Ecological Purification System for Safe Drinking Water

- Application of Natural Process -

Eco-friendly technique to make artificial spring water

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Fig.0. Fijian EPS using rain harvest tanks in a village.

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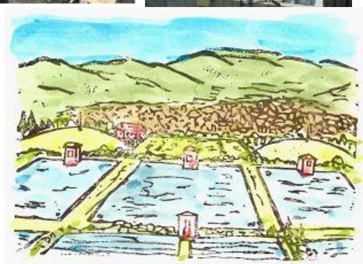
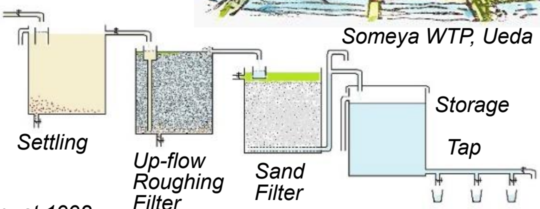
Contents

Cast off skins of midge larvae



Someya WTP, Ueda

August 1992



1. SMART TECHNOLOGY

Ecological Purification System (EPS), this is a new concept and a new treatment system to make safe and delicious water. This was focused to the ecological process. This was originated from Slow Sand Filter (SSF). The name of SSF came from the mechanical function through a sand layer under the slow filter rate 2-3 m/day (about 10 cm/h). The real purification mechanism had been not clear for long time since the SSF system developed in the United Kingdom in 1829 by James Simpson. Ecological purification process was recognized as the key in the 1990's in Japan.

James Simpson

Algae and associated microscopic organisms which grow on the surface of the filter sand. These organisms purify the impurities in the water, though some people might think algae relate the odor problem. Algae produce oxygen by photosynthesis and absorb dissolved nutrients. In addition, filamentous algae trap particles in the water, and the associate organisms decompose organic matters. They trap and graze the suspended matters. Real purification is done through the food chain from microbe to small animals. As the result of ecological process, undesirable impurities such as turbidity, pathogenic bacteria, other organic matters, bad smell, iron and manganese are removed effectively from the original raw water. Ecological Purification System seems to be a primitive low technology, but this is a wise use of natural process. This is a real smart technology for our life.

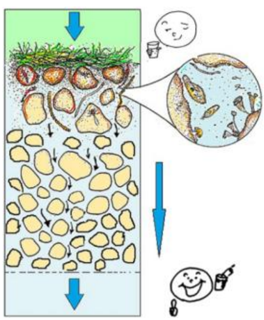


Fig. 1-1. Image of Ecological Purification System.

2. ECOLOGICAL POINT ON SLOW SAND FILTER

Slow sand filter plant in Ueda city was constructed in 1923. The plant consisted only 3 filter ponds and a storage tank. Clear seepage water appears naturally through gravel and sand layer. The original raw water for this plant was taken a subsurface water by a porous pipe under a flood plain of the river Chikuma. This suspended free water produced by wise use of natural process.

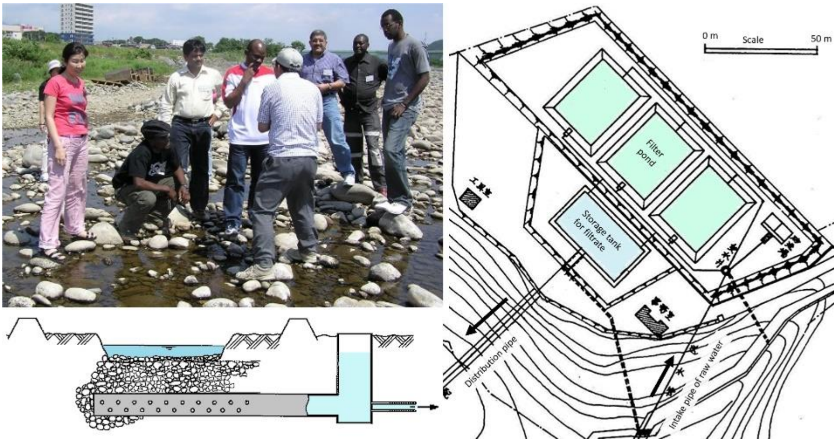


Fig. 2-1. Subsurface intake system is the best for raw water for a filter plant.

The infiltration pipe for subsurface water was lost by a typhoon in 1944 (during the world 2nd war). Then surface water of a river was taken for this plant. They had to install a small shallow pre-filter to reduce turbid matter.

Fig. 2-2. Clear surface water turns to muddy water by a storm event.

The slow sand filters were easily blocked even light muddy water passing through a small pre-filter. Then, **coagulant (PAC)** for turbid

water was added to raw water. **Pre-chlorination** and **cupper-sulfate** as **algicide** were also used and **chlorination** was done to filtered water. These chemicals were used for chemical treatment so called rapid sand filter. The water demand expanded with population growth of the city. Water purification plant also expanded and a surface water from an irrigation channel derived a tributary became as a major water source for this plant.

Fig. 2-3.　Present Someya WTP and main water source

After the construction of Sugadaira reservoir in this tributary in 1968, **odor problem** of tap water was occurred in Ueda city.

Tri-halo-methane formation risk by chlorine dose was worried among water treatment plant especially in case of chemical treatment of rapid sand filter in early of 1970s. Water industry to produce drinking water hesitated to dose chemicals to purification process. Water works of Ueda city also payed attention to the risk of chemicals in slow sand filter as biological treatment. After the stop of the algicide in Ueda city, algal growth became remarkable in the filter pond. However, the odor problem was disappeared. There were nuisance algae and beneficial algae.

I studied on ecology of phytoplankton in Tokyo Metropolitan University. I got a post of Shinshu University in 1974. At first, I studied on phytoplankton bloom in Sugadaira reservoir. Then, I shifted to study on the **role of algae** in a filter pond of Someya water purification plant of Ueda city with my students from 1984.

Fig. 2-4. Algae grew well after the stop of the chemicals.

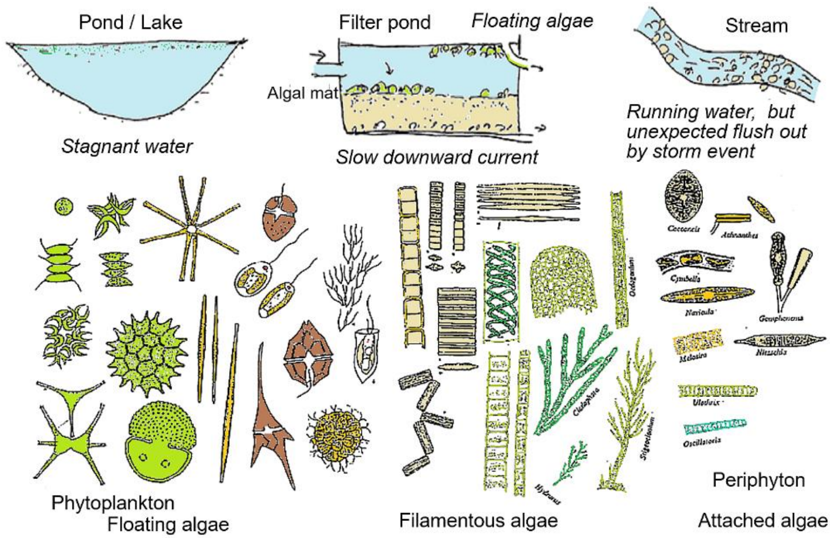


Fig. 2-5. Filamentous algae dominate in a slow sand filter.

There is slow down ward current in a filter pond. Filamentous form of algae dominated on the bottom of sand surface. Enough radiation reached to the shallow bottom of about 1 m depth. This

was suitable for filamentous algae.

I picked up the surface algal mat on the bottom sand. Sand was clear at the site in water. Filamentous algae grew on the sand surface and they just laid on. When we pulled slowly up this mat from the bottom to surface into air, clear sand turned dirty color. A large amount of trapped the turbid matter among filamentous algal dropped into sand layer.

Fig. 2-6.　Algal mat on the bottom sand. Sand is clear in water.

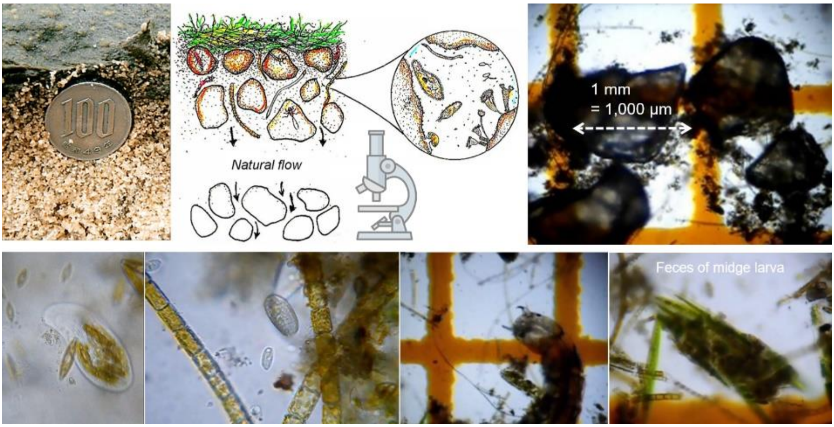


Fig. 2-7.　Biological active site is on the sand surface and beneath the surface.

Using a microscope, we could see small organisms of algae and small animals. They lived on the sand surface and beneath the surface. Sand was just gentle habitat for them. These organisms purified impurity. Then the filtrate became clear and delicious water like natural spring water.

3. REFOCUS TO CHEMICAL FREE SSF

"Silent Spring" (Rachal Carson 1962) pointed pesticide of DDT, food chain, biological concentration and caution to chlorine compounds. Robert Harris pointed out as "Is the water safe to drink?" on cancer risk by chlorination in the consumer report in 1974. New Orleans, like many other American cities, gets its drinking water from a heavily polluted source – the Mississippi River. 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 Mississippi's pollution burdens. People in the world searched more safe treatment system without chemicals. Slow sand filter was refocused by WHO and issued a textbook on SSF in 1974.

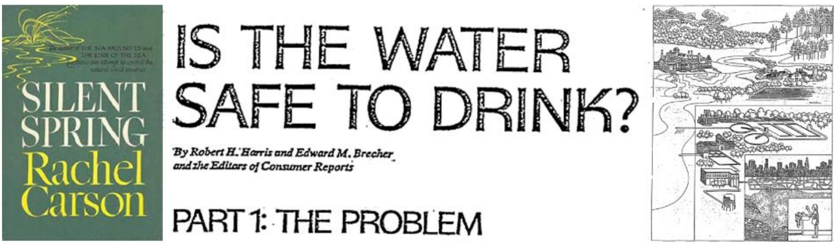


Fig. 3-1. Risk of tri-halo-methane was focused to the people.

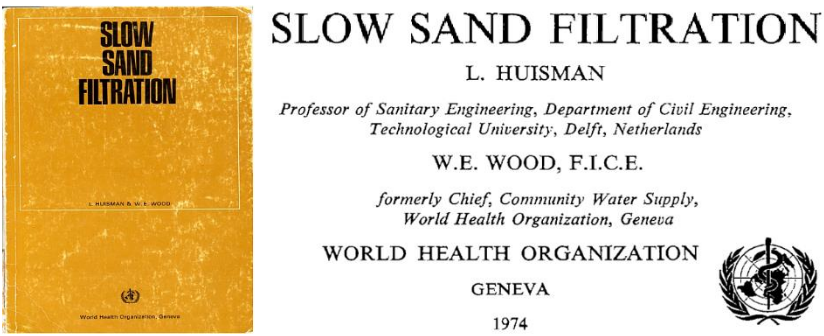


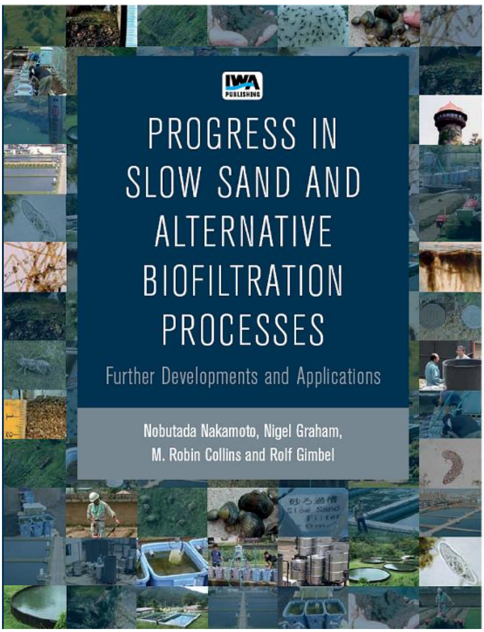
Fig. 3-2. SSF textbook was published in 1974 by WHO.

A large outbreak of diarrhea was occurred in Milwaukee, USA, in 1993. Over 400,000 people were sickened by *Cryptosporidium*. Slow sand filtration system was refocused. And SSF workshop organized by American Water Works Association was held at Salem city, Oregon state in September 1994. I attended this workshop from Japan. They said “Re-focus, Re-discovery, Timeless Technology for Modern Application”.

The village of Ilion in New York state maintains the second oldest working slow sand filter bed system in USA which was constructed in 1891. Mr. Michael McCormack (Ilion Water Commission) organized “The American Slow Sand Association” in 1994 (until 2004 at his retirement) after the large outbreak in 1993.

Fig. 3-3. The old SSF still runs from 1891. SSF workshop in 1994.

The 1st international SSF conference was held in London, in 1988 organized by Prof. Nigel J. D. Graham (Imperial College of London). The 2nd SSF conference was held in New Hampshire, USA in 1991 organized by Prof. Michael Robin Collins (University of New Hampshire). I studied on Thames filters in London during 1994 -’96. The 3rd SSF conference was held in London and in Netherland. The 4th SSF conference was held in Germany and in Netherland. The 5th SSF conference was held in Nagoya, Japan in 2014. I proposed **Ecological Purification System** instead of slow sand filtration. In this conference, the ecological point was highlighted.



We had been misunderstood the real mechanism of slow sand filter by name. We can easily imagine the real purification mechanism of slow sand filter from the cover of our new book.

***Ecological point was highlighted** in the **5SSABC** (5th International Slow Sand and Alternative Biological Filtration Conference) **in Nagoya in June 2014. Food Chain** is the Key in **Ecological Purification System** : New Concept and New Name of Slow Sand Filter*

Fig. 3-4. International congress on SSF continued from 1988.

4. FOOD CHAIN

There is vertical downward current in a filter pond. This is gentle environment for small organisms where sand does not move. Food chain by small animals is the key for purification system. Healthy and hungry condition of animals are important to collect any particles under gentle condition.

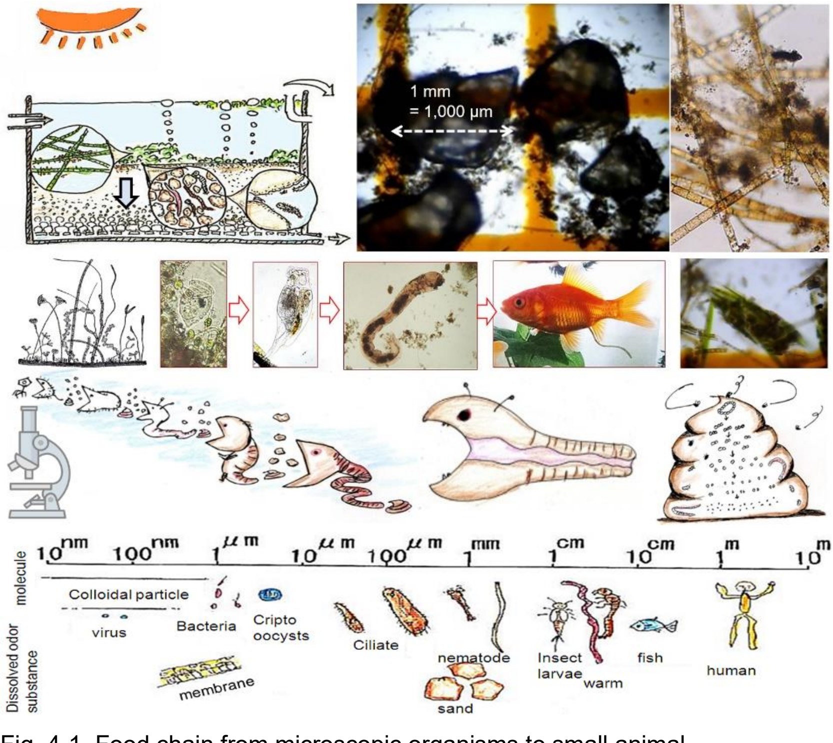


Fig. 4-1. Food chain from microscopic organisms to small animal.

Collection time of food is very short. Passing time of food in body is also very short. Dissolved oxygen (DO) in water and food are necessary for small organisms to survive. Algae produce oxygen by photosynthesis. Algae, themselves are also food for them. Dissolved matter adheres to the surface of cell. Some of adhesive matter pass through the cell surface into the cell. Small animals excrete feces.

When the dissolved oxygen is consumed up inside the feces, fermentation occurred under anaerobic condition. Large molecules are broken to small molecule. Complete purification occurs during these processes. The collection time of food and the passing time of intestinal tube are short. However, a long time is necessary for fermentation. Collection, decomposition and fermentation among small organisms repeat many times in the biological active layer where is on the surface of sand and beneath the surface. This natural process is called Ecological Purification System. We can see same process at the soil profile.

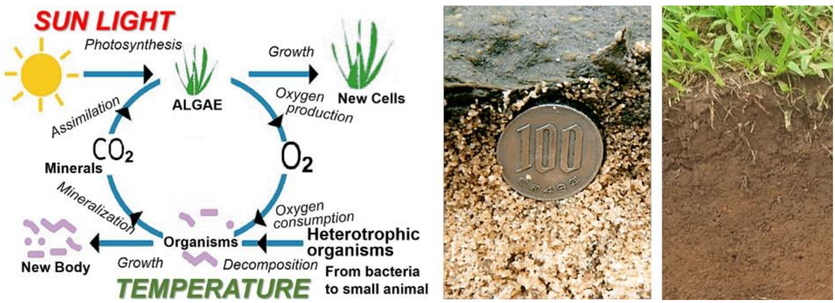


Fig. 4-2. Food chain from microscopic organisms to small animal.

Algal photosynthesis relates to solar radiation and the activities of bacteria and animal relate to temperature.

This is a new concept to make safe and delicious drinking water. I proposed the new name of Ecological Purification System (EPS) instead of SSF. On the standpoint of EPS, new structure of filter pond and new maintenance technique are evolved.

5. BUBBLE FORMATION

Algae grow well on the sand surface under sun shine. Algal mat lifts from the bottom by the bubbles and we can see floating algal mat on the surface of filter pond. Dissolved oxygen is super saturated condition on the surface of the sand layer at the bottom. Bubbles are seen soon on the exfoliated spot of algal mat. Then the spot is covered again with new algal mat.

Fig. 5-1. Active photosynthesis produces oxygen bubbles.

Fig. 5-2. Bubbles formed under supersaturated condition at the site.

Algae produce oxygen in day time only under the sun. Dissolved oxygen is consumed by algae during day and night. Hetero-trophic organisms such as bacteria, small animals also consume dissolved oxygen during a whole day. Oxygen bubbles are formed under super saturated condition by an active growth of algae on the sand bed.

I checked diurnal changes of DO in inflow and filtrate waters. Super saturate condition in filtrate kept during several hours after sunset. But DO concentration increased rapidly after sunrise. The passing time of water was only 2 or 3 hours. I also checked the

partial pressure of oxygen in the bubbles on the bottom.

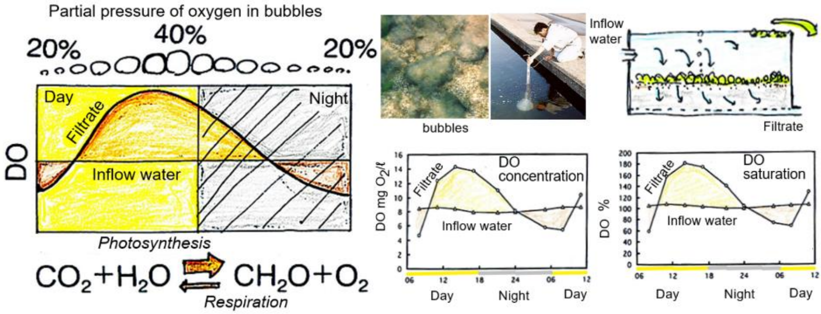


Fig. 5-3. Diurnal changes of dissolved oxygen in inflow and filtrate waters

The maximum value of the partial pressure was about 40 % in the afternoon, then this value decreased gradually until sunrise time. The minimum pressure was 20 % at sunrise time. I expected the super saturated DO after sunset caused by the high pressure of bubbles in the afternoon. And continuous culture condition of algae keeps aerobic condition in the filtrate even in the night.

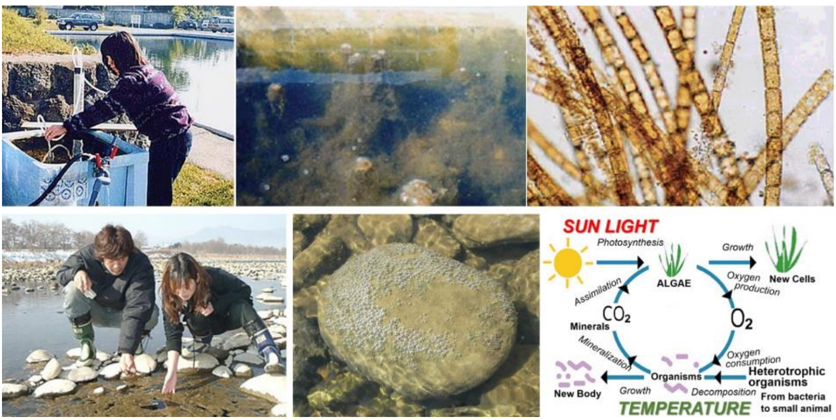
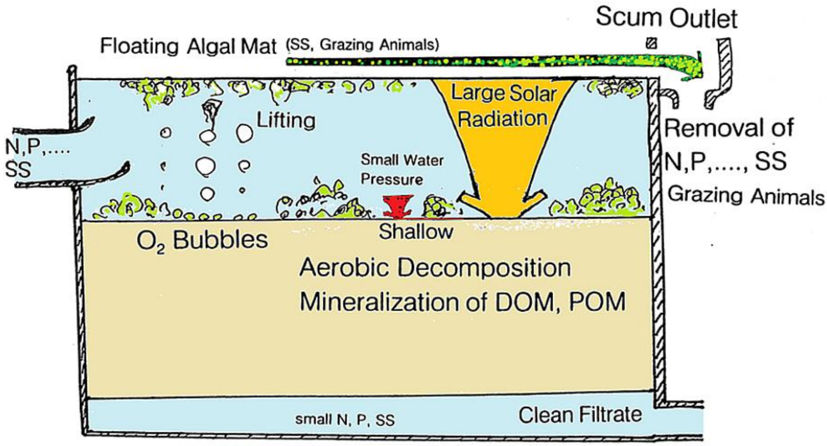


Fig. 5-4. Shallow depth is effective to algal growth.

Shallow depth is an effective key for Ecological Purification System. When no growth was observed on the filter bed in winter, active growth of filamentous diatom was observed in a shallow model. Algae grow well in shallow depth even in cold period where

the grazing activity by animal was weak in cold water. Bubble formation is remarkable in shallow depth in the river bed.



$$106CO_2 + 16HNO_3 + H_3PO_4 + 122H_2O + \text{Minerals}$$
$$\rightleftarrows (CH_2O)106(NH_3)16H_3PO_4 + 138O_2$$

Fig. 5-5. Shallow depth promotes biological activity.

Algae produce oxygen by photosynthesis. Algal growth promotes heterotrophic activity (bacteria, animal), removal of nutrient and suspended matter and prevention of filter clog. This means shallow depth is the key for Ecological Purification System.

Bubble formation at Ishifune WTP (altitude about 700 m) was remarkable than Someya WTP (altitude about 500 m). We noticed that saturation of dissolved oxygen (DO) related with temperature and atmospheric pressure (depth and altitude). We can calculate the DO saturation (DOsat) with temperature at 1 atmospheric pressure and absolute DO saturation (DOabsat) under the pressure.

DOsat(O2 mg/l)=14.161-0.3943xT+0.007714xT-0.0000646xTxTxT

DOabsat(O2 mg/l)=DOsat x (Ba+Bw)/1013

T: degrees Celsius temperature, Ba:hPa atmospressure, Bw:cm water depth

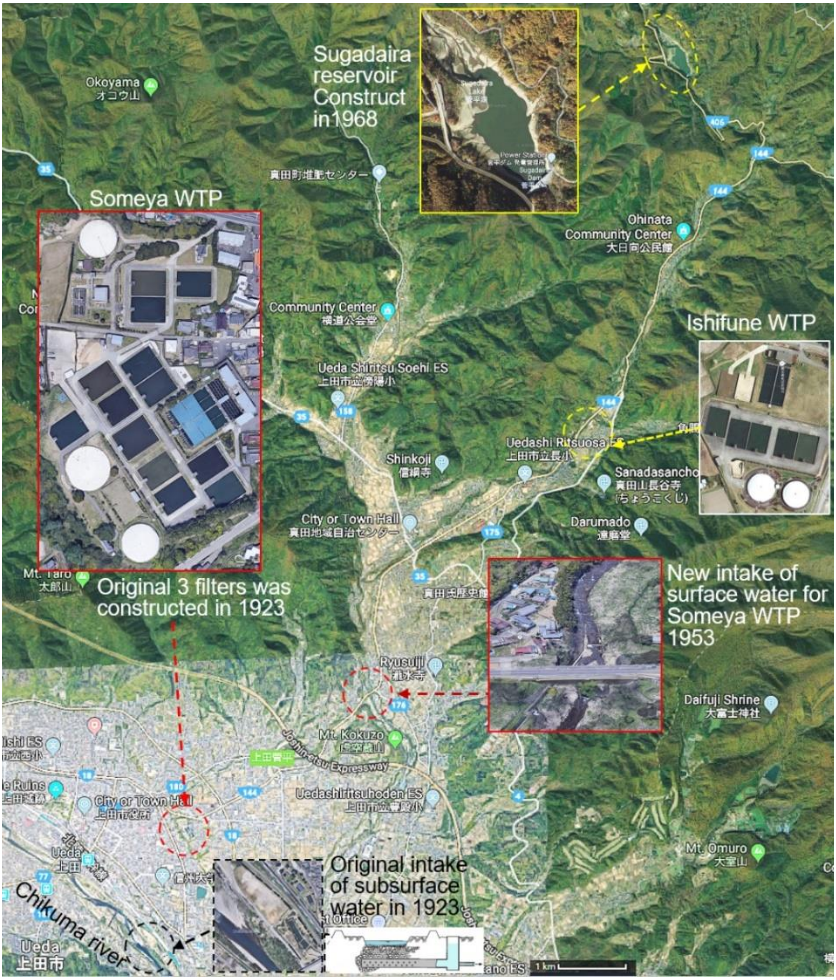


Fig. 5-6. There are 2 plants (Someya and Ishifune) in Ueda city.

There are about 200 m difference (higher altitude) between Ishifune WTP and Someya WTP. One-meter water depth at Ishifune WTP equals to about 20 cm shallower depth filter pond of Someya WTP on the saturation of dissolve oxygen.

I checked the algal condition at Wakata WTP (altitude about 150 m) in Takasaki city. Algal development was not remarkable than that of Someya WP (altitude about 500 m). The filter depth was so deep

than Someya WTP. So, I recommend making shallow depth to put large size of sand for better condition to emphasize biological activity of Ecological Purification. Shallow depth activates algal growth and heterotrophic activity near the sand surface. Shallow depth is effective to Ecological Purification System. This shallow means weak pressure at the site where algae grow under enough solar radiation.

Fig. 5-7. From the deep depth to shallow depth to activate biological activity.

Shallow depth Weak pressure Small DO	High altitude Weak pressure Small DO	Deep depth High pressure Large DO	Law altitude High pressure Large DO

Active bubble formation

Hardly bubble formation

Fig. 5-8. DO saturation and pressure

6. ALGAL SUCCESSION

My first visit to Thames Water WTP in London, UK was in August 1992. Filamentous green algae were remarkable in filter ponds. They told me “Please come in winter. There is a bloom of filamentous diatom of *Melosira*”. Then I checked developmental pattern of algae in Thames filters of Ashford Common WTP and Copper mill WTP which were the largest plants in the world during 1994 to 1996. I noticed the succession of algal flora was caused by grazing activity.

Fig. 6-1. Ashford Common WTP and algal blooms in the filter ponds

Raw water of WTP is derived from the surface water of a eutrophic reservoir. At first, surface water is passed through a biological rapid filter (small gravel filter?) to remove plankton. This water flows to sand filters. The filters run during about 3 months. Algae grow well. They called blanket weed to green alga of *Cladophora* in warm period. This is hard to remove from the filters. However, filamentous diatom of *Melosira* bloom was remarkable in cold period. These

heavy algal blooms were caused by nutrient rich water from River Thames. Source of nutrients is sewerage and agricultural activity. Thames bubbler boat is also famous to aerate the river water to avoid anaerobic condition which produces bad smell.

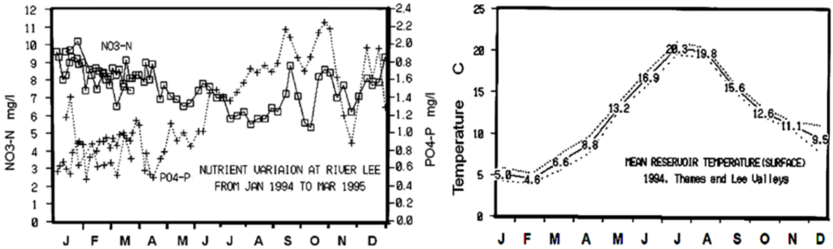


Fig.6-2. Seasonal change of nutrient and temperature.

Fig. 6-3. Famous cartoons of Thames water and Thames bubbler.

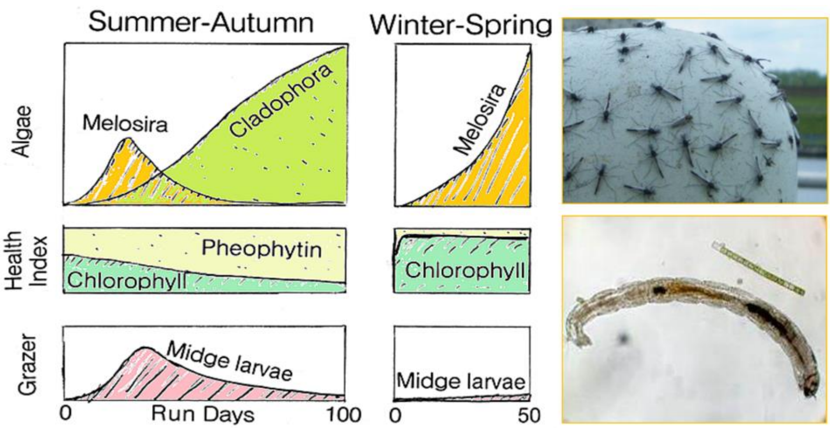


Fig. 6-4. Algal succession by grazer (midge larvae).

Algal succession from filamentous diatom to filamentous green algae was due to grazing animal activity during a long filter run. This succession of algal flora was also seen in Japan.

Fig. 6-5. Algal succession relates to grazing activity.

Filamentous diatom of *Melosira* in cold water. Casting skin of midge (*Chironomid*) and adult midge are remarkable in warm period. Filamentous diatom was grazed up and filamentous green algae are remarkable in warm water or in case of long filter run. After diatom is grazed by small animals, filamentous green algae (*Cladophora, Spirogyra, Hydrodictyon, etc.*) become remarkable algae. These green algae have a hard cell wall and larger size. Then, Mollusk appears as a grazer on green algae.

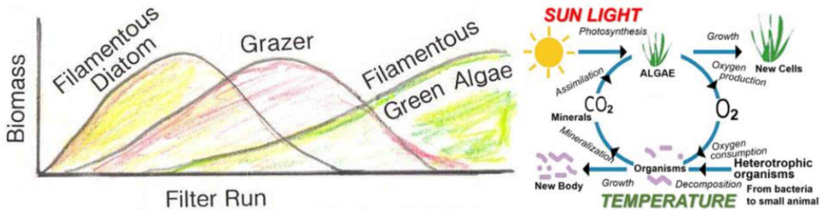


Fig. 6-6. Algal succession caused by grazer.

At the beginning of filter run, filamentous diatom dominates. However, filamentous green algae become dominant during the long filter run.

7. BIOLOGICAL ACTIVE LAYER

Ecological purification was done on the sand surface and beneath the sand surface. The thickness of this active layer is thin. Sand beneath the surface in water is clean (see Fig. 2-6). The depth of the real active sand layer is less than 1cm.

Fig. 7-1. Thin active layer is only at the top of sand layer.

I sampled the algal mat on the sand surface using a handmade sampler during filter run.

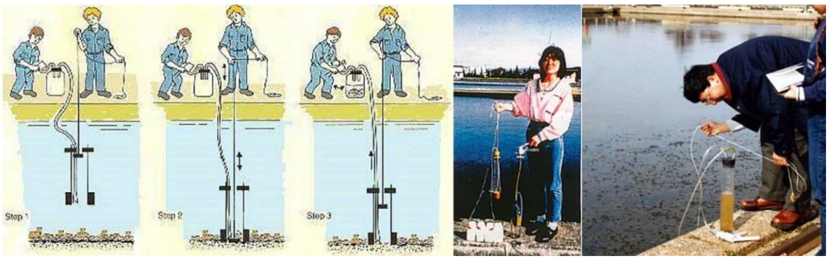


Fig. 7-2. Algal mat sampling on the sand surface during filter run.

Filamentous algae grew rapidly on the sand surface after scrape the surface in warm period. Logarithmic growth was observed at the beginning. Then algal mat lifted to the surface from the bottom and flew out through the scum outlet. And grazing activity became active at this time. The daily grow mass of algae became almost same mass which flew out and grazed by animal. Filter pond became a continuous culture condition.

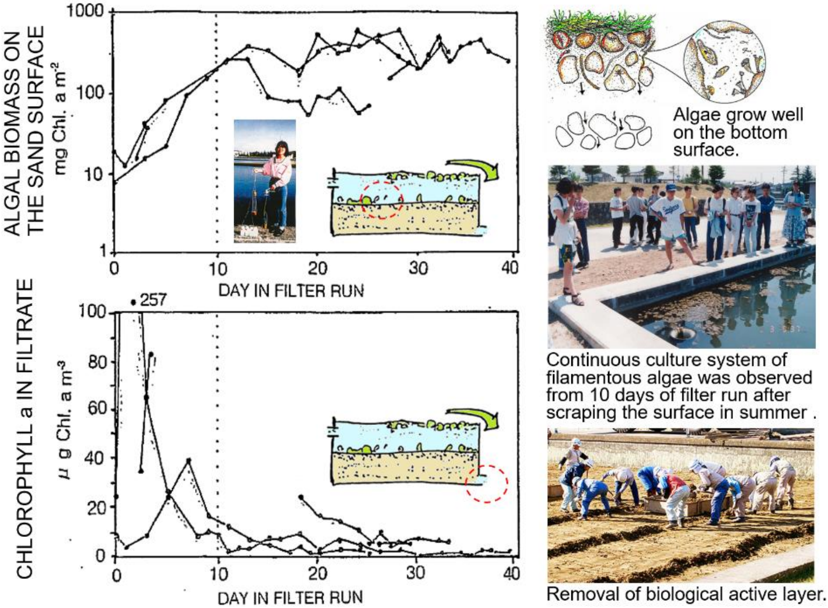


Fig. 7-3. Algal development and leak of algae in filtrate during filter run

Leak suspended matter in filtrate as an algal fragment was measured. A large amount of small algal fragment passed the sand filter after scraping the sand surface. This leak decreased rapidly then this amount became almost nothing.

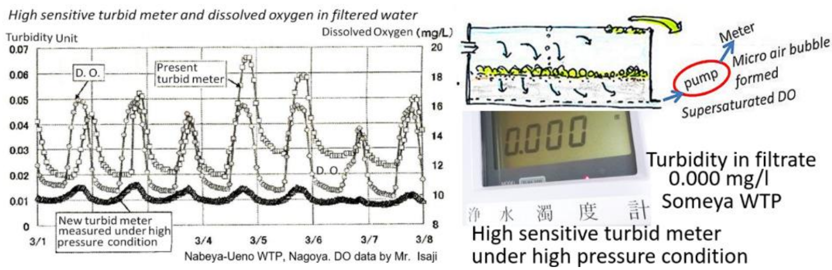


Fig. 7-4. Daily variation of DO and turbidity in filtrate

This result means "**Don't remove biological active layer**". We made mistake that the important active layer was called to **dirty** layer. We have to say **biological active layer**.

8. FILTER RESISTANCE

Most of small organisms live on the surface of substrata (sand particle, stone or gravel) under slow current condition. The current speed is almost none just on the surface of the sand and gravel. They can escape to the behind the stone where is almost no current.

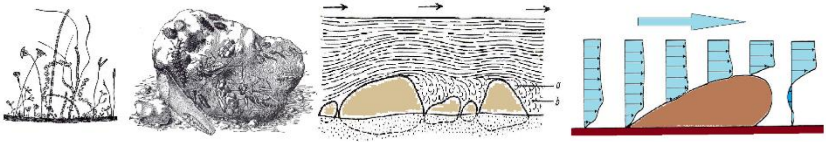


Fig. 8-1. Small organisms can live on the surface where is gentle condition.

In case of sand filter, there is vertical current. Small organisms live at the top of sand layer where food comes. They are always waiting for food near the surface. It is better to enlarge the living surface space for small organisms. Small size of sand is better than large size of sand. Total surface area of top layer of sands (balls) is always same of 3.14 times than flat area. Smaller sand makes larger area where is almost no current area. And, total volume of sands is always same of 52 % (porosity: 48%) in a box. However, filter resistance increases toward smaller size of particle. Too small particle becomes a flat surface.

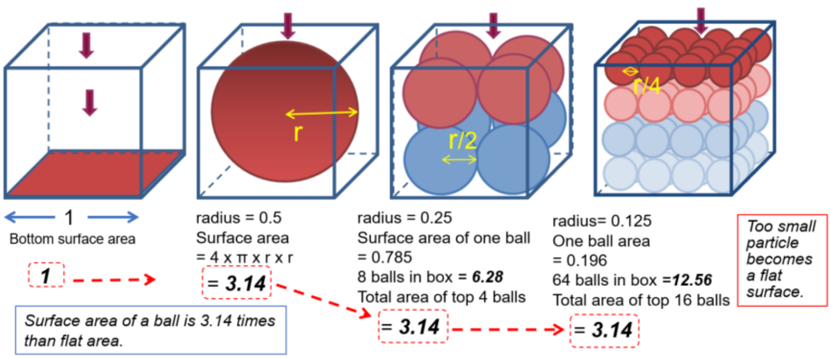


Fig. 8-2. Particle size and surface area of sand (ball).

Filter resistance of sand filter relates with total area of sands which means sand depth (A and B, D and E in Fig. 8-3). Smaller size of sand is larger resistance than larger size of sand (A and D, B and E in Fig. 8-3). The total volume of sands is always same of 52 % and the porosity is 48% in a sand filter, even any size of sand (Fig. 8-2).

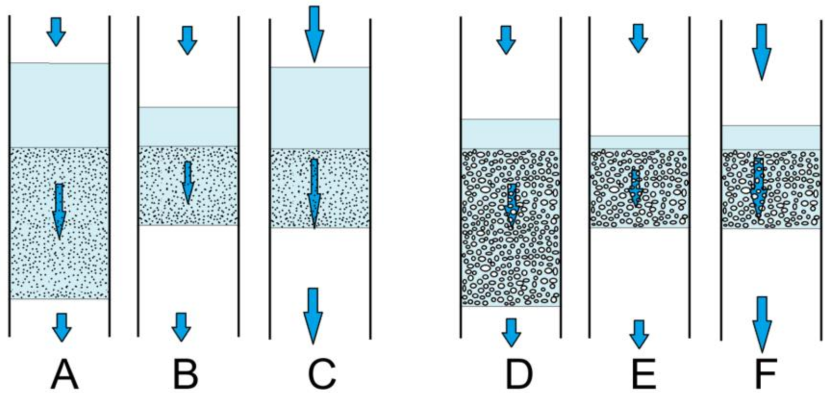


Fig. 8-3. Filter resistance relates with flow rate and sand size.

Above phenomena are explained on only at the beginning of filter run after the scrape the filter. Filter resistance of sand filter caused by the accumulation of fine silty mud during filter run.

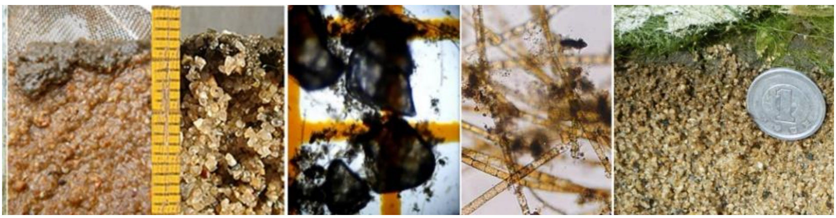


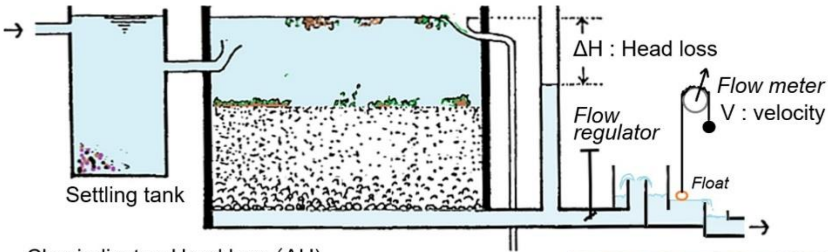
Fig. 8-4. Fine mud accumulated on the surface.

This accumulated mud is not only mud. Filamentous algae grow well, and grazing animals also grow. This biological active layer just lays on the sand surface.

Above phenomena are explained on only at the beginning of filter

run after the scrape the filter. Filter resistance of sand filter caused by the accumulation of fine silty mud on the surface during filter run.

Filter resistance of clog indicator is expressed by Head Loss (ΔH). However, head loss is proportional to flow rate (V: velocity). Calculated head loss of NHL (**Normalized Head Loss**) under the normal filter rate of English standard filter rate (20 cm/h: 4.8 m/d) is used as the comparable clog indicator.



Clog indicator: Head loss（ΔH)
Head loss（ΔH) is proportional to velocity (V).

$$\Delta H = kV$$

Normal filter rate is 20 cm/h (4.8 m/d：Vn).

NHL(Normalized Head Loss：Hn)
at normal flow rate can calculated by the observed head loss and the observed flow rate.

NHL: Normalized head loss：Hn (cm)

$$Hn=(H \times Vn) \div V$$

Observed head loss：H (cm)
Observed flow rate：V (cm/h or m/d)
Normal flow rate：Vn (20 cm/h or m/d)

Fig. 8-5. Clog indicator is calculated with head loss and velocity.

We measured the seasonal changes of filter resistance during the filter run at Someya WTP in Ueda (see Fig. 2-3). Water temperature of inflow water was very cold less than 4 degrees (4 C) from January to March due to snow fall in upper mountain area. When extra-ordinary muddy raw water (over 15 mg/l in raw water) came to WTP after heavy rain, coagulant (PAC) was added into raw water. Filter resistance (NHL) increased gradually during the filter

run in cold water period (from December to April). Filter resistance did not increase from May to November when algal growth of filamentous diatom was observed on the filter bed. In this period, load of suspended matter was higher than in cold period.

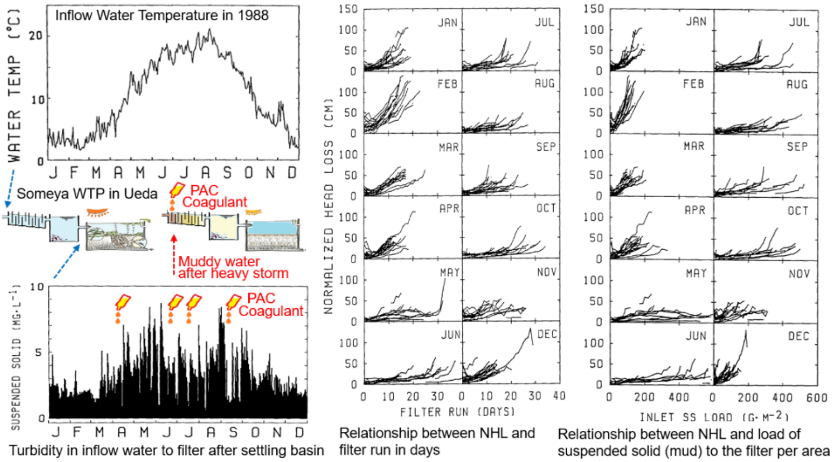


Fig. 8-6. NHL in Someya WTP during filter run

Wakata WTP is located at 150 m altitude. There is almost no effect of snow fall. The lowest temperature did not reach 4 C. The filter did not clog whole the year. Coagulant was not used in this plant even in the heavy rain. They treated only by settling basin.

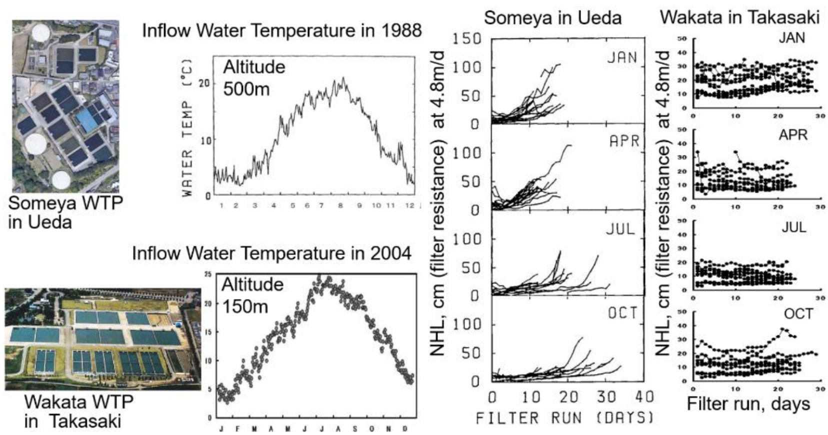


Fig. 8-7. NHL in Someya WTP and Wakata WTP

Filter resistance relates with water temperature. When the inflow water temperature is less than 4 C, sand filter clogs easily. This clog relates with viscosity of water and weak biological activity.

Someya WTP occurred odor problem after the construction of Sugadaira reservoir. At that time, algicide was added to raw water (Fig. 2-3 and 2-4). I checked NHL in June 1979. The filter quickly clogged by the addition of algicide like as in cold winter time. The biological activity of filter was blocked by algicide. The filter without algicide was also clogged with small amount of suspended solid load in raw water in February 1990. This filter was blocked with periphyton from a river and filamentous algae did not grow. When algal growth was seen in warm period, the filter did not clog. Biological activity is key to prevent filter clog.

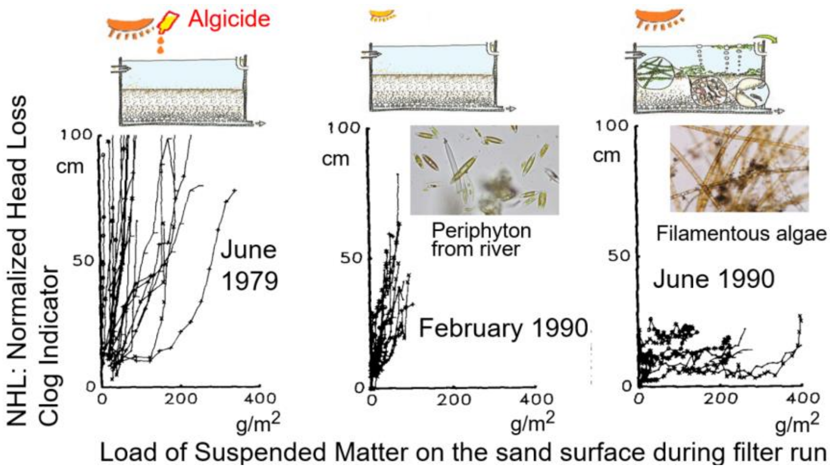


Fig. 8-9. Filter quickly clogged by the addition of algicide.

9. FLOW RATE

Algae produce oxygen under the sunshine. Algae and other hetero-trophic organisms (bacteria, protozoa, other small animals, etc.) consume DO in night. And algae are food for small animals. Small animals on and at the top of sand layer graze any particulate matters. They live near the surface of sand layer. And these animals among sand grains avoids filter clog.

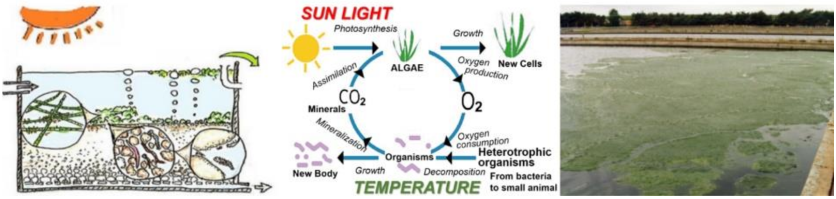


Fig. 9-1. Filter quickly clogged by the addition of algicide.

A large biomass of algae and animals occurs a large fluctuation of DO in filtrate. In early morning, DO in filtrate becomes sometimes serious level in case of slow flow rate. Faster flow rate makes better environment for small animals. This is gentle for small animals.

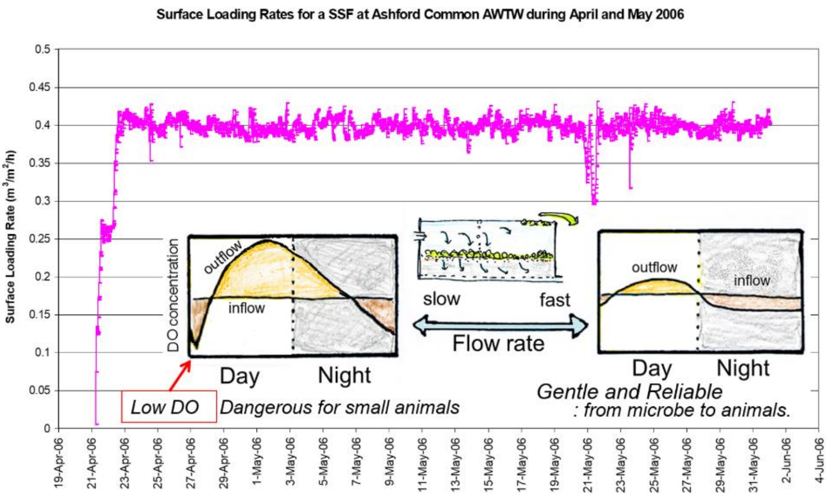


Fig. 9-2. Thames filters shifted to faster flow rate.

All the plant of Thames waterworks already adopted 9.6 m/d (0.4 m/h) from English standard of 4.8 m/d (0.2 m/h). Higher flow rate makes better quality in the filtered water. It is better to avoid low oxygen concentration in the morning. The filter rate of 0.4 m/h (9.6 m/d) is adopted in Thames filter plants in London to escape oxygen drop in filtrate during the night time.

Biological activity in warm region is higher than in cool region. Large diurnal fluctuation of DO in filtrate is observed in warm region.

We examined the possibility of more faster flow (20 m/d) in this system using a simple model in Samoa located in tropical pacific region in 2013. We compared the water qualities by different flow rates (5 m/d, 10 m/d and 20 m/d) using a large size of beach sand. All the filtrates became germ free safe water.

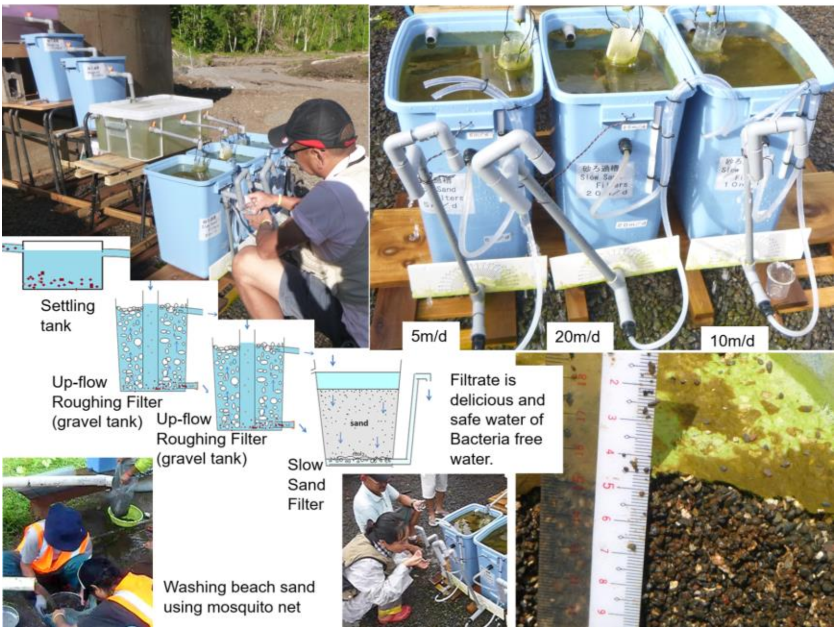
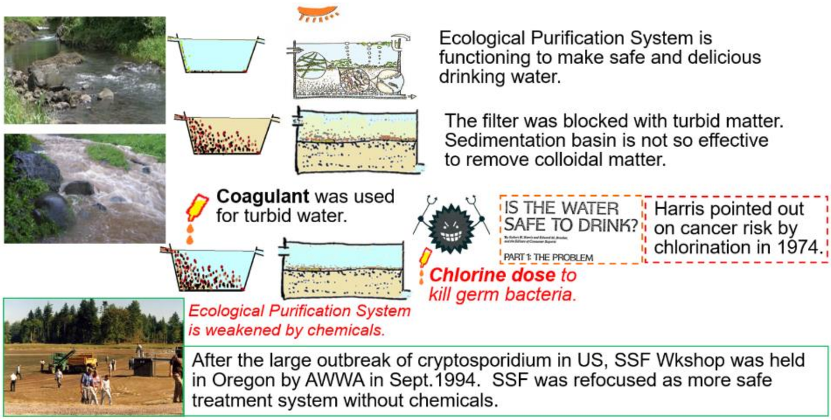


Fig. 9-3. EPS mode experiment in Samoa

10. UP-FLOW ROUGHING FILTER

Guarantee system for unexpected event such as a storm is necessary to a water supply system. Safe treatment system was searched without chemicals after Harris report 1974 (Fig. 3-1). Prof. Luiz Di Bernardo (Univ. São Paulo) examined Up-flow Roughing Filter (URF) to reduce turbid matter without chemicals in 1980. He reported his result of URF at the SSF conference in London in 1988. Then the international workshop on URF started and the final report (Surface Water Treatment by Roughing Filters, Wagelin 1996) was issued in 1996 in Switzerland.



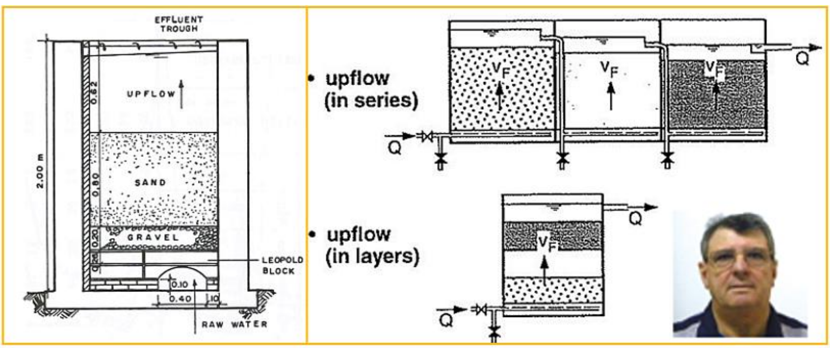


Fig. 10-1. Safe reduction system of turbid matter without chemical was issued.

I was a short term JICA expert in 1974 and in 1976 for algal

culture and reservoir ecosystem research to Univ. São Paulo (São Carlos campus) and Federal University of São Carlos. Prof. Luiz Di Bernardo worked at the same department of Univ. São Paulo. However, I did not know him at that time. I had a chance to visit again this campus in 1994. I met him, and he guided his pilot plant. I noticed he had worked on URF from 1988 to 1994. All basic idea and principle of various roughing filters were already written in his Portuguese textbook (1993).

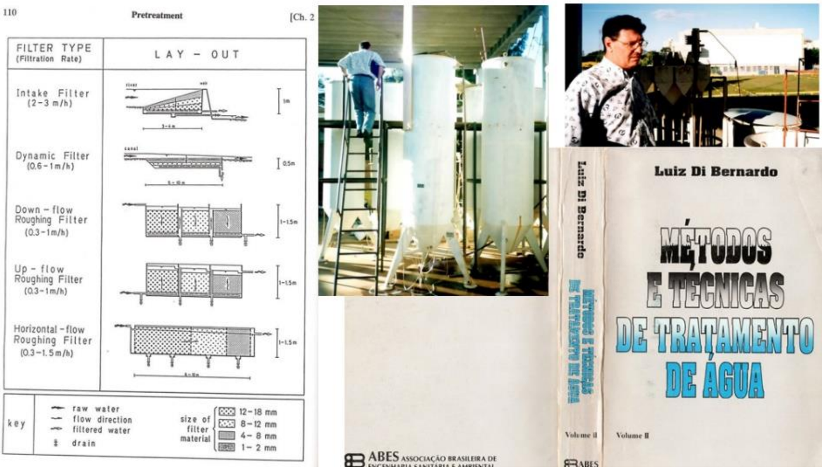


Fig. 10-2. I met Prof. Bernardo in 1994 and his textbook (1993).

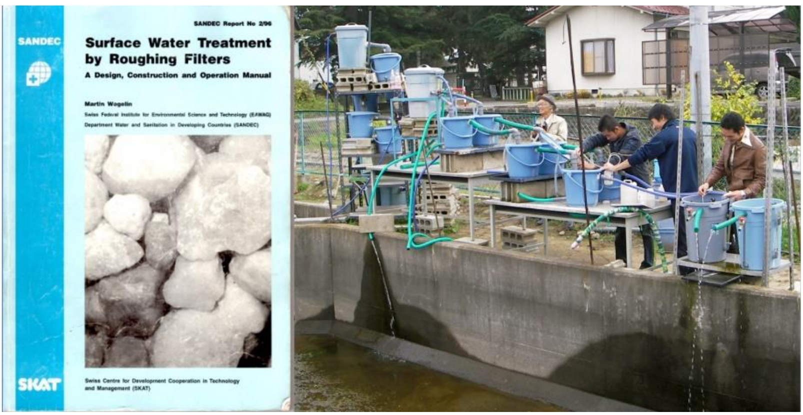


Fig. 10-3. Textbook by Wegelin (1996) and an experiment with students.

I also examined the performance of URF with my students after I got the textbook by Wegelin (1996).

We also examined the URF performance using pilot plant experiments in Japan. Serious and multilayer types were tested.

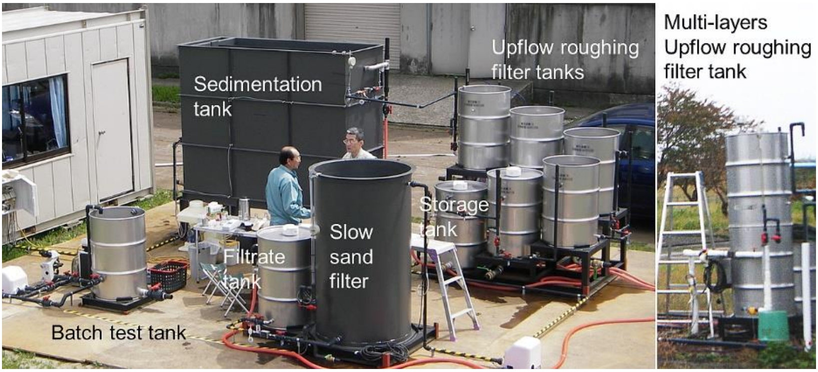


Fig. 10-4. Pilot plant experiment of URF

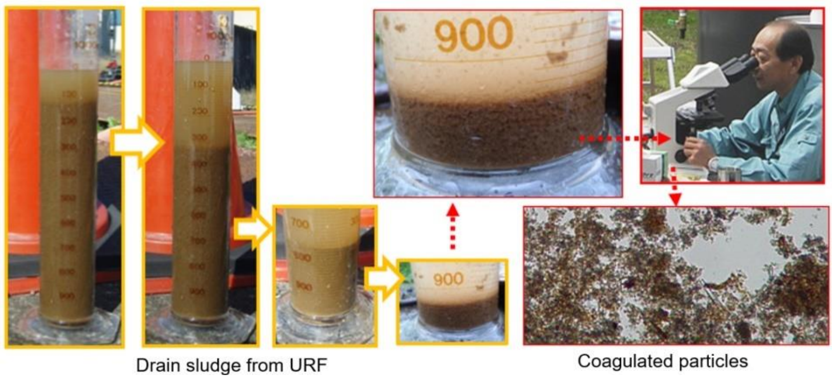


Fig. 10-4. Pilot plant experiment of URF

Drain sludge from URF (gravel filter) was like activated sludge. This means URF is also ecological purification system. Light colloidal fine particulate matter in inflow water from the bottom adhered to the gravel surface. This matter was scraped by small microscopic organisms as a food for the. And there was a food chain under aerobic condition in this URF. Mineralization occurred under aerobic condition in URF. The accumulated mud can be easily

drained off from bottom valve.

We also checked the duration time for settling using a batch tank. There were extremely small particles like as colloidal particles in case of small turbidity, like as less than 20 NTU. The rapid settling of turbid matters was observed **within 4 hrs**. However, a large portion of turbidity did not decrease.

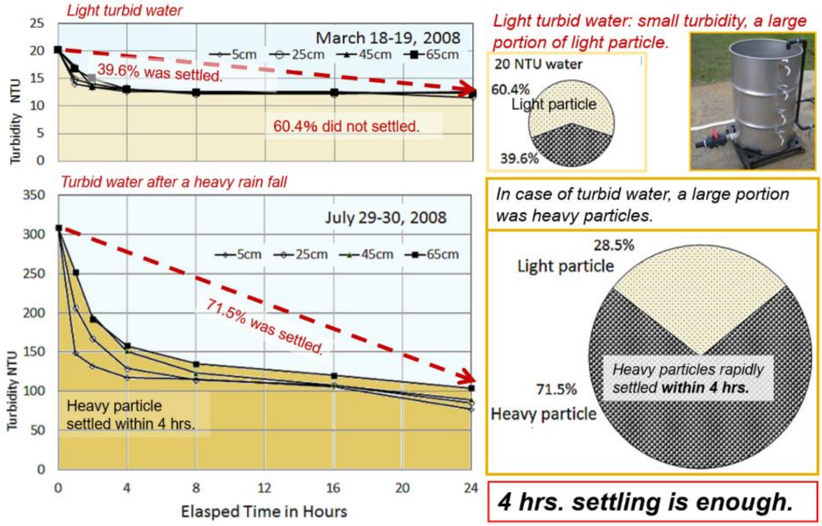


Fig. 10-5. Batch test for settling tank.

URF is an artificial technique to make clear seepage water (Fig. 2-1) or similar way of bank filtration to take subsurface clear water.

Fig. 10-6. Clear seepage water and bank filter using collection pipe.

11. INSTANT PURIFICATION

The image of slow sand filter is SSF requests a large area and a long purification time. This image is caused by the word of slow sand filter. The real purification time is an instant purification with guarantee and insurance layer.

Fig. 11-1. Someya WTP in summer.

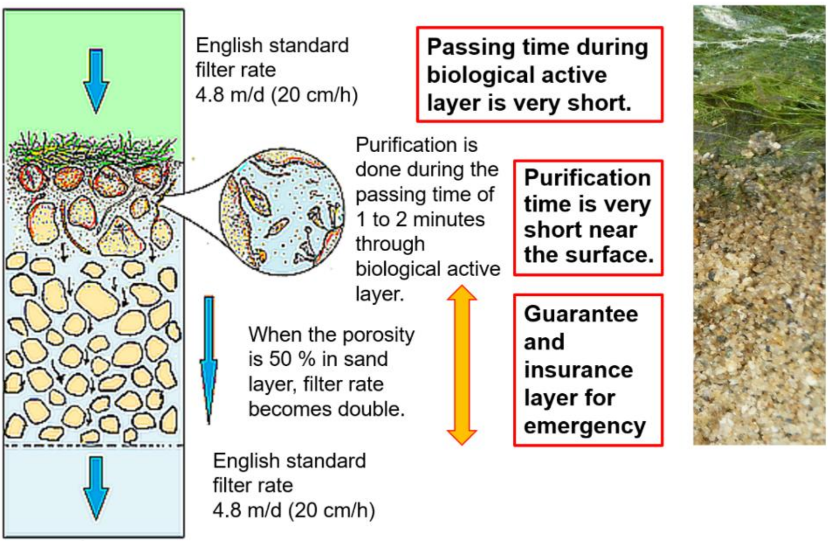


Fig. 11-2. Instant purification with guarantee and insurance layer.

Allen Hazen 1905 (The Filtration of Public Water Supply) explained the purification mechanism as follows. Report in 1893 (Berlin): Bacteria and dirty matter were accumulated at the top of sand layer. Depth of scraping was deep in winter, shallow in summer. However, algae were in bloom. Reduction of bacteria in open filters

is effective and clearer filtrate water in comparison with open and covered filters for 20 years. It may be especial case.

It was notified to biological phenomenon. However, he said that physical process was main. Removal of pathogens is not explained by these phenomena in comparison with size of microbial pathogens and opening space of sand grains. We can operate the filter without any clog during long filter run. We cannot explain the reduction mechanism of pathogens by physical phenomena. This explanation relates with biological function. It is better to **rename Ecological Purification System from Slow Sand Filter**.

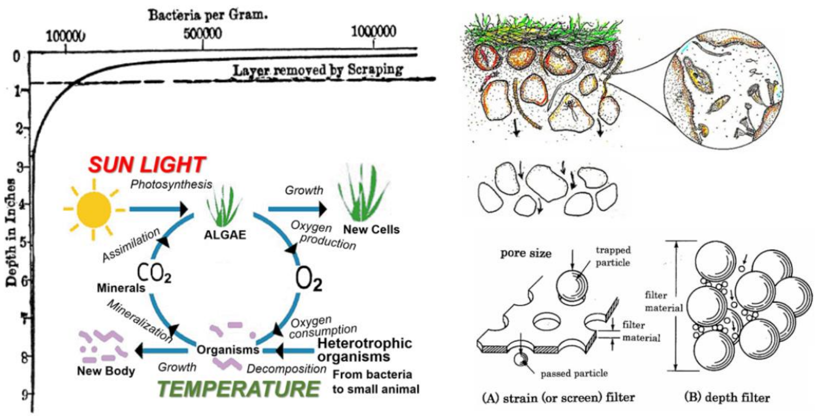
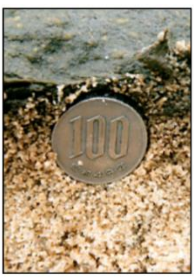


Fig. 11-3. Sand filter is Ecological Purification System.



	unit	Simpson 1829	English Filter	Present Thames Filter	Experiment in Samoa
Flow rate	m/d	2	4.8	9.6	20
	cm/h	8.3	20	40	83
Flow rate in sand layer (50% porosity)	cm/h	16.7	40	80	167
Passing time of 1 m sand layer	hr	6	2.5	1.25	0.6
Passing time of upper active 1 cm	min	3.6	1.5	0.75	0.36

Fig. 11-4. Passing times of active1 cm and sand layer of 1 m

12. DRY AND REWETTING

Ecological Purification System works well under gentle condition for small organisms which is almost constant flow. Algae grow on the sand surface. Grazing animals and other microscopic organisms live in algal mat and beneath the surface. If some unexpected sudden change of water quality or interruption of inflow water, grazing animals escape to deep layer from the surface where is more gentle and safe condition to survive. Some turbid matter passes the surface to deep layer. And this passed matter adheres to the surface of sand. This phenomenon occurs in soil. Rain fall is not constant. Penetrated rain drops flow slowly into deep place.

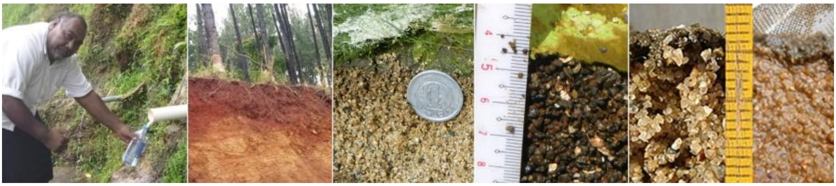


Fig. 12-1. Different biological active layer.

In case of EPS, interruption of water flow happened then the surface nearly dried up. After dry condition, it takes time re-start and re-develop an active healthy ecosystem. Before re-start the ecosystem, some impurities may leak through the system.

Fig. 12-2. Dry and re-wetting cycle of URF and sand filter

Small organisms escape from the top and some particles leak

through the gravel filter (URF) and the sand filter.

Biological community develops at the boundary region where is almost constant flow. When dry and re-wetting condition or a sudden change of water quality attack to this column, biological organisms escape to deep layer. In the deep layer, escaped organisms become a resting form. Living organisms has an ability to bear up and to escape from risks. Snail survives during dry period. When rain comes, snail move around quickly.

Fig. 12-3. Dry, rewetting and resting form

There are dry and re-wetting phenomena. Anhydrobiosis and cryptobiosis phenomena are common in nature. Organisms, especially aquatic small organisms have a strong ability to tolerate and escape the severe period. The life span of micro-organisms is short. Their adaptability is high. They can tolerate severe period.

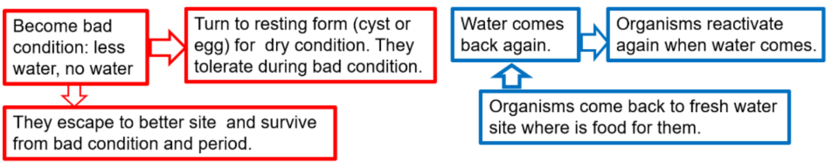


Fig. 12-4. Anhydrobiosis and Cryptobiosis, Drying-Rewetting

13. AERATION

Natural spring water is natural filtered water. It is usually safe to drink. Dissolved oxygen in raw water is key for the performance of EPS. Food chain among small organisms in EPS is essential. Aeration to raw water is popullar in case of low dissolved oxygen as pre-treatment.

Fig. 13-1. Delicious natural spring water and bad taste of tube well water

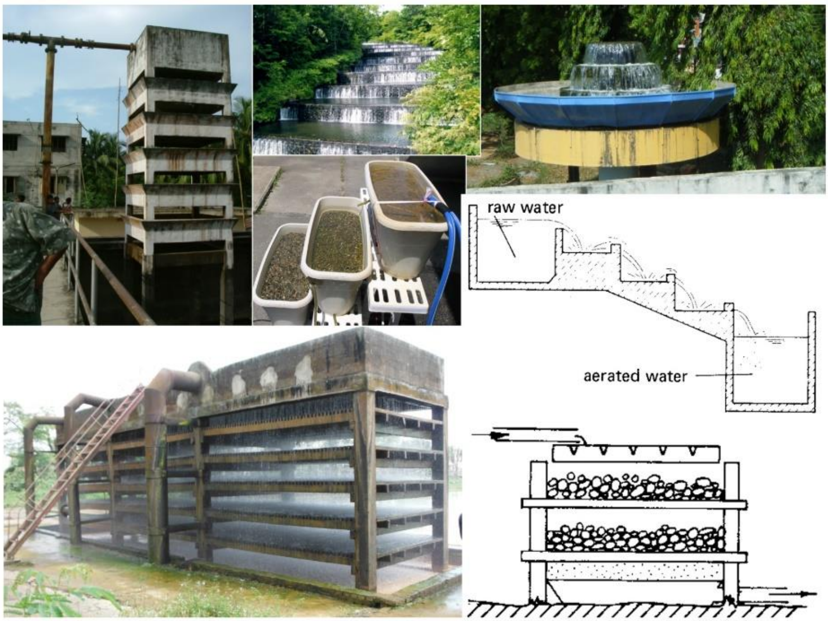


Fig. 13-2. Various aeration system to raw water

14. CAPACITY

Present Slow Sand Filter system was completed by James Simpson in 1829 in London. At that time, the filter rate was 2-3 m/d (10 cm/h). Present English standard rate is 4.8 m/d (20 cm/h) which is used in the world. However, present Thames Water Utilities adopted 9.6 m/d (40 cm/h) due to escape oxygen drop in the morning (Fig. 9-2). On the stand point of biological activity in warm region, we tested faster rate of 20 m/d in Samoa. The result was good even 20 m/d. Slow Sand Filter is Ecological Purification System which relates with biological activity.

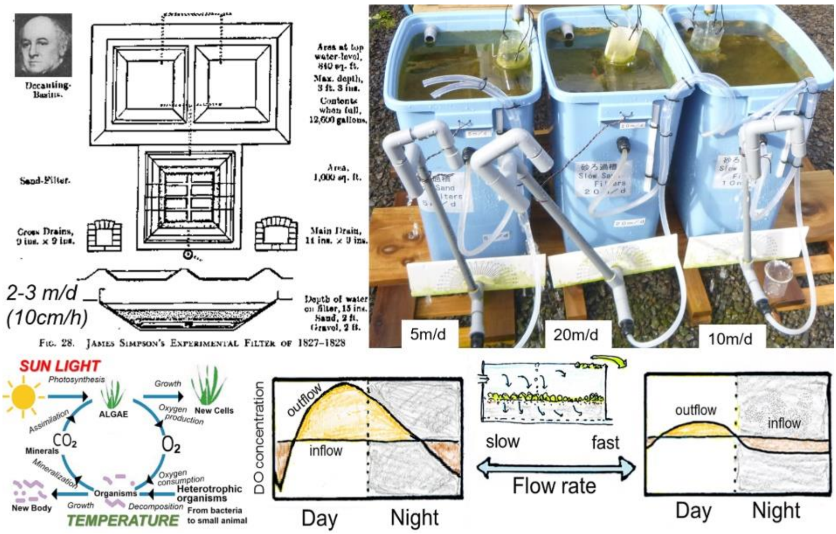


Fig. 14-1. Filter rate relates with biological activity.

In case of Someya WTP, Ueda Japan, there are 13 filter ponds and two sets of pre-treatments (mixing channel for coagulant dose and settling basin). Surface water of a river is raw water to the plant. Usually, no-chemicals add to raw water. After heavy storm, muddy water comes, coagulant (PAC) is added to reduce turbidity for sand filter (Fig. 8-6).

Fig. 14-2. Someya WTP has 13 filter ponds of each 780 m2.

The filter capacity by one filter pond (780 m2) under English standard rate (4.8m/d) is as follows;

780 m2 x 4.8 m/d = 3,744 m3/d

If one day water demand per one person is 0.3 m3 (300 liters);

3,744 m3/d ÷ 0.3 m3/d = 12,480 persons (by one filter)

Total capacity of 13 filters per one day;

3,744 m3/d x 13 filters = 48,672 m3/d

48,672 m3/d ÷ 0.3 m3/d = 162,240 persons (by 13 filters)

EPS functions effectively for clear raw water. We can make suitable raw water by different pre-treatment without chemicals.

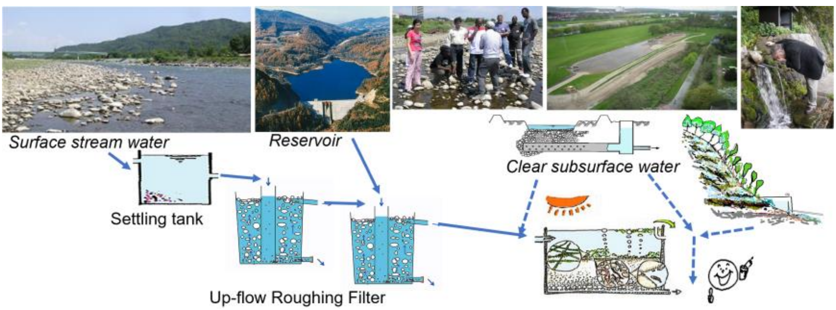


Fig. 14-3. Pre-treatment for different water source

15. JICA TRAINING

International training by JICA on Ecological Purification System (Slow Sand Filter) started from 2006 at Miyako-jima (island) in Okinawa, Japan. Okinawa is in sub-tropical climate region. Miyako-jima is a raised coral island. There is no mountain and no river. Raw water for Sodeyama WTP is infiltrated underground water which is called a freshwater lens. This raw water is suspended free water like a clear subsurface water. WTP has only filters. However, JICA trainees came from various countries. I had to explain how to treat various water sources. I taught the purification mechanism of turbid water using a simple model. The model composed a settling tank, up-flow roughing tank(s) and sand filter.

Fig. 15-1. JICA training on EPS at Miyako-jima, Okinawa

JICA EPS training expanded for more countries from 2010. And our training was done at Miyako-jima (island) and Ishigaki-jima (island) in Okinawa. In Ishigaki-jima, there are various sizes of WTP and there are various water sources (surface water of a river, reservoir and underground water). Water authority of Ishigaki-jima selects better water source among various sources, depended on source condition. Pre-treatment for turbid water is only settling basin. They can make safe drinking water without coagulant.

Fig. 15-2. Various water sources for Ishigaki WTP

Fig. 15-3. Large Ishigaki WTP and small Yoshihara WTP

Drain off after for scraping, many fishes and mollusks are remarkable. And inflow mud does not enter from the sand surface. Sand beneath the surface is clear.

Fig. 15-4. Fish and mollusks are remarkable

I showed the microscopic organisms in biological active layer using a microscope. It was called dirty sand. And I made a simple

EPS model to understand the principle and mechanism. I emphasized that shallow water depth over sand is important to keep aerobic condition. Passing time of water is shorter in shallower depth. And higher flow rate is also better to keep aerobic condition.

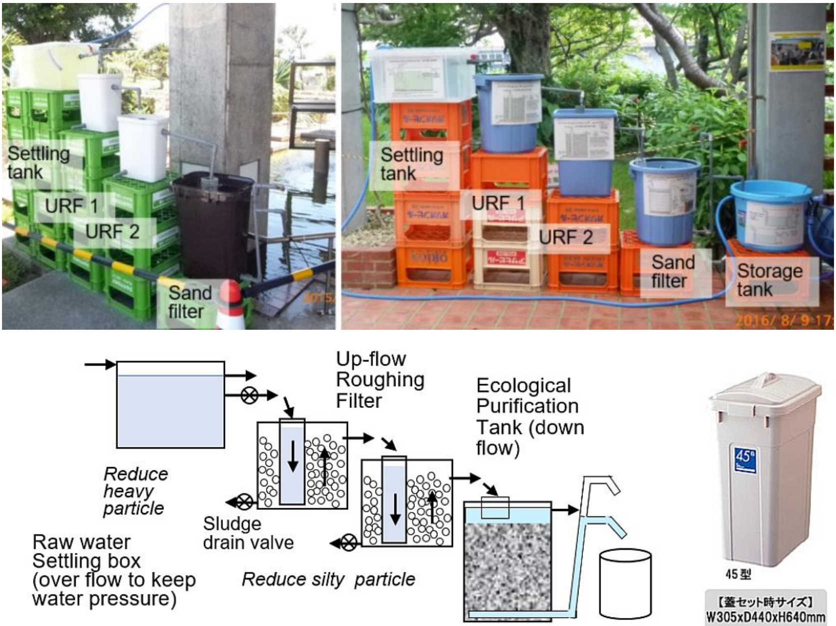


Fig. 15-5. EPS model

JICA training on EPS from 7th to 12th August 2010 in Miyako-jima and Ishigaki-jima in Okinawa. I cannot forget the thanks speech by Ms. Manista from Solomon Islands at the closing ceremony on 1st September 2010.

It is also worth appreciating the Ecological Purification System as taught by you, Dr. Nakamoto; a simple, natural and yet an effective water purification technology, we can all agree to as the most relevant technology for the Islands. It is cheap to construct, operate and maintain which makes it even more attractive. We are grateful to your pioneering research on this technology and for generously impart this to us, so that the people of the pacific may in the very near future will have access to the high quality and delicious taste that this technology provides.

Fig. 15-6. EPS trainees from Pacific island countries in 2010

JICA also published the multimedia-text through the internet; https://jica-net-library.jica.go.jp/lib2/08PRDM007/index.html

Fig. 15-7. Multimedia internet text by JICA

Design of EPS model for JICA training as follows;

Heavy turbid matters are easily settled in a receiving tank. Residence time (about 4 hours) is the key for settling. However, colloidal fine particles are not settled in a settling tank.

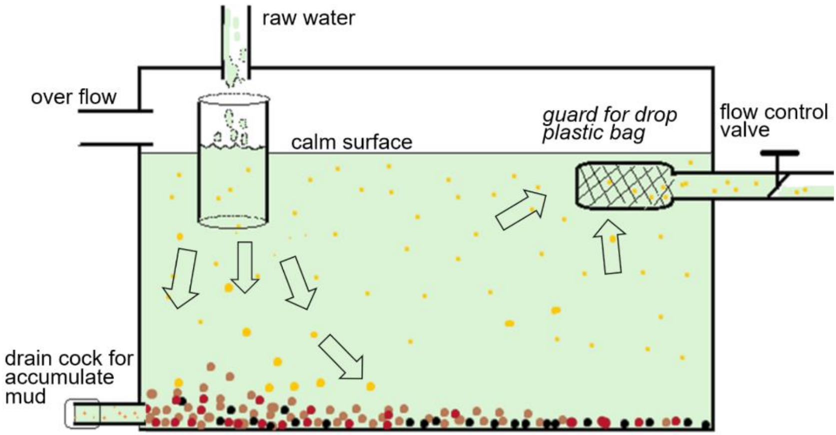


Fig. 15-8. Receiving tank (settling tank)

Large size of gravel (stone) at the bottom of URF is better to drain easily. A large adhesive area of stone surface (small size of stone and enough depth of gravel layer) gives better performance.

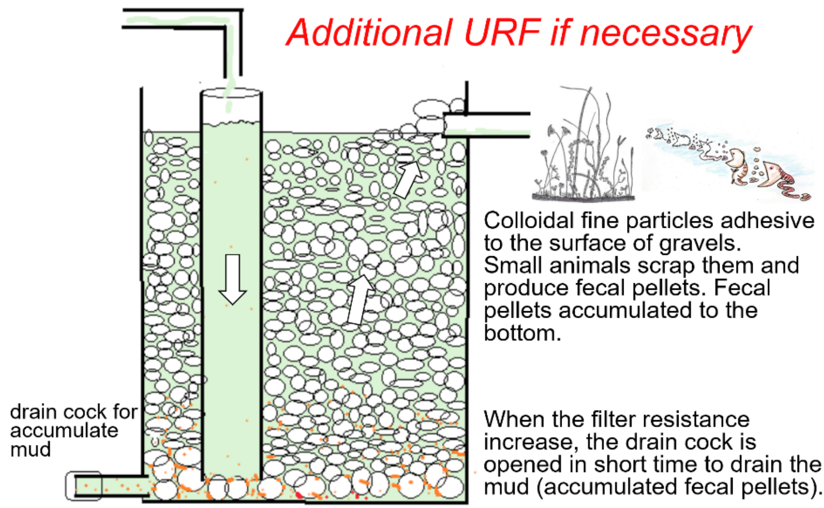


Fig. 15-9. Up-Flow Roughing Filter (URF: gravel filter)

Depend on source condition, additional URF is recommended (Fig. 10-3, 10-4, 14-3 and 15-5). This is a guarantee system against unexpected drastic change of water quality like a storm event.

Complete purification is done in EPS (sand) tank under natural down flow. Algae and animals grow well on the sand surface. Deep sand layer is a guarantee layer for emergency.

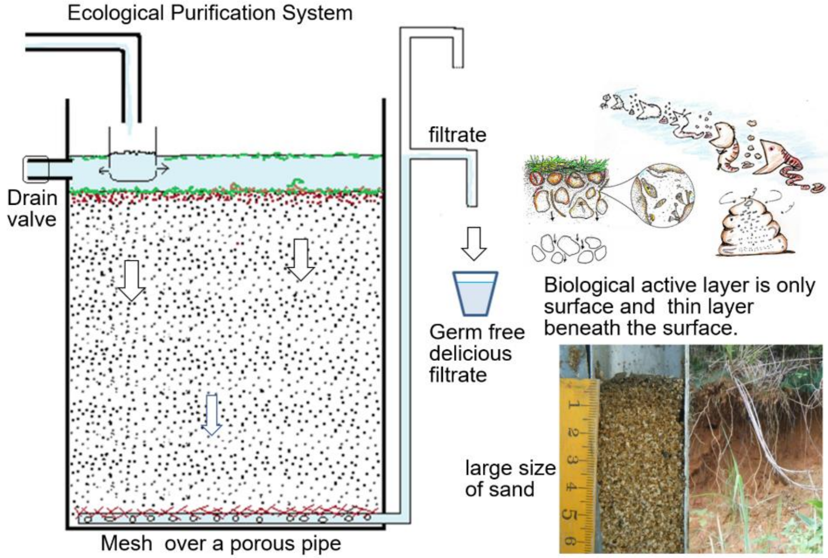


Fig. 15-10. EPS tank (sand tank)

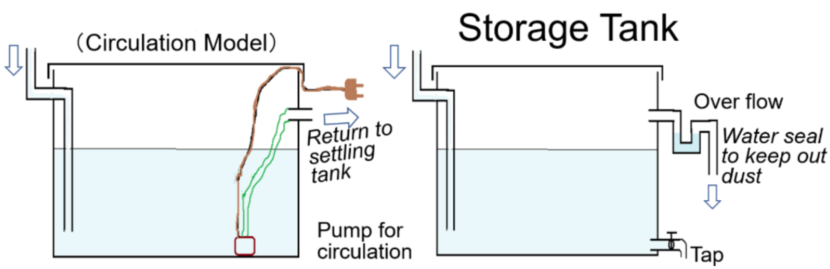


Fig. 15-11. Storage tank

16. SAMOA

After 3 years JICA training project in Miyako-jima, Mr. UECHI Akito from Miyako-jima and I visited Alaoa WTP in Samoa in 2009. This plant had a filter block problem in rainy season.

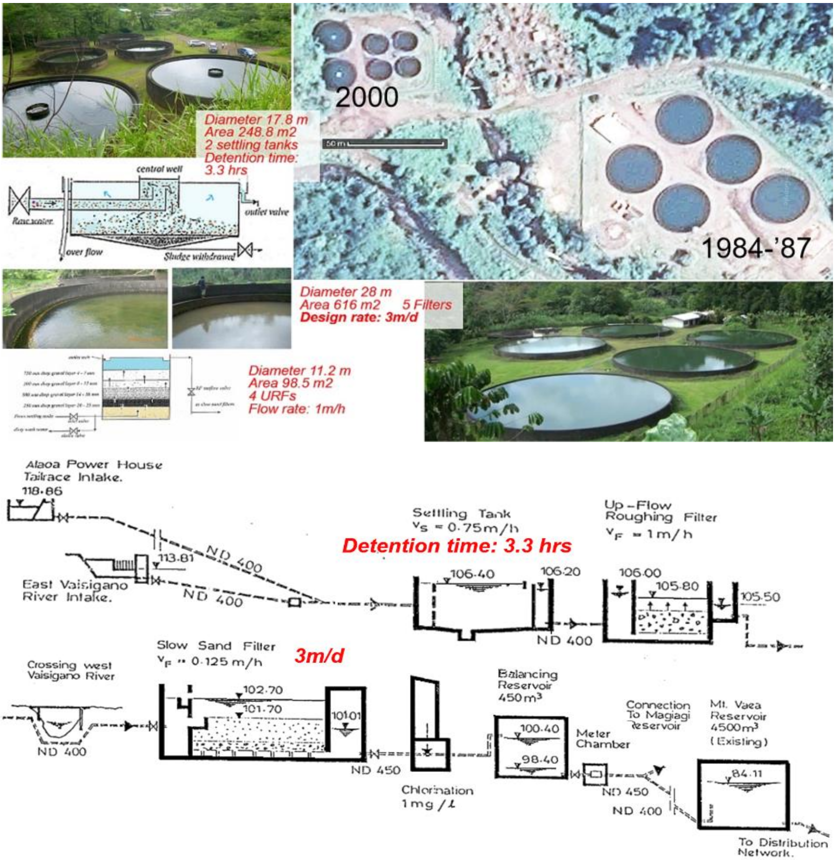


Fig. 16-1. Alaoa WTP in Samoa

People in Apia drank non-treated water before WTP construction in 1984. During 1984-1987, 5 slow sand filters were constructed. However, these filters were easily blocked by turbid water due to heavy rain. URF manual was just issued by Wegerin in October 1996 (Fig. 10-3). Then, this latest technique of Up-flow roughing

filter (URF) was introduced in 2000 by German consultant.

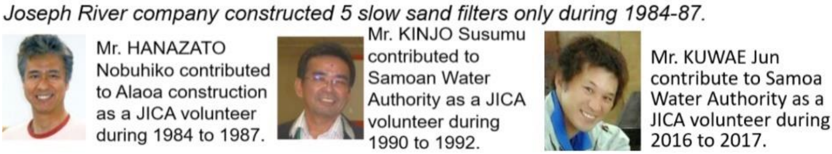


Fig. 16-2. JICA volunteers for Samoa water supply

We searched for the cause of filter block in rainy season from 2010. Water depth was too deep in comparison with original design depth. There was almost no sand layer. There was thick mud on the bottom in the deep filter. However active bubble formation by algal photosynthesis on the bottom of the shallow filter was observed and algal mat with mud lifted to the surface (Fig. 5-8).

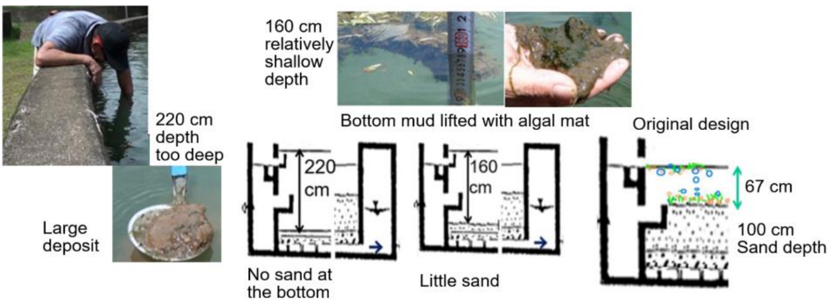


Fig. 16-3. Water depth of Alaoa WTP in November 2010

We measured the original design of the filter. The original water depth over the sand layer was 67 cm and we estimated 100 cm of sand depth.

They scraped dirty sand when filter was blocked after heavy rain. However, they could not re-sand by new sand. There was not suitable sand in Samoa. They had to import suitable filter sand from New Zealand or Australia. Its cost was too expensive for Samoan Water Authority (SWA). They could not buy new sand. As the result, water depth became so deep. I advised to put beach sand near river

mouth to make shallow depth. Beach sand was washed to remove fine sand.

Fig. 16-4. Beach sand was taken and washed to put on the filter bed.

There are several layers with different size of gravel which is supporting layer of sand in common manual in the world. I recommended to put the textile over the drainage system and to put sand only. This is easy work, and this became bigger surface area of sand layer which is contact surface of sand.

	size (mm)	depth (mm)
Sand media	0.15 - 0.60	1000
Supporting Gravel	2 - 4	100
	4 - 10	100
	10 -25	100

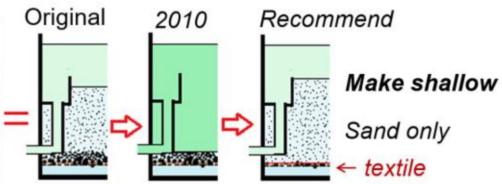


Fig. 16-5. Recommend profile from original

Deep water depth became shallow depth. However, the big cyclone attacked to WTP. They had to refresh the WTP. SWA members tried to make shallow water depth which reduced the water depth.

Fig. 16-6. Different water depth over sand surface

SWA members (James, Eiko and Siatua) reported at 5th International Conference of Slow Sand and Bio-filtration Conference, Nagoya, Japan, June 2014 (Fig. 3-4). This is the improvement to Samoa from JICA- training in Okinawa.

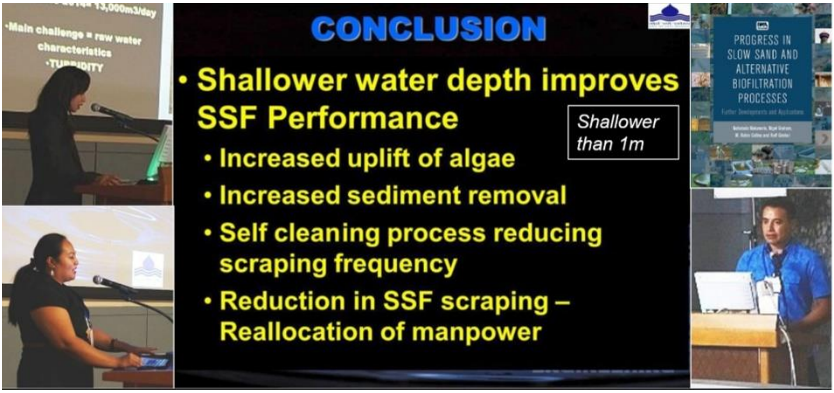


Fig. 16-7. Shallow effect was reported SSF conference 2014

The water depth was about 1 m over the gravel layer in URF in the manual (April 2000). The real water depth was more than 1 m. I recommend putting more small stone in URF. Then SWA started to put crushed sand (1-2 cm) which was used for the road pavement.

Fig. 16-8. Top up small stone in URF, March 2017

However, pre-treatment was not enough. Enough pre-treatment is necessary. JICA supported new small suitable plants in 2014.

Fig. 16-9. Suitable pre-treatment is necessary.

17. Fiji

Mr. Vishwa Jeet from Fiji learned EPS in JICA training in August 2011. He returned to Fiji, he made a model to make safe drinking water by EPS technology at the yard of Department of Water and Sewerage (DWS) in Fiji. Water source was rain harvest tank.

Fig. 17-1. JICA EPS training in Okinawa in 2011

The PM had attention for EPS display during the World Marine Time Day on Sept. 28, 2012. He informed to the PM on the functions of the EPS and reference to JICA was made. Then, kick off workshop on January 16, 2013 at Holiday Inn. Opening speech was done by Commander Francis B. Kean, Permanent Secretary, Ministry of Works, Transport, Public Utilities (MoIT).

Fig. 17-2. EPS project for rural people in Fiji started in January 2013.

EPS was planned to set ween the existing distribution pipes of non-treated water supply using 3 rain harvest tanks (each 2,700 liters). A public tap system of water supply for germ free safe water was proposed. There was a receiving tank in a village. Three tanks (URF, EPS and Storage) were enough for Fijian EPS project. Filtrate water is germ free safe water. EPS water can provide 6 liters per person of water for drinking and cooking using public tap system. Two villages were selected for pilot EPS. Opening ceremonies were

held at Kalokolevu village on July 16, 2013 and at Navatuvula village on September 11, 2013. I as short time expert of about one month visited 2 times per year from November of 2014. I was assisted by JICA volunteers from 2015 to 2018 (Fig. 17-8).

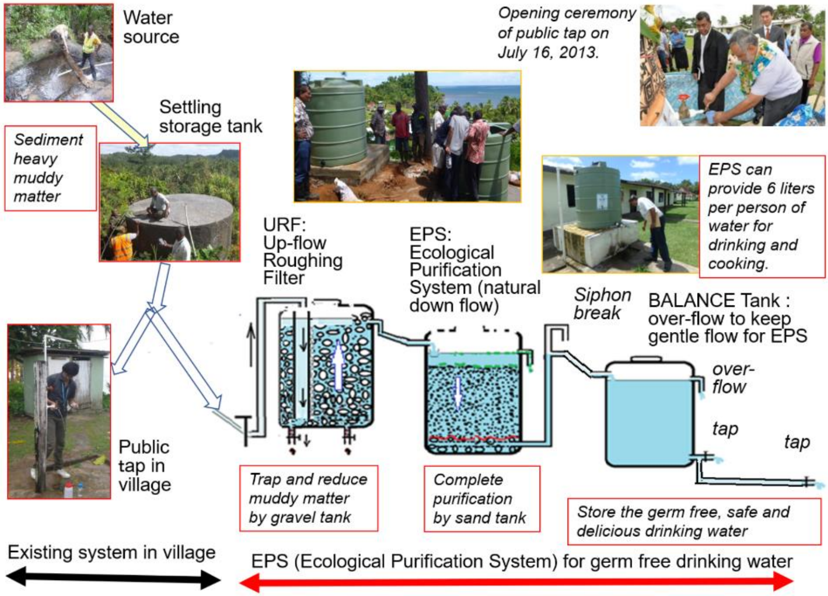


Fig. 17-3. EPS project for rural people in Fiji using rain harvest tanks

EPS capacity of 2,700 liters tank									
radius（r）＝0.7m、（π x r x r）=1.54m2									
flow rate			filtrate			Available persons			remarks
m/d	cm/h	m3/d	liter/d	liter/h	liter/min	2 liter/d	6 liter/d	100 liter/d	
2	8	3.1	3,080	128	2.1	1,540	513	31	Original flow rate in UK, 1829
5	20	7.4	7,392	308	5.1	3,696	1,232	74	English standard rate
10	42	15.4	15,400	642	10.7	7,700	2,567	154	Present Thames Water rate
15	63	23.1	23,100	963	16.0	11,550	3,850	231	Possible rate in warm region
20	83	30.8	30,800	1,283	21.4	15,400	5,133	308	Possible rate in warm region

Fig. 17-4. EPS capacity using 2,700 liters tank

The EPS capacity of 2,700 liters is very large. We can supply many villagers by one EPS. However, there is leak problem from tap and pipe connection, etc. We recommend setting new pipe line for EPS water and training for villagers. Especially save water in a clean

water tank and keep tap close. And we emphasize changing the rubber ring for tap seal.

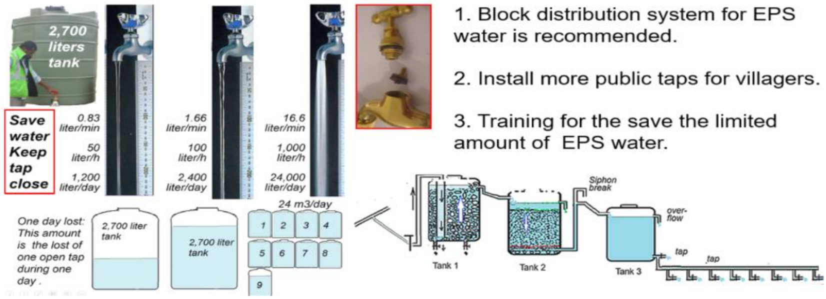


Fig. 17-5. Save water, and keep tap close for clean EPS water

We can supply many villagers from one EPS using many public taps. If villager number is over 200 persons, we recommend putting additional storage tanks with ball tap.

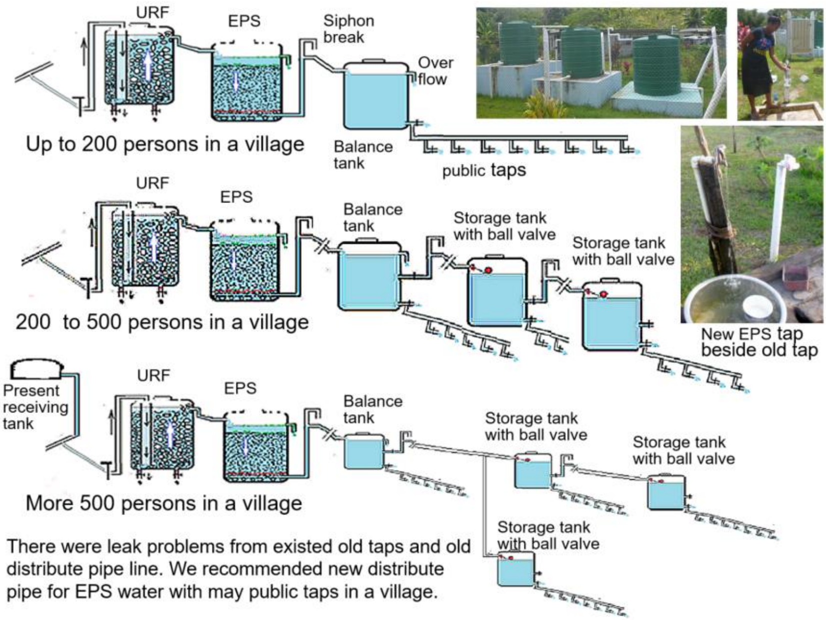


Fig. 17-6. Additional storage tanks are useful for large number of villagers.

Detail design of EPS and manual of EPS are available by electric form from the DWS, MoIT, Fiji government.

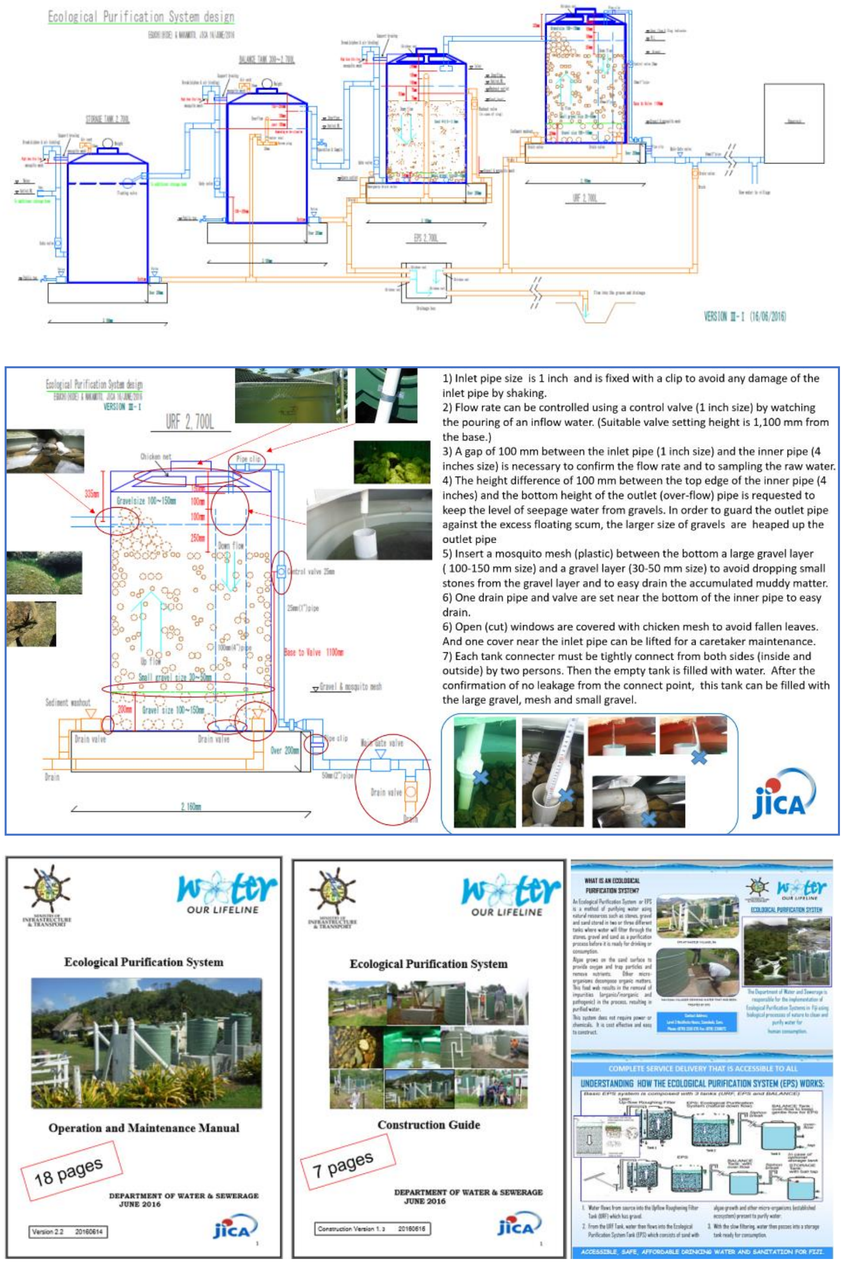


Fig. 17-7. CAD design and manuals.

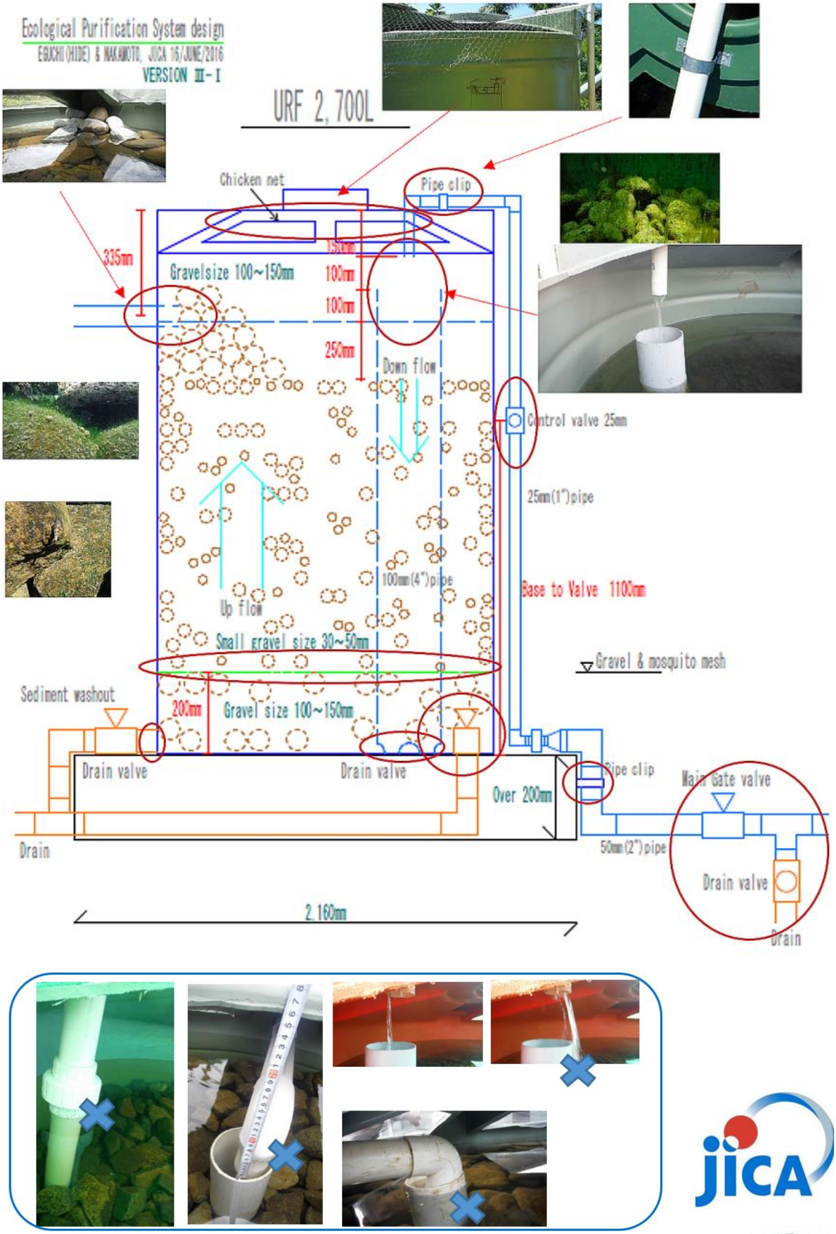


Fig. 17-8. Construction guide of UR

Mr. EGUCHI Hidemitsu, JICA volunteer helped to draw CAD design.

1) Inlet pipe size is 1 inch and is fixed with a clip to avoid any damage of the inlet pipe by shaking.

2) Flow rate can be controlled using a control valve (1 inch size) by watching the pouring of an inflow water. (Suitable valve setting height is 1,100 mm from the base.)

3) A gap of 100 mm between the inlet pipe (1 inch size) and the inner pipe (4 inches size) is necessary to confirm the flow rate and to sampling the raw water.

4) The height difference of 100 mm between the top edge of the inner pipe (4 inches) and the bottom height of the outlet (over-flow) pipe is requested to keep the level of seepage water from gravels. In order to guard the outlet pipe against the excess floating scum, the larger size of gravels are heaped up the outlet pipe

5) Insert a mosquito mesh (plastic) between the bottom a large gravel layer (100-150 mm size) and a gravel layer (30-50 mm size) to avoid dropping small stones from the gravel layer and to easy drain the accumulated muddy matter.

6) One drain pipe and valve are set near the bottom of the inner pipe to easy drain.

6) Open (cut) windows are covered with chicken mesh to avoid fallen leaves. And one cover near the inlet pipe can be lifted for a caretaker maintenance.

7) Each tank connecter must be tightly connect from both sides (inside and outside) by two persons. Then the empty tank is filled with water. After the confirmation of no leakage from the connect point, this tank can be filled with the large gravel, mesh and small gravel.

Fig. 17-9 Using microscope at the site

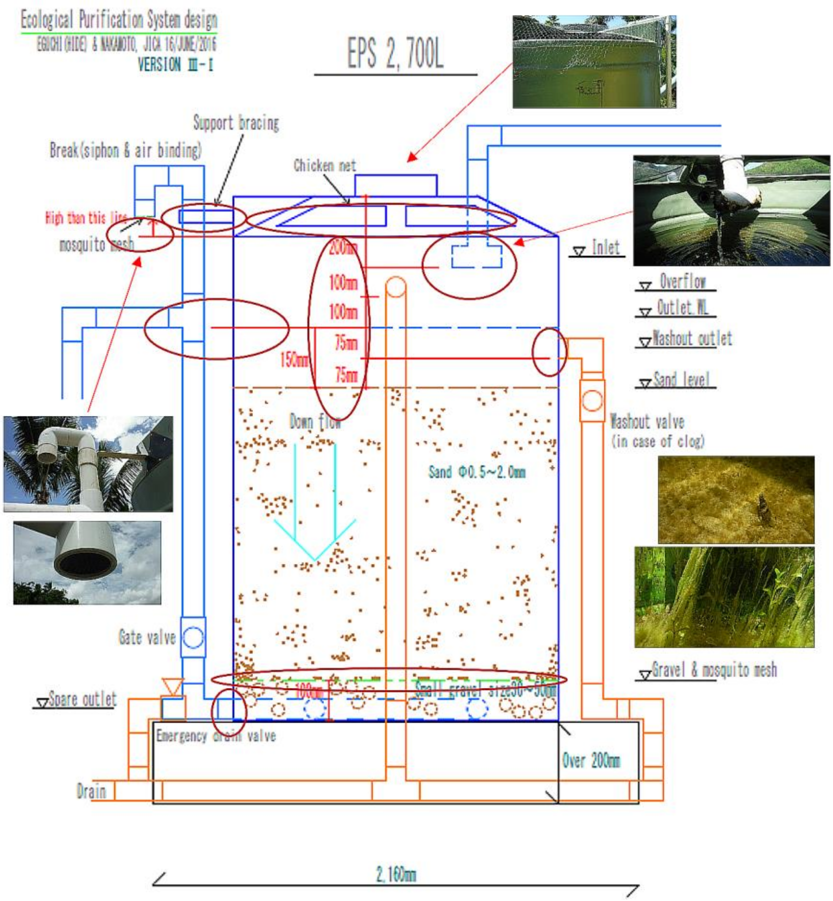


Fig. 17-10. Construction guide of EPS

1) T pipe is connect to the inlet pipe. to avoid the disturbance the sand surface. This is protect the disturbance of sand surface from the un-expected large amount of inflow water.

2) Open (cut) windows are covered with chicken meth same as URF.

3) Height difference of each pipe are the key for normal operation. The order is siphon, inlet, over-flow, outlet, scum out and sand surface.

4) At the bottom, one layer of gravels (30-50 mm size) is placed until little bit over the drainage porous pipe (50 mm) for the filtrate in order to easy drain.

5) Insert mosquito mesh (plastic) between the gravel layer and the sand layer (sand size: 0.5 – 2 mm) to avoid the leak of sand particle.

6) At the bottom end of the siphon break system for filtrate is sealed with a mosquito mesh to avoid dust, rain drop and inversion of any animals.

7) Outlet pipe for the filtrate must be tighten using a brace or a clip to avoid any damage of the inlet pipe by shaking.

8) Each tank connecter must be tightly connect from both sides (inside and outside) by two persons.

9) Then the empty tank is filled with water. After the confirmation of no leakage from the connect point, this tank can be filled with the gravel, mesh and sand.

Fig. 17-11
EPS model for the event

Fig. 17-12
Village chief of Kalokolevu came to DWS

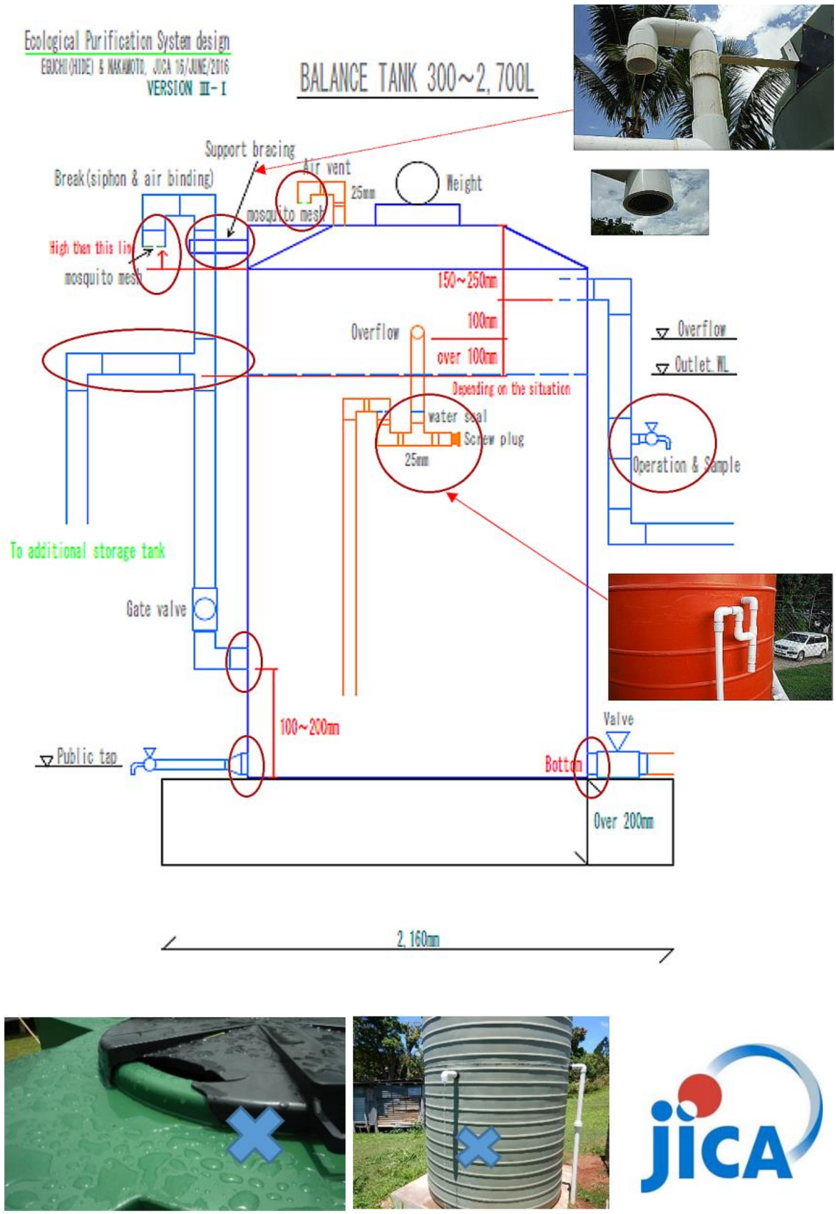


Fig. 17-13. Construction guide of Balance Tank

1) A sampling tap is set before the inlet point to the balance tank to startup operation and to check the water quality of the filtrate.

2) Correct pipe setting order is the key to normal operation. The order of setting height is siphon, inlet, over-flow and outlet.

3) At the downward ends of a siphon break system and an air ventilation are sealed with a mosquito mesh to avoid dust, rain drop and inversion of any animals.

4) Outlet pipe for the filtrate must be tighten using a brace or a clip to avoid any damage of the inlet pipe by shaking.

5) Adjust the height of the water level of the outlet of the balance tank in case of usage of a storage tank. Caution to natural gravidity flow to a storage

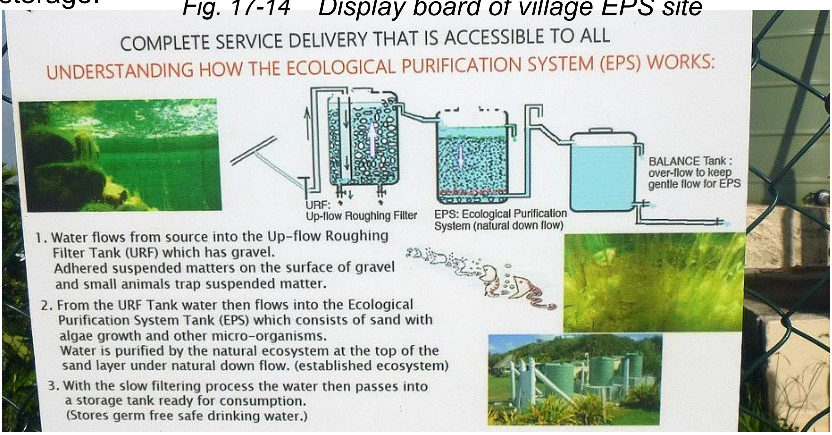
6) S shape over-flow should be set to avoid inversion of any animals.

7) A screw plug is set at the bottom for an emergency drain and cleaning.

8) Each tank connecter must be tightly connected from both sides (inside and outside) by two persons.

9) Then the empty tank is filled with water. After the confirmation of no leakage from the connect point, this tank can be used for normal storage.

Fig. 17-14 Display board of village EPS site



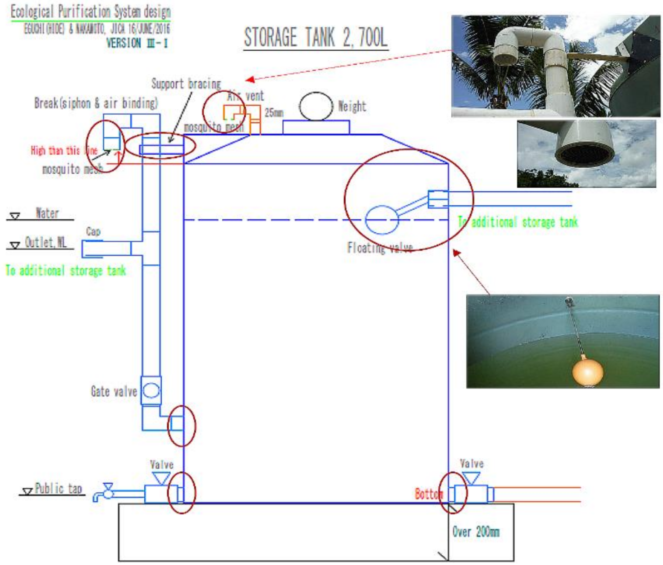


Fig. 17-15. Construction guide of Storage Tank

1) Floating valve is set to the inlet from a balance tank.

2) Correct pipe setting order is the key to normal operation. The order of setting height is siphon, inlet, over-flow and outlet.

3) At the downward ends of a siphon break system and an air ventilation are sealed with a mosquito mesh to avoid dust, rain drop and inversion of any animals.

4) Outlet pipe for the filtrate must be tighten using a brace or a clip to avoid any damage of the inlet pipe by shaking. If any other optional storage tank is not necessary in future, this outlet pipe is not necessary to set.

5) Each tank connecter must be tightly connected from both sides (inside and outside) by two persons.

6) Then the empty tank is filled with water. After the confirmation of no leakage from the connect point, this tank can be used for normal storage.

EPS for rural people in Fiji is already completed in 98 villages until January 2018.

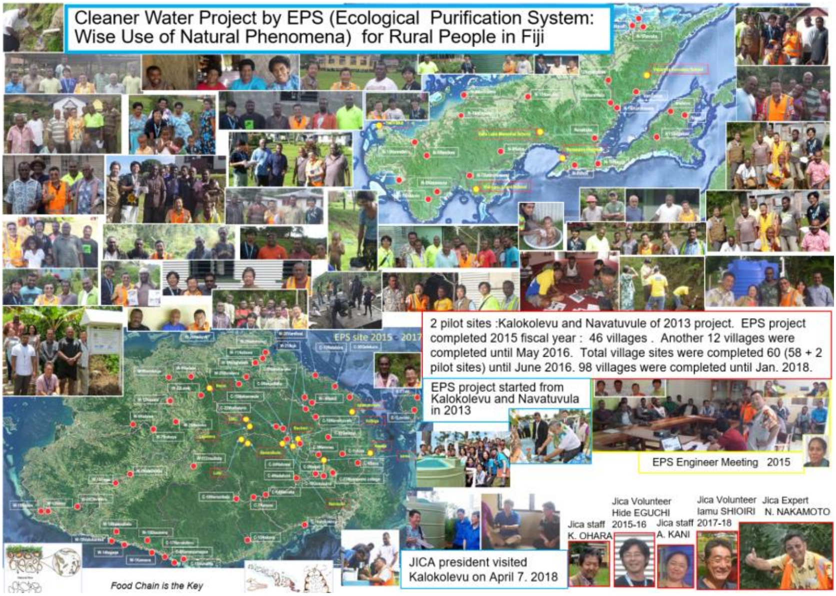


Fig. 17-16. Fiji EPS sites in 2018

Member of the department explains at the event showing their EPS model. This EPS project fund has covered by Fiji government. Villagers assisted collection of local sand and gravel and helped to construction. JICA contributed just advise. This is the technical transfer result of JICA training in Okinawa, Japan.

Fig. 17-17. EPS display at the event

18. China

I published an introduction book on “Natural filter of slow sand filter” in May 2002 and a manual book of “How to make drinking water by Ecological Purification System” in August 2005. I also opened my homepage on slow sand filter as Ecological Purification System at my laboratory of Shinshu University. Mr. Jin Shengzhe (金胜哲) was a Chinese electric engineer who worked at Japanese Electric Power Company in Japan. He kept a goldfish as a hobby in his home. He interested in my homepage on EPS. He came to my laboratory on February 24, 2007. I introduced my manual book and asked to translate in Chinese. He retired the Japanese company and returned to Nantong city (north Shanghai city) in China.

May, 2002. Natural filter of slow sand filter

Aug. 2005. How to make drinking water by **Ecological Purification System**

Feb. 24, 2007 Nov.24, 2011 Jin Shengzhe 金胜哲

May, 2009. Portuguese, Brazil

July, 2010. Chinese, China

Fig. 18-1. Books on EPS, Portuguese version and Chinese version

He made a model and confirmed its performance in China. The great earthquake happened in Sichuan province on May 12, 2008. He stopped the translation and went to Sichuan for the earthquake disaster relief. He made three WPT by EPS in Sichuan.

He visited again to my house on November 24, 2011. He reported his activity in Sichuan showing his video. Construction speed of EPS plant was so fast. It took only one month to construct one plant which produced 30 tons of safe drinking water per day. So many people assisted to construction. He made 3 plants.

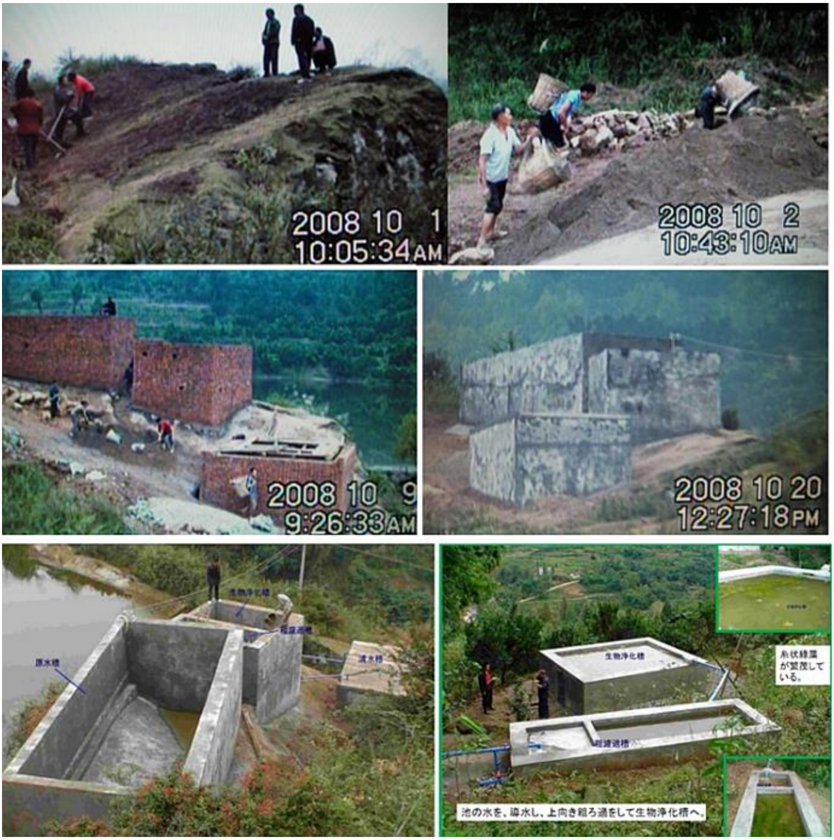


Fig. 18-2. EPS construction after the Great Sichuan earthquake

He said to me that he started to rescue people from cancer risk due to underground contamination by industrial waste water in Shenqiu County in Henan province. It called “cancer villages.” He started to rescue the activity of Mr. Huo Daishan (霍岱珊) who organized an environmental NGO “Guardians of the Huai River”. They examined to purify the contaminated underground water by EPS technique. The treated water by EPS became safe drinking water without cancer risk. Activity of Mr. Huo became well-known. He received Ramon Magsaysay Award in 2010. And he also received the International **Energy Globe Awards** (the ***World***

Awards for Sustainability or ***Nature's Nobel Prize***) in 2012. Mr. Huo constructed more than 40 EPS plants for villagers. NHK World TV in English reported his activity on December 13, 2014.

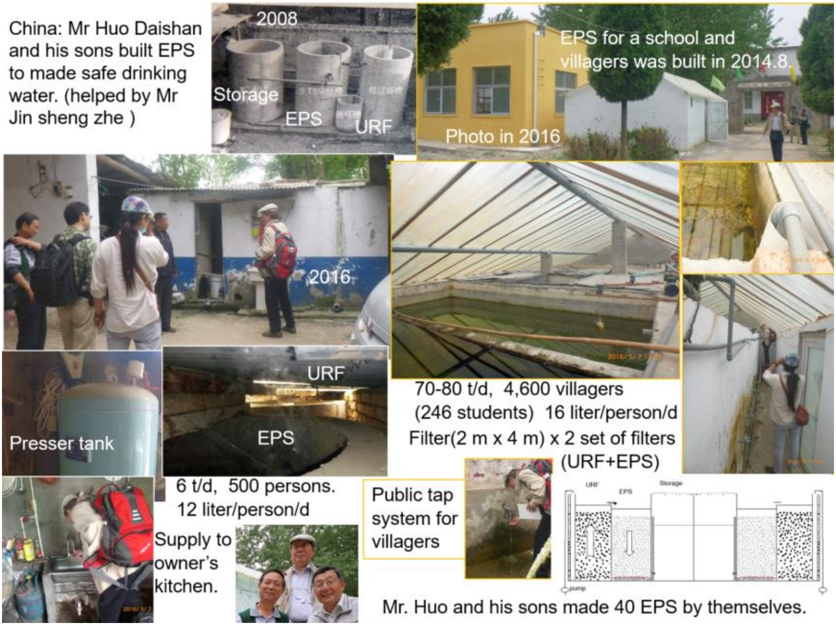


Fig. 18-3. I visited Shenqui County in May 2016

Fig. 18-4. Japanese NHK-World TV in English on December 13, 2014

Jin Shengzhe said that a common saying “Accumulation of good deeds and virtues (積善積徳)” in China.

19. SOCIAL CONTRIBUTION

SRI LANKA: Mr. OKADA Motohiro planed a water purification plant for the National Ratnapura Hospital in Sri Lanka. Raw water was muddy water in tropical climate region. The original plan was a rapid sand filtration (RSF) using coagulant. He visited Ratnapura to see the RSF plant. The facility was almost broken. He knew my work from newspapers and my homepage. Then he visited me and asked the applicability of SSF. I gave him EPS information and the new URF technique without chemicals. He designed an EPS WTP.

Fig. 19-1. New WTP by EPS supplied 140 m3 per day of safe water.

Fig. 19-2. I explained the mechanism.

I also visited several times. WTP was completed in January 2010. This WTP (140 m3/d) had two treatment lines. One line had 1

settling tank, 3 URF, 1 sand filter and 1 storage tank.

The plant manager of Mr. Arnanda Weerante spork that this was a **natural filter** and old RSF was a **commercial filter**. We need simple low technology.

The operational maintenance is only drain valve operations of settling tank and URF tank. Biological activity is always high in this warm region. Sand filter does not clog. Scraping of sand surface is not necessary. This system was almost maintenance free system. We visited again this plant after 10 years. The director of the hospital said to us that this plant was no problem.

BANGLADESH: I noticed Asia Arsenate Network, Japanese NGO in Miyazaki, Japan worked to supply safe drinking water by SSF in Bangladesh. As their SSF design was not suitable, I gave them better idea to eliminate contaminated heavy metals and germ cell by EPS. Mr. KAWAHARA Kazuyuki asked me to explain more detail and to visit the working site in Bangladesh.

Fig. 19-3. Contaminated underground water by arsenate

Underground water in the delta area in Bangladesh contained

iron associated with arsenate. They tried to get safe water. They asked me how to eliminate toxic heavy metals in water and agricultural strong chemicals of herbicide and pesticide in water without chemical treatment. I advised series of URF using food chain action and public tap system to save the water. This NGO introduced 4 times of URF steps to eliminate the hardly decomposable matters of harbicide and pesticide by the fermentation action in the fecal pellet of ecological decomposition.

The public water supply system by EPS was completed in June 2003 with using 62 public taps in a village.

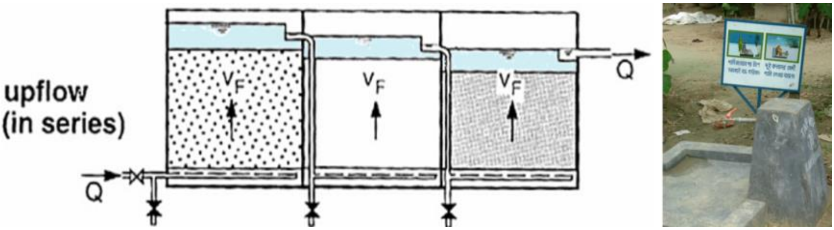


Fig. 19-4. Series of URF and public tap

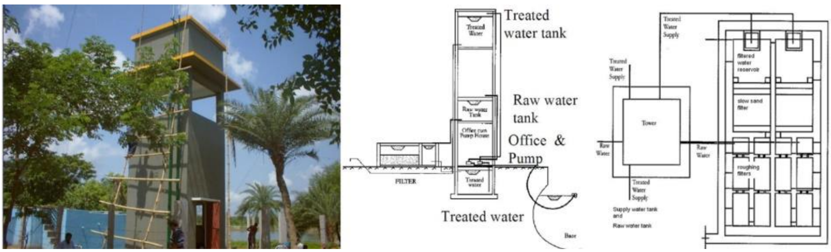


Fig. 19-5. Water tank and design

We can eliminate arsenate by EPS from water. However, we cannot decompose arsenate, because of atomic. Then, NGO selected surface water of an oxbow lake as raw water for the plant.

Active growth of algae was seen in EPS. Oxygen consumption by decomposer (bacteria and small animals) were also big. Sometimes serious oxygen depression happened. I had to emphasize presence of dissolved oxygen was necessary in EPS. I

advised more faster flow rate to keep aerobic condition.

Fig. 19-6. EPS in Jessore, Bangladesh

Fig. 19-7. Algae and grazing animals in EPS

INDONESIA: Mr. YAGI Sumio from Yamaha Motor Company came to my laboratory. He asked how to make safe water safe water as a social contribution of the company. I gave applicable EPS principle in nature.

Underground water contains iron and manganese in Bekasi,

Jakarta plain in Indonesia. They tried a cascade aeration for bad underground water. Well water was clear. But the brown colloidal particle was formed soon. They could make clear water without any chemical reagent. They also tried how to reduce colloidal matter in muddy creak water and constructed a pilot plant for practical use in Karawang village in 1999.

Fig. 19-8. Cascade aeration channel

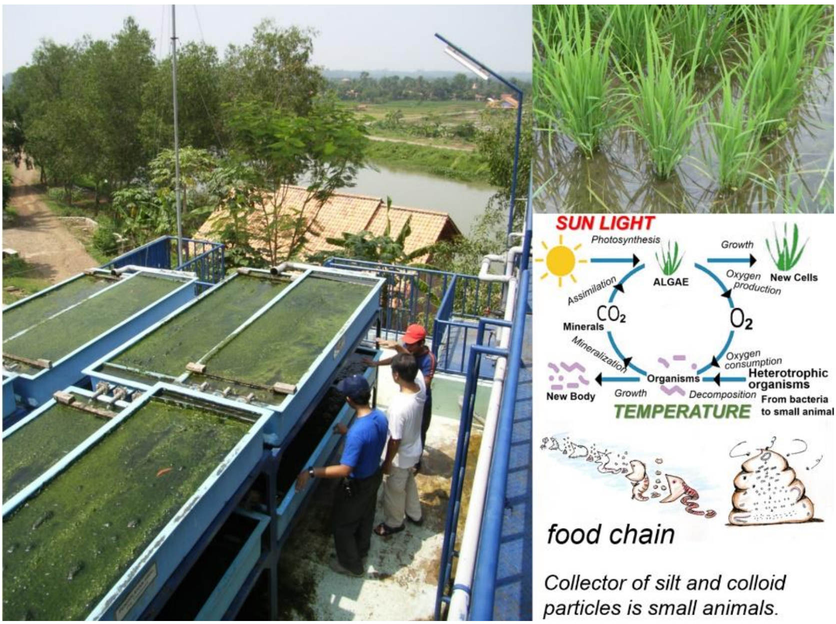


Fig. 19-9. Cascade aeration channel

Water in paddy field is clear by the activity of algae and small

animals. Filamentous algae grew in water channel. Turbid colloidal particles were trapped to algae and small animals among the algae. Animals graze particulate matter (living and non-living). Periodical small drain to eliminate precipitate matter and unhealthy organisms.

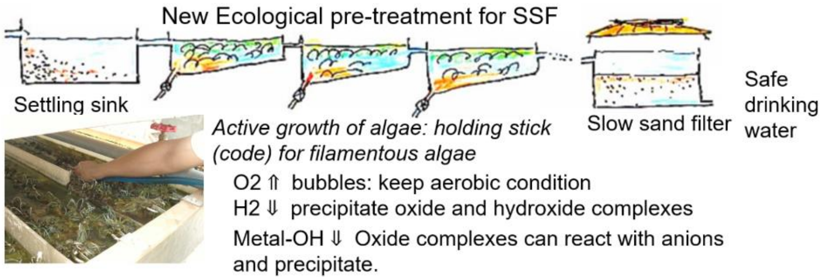


Fig. 19-10. Principle of new Ecological Pre-treatment for SSF

Fig. 19-11. Pilot WTP in Karawang

There were 3 public tap stations. Tap keeper was important to save the storage water. Lady collected small money per bottle. They supplied 2 tanks (40 liters) per family for drinking and cooking. Eye sickness and diarrhea disappeared in village. Villagers keep to attention for clean and health. This village turned to health village.

Fig. 19-12. Risk and safe water image

Fig. 19-13. Important tap keeper

The capacity of daily production was 25 tons per day for 2,000 villagers. The capacity was over the total demand of villagers. Then deliver service started for other villages. This plant was fully managed by the village water committee.

OISCA: Mr. KIZUKI Fumio (The Organization for Industrial, Spiritual and Cultural Advancement-International) checked the performance of EPS using a model plant by himself. He propagated family size EPS in the world.

Fig. 19-14. Mr. KIZUKI made small size of practical EPS.

20. ACCEPTABLE RISK

It is popular in the world to eat with our bare hands. This is necessary to remove the contaminated small stones in food. This is a reasonable way.

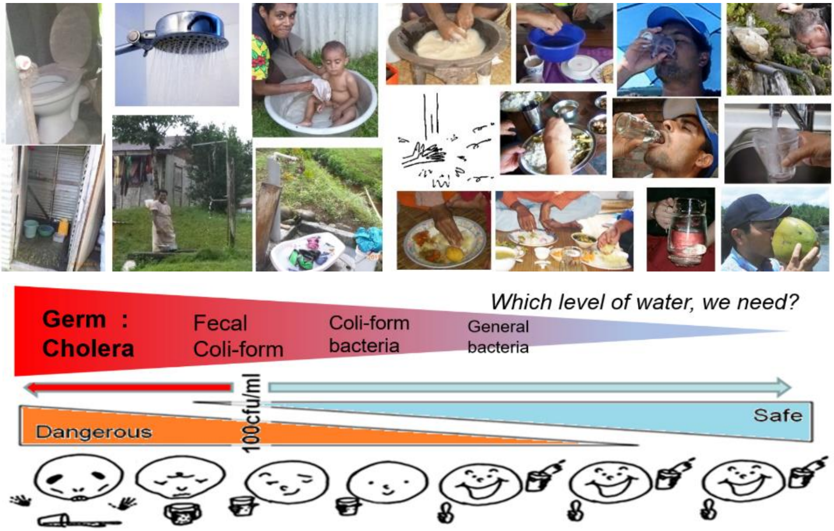


Fig. 20-1. Different level of Risk in water

There are different groups of bacteria in the field.

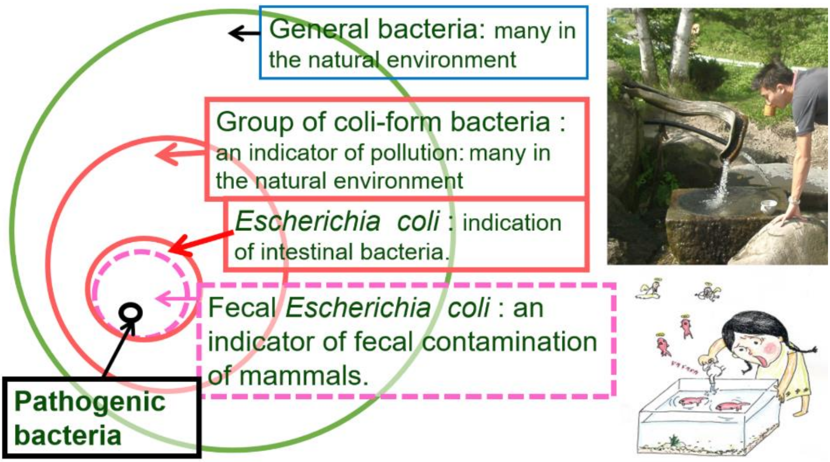


Fig. 20-2. Different groups of bacteria

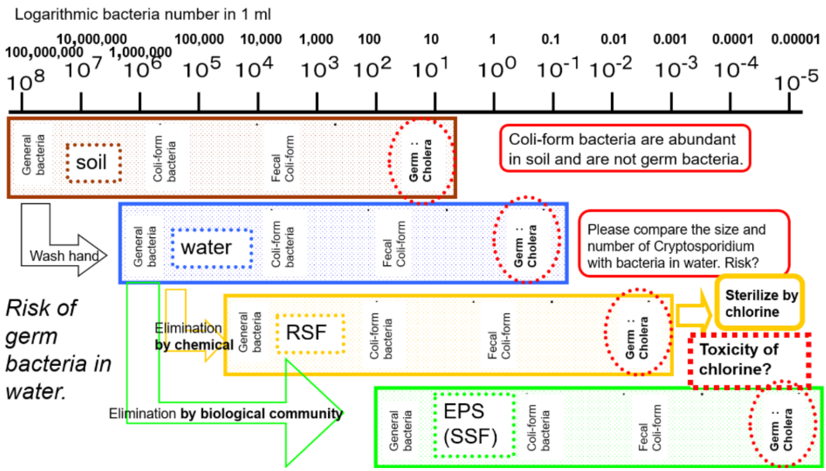


Fig. 20-3. Relative abundance of bacteria

Small organisms are larger ratio of surface per body volume. Smaller organisms are more sensitive than larger organisms. We are insensitive than natural small organisms. Wild organism responses to scarcely small changes in nature.

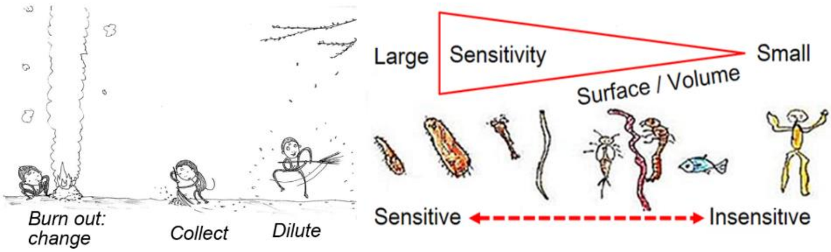


Fig. 20-4. Making non-detectable level and sensitivity

Small organisms in EPS is more sensitive than large human being. We have to think about acceptable level of risk on the sense of small organisms which we need.

We can easily test the viable bacteria number in water using a commercial bacteria incubation strip. We use Japanese bacteria test paper (http://suncoli.com/), its sales agent for oversea is SIBATA company (https://www.sibata.co.jp/english/).

Viable number of coliform group bacteria test paper and general bacteria paper in water are easily counted by bacteria test pater. We can incubate at room temperature. Development speed relates with temperature.

After one day incubation, pink colonies develop. These colonies are general (total) bacteria

After one day incubation, blue colonies develop. These colonies are Coliform group bacteria. And under UV radiation, luminescence colonies are Coliform bacteria.

Fig. 20-5. Bacteria test paper for general bacteria and coliform bacteria.

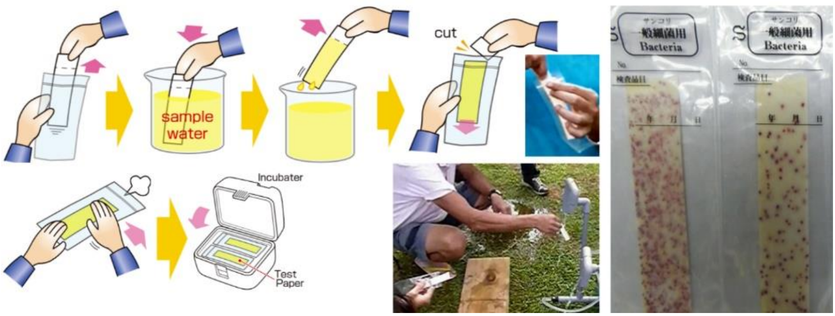


Fig. 20-6. How to manage a bacteria test paper.

Fish in brown water is comon. Is there cancer risk for fish in brown water ? We have to think what is safe in ecological sense.

Fig. 20-7. Northern pike in brown water.

21. FROM JAPAN TO THE WORLD

EPS is new technique. EPS spreading from Japan to the world.

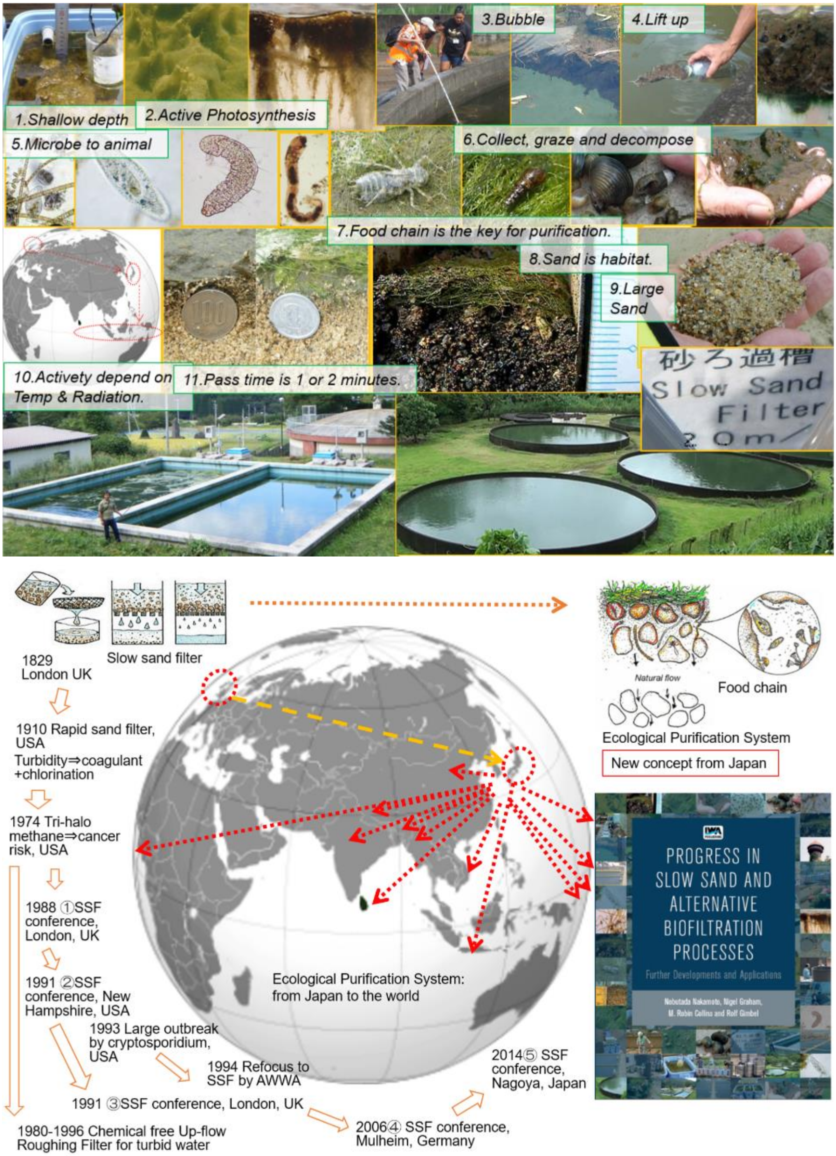


Fig. 21-1. New concept of EPS, from Japan to the world

22. ECOLOGICAL SENSE

EPS is an application of natural process. Ecological sense is important. Especially, we must know the behavior of microscopic organisms and small organisms. However, people get safe and delicious water without scientific knowledge of biology. They have ecological sense.

Fig. 22-1. People know natural safe and delicious water.

I was interested in phytoplankton in the high school. I found *Paramecium* (Protozoa) and other tiny organisms move around so quickly under a microscope. They look like to struggle seriously for survival. I studied biology and ecology in the Tokyo Metropolitan University. I as a biologist want to be a spokesman for small organisms. There are so many resting forms of microscopic organisms in open ocean and in a reservoir in savanna region.

Fig. 22-2. Ocean survey ship, Broa reservoir in Brazil and resting form plankton

Hungry condition is normal. They are always waiting for food in nature. Shallow littoral zone is easily dried up in dry season.

Microscopic and small organisms in this zone become resting form to survive from severe period. They are waiting for rainy season.

Nagano is in montane area and cold in winter. There is a covered filter plant. The biological community of this plant was poor in comparison with Someya WTP. I recommended to make windows at the roof for sun shine to activate ecological function.

Fig. 22-3. Activate ecological function on the filter bed

Chironomid (Midge) is not same as Mosquito. Chironomid is called non-bite mosquito which has not a needle to suck blood. Midge larvae live at the bottom. Mosquito larvae live in stagnant water and bless air beneath the surface.

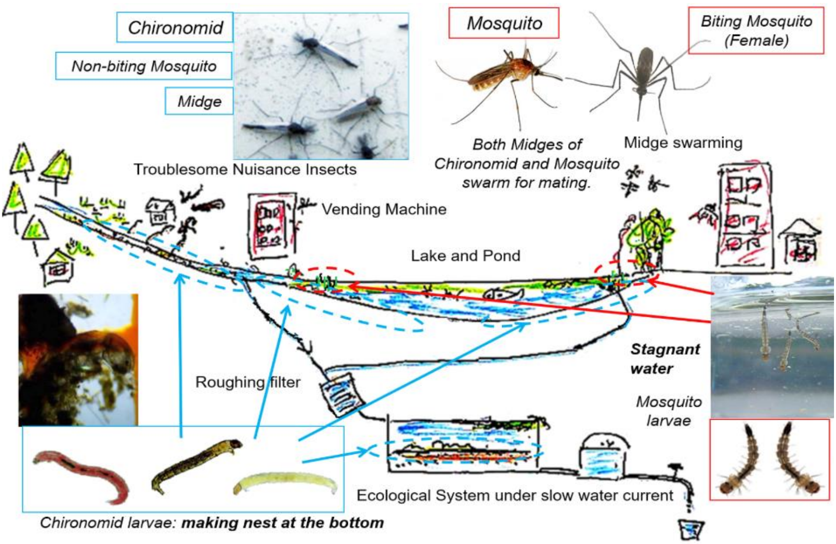


Fig. 22-4. Chironomid and Mosquito

Chironomid (Midge) larvae in the filter pond are best food for fish.

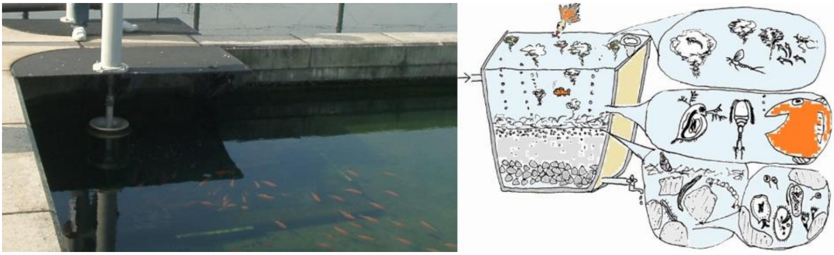


Fig. 22-5. Fish in a filter

Biological phenomenon is not simple. The phenomenon changes in different environment and during the time of period. There is a capacity of adaptability and acceptability to changing environment. But it takes time. EPS is an Eco-Friendly, Smart Technology. When you understand the system, you can manage it by yourself. I hope this book is useful to solve your problem.

NAKAMOTO Nobutada 中本信忠

Professor Emeritus of Shinshu University, Dr. Science.

He was born in Tokyo in May, 1942 and graduated the Tokyo Metropolitan University (Department of Biology, Faculty of Science) in March, 1965. He entered the master and doctor courses of the same university. He studied on microbial ecology, especially algal growth and nutrient in a laboratory experiment and in the fields. He obtained the doctor of science from the Tokyo Metropolitan University in 1980.

After a short term OTCA (JICA) expert of algal culture and eutrophication for the reservoir project of Univ. São Paulo, Brazil in 1974, he appointed a research associate, Department of Applied Biology, Faculty of Textile Science and Technology of Shinshu University in 1975, an associate professor in 1981, a full professor in 1990. After his retirement of the university, he became professor emeritus of Shinshu University in April, 2008. He participated to the Community Water Supply Support Center of Japan (NPO: Non Profit Organization) as the chief director from 2006 to 2017. And he becomes an exective director from 2017 until now. He also participates to the Okinawa Blue Water (NPO) as an exective director from May 2018.

Contact: cwscnkmt@yahoo.co.jp

1218-5, Suwagata, Ueda, Nagano 386-0032, Japan

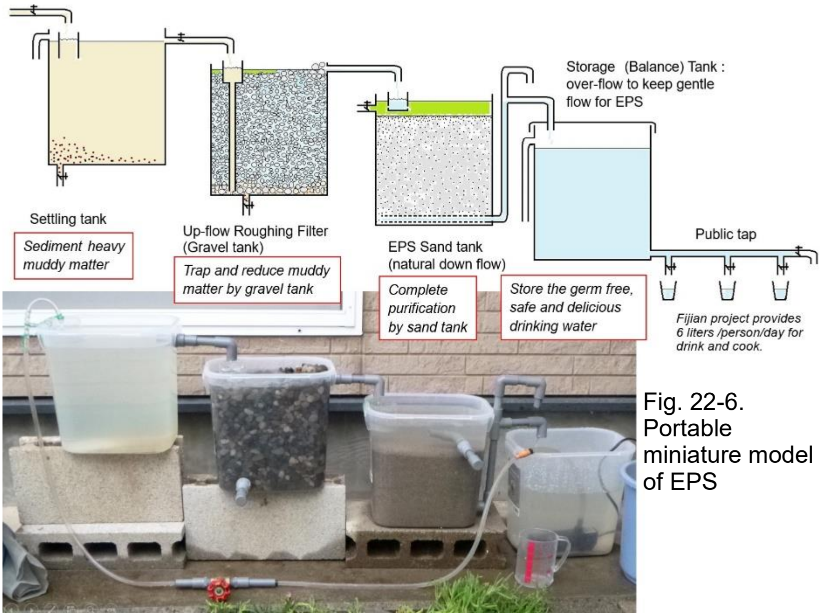


Fig. 22-6. Portable miniature model of EPS

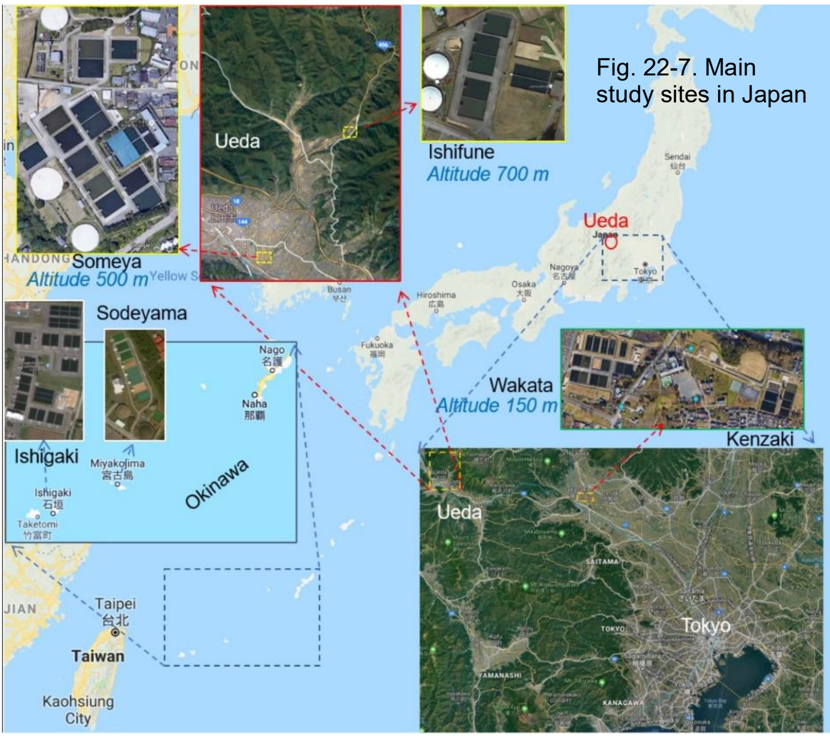


Fig. 22-7. Main study sites in Japan