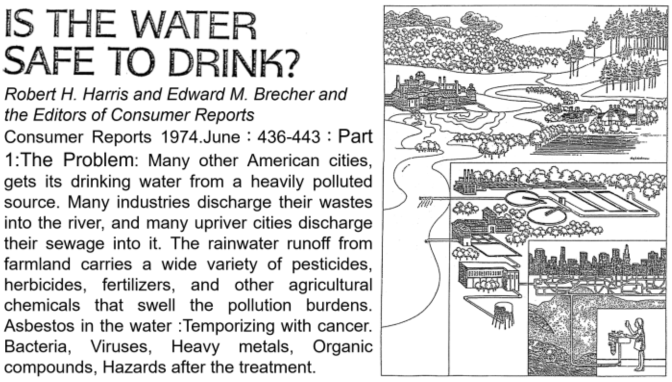
Safe Drinking Water by Ecological Purification System

NAKAMOTO Nobutada 中本信忠

1. To safe purification process without chemicals

Tap water in Ueda City, Nagano Prefecture, has been supplied by slow sand filtration since 1923. When the Sugadaira reservoir was constructed in 1964 upstream of the source river, tap water in Ueda City became odor problem. At that time, algicide was added to the source pond and the filter pond to prevent the smell of tap water and clog the filter pond.

The "Is the water safe to drink ?" warning (Fig. 1) was issued in 1974. Rapid sand filter using chemicals has a high cancer risk by the tri-halo methane formation. People has minimized the use of chemicals.


IS THE WATER SAFE TO DRINK?

Robert H. Harris and Edward M. Brecher and the Editors of Consumer Reports

Consumer Reports 1974.June : 436-443 : Part 1:The Problem: Many other American cities, gets its drinking water from a heavily polluted source. Many industries discharge their wastes into the river, and many upriver cities discharge their sewage into it. The rainwater runoff from farmland carries a wide variety of pesticides, herbicides, fertilizers, and other agricultural chemicals that swell the pollution burdens. Asbestos in the water :Temporizing with cancer. Bacteria, Viruses, Heavy metals, Organic compounds, Hazards after the treatment.

Fig.1. "Is the water safe to drink ?" Harris report 1974

2. Attention to the role of algae and micro-animals

Also in Japan, the cancer risk by tri-halo methane formation has become a problem, and chemical addition has been minimized. In Ueda City, tap water became delicious after stopping chemical addition as algicide from around 1980. A remarkable growth of algae was observed in the slow filtration pond and the biological community began to play an active role (Fig. 2). This was an Ecological Purification System (EPS).

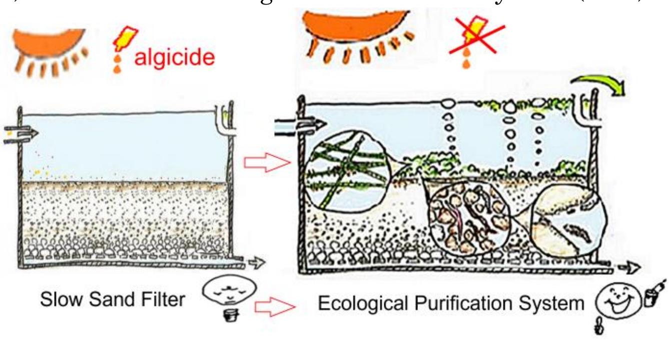


Fig. 2-1. Delicious water by stopping the algicide

I started to study the role of algae growing in a filter pond from April 1984 at Shinshu University. Algae grew well on the surface of the sand layer of the shallow filtration pond. Algal mat lifted and floated to the water surface due to the buoyancy of oxygen bubbles produced by photosynthesis by algae (Fig. 3). It flowed out from the overflow.

Fig. 2-2. The floating algae flew from the overflow pipe

The filter has a flow from top to bottom. The water depth was shallow and algae that became threadlike on the sand surface were predominantly propagated. This algal mat traps turbid matter and has the effect of not clogging the filter (Fig. 4). Algae produce oxygen by photosynthesis and create an environment in which micro animals in the upper part of the sand layer are more active.

Fig. 2-3. Floating algal mat and trap suspended matter

The size of organisms is much smaller than sand particle size of about 0.5 mm (Fig. 5). It is an organism that looks like trash around the sand. It is microscopic organisms of unicellular protozoa or micro-animal. At the upper part of the sand layer, a food chain has been established in which bacteria and small animals are active, eaten and eaten, and trapping and decomposition of turbidity have been performed. It was different from the image of the term of slow (sand) filtration.

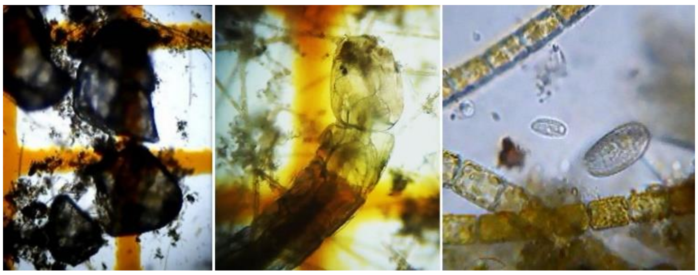


Fig. 2-4. Sand and organisms, 1 mm grid interval

3. Slow filtration is instant purification

The algae on the surface of the sand layer was food for the animals, and the animals sought food and gathered near the surface of the sand layer (Fig. 6). In an environment with a flow from top to bottom, the sand did not move, and the small animals were active on the surface of the sand, in the shade of the sand and among sand particles.

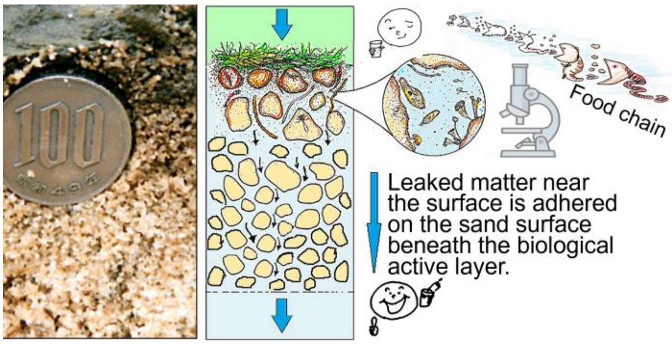


Fig. 3. Algae and small animals are active at the top

The activity of micro-organisms captured and degraded dissolved substances that pathogens and organisms react to. The English standard filtration rate (flow of water on sand) is as slow as 4.8 m (20 cm per hour, 0.33 cm per minute) per day. Most of the organisms were active within about 1 cm near the surface sand layer. The time for the water to pass through this active layer was about one minute. It was an instant purification by biological communities. Slow filtration was not mechanical physical filtration with fine sand. It was essential to develop the ecosystem in the upper layer to perform the complete purification by an Ecological function.

When there is a un-expected change in water quality, the micro-organisms shrinks and turbidity passes through the biological active layer. The turbidity which has passed is adsorbed on the surface of the sand below the active sand layer. The sand layer was thickened so that turbidity would not leak even in un-expected events.

4. Turn to a health village with safe clear water

Safe water supply system was considered that can be maintained and managed by residents in Indonesia for a social contribution activities of Yamaha Motor Company. Mr. Sumio Yagi 八木澄夫 visited my laboratory at Shinshu University. Tropical rivers are usually brown water with fine colloidal mud. This brown water explained the mechanism of trapping turbidity in the paddy field by the reproduction of algae and the activity of small animals, and forming it as a fecal mass. I suggested that if this system is applied, it will be possible to eliminate pathogens and create safe drinking water even in brown river water without chemicals. An experiment was conducted on a factory site in Jakarta and a real plant was constructed in 1999. This plant was constructed and donated to the village (Fig. 4-1 and 4-2).

Fig. 4-1. Algae and small animals grow well

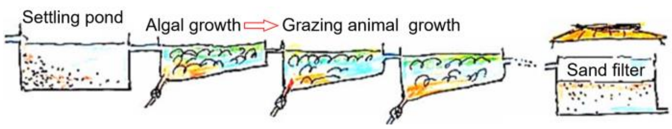


Fig. 4–2. Settling, shallow waterway, sand filter

Purified water was used for drinking and cooking. Two bottles of 20-litters were supplied to all families using public taps. The residents decided to take the water charge for maintenance and future facilities repair. The water committee managed the public tap with a charge of 500 ml plastic bottle per every 20 liters (Fig. 4-3).

Fig. 4–3. Public tap and tap keeper

Villagers used this water and used only drinking and cooking, but eye sickness and diarrhea disappeared and this village became a health village. The reputation of this treated water was transmitted to the neighboring village. As there is enough capacity for the purification of this facility, this water committee has developed a water supply business that purified water to the next village using a water supply tank (Fig. 4-4). We visited this facility 10 years later. The villagers managed independently the plant without problems.

Fig. 4-4. Water supply business to neighboring villages

This system was developed as a Yamaha clean water system. Total number of installations of this system is 24 in 12 countries in Africa and Asia until December 2017.

5. Up-flow roughing filter for turbidity reduction

Luiz Di Bernardo, Brazil, devised an Up-flow Roughing Filter (URF) for turbidity reduction without chemicals in 1980 (Fig. 5-1) and presented it at the International Conference, 1988, London. The report of the international joint research was published from Switzerland in 1996.

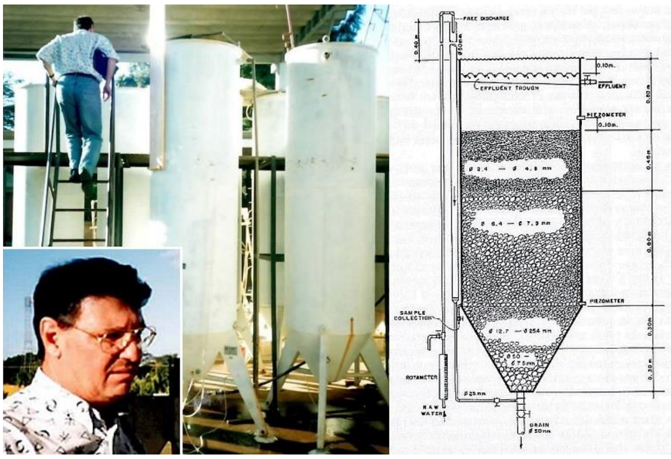


Fig. 5-1. Up-flow Roughing Filter experiment device

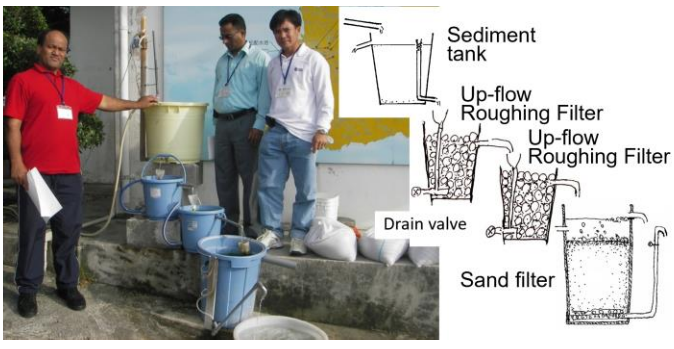


Fig. 5-2. Explain URF using a bucket model

I also tested the performance of URF at my university. There was a function of an Ecological Purification System to remove the turbidity . Colloidal silty matter was hard to sink and it was adsorbed on the surface of the gravel in URF and it was trapped and decomposed by the action of a small animal. From 2006, I contributed a water supply training course by JICA training in Miyako-jima island, Okinawa. I explained the mechanism of URF to remove turbidity without chemicals as a recent new technology (Fig. 5-2).

6. Water supply to a national hospital by EPS

There was a plan to construct a rapid sand filter plant at a national hospital in Sri Lanka. After Mr. Motohiro Okada 岡田有弘, a Japanese General Consultant Co. Ltd. surveyed in the field, he judged that the local staff could not be maintained the rapid sand filter of chemical treatment. Then he came to my laboratory in 1999 to ask the possibility to introduce slow sand filter system. I advised him new URF (Up-flow Roughing Filter) to reduce turbid matter without chemical, even in the case of tropical brown turbid water (Fig. 6-1). When URF is used, safe drinking water can be produced by the activity of the biological community.

Fig. 6-1. Muddy water of tropical rivers

Muddy brown river water is common in tropical continent region. Settling tank can only trap heavy turbid matter. I recommended a sufficient pre-treatment using 3 times repetition of URF to reduce colloidal turbidity (Fig. 6-2).

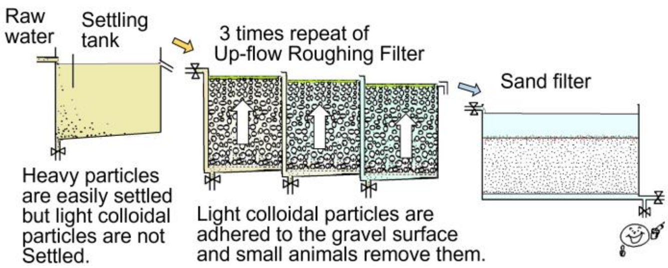


Fig. 6-2. Settling tank and URF for turbid reduction

Accumulated mud on the bottom of URF drains from the drain valve from time to time. The plant composed 2 sets of purification line considering maintenance and management (Fig. 6-3). This system does not use chemicals, but this purification process depends on the activity of natural biological communities. This treated water was stored and supplied to a large hospital. This plant was completed and I explained the purification mechanism to local engineers in January 2001.

Fig. 6-3. Two sets of 3 steps of URF

In the up-flow gravel tank, fine turbidity adheres to the gravel surface. The small animals play an active role, scrape off the attached turbidity and turn them into feces and sink them to the bottom. From time to time, it is maintained and drained from the bottom.

Fig. 6-4. Explain the ecological purification mechanism

Finally, algae and small animals on the surface of the sand filter also capture and decompose pathogens etc. The filtrate becomes safe and delicious water. Mr. Ananda Weerante, the director of the contractor who understood the mechanism, said, "Conventional is a commercial filter. This is a natural filter" (Fig. 6-4).

7. Pesticides are also decomposed by EPS

In 2002, I noticed that there is an Asia Arsenate Network (NGO in Miyazaki City) that is trying to supply safe water by slow sand filter in Bangladesh where the groundwater is contaminated with arsenic. I sent a message that purification of slow sand filter based on the biological activity. They asked me that please tell us the way to remove pesticides. I advised that it is better to promote the use of the food chain by algae and animals by the repetition of the up-flow roughing filter. Hardly decomposable compound of pesticides may decompose in the feces which is anaerobic environment (Fig. 7-1).

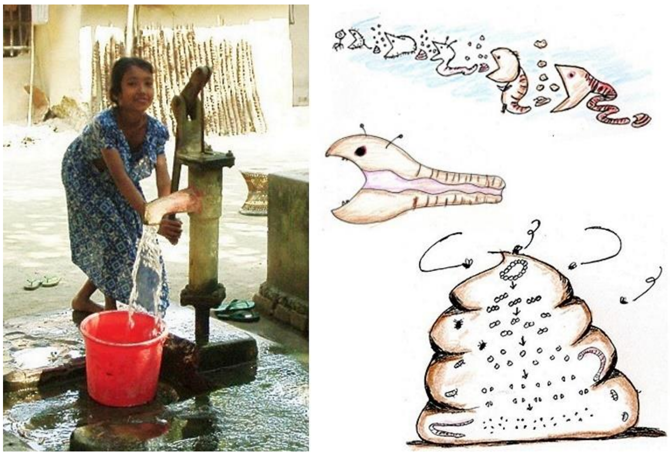


Fig. 7–1. Safe water from arsenate and pesticide

I explained in detail the importance of food chain in the ecological purification system and the smart technique of up-flow roughing (gravel) filter (URF) at the EPS site of Bangladesh. In order to thoroughly decompose persistent pesticides, I recommended to repeat URF and I advise how to maintain the system. The first water purification facility for residents based on slow sand filter in Bangladesh was completed (Fig. 7-2 and 7-3).

Fig. 7-2. EPS with 4 times URF

Fig. 7-3. Explaining the role of algae and predators

The leader, Mr. Kazuyuki Kawahara 川原一之, suggested me that the name "Slow Sand Filter" be used to misunderstand the real purification mechanism and to consider a new name for this purification system. As the mechanism of purification is importance of the food chain in the ecosystem where the biological community plays an active role, we chose "Ecological Purification System：生物浄化法 in Japanese." In "How to make delicious water" published in August 2005, the new term "生物浄化法 Ecological Purification System" was used.

This group subsequently built a number of new purification plants by themselves and in 2019 a new plant with the UNICEF Fund (Fig. 7-4).

Fig. 7-4. New construction by UNICEF fund in 2019

8. Mr. Jin Schengze constructed EPS in China

Mr. Jin Shengzhe 金胜哲, who was interested in my ecological purification system, visited Shinshu University a year after publishing a technical book on EPS (2006). So, I asked for a Chinese translation, and in May 2009, the Science Publishing Company in Beijing published "Safety Water Purification Act Guidance" (Fig. 8-1).

Fig. 8-1. Chinese translated book on EPS in May, 2009

The great Sichuan earthquake occurred on May 12, 2008, and Mr. Jin went to Sichuan and built three EPS plants. He shot a video of the EPS construction. He came to my home in Ueda City on November 24, 2008. I was surprised that a 30 ton settling tank, an URF, and a EPS tank were constructed in a short period of about one month by human power (Fig. 8-2 and 8-3).

Fig. 8-2. Construction by human power

Fig. 8-3. The construction speed was surprisingly fast

In Shenyang County, Henan province, groundwater in the Huaihe basin was polluted due to the influence of industrial drainage, causing frequent cancer and causing problems. Mr. Jin and Mr. Huo Daishan 霍岱珊, who were working to prevent pollution, have since 2008 built a facility to make safe drinking water from contaminated groundwater in this area by EPS technology. The small plant (Fig. 8-4) can purify 6 tons of groundwater per day, and can supply 500 people with 12 liters of water per day. The water quality has cleared all drinking water safety standards in China.

Fig. 8-4. Small-scale purification system

Mr. Huo applied for construction funds to a number of aid organizations and constructed EPS plants at more than 40 plants. I visited the site in May 2016 with the guidance of Mr. Jin. The climate in this region was to have a roof like a greenhouse and secure solar radiation as the water freezes during the extremely cold season (Fig. 8-5). Mr. Jin said that China has a proverb called "Accumulating good virtues increase 積善積徳"

Fig. 8-5. EPS was covered with a translucent roof

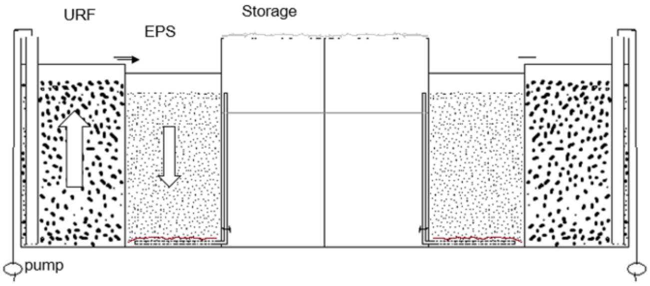


Fig. 8-6. The plant has two sets of EPS

The plant built at the elementary school in August 2014 were 70 to 80 tons per day. This plant supplied 4,600 (include 246 school children) persons per 16 liters per day. Public tap systems was adopted for the villagers. There were two sets of EPS line (2 m x 4 m) (Fig. 8-6).

9. Advise for a better plant system to Samoa

We went to Samoa as a follow-up survey (November 8 to 17, 2008) of JICA (Japan International Cooperation Agency) training on Miyakojima, Okinawa that has been continuing since 2006. A slow sand filter plant that supplies water to the capital, Apia, was constructed in 1984-87 with the German aid (Fig. 9-1).

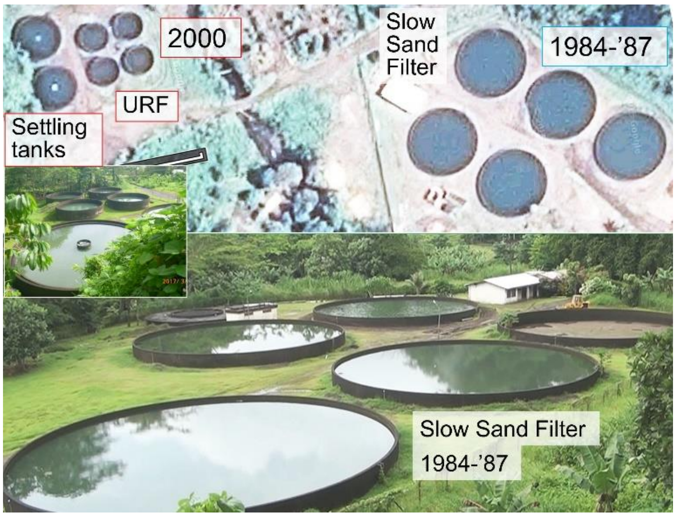


Fig. 9-1. Water purification plant built with German aid

The latest Up-flow Roughing Filter, which report was published in 1996 in Switzerland, was introduced in 2000. Judging from my experience, it was too small as a countermeasure against turbidity of a storm event in tropical area. Also, in this plant guideline by German consultant, the standard rate of the slow sand filter pond was 3 m per day and the depth of the filter pond was deep. This plant manual was depended mainly on the mechanical filtration without considering the biological activity.

It was thought that the filter rate would be faster if the amount of influent water was large, and the turbidity did not settle in the settling tank. In addition, they thought that the higher the water pressure in the filtration, the better the water depth was. I advised that if the water depth is shallow, the water pressure will be small and the bubble production by photosynthesis will be good, the algae will rise up, and it will be difficult to carry out filter blockage (Fig. 9-2).

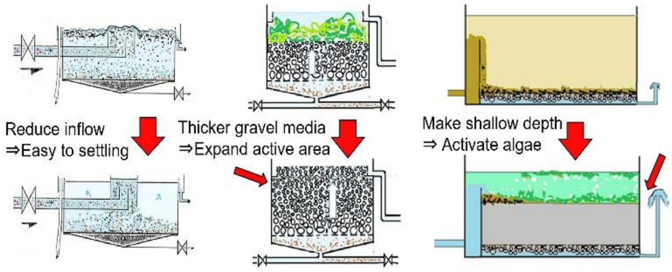


Fig. 9-2. Improvements to the Purification Function

Unlike Germany, Samoa is warm and biologically active. In order to improve the function and activity of the organisms, we increased the thickness of gravel layer in URF to increase the adhesion surface where the organisms are active, and the depth of the filter pond was shallow. I advised maintenance and management methods based on the idea of the ecological point. After that, JICA newly constructed two purification plants based on the EPS with grant aid to Samoa.

10. Safe water by EPS to all the villages in Fiji

Mr. Vishwa Jeet from Fiji who participated in the JICA training in Miyakojima in August 2011 learned that safe drinking water could be made by slow sand filter and EPS without any chemicals. He noticed these technology could provide safe drinking water by Fijian staff to the village people (Fig. 10-1).

Fig. 10-1. JICA training at Miyakojima

He drank the filtered water and was impressed by the taste. Furthermore, I learned about the mechanism of the measures against turbidity and purification system with the bucket model. He was convinced that this system could do it himself (Fig. 10-2).

Fig. 10-2. Learning from the model and how delicious is

At that time the Fiji village used untreated water, and when it rained, the water became turbid and there was a problem with safety. So he made a model by himself and checked the safety with the rainwater tank water (Fig. 10-3). It was thought that a device of the size of the rainwater tank (2.7 m3) could supply safe drinking water to all the villagers. The model was exhibited on "World Water Day". So he told the prime minister that he could supply the village with safe water. As a result, the national project "Safe Water to All Villages by use of EPS technique" has started. January 16, 2013 The launch ceremony of the project was held at a grand scale. Mr. Akito Uechi, director of Miyakojima, and I participated in the ceremony and gave lectures.

Fig. 10-3. An EPS model and clean water project started

The untreated tap water from an existing receiving tank was purified to safe drinking water by the EPS technique (Fig. 10-4). The Water and Sewerage Department of Fiji government built two pilot plants in two villages in cooperation with the Division of Engineering and completed two water supply plants in July and September 2013.

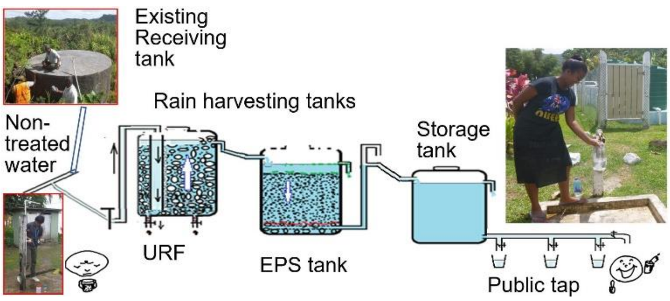


Fig. 10-4. From Untreated Water to Safe Drinking Water

However, it was difficult for the Fiji government alone to construct the implementation facility and requested JICA. JICA cooperated with short-term expert twice a year for about one month from October 2014 for two years. There was a lot of misunderstanding about the construction and the method of maintenance and maintenance. Therefore, detailed design and construction drawings and guidelines for maintenance and construction were prepared (Fig. 10-5 and 10-6). After that, another two-year dispatch request was issued and we cooperated. As a result, more than 100 EPS plants are in operation at the end of 2018 in Fiji (Fig. 10-7).

Fig. 10-5. A village EPS plant using a rainwater tank

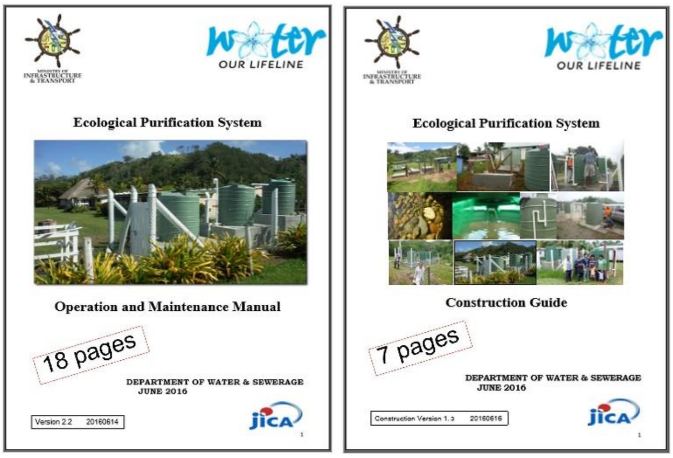


Fig. 10-6. Operation and construction guides

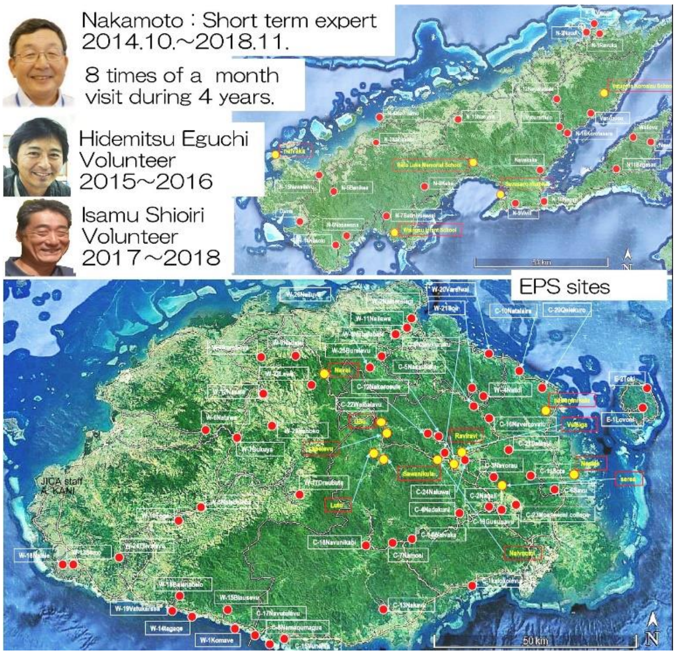


Fig. 10-7. Locations installed for four years by 2018

The project was implemented under the initiative of the Fiji government, and construction of around 30 plants was covered by the government budget every year, and JICA only provided technical cooperation by dispatching Nakamoto and volunteers. EPS technology has been transmitted from Japan to Fiji as a technology that can be done by themselves

11. Japanese EPS was transferred to the world

A technical commentary on the EPS was published in China in Chinese and in Portuguese in Brazil (Fig. 11-1). JICA published Japanese and English online teaching video text which can access through the internet. I helped to hold the 5th International Conference on Slow sand and Biofiltration in Nagoya City (2014), and distributed an English commentary (see following address) in the Pacific Water & Wastewater Conference in New Caledonia in August 2018.

http://www.cwsc.or.jp/files/member_lmtd/doc25.pdf

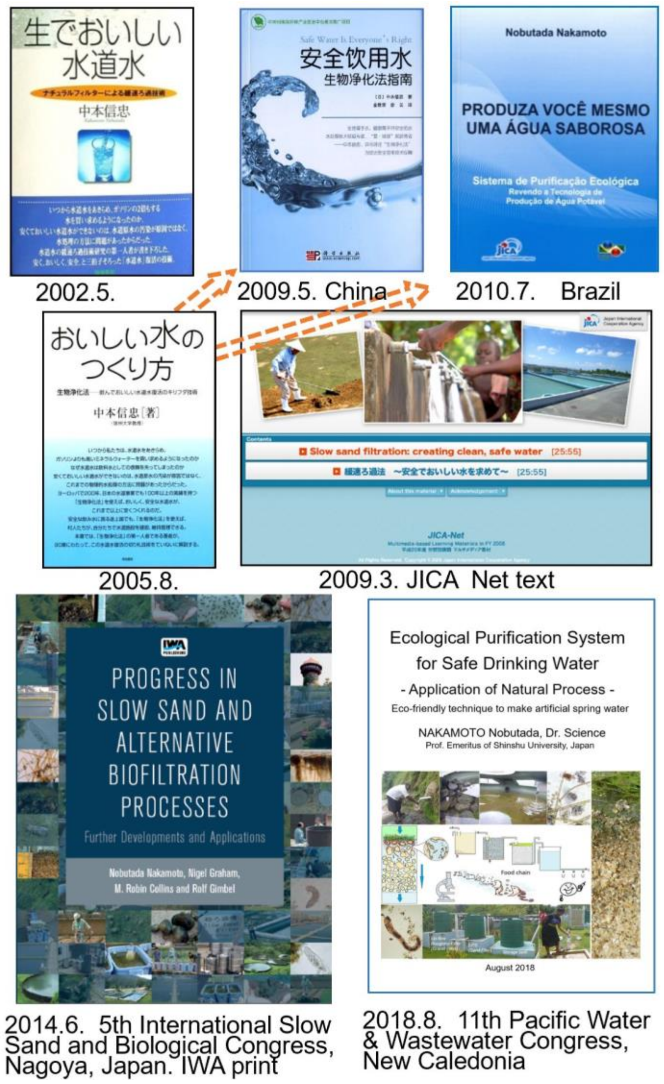


Fig. 11-1. Books on EPS

The slow sand filter was born in London, England in 1829 and spread throughout the world as safe drinking water can be produced (Fig. 11-2). However, the use of chemicals to prevent turbid water caused problems such as odor, filter clogging, and carcinogen formation. In Brazil, chemical-free, Up-flow Roughing Filter was developed, and I noticed in Japan that the capture and decomposition of turbidity depends on the activity of the biological community as the key. And I changed its name to the Ecological Purification System. As a new purification technology from Japan, the EPS is spreading to the world.

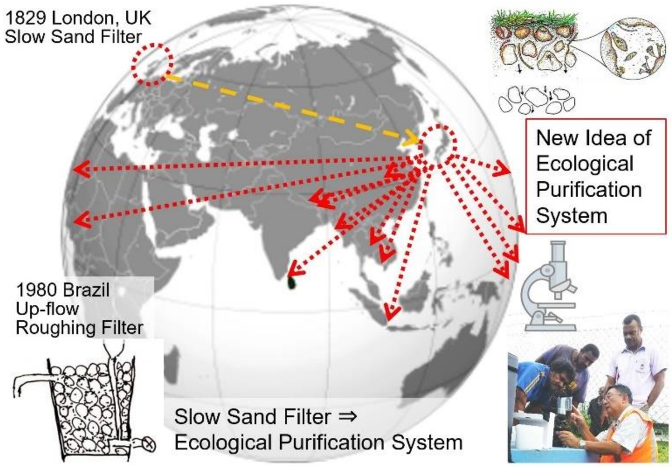


Fig. 11-2. EPS spreading from Japan to the world

The EPS from Japan was a technology that could be made with familiar materials if we understood the system. The white paper on ODA (Official Development Assistance) in the Japanese Ministry of Foreign Affairs highlighted the status of JICA training on Miyakojima in “Understanding International Situation-60th Anniversary of International Cooperation” (July 1, 2014) (Fig. 11-3). We hope that this technology will spread not only overseas but also in Japan.

Fig. 11-3. ODA paper as “Investment in the Future”