the Mekong Watershed Considering Water Supply Systems，Environmental Engineering Research，2006，43，245-254.

2) Shingo KANEZAWA，Takashi HASHIMOTO，Kumiko OGURA, et al.：Membrane Fouling and Particle Rejection by Microfiltration of Upstream and Downstream Waters Taken from a Highly Turbid River，Journal of Japan Society of Civil Engineers, SER. G Environmental Research，2017，73(7)，III_419-III_428.

3) Proceedings of JWWA’s Annual Conference and Symposium，2019，4-73，416-417.

4) Naoki MURATA，Nobuhiro AOKI, Nobuyuki MOTOYAMA, et al.：Inhibiting effect of chlorination and coagulation on membrane fouling during ceramic membrane filtration for water containing algae，Journal of Japan Society of Civil Engineers, SER. G Environmental Research，2013，69(7)，III_29-III_38.

## Authors

Tetsuro Fujita，Makoto Fujioka
Water & Sewerage Design Section No.1 Group，
Water Treatment Design & Engineering Department，
Kanadevia Corporation
E-mail：hitzgiho001@kanadevia.com