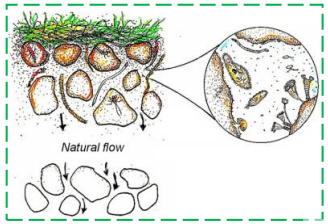
Slow Sand Filtration is Ecological Purification System

Slow Sand Filtration

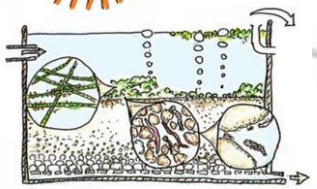


Ecological Purification System

Jan.10. to Feb.10., 2024 at Okinawa

Nakamoto joins the training from Jan.15. to 19. 2024.

Part 2



Treatment System for Safe Water by Wise Application of Natural Phenomena

cwscnkmt@yahoo.co.jp

Lebanon

Bhutan

Okinawa

https://www.youtube.com/watch?v=Ye-POV6qBU0&t=39s

DIY EPS bucket model making 2022 - YouTube / 38:01
https://www.youtube.com/watch?v=jz94KFkLL3E

Malaysia

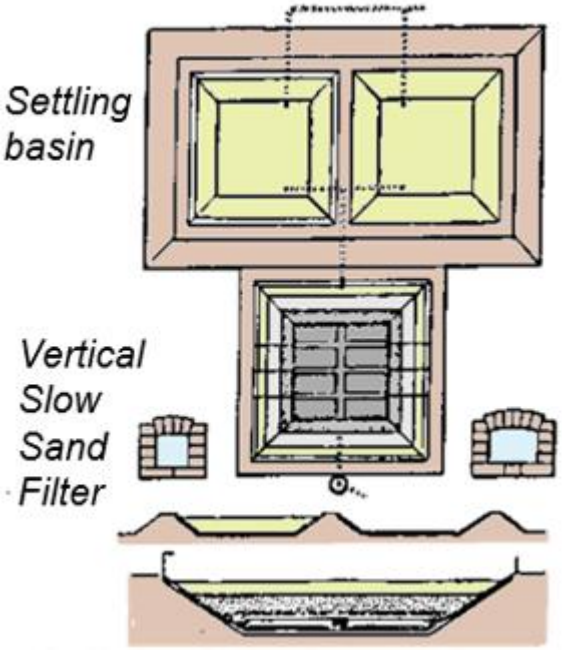
Marshall

Nauru

Tuvalu

East Timor

Fiji



1:**Water depth**

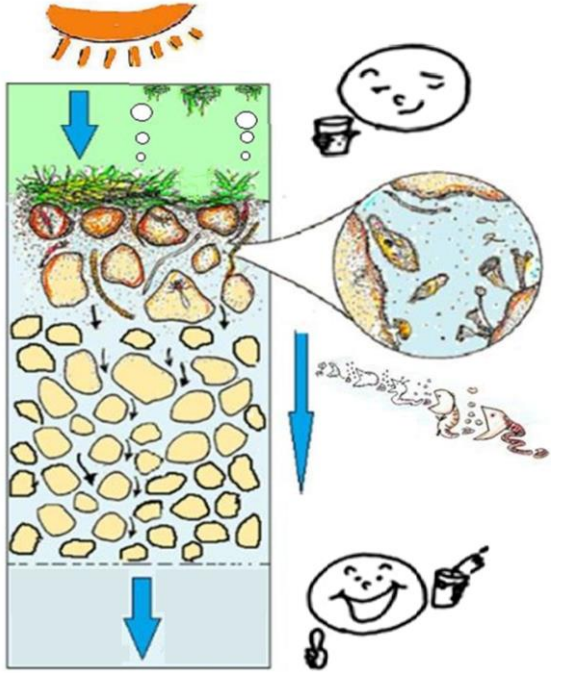
2:Sand size

3:Flow rate

4:Ecosystem

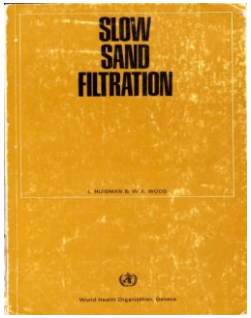
Gentle for small organisms

Vertical



The filter rate was 2-3 m/d (10cm/h).

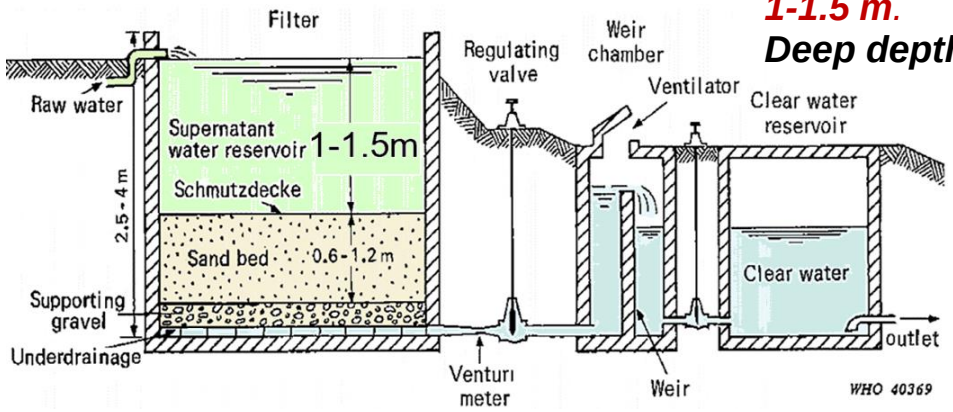
38 cm	Water depth
61 cm	sand layer
61 cm	gravel layer



Huisman & Wood 1974: WHO manual of Slow Sand Filtration for safe drinking water

*Simpson filter in 1827 is **38 cm**.*
Shallow depth

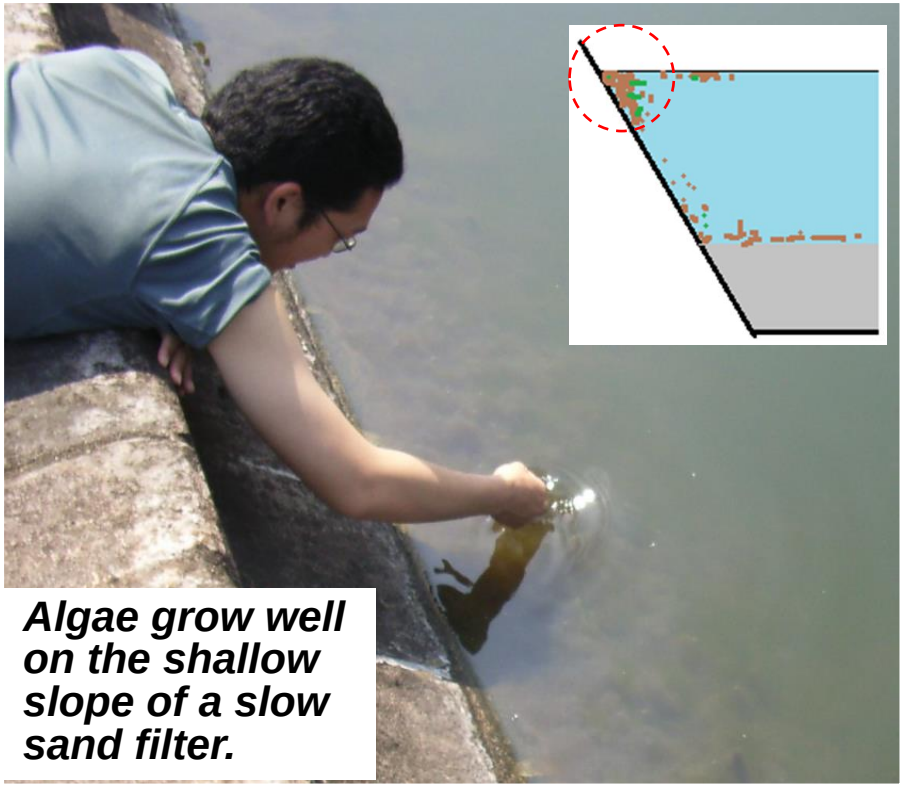
WHO manual 1974
*Water depth is **1-1.5 m**.*
Deep depth



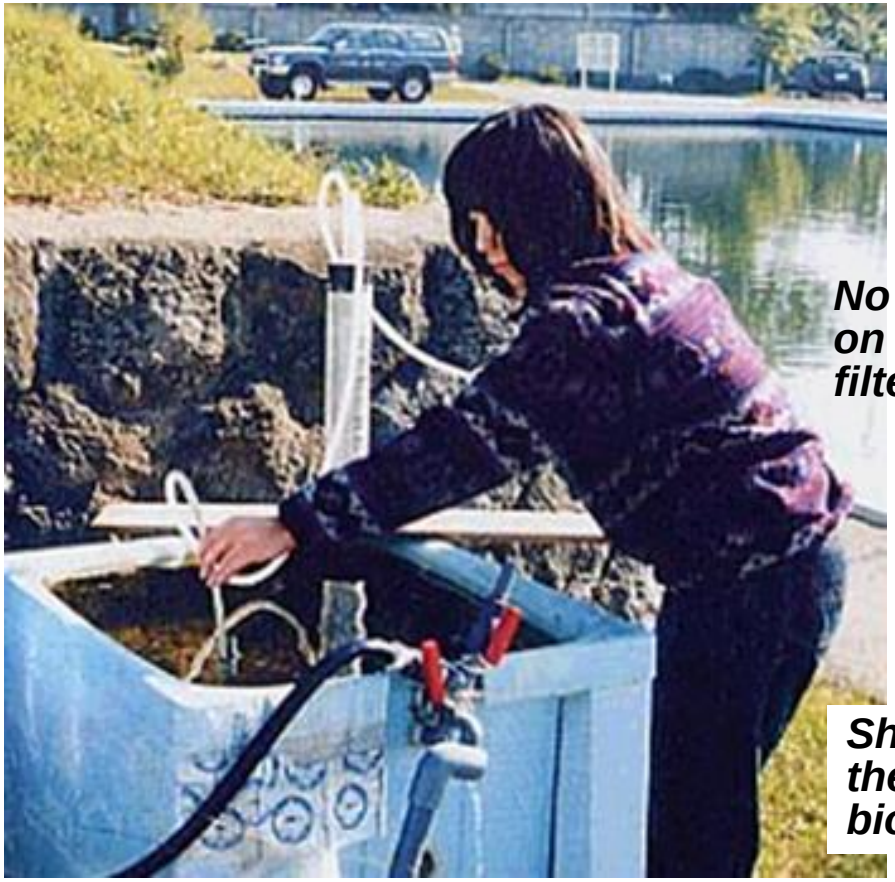
Huisman & Wood didn't know the role of algae.

Algae grow well on the shallow river bed even in cold winter.

Shallow depth activates algal photosynthesis and other biological activity.



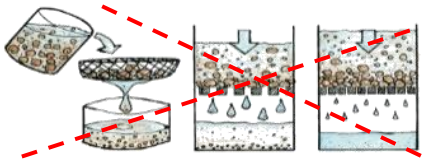
Algae grow well on the shallow slope of a slow sand filter.



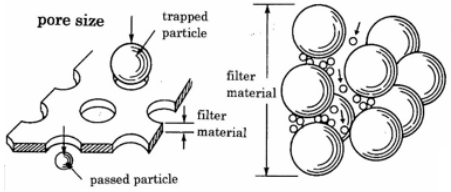
No growth on the deep filter bed.

Algae grow well in shallow model.

Shallow depth is the key for biological activity.

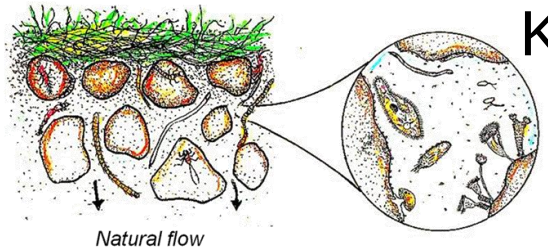


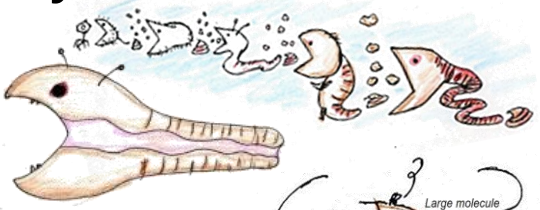
SSF is not mechanical filter.



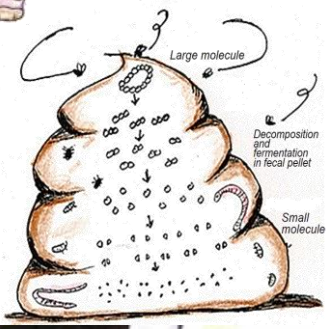
This is not mechanical reduction.

Key is Food Chain.

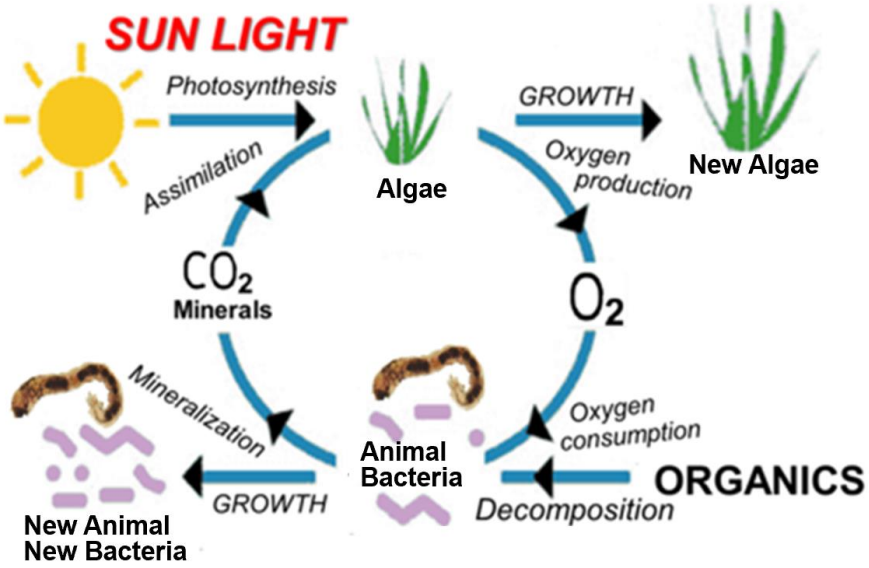




Large molecules are broken to small molecules under anaerobic condition in fecal pellets.



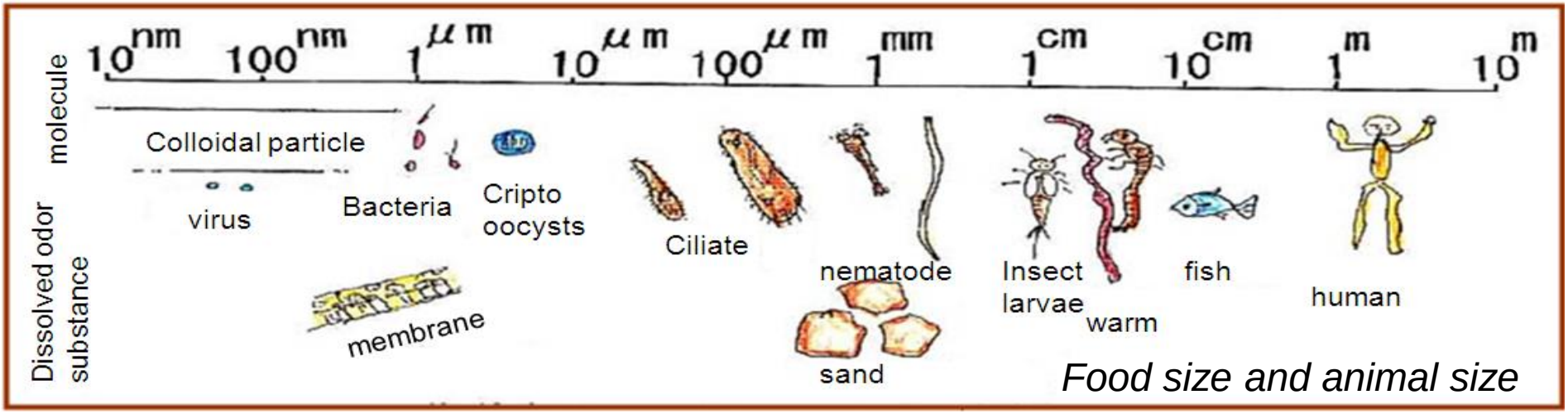
Algae=food for small animal
Algal growth:
photosynthesis=oxygen production
=Good for animal activity



Shallow depth =better for algal growth

This is an Ecological Purification System.

Food chain among small animals is the key for purification system.



Short time work

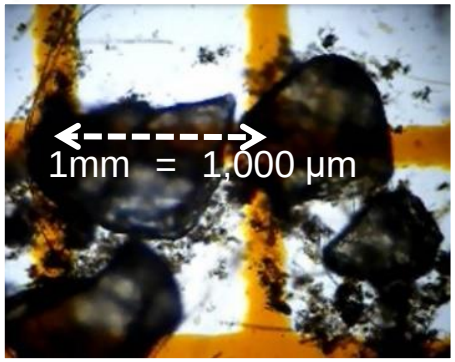
Passing time of food in body is also very short.

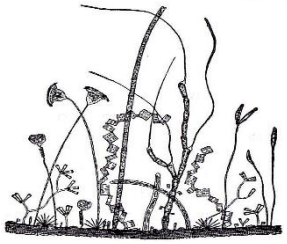
Trap and collection time of particle by small organisms is very short.

Long term action

Complete decomposition (mineralization) in the faecal pellet.

Anaerobic condition inside of fecal pellet.



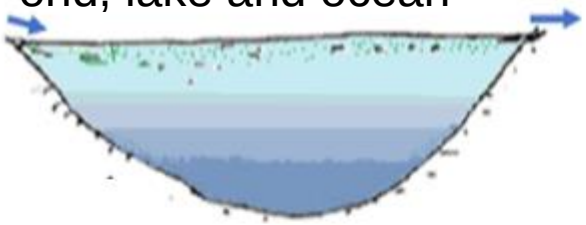


Hungry creatures are important to trap any particles under gentle condition.

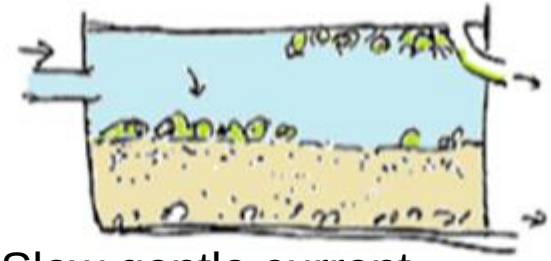
Different type of water environment and algae

In Slow Sand Filter pond, there is down ward current from surface. Filamentous form of algae can grow on the sand bed.

Pond, lake and ocean



Stagnant water

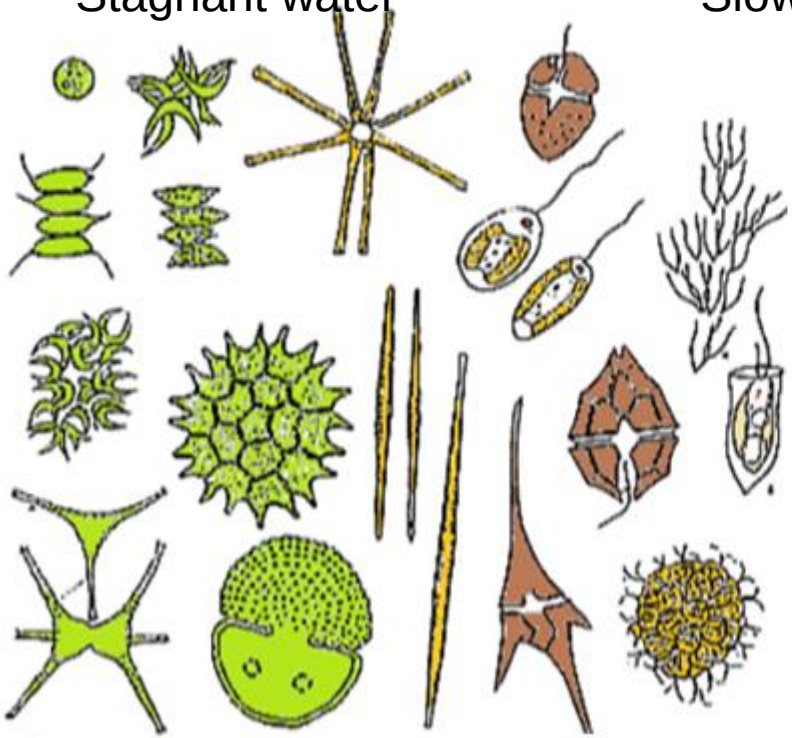


Slow gentle current

Stream, river

Horizontal running water

Occasional storms and rapid currents.



Float and drift algae

Phytoplankton

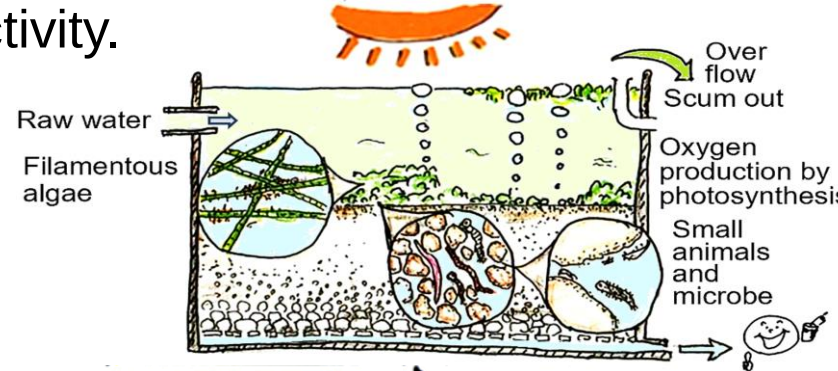
Flagellated algae

Filamentous algae

Periphyton

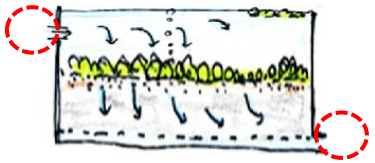
Attached algae

Aerobic condition is essential for biological activity.

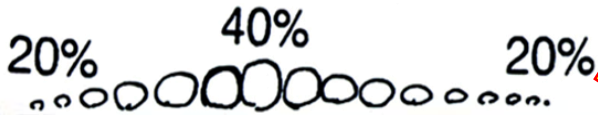


$$CO_2 + H_2O \rightleftharpoons CH_2O + O_2$$

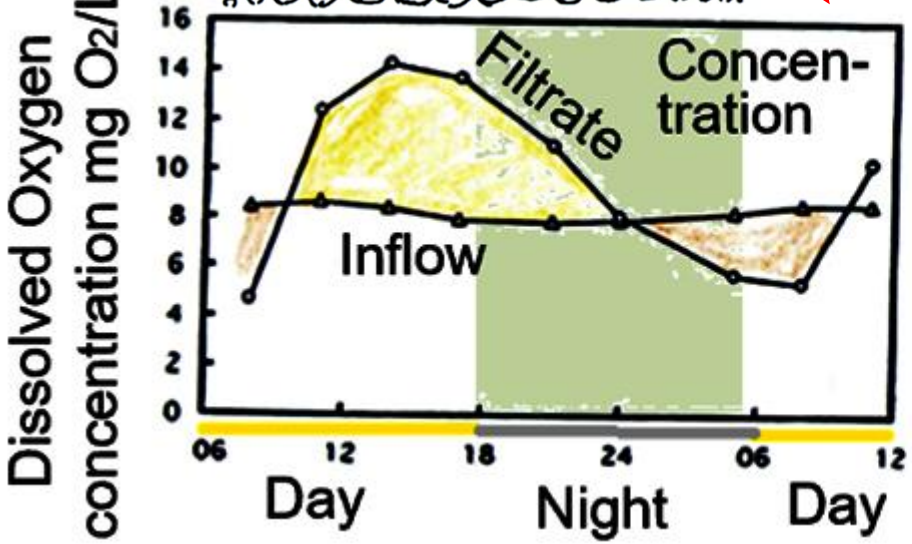
There is down ward current.



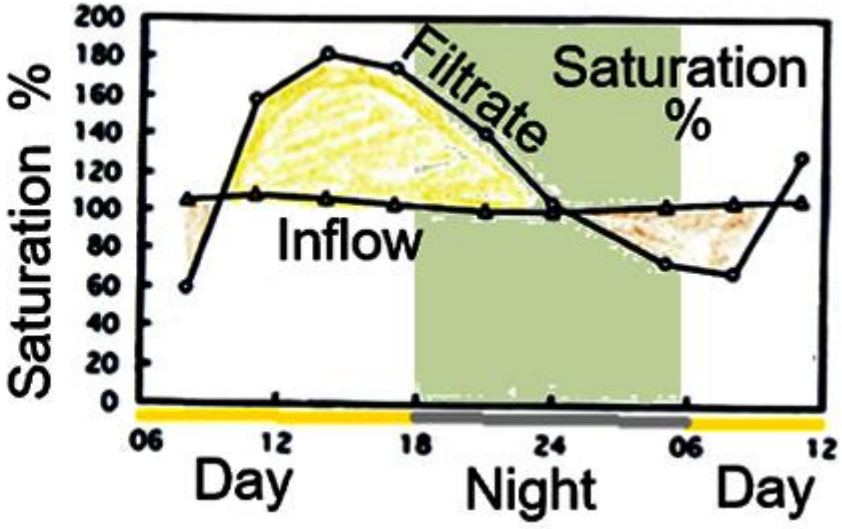
Diurnal change of dissolved oxygen (DO) was measured.



Partial pressure of oxygen in bubbles was also measured.



Soon after sun rise, DO in filtrate was rapidly increased.



Even after sunset, DO in filtrate was super saturated condition.

Algal photosynthesis accelerates purification process.

I investigated the seasonal change of algae in Thames filters in London from 1994 to 1996, more than 30 years ago.

Ashford Common WTP, Thames Water

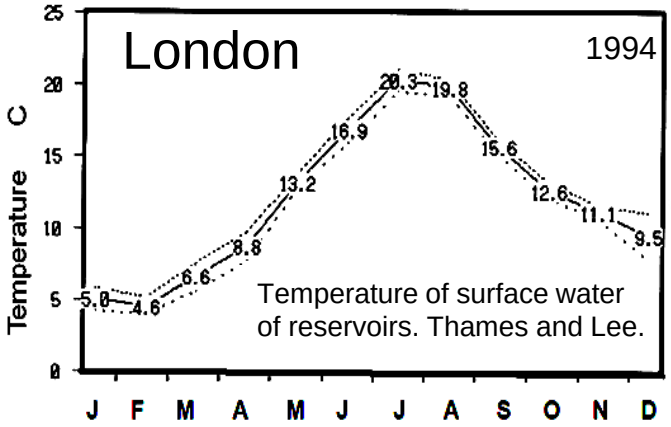
Nutrient rich water

Biological roughing filter without chemical.

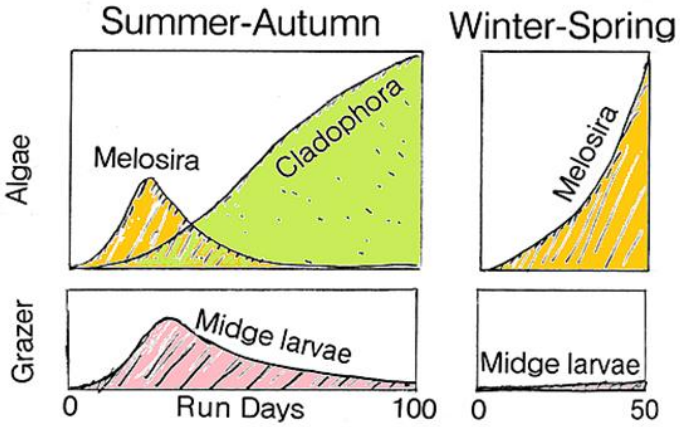
100mx35m
32 Filters

Filamentous green algae bloom in summer

Filamentous diatom in winter

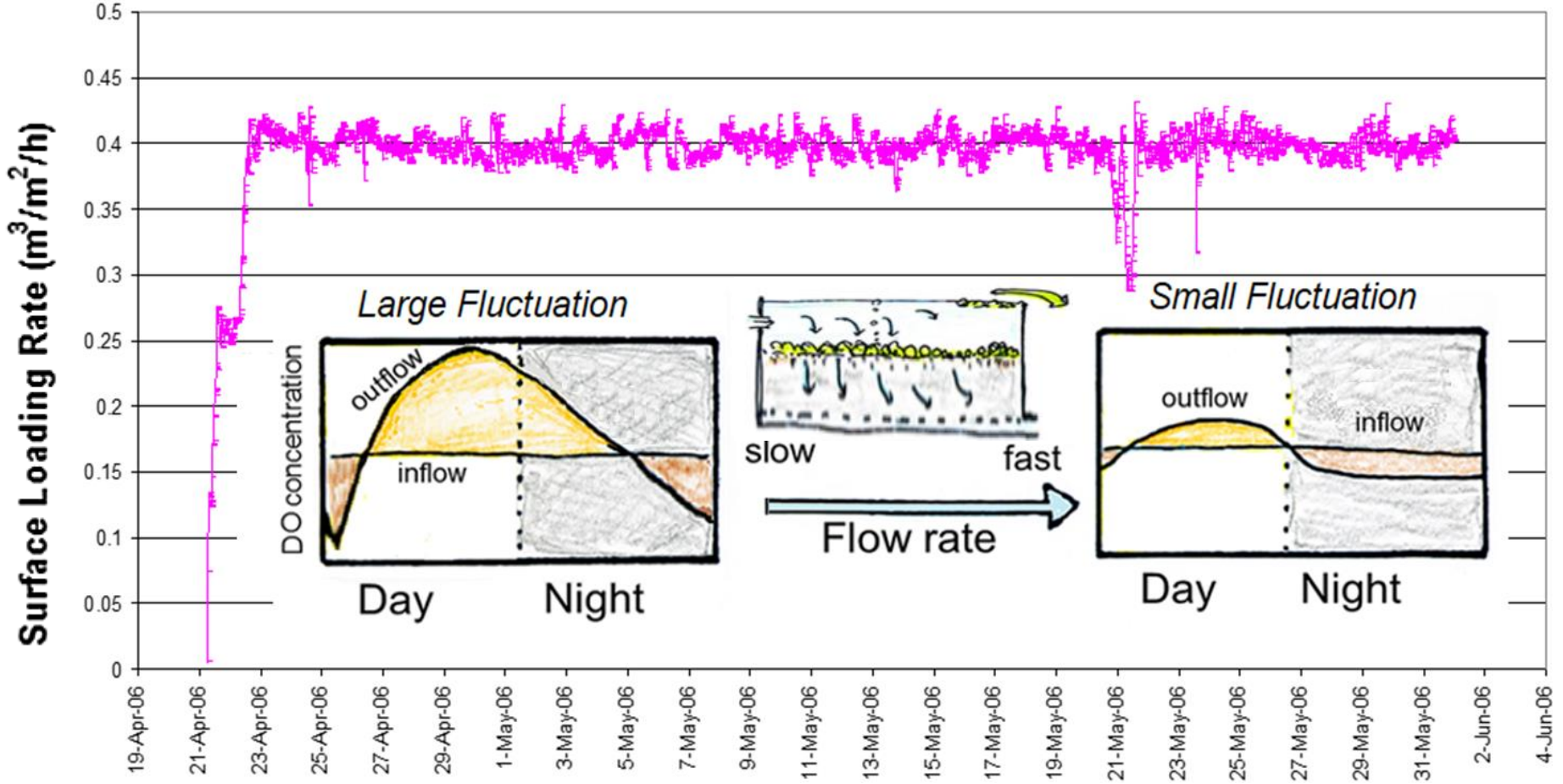


Temperature of surface water of reservoirs. Thames and Lee.

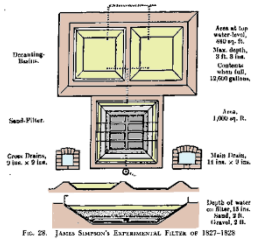


Diatom to Green algae in summer is due to grazing activity.

Surface Loading Rates for a SSF at Ashford Common during April and May 2006



Aerobic condition is essential for hetero-tropic organisms in the sand layer.



The filter rate was 2-3 m/d (10cm/h).

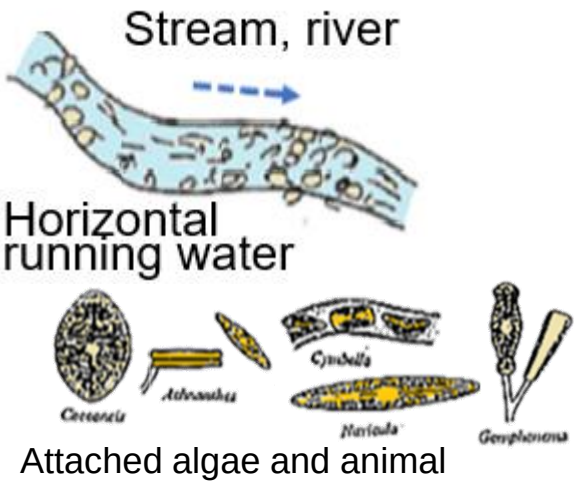
38cm water depth

200yrs ago

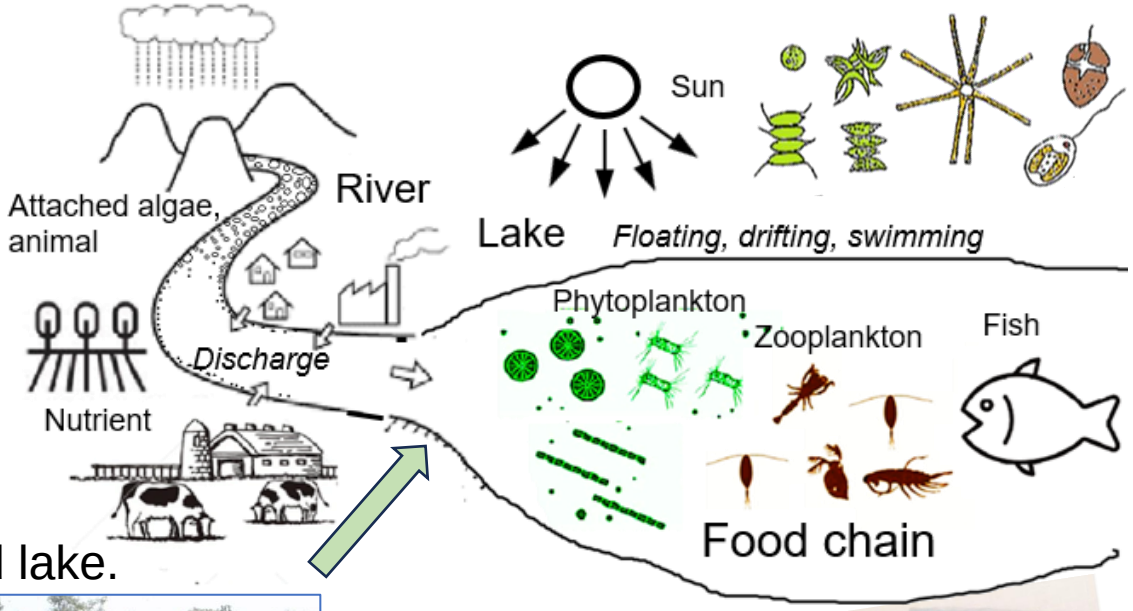
→ *4.8 m/d (20 cm/h)*
World wide English Standard Filter rate

→ 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.

Faster flow rate is better for small organisms in the filter.



Attached algae and animal



The boundary between land and lake.

There is a transition phenomenon. Suitable organisms grow at new environment.

All living things are in a hungry condition, always waiting for an opportunity to reproduce.

Clean delicious spring water

Clear subsurface water in a river bed

Dirty materials are broken passing through the soil or sand layer by biological activity.

Dissolved Oxygen is important.

Covered filter: Iizuna, Nagano, Japan from 1974(S49).

Covered filter from 1849, at Albany, NY, US
Microscopic organisms play an active role in the covered filter.

Made windows for solar radiation.

Biological activity was increased.
Filter resistance was decreased.

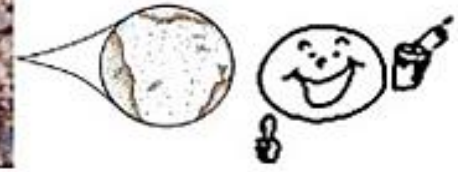
Covered filter: Otaru, Hokkaido, Japan from 1927

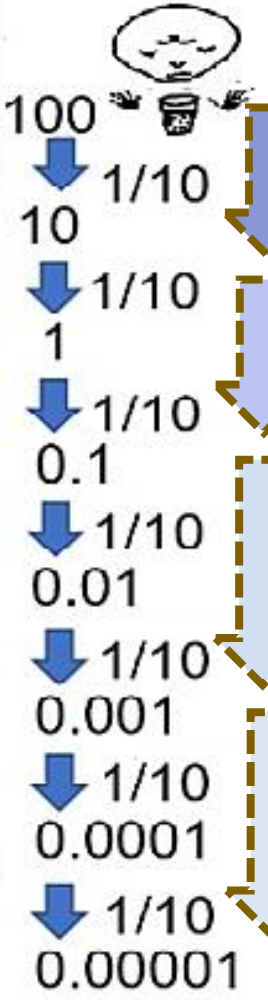
Organisms living on the surface and beneath it are not the same. Different creatures are active. Creatures that are suitable for that food will be active.

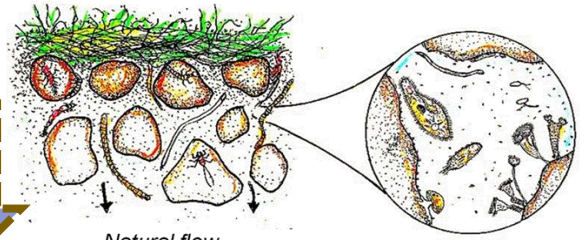
Vertical flow from top to bottom. The most important thing is that the sand does not move.

Different creatures

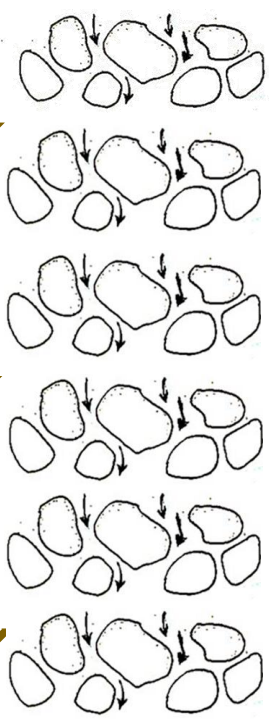
Different creatures





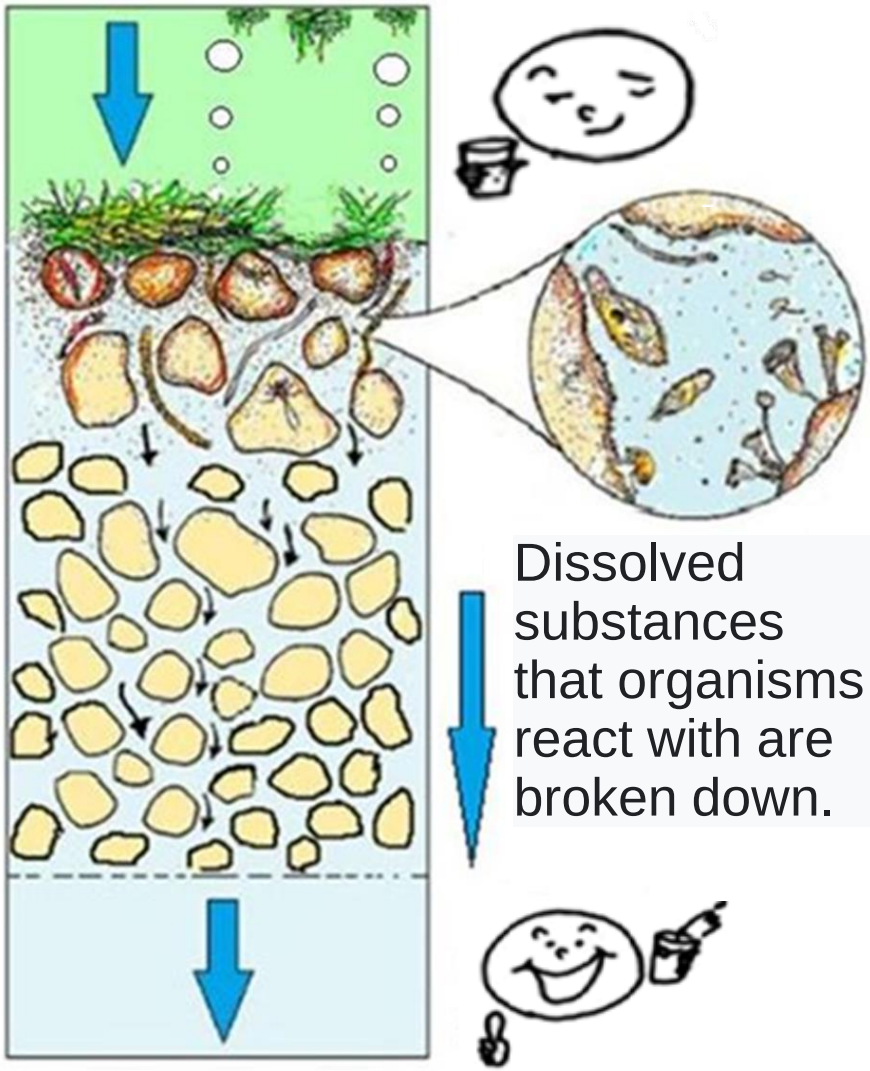


Natural flow



Microscopic organisms that attach to the sand surface can play an active role with peace of mind. Completely decompose things that can be biodegraded.

Purification by Biological Communities



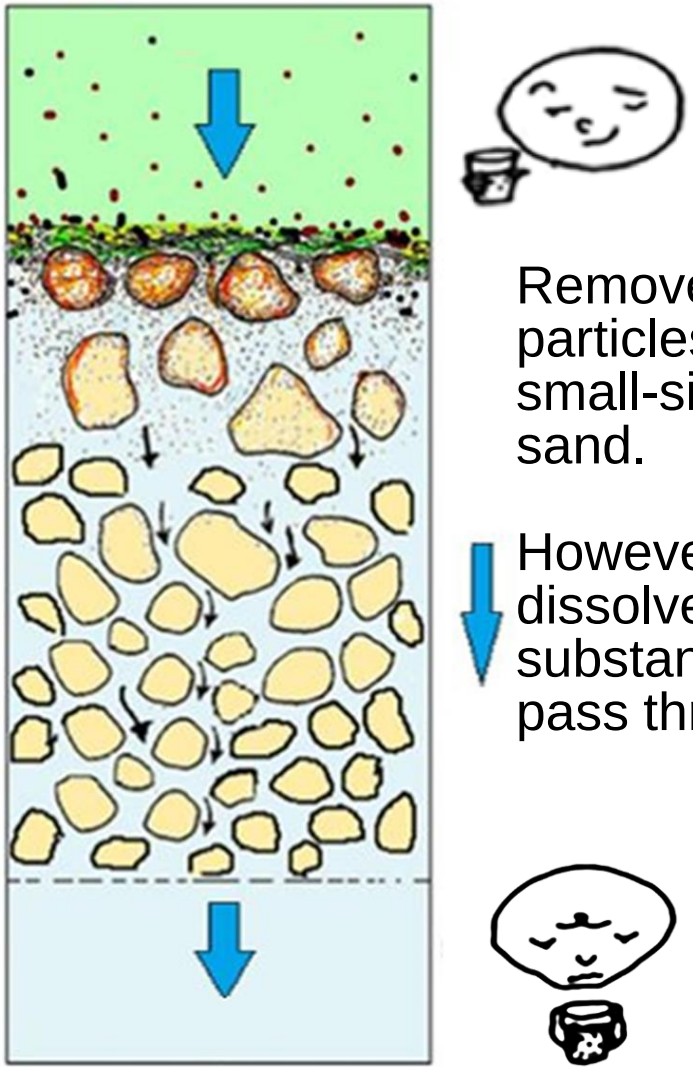
Dissolved substances that organisms react with are broken down.

Ecological Purification System

This is an ecosystem.

Algicide

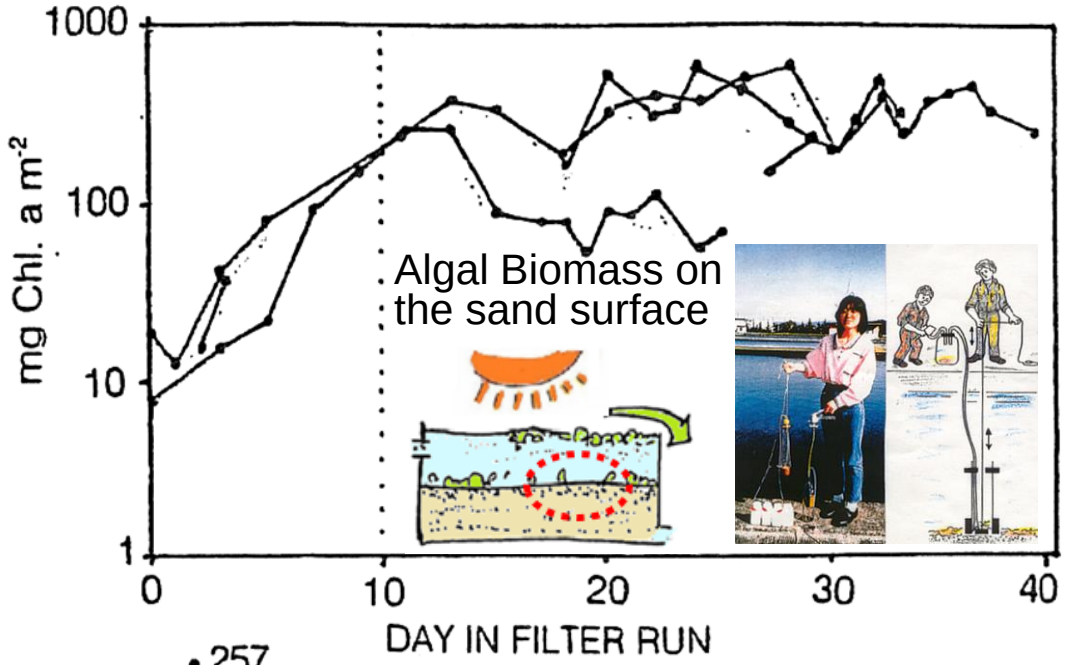
Slow Sand Filter Mechanical Filter



Remove turbid particles with small-size of sand.

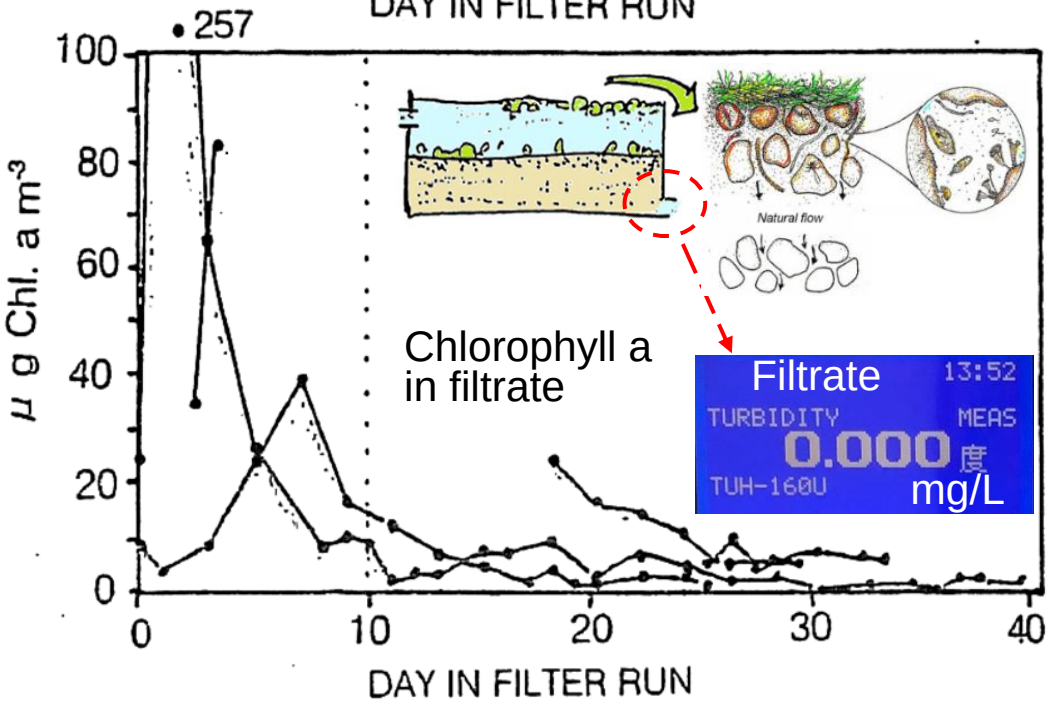
However, dissolved substances pass through.

Mechanical filtration by fine sand



Algae grow well in summer. Continuous culture system of filamentous algae becomes after 10 days.

In summer, scrapping of surface mud is not necessary.

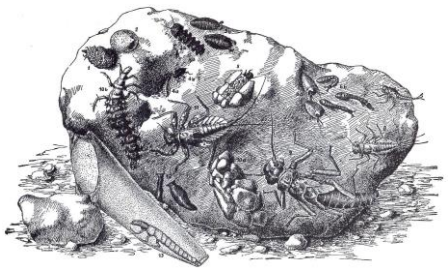


Filtrate water became clear water in 10 days. Grazing animal community grew well within 10 days.

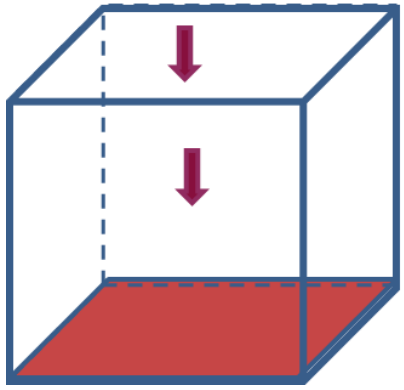
Japanese standard filtrate is 2 degrees (mg/L).

Super clean filtrate.

Most of small organisms live on the surface of substrata (sand particle) under slow current condition. They live at the top of sand layer where food comes. They are always waiting for food. They are hungry.

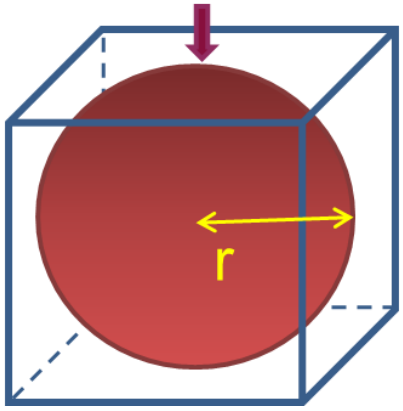


Large surface area is better. Small sand is better.

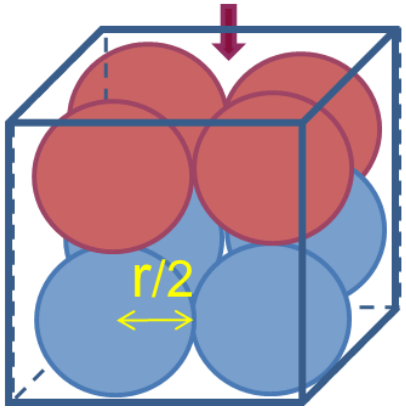


1

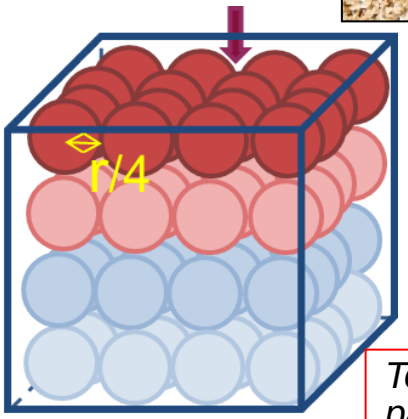
Bottom surface area



radius = 0.5
Surface area
= 4 x π x r x r



radius = 0.25
Surface area of one ball
= 0.785
8 balls in box = ***6.28***
Total area of top 4 balls



radius= 0.125
One ball area
= 0.196
64 balls in box =***12.56***
Total area of top 16 balls

Too small particle becomes a flat surface.

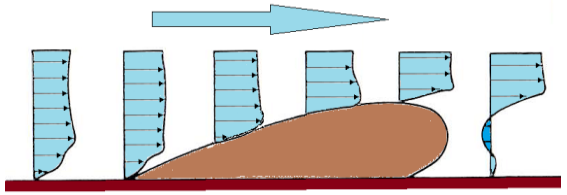
1 → ***= 3.14*** → ***= 3.14*** → ***= 3.14***

Surface area of a ball is 3.14 times than flat area.

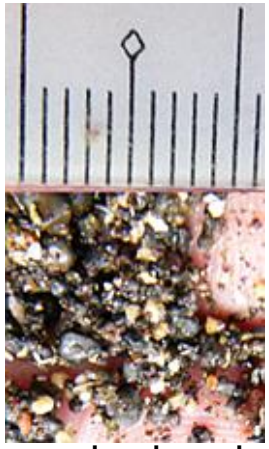
Total surface area of top layer of balls is always same of 3.14 times than flat area.
Smaller ball makes larger area.
And, total volume of balls is always same of 52 %
(porosity : 48%) in a box.

Filter resistance increases toward smaller size of particle.

Viscosity relates to temperature

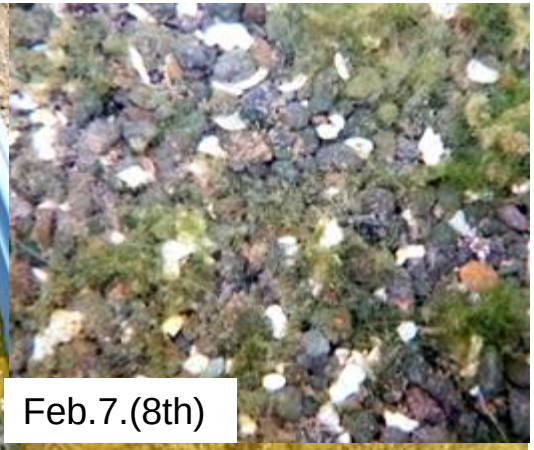


Points: shallow depth, enough radiation on the bottom, rapid growth, large size of sand.

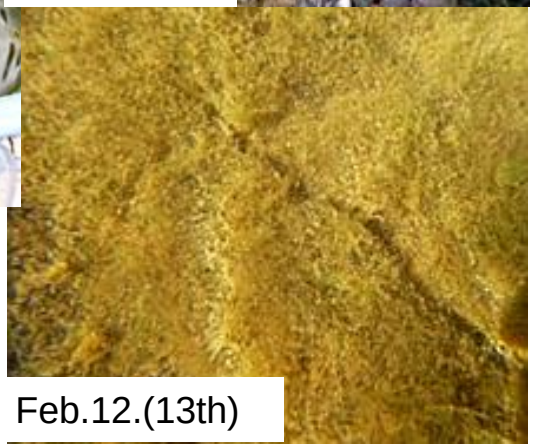


Sand washed and separated with mosquito mesh (1-2 mm)

Feb.14.(15th)



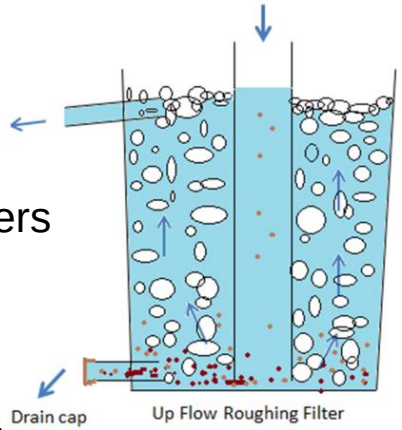
Feb.7.(8th)



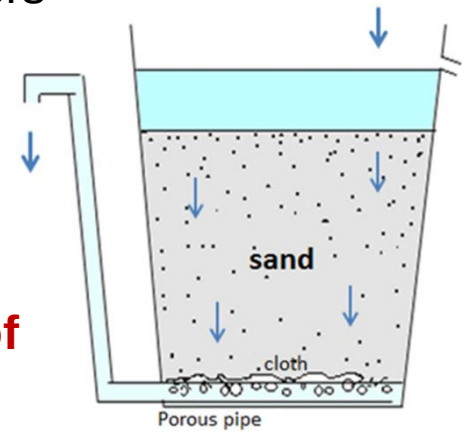
Feb.12.(13th)

Shallow depth:
Algae grow well

Two up-flow roughing filters

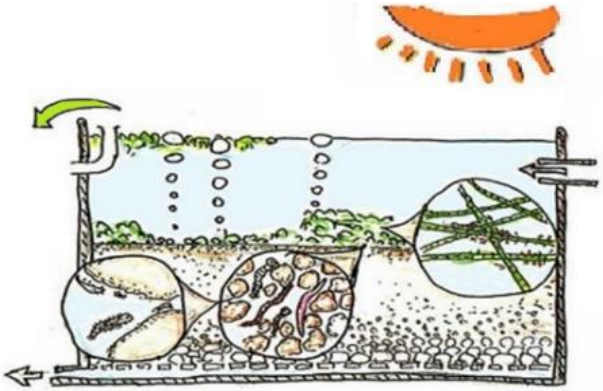


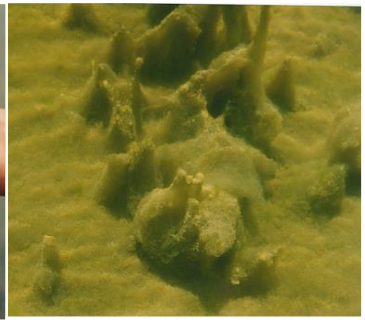
Sand filters (**5m/d, 10m/d, 20m/d**)

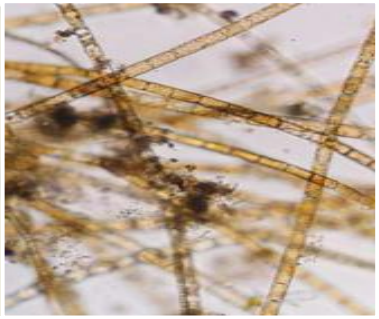


All good quality of filtrates.

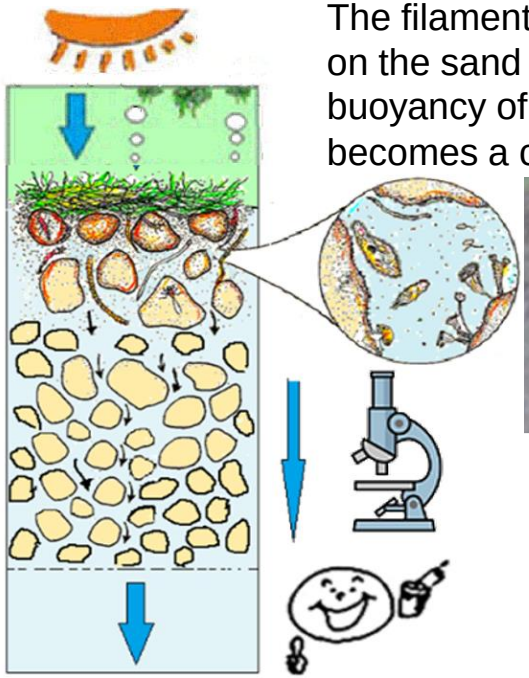
Large size of sand.







The filamentous diatom *Melosira* grows predominately and develops into a cotton-like shape on the sand surface. The algae mat floats along with the inflowing turbidity due to the buoyancy of oxygen bubbles caused by photosynthesis. Outflow from overflow pipe. It becomes a continuous culture system. It also serves as an automatic garbage collector.



Underwater the sand is clean and uncontaminated. ⇒The sand gets dirty because the water is pulled down.

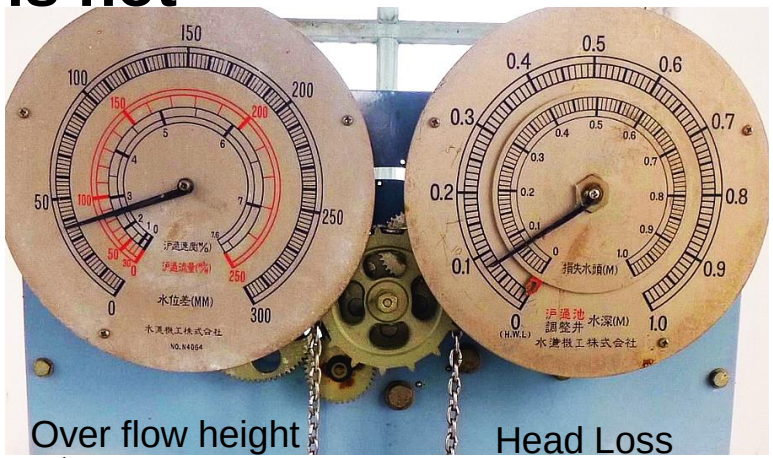
The sand layer is similar to the forest soil profile.
Food for organisms comes from the surface.

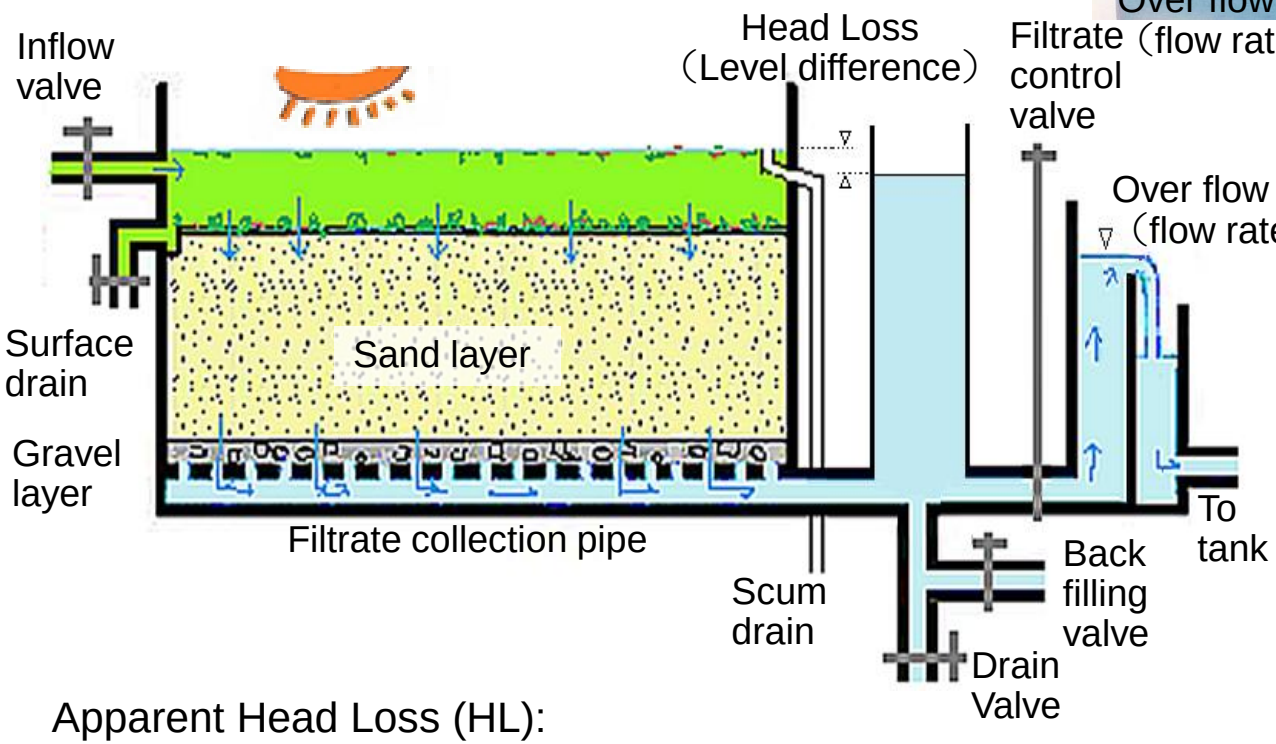
https://www.youtube.com/watch?v=1ixdARf3Tk0&t=15s

Slow Sand Filter Plant (EPS) in Ueda, and NHL (youtube.com)　4 min

https://www.youtube.com/watch?v=1ixdARf3Tk0&t=15s

Filter resistance：Actual head loss is not an index of filter resistance as it is.



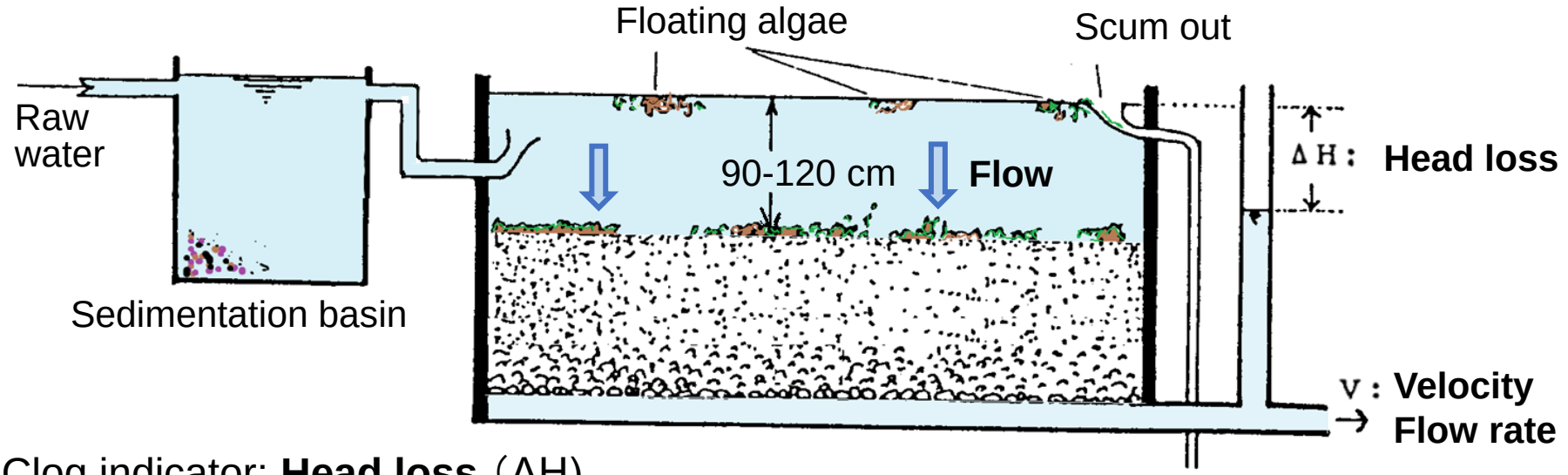


Head Loss relates to flow rate.

Head Loss is proportional to flow rate.

Apparent Head Loss (HL):
=This value is not an index of filtration resistance as it is.
Calculate HL when filtered at standard filtration rate.
= Normalized Head Loss

Clog indicator:
Head Loss (Filter Resistance) is proportional to flow rate.



Clog indicator: **Head loss**（ΔH)

Head loss（ΔH) is proportional to **velocity** (V).

$$\Delta H = kV$$

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

NHL(Normalized Head Loss ：Hn)

at normal flow rate can calculated by the actual head loss and the observed actual 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 (20cm/h or m/d)

Ueda Water Supply System from 1923,

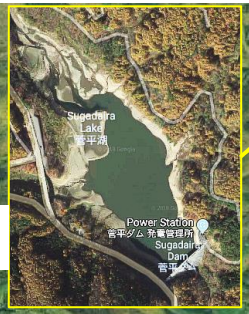
Someya WTP

Altitude 500 m

Original 3 filters was constructed in 1923

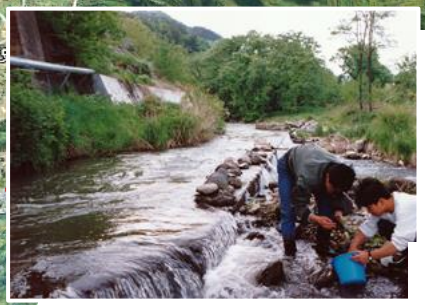
Sugadaira reservoir Construct in1968

Altitude 1,140 m



Ishifune WTP In 1969

Altitude 700 m



New intake of surface water for Someya WTP from 1953.

Altitude 600 m

underground water pipe:
4 km, using natural gravidity

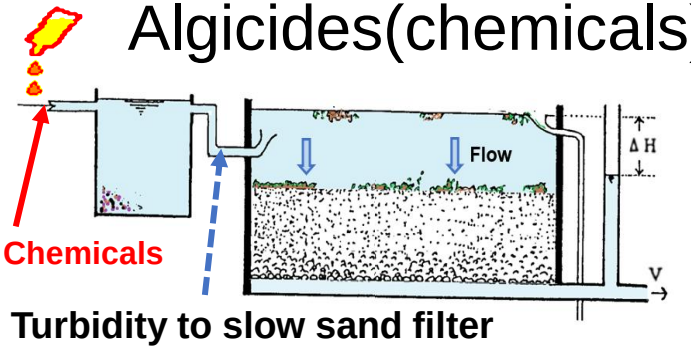
Original intake of subsurface water in 1923, pump up to WTP.

Chikuma river

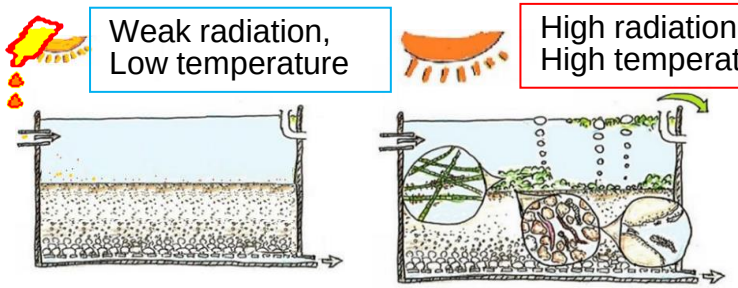
Pump up

Altitude 450 m

Algicides(chemicals) and filter resistance

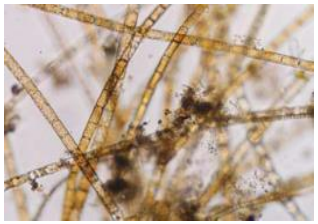


Turbidity to slow sand filter

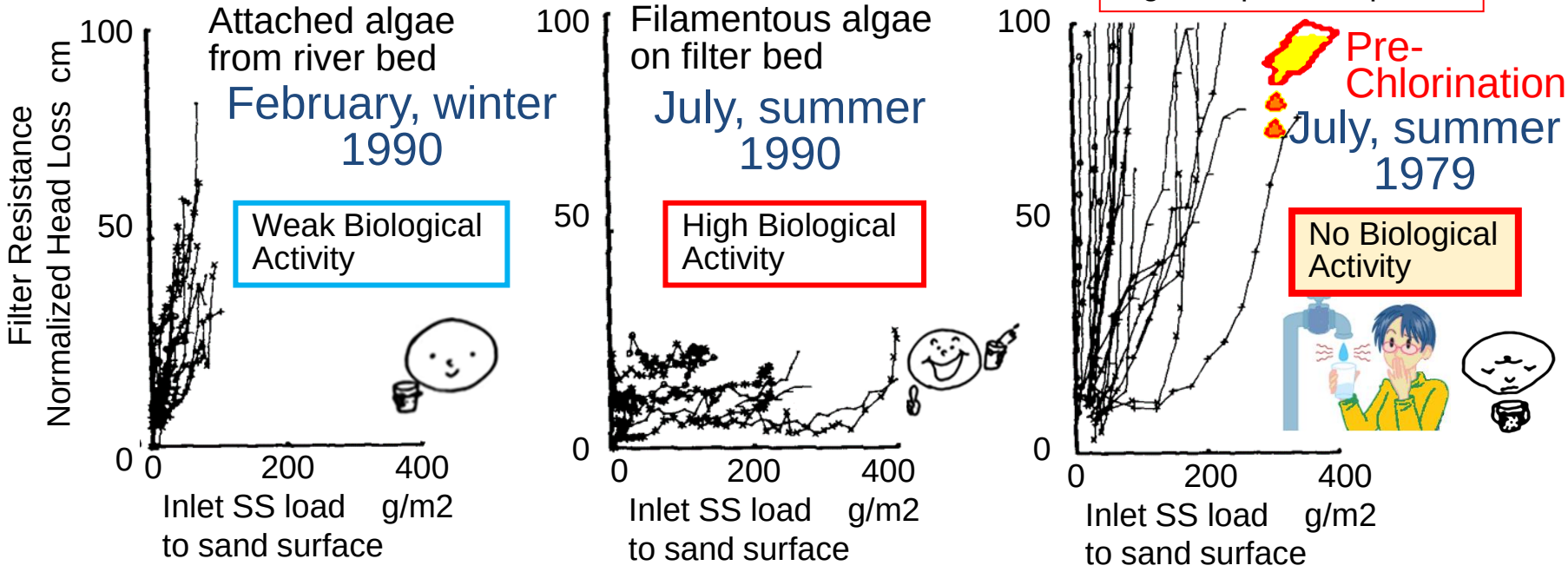


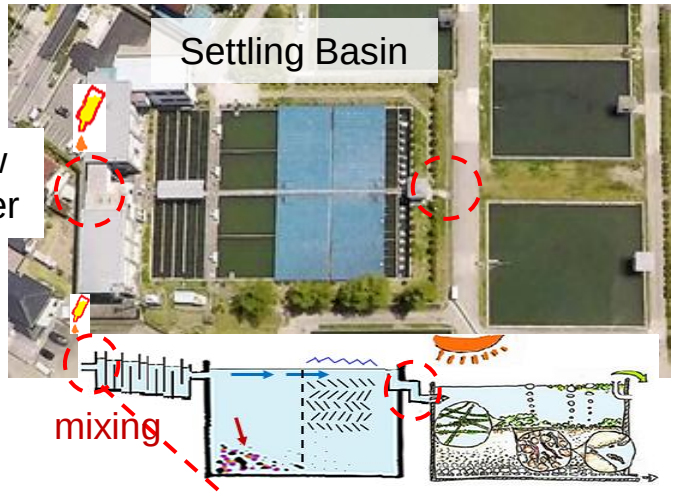
In rapid sand filter, it was common knowledge to add chemicals that biological communities dislike. Chemicals were also added during slow filtration in biological treatment.

At Someya Water Purification Plant, pre-chlorination and copper sulfate were added as algaecides to suppress algal growth. Then, the filters clogged easily. There was also a problem with the smelly tap water.



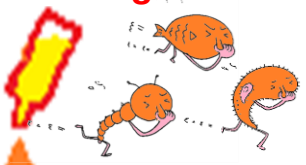
High solar radiation and high temperature period





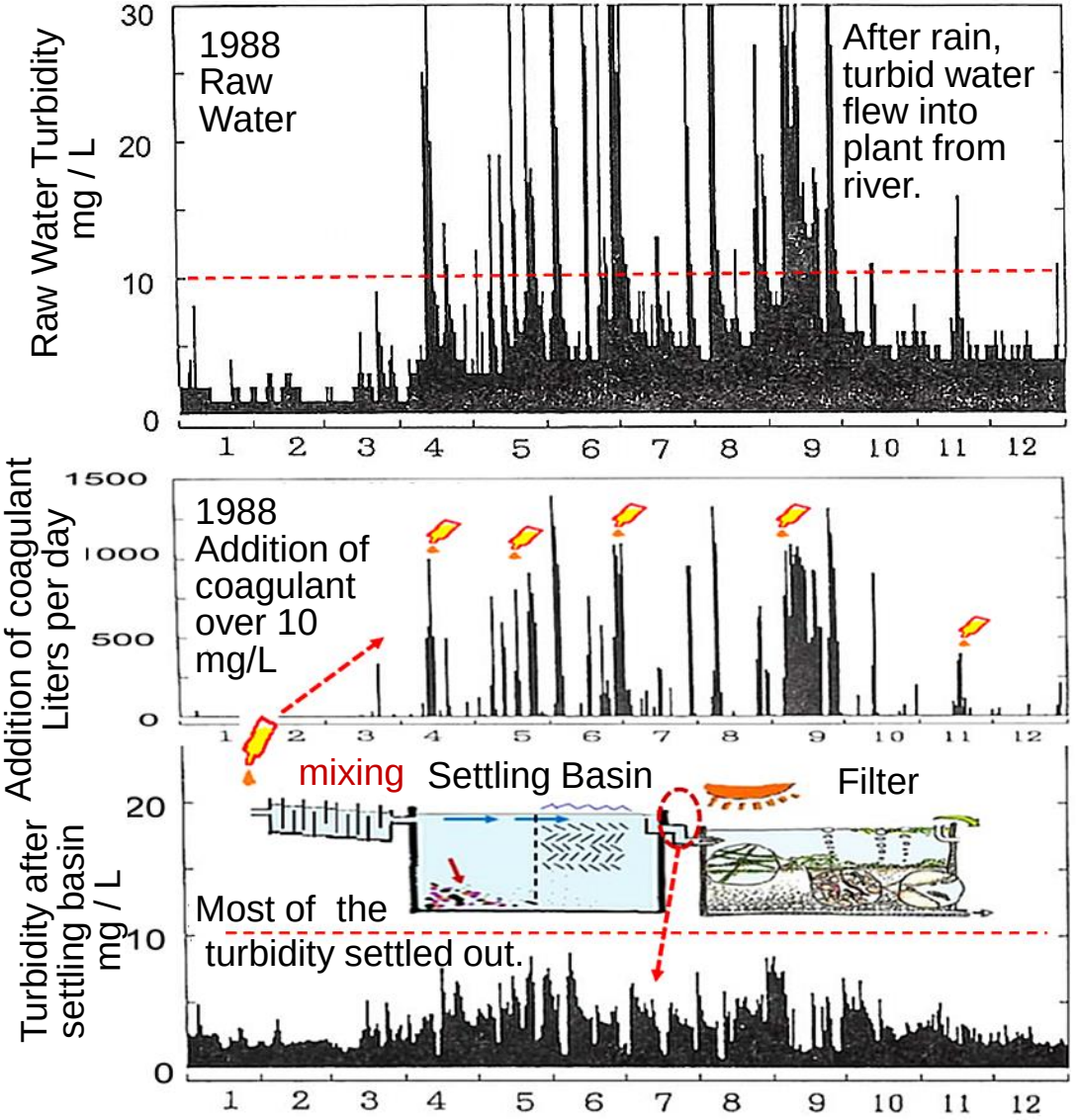
Algae grow even small turbid water

Addition of coagulant over 10 mg/L



Water became **clear** but algal mat **was covered with white powder.**

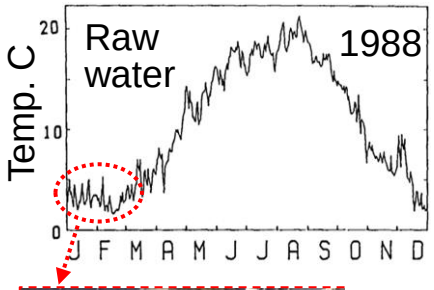
Stop algicide



At the Someya Water Purification Plant, even when turbid water came, the turbidity of the inflow water to the filter was reduced to below 10 degrees due to the sedimentation basin alone.

In Japan, a mountainous country, settling tanks are sufficient and flocculants are not necessary.

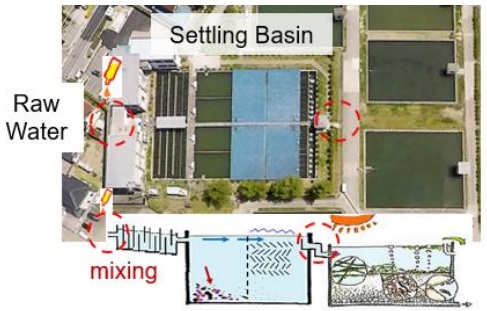
Filtration resistance is related to water temperature, water viscosity and biological activity.



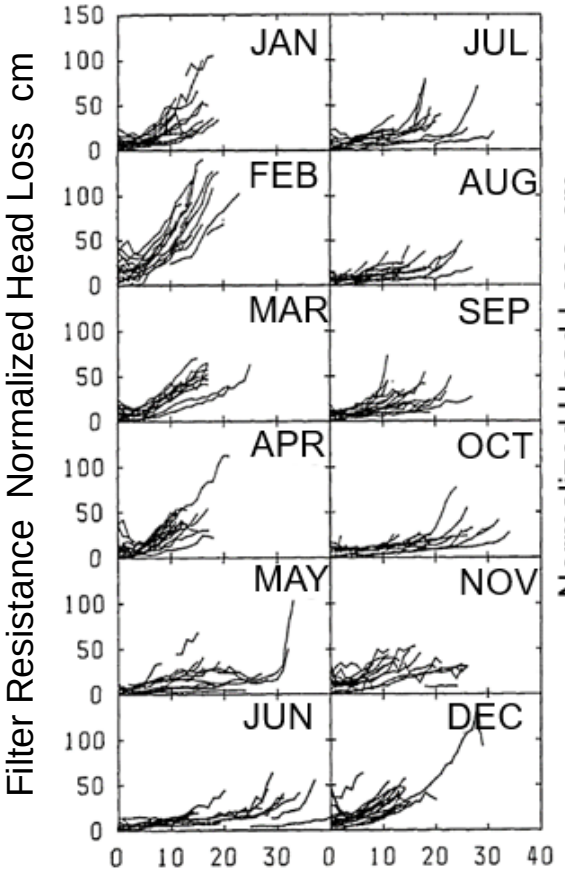
The water is heated in 4km of underground water pipes.

During the coldest months, the water surface of the filtration pond freezes.

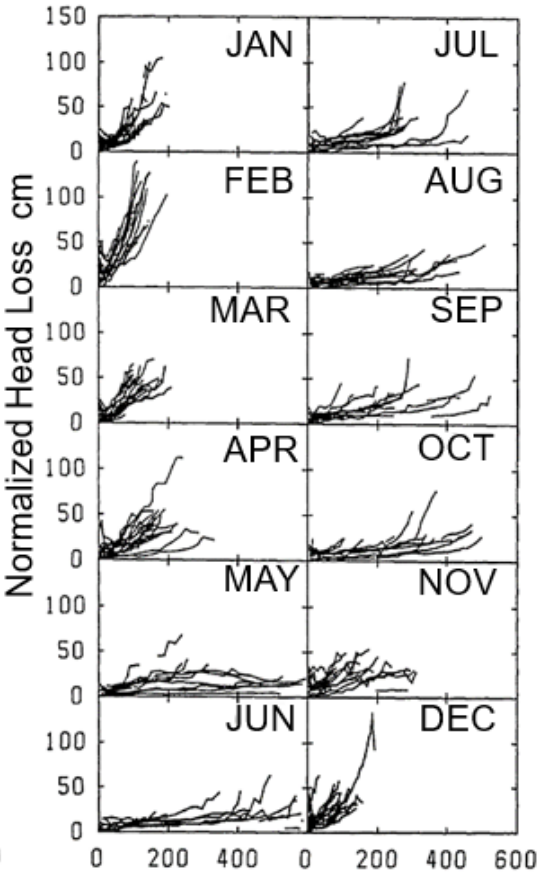
Biological activity is low during the coldest months.



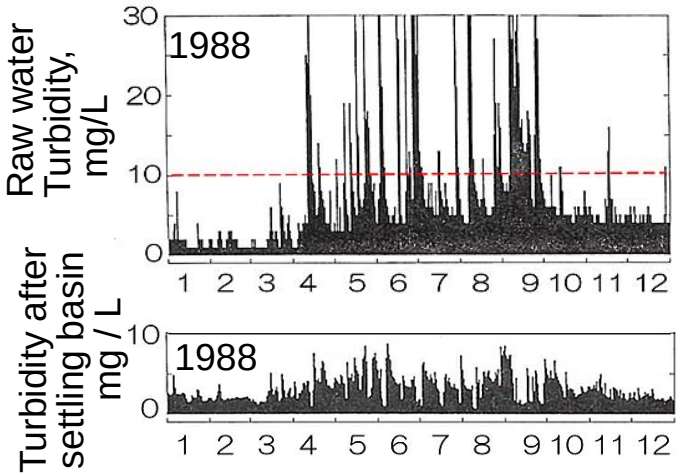
And the viscosity of water is high, so resistance increases.



From May to November, when algae begins to grow in the filtration pond, the resistance does not increase.



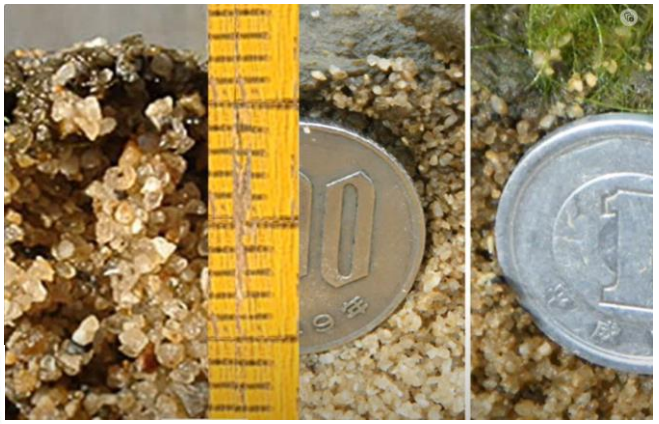
When algae began to grow, resistance did not increase even when turbidity entered the filtration pond.

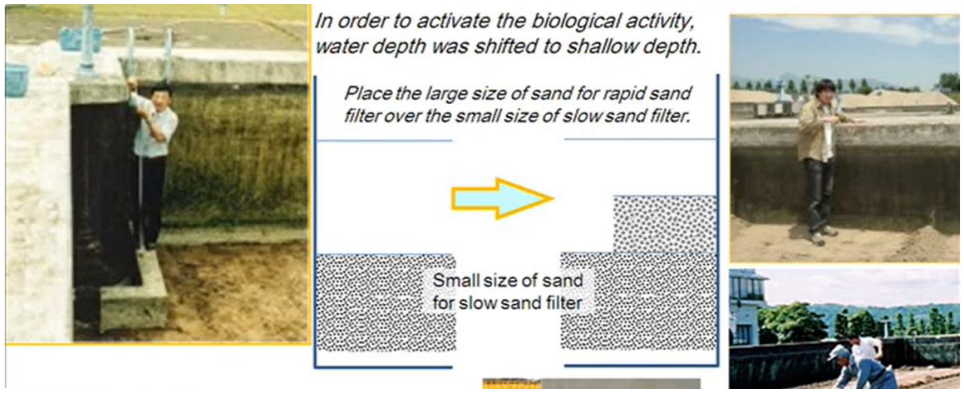


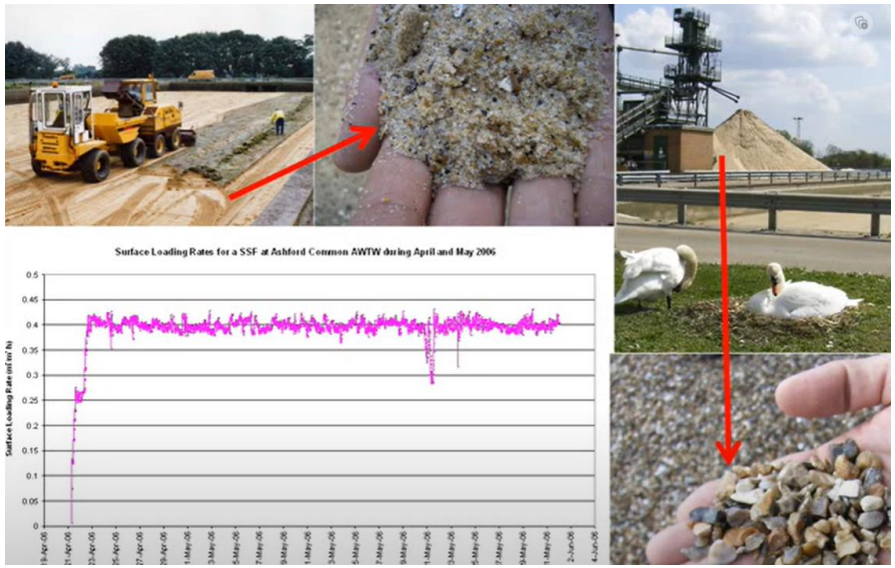
If biological activity is good, filter resistance will not increase even if mountain river water becomes cloudy.

Water depth is the key.

Sand size is not so important.







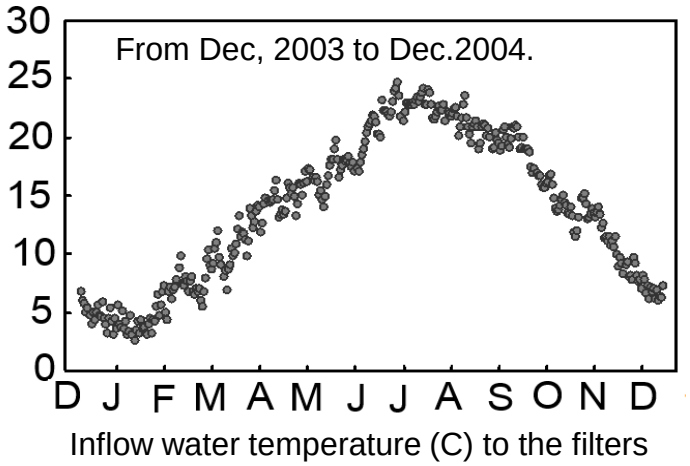
Shallow depth accelerate biological activity.

6 min

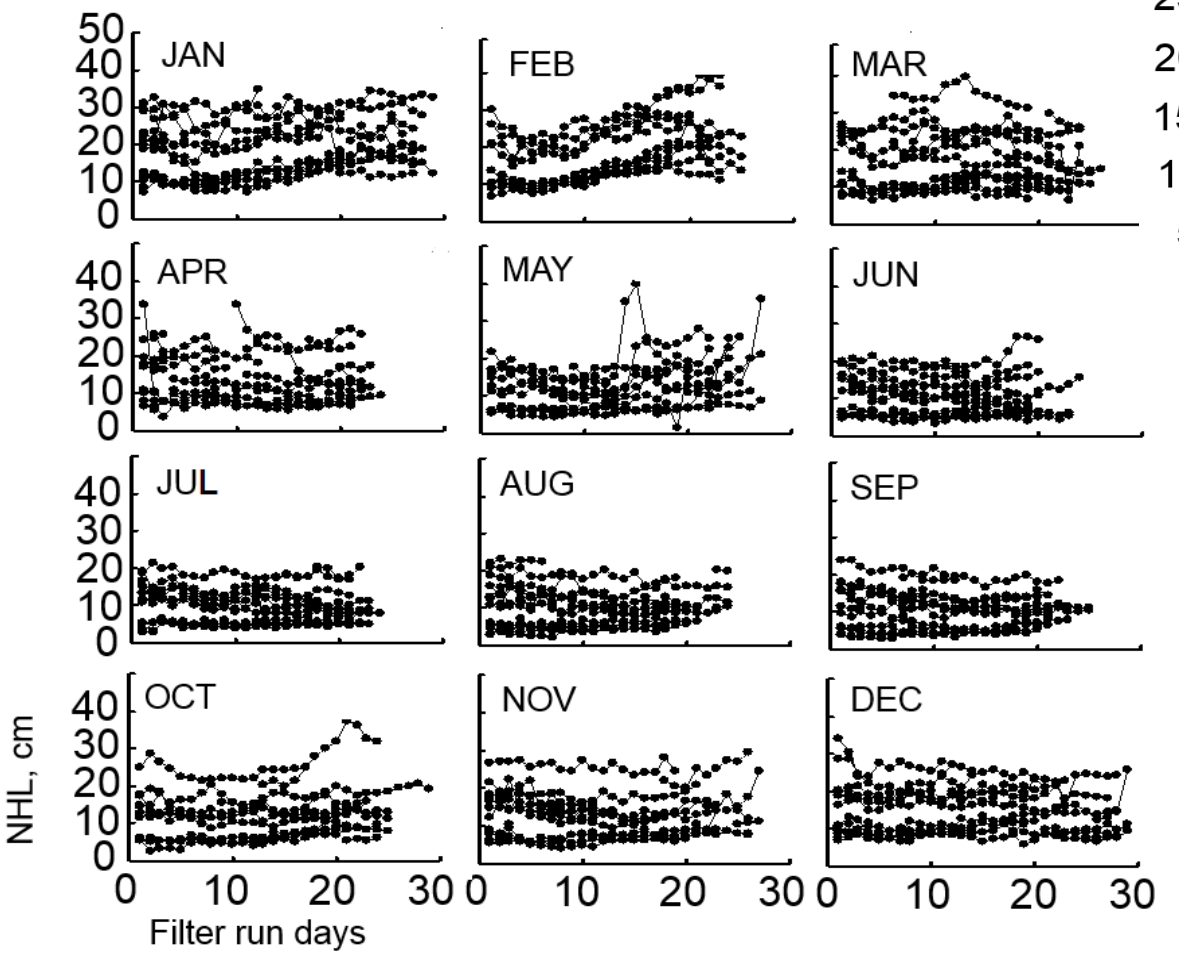
https://www.youtube.com/watch?v=4toIA05VYF8&t=1s

Wakata plant, Takasaki city, Gunma, Japan

Surface water of river → Sedimentation basin → Slow Sand Filter



Inflow water temperature (C) to the filters

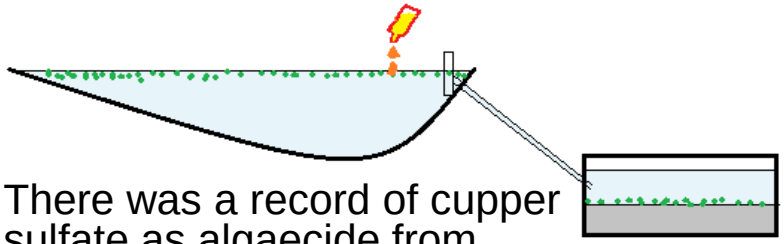


Filter does not clog in all the year.

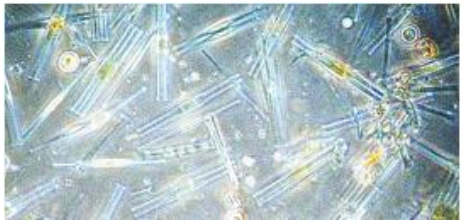
The water surface of the filtration pond does not freeze.

Resistance did not increase even in winter.

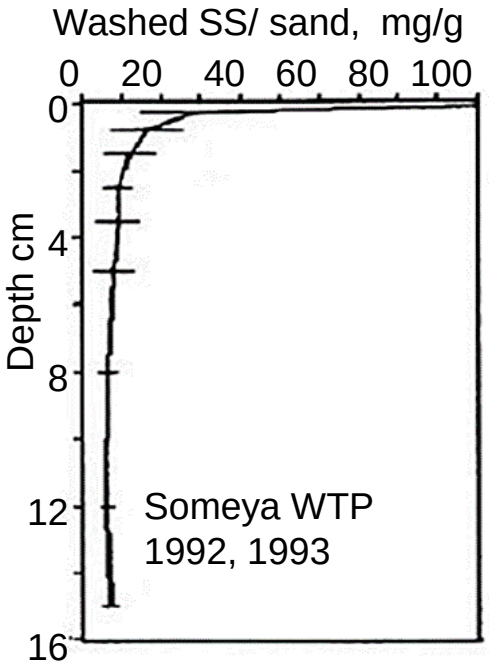
It may be related to biological activity.

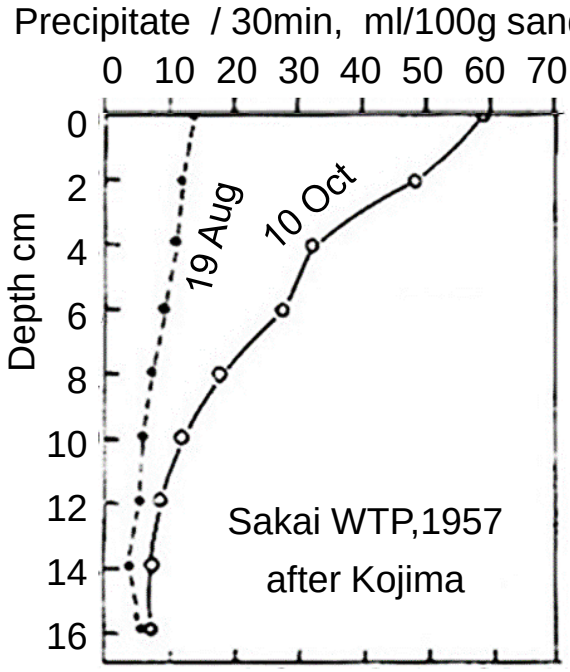


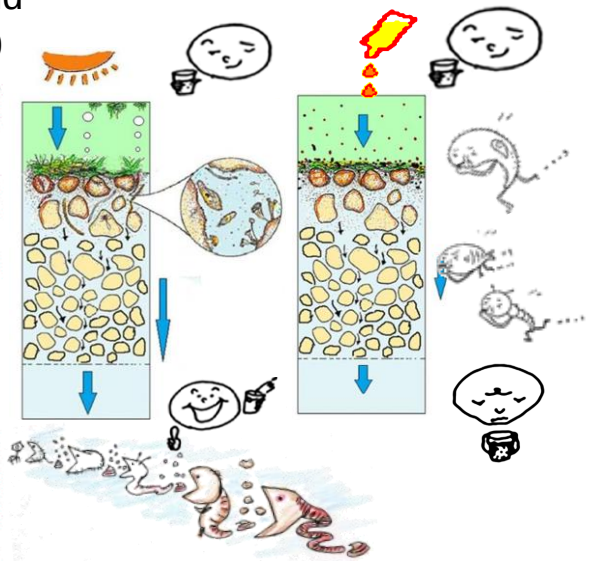
There was a record of cupper sulfate as algaecide from 1928.



Phytoplankton from the reservoir is just accumulated on the filter bed. There is no growth of algae in this filter due to the influence of algaecide in the reservoir.







Microscopic organisms is very sensitive to small amount of toxin.

If living organisms cannot play an active role, the sand layer becomes contaminated deep down.

Natural sweet spring water

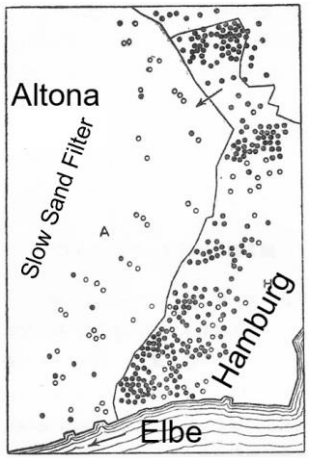
감로수 Sweet drop water 甘露水

Natural springs and rainwater are usually sweet and delicious.

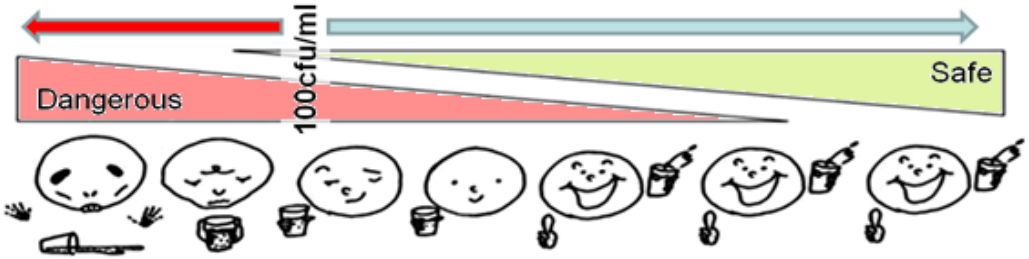
Rain harvest tank

Tap water is for drinking water.
But people don't drink water directly from the tap.

Something wrong.



Dr. **Robert Koch** found in **1892** that when bacterial counts were less than ***100 colony-forming units per mL*** (cfu/mL), epidemics of cholera and typhoid were reduced.

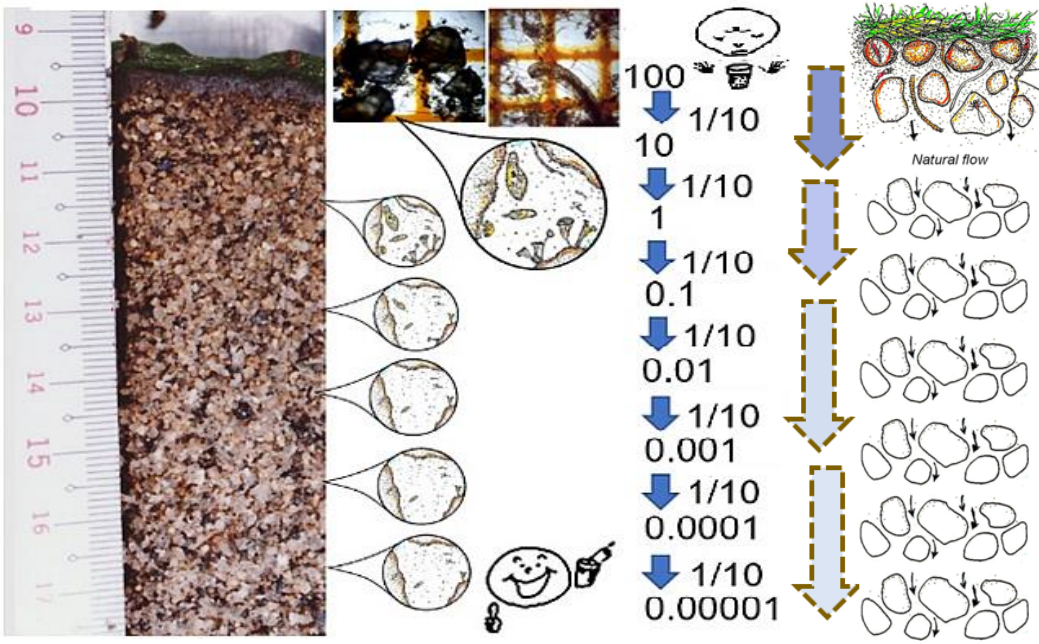


Present WHO safe standard for bacteria is referred to this 100 cfu/mL by Dr. R. Koch.

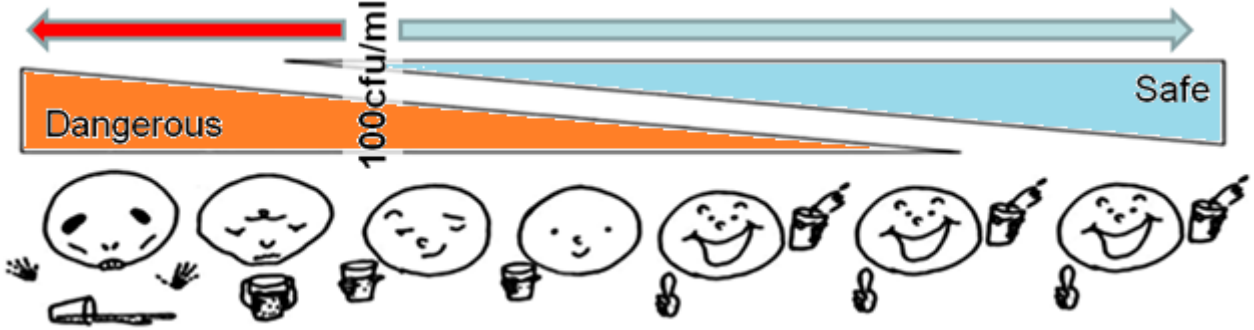
*This idea is so called **Acceptable Risk.***

Organisms living on the surface and beneath it are not the same. Different creatures are active. Creatures that are suitable for that food will be active.

How to reduce the risk.
Wash our hands!



We have to think about acceptable risk.



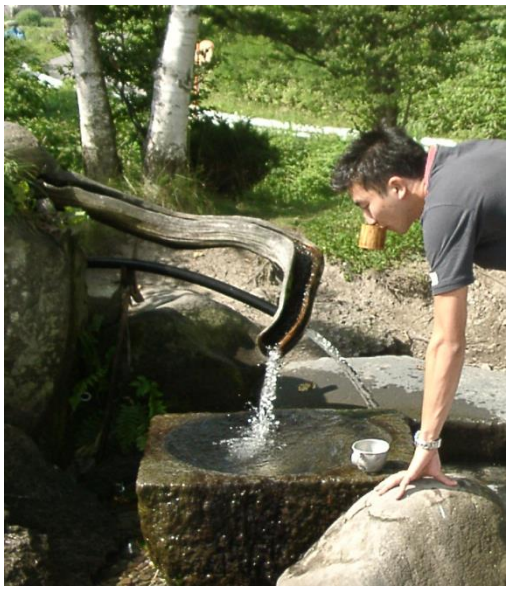
General bacteria: many in the natural environment

Group of coli-form bacteria : an indicator of pollution: many in the natural environment

Escherichia coli : indication of intestinal bacteria.

Fecal *Escherichia coli* : an indicator of fecal contamination of mammals.

Pathogenic bacteria



There are so many bacteria.→Medical doctor touches with patients. Doctor is safe.

Logarithmic bacteria number in 1 ml

100,000,000	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	0.00001
10^8	10^7	10^6	10^5	10^4	10^3	10^2	10^1	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}

General bacteria | soil | Coli-form bacteria | Fecal Coli-form | **Germ : Cholera**

Coli-form bacteria are abundant in soil and are not germ bacteria.

Wash hand

General bacteria | water | Coli-form bacteria | Fecal Coli-form | **Germ : Cholera**

Please compare the size and number of Cryptosporidium with bacteria in water. Risk?

Risk of germ bacteria in water.

Elimination **by chemical**

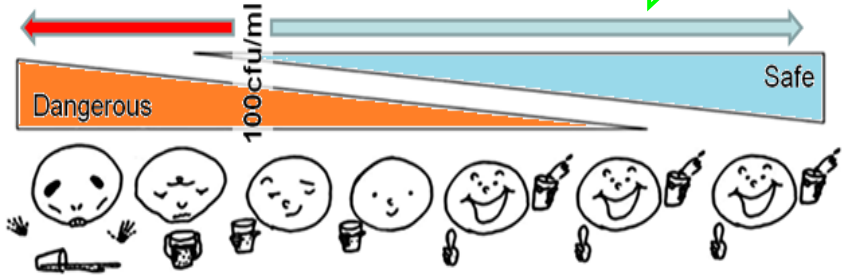
General bacteria | RSF | Coli-form bacteria | Fecal Coli-form | **Germ : Cholera**

Sterilize by chlorine

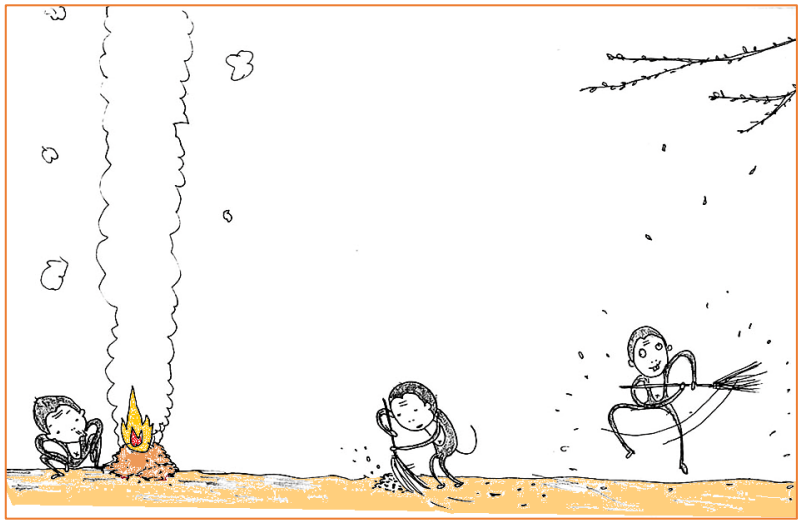
Toxicity of chlorine?

Elimination **by biological community**

General bacteria | EPS (SSF) | Coli-form bacteria | Fecal Coli-form | **Germ : Cholera**

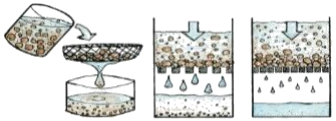


We have to think about acceptable risk.

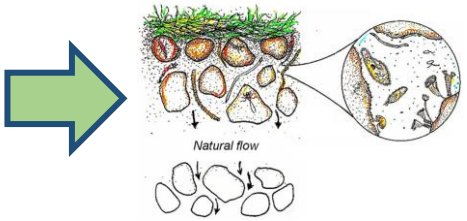


Burn out: change　Collection　Dilute

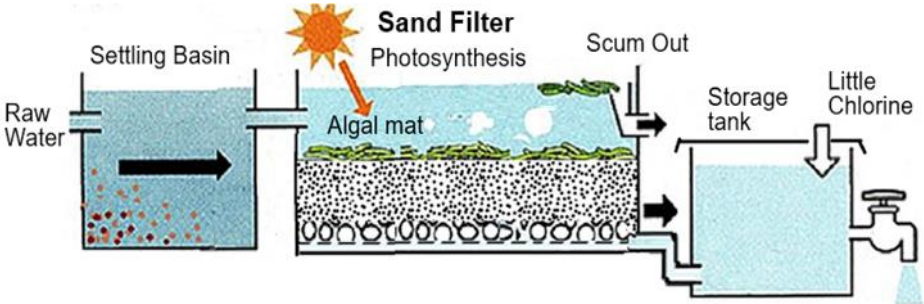
What is real purification?



Original Image of Slow Sand Filter.

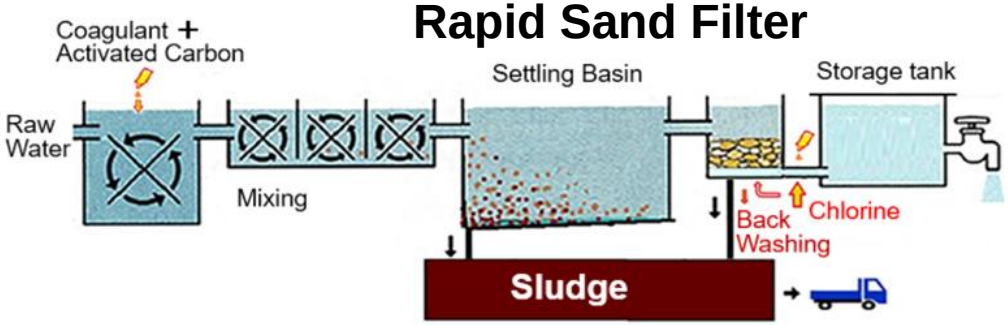


Ecological Purification System

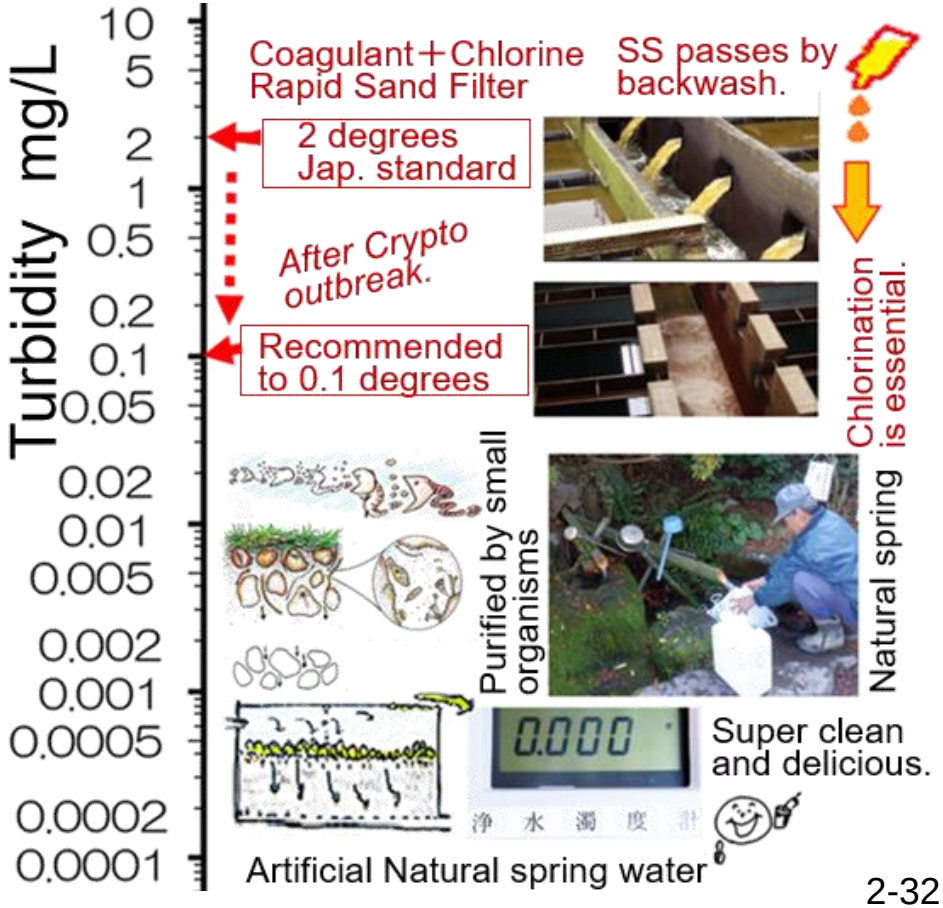


Biological Purification without chemicals

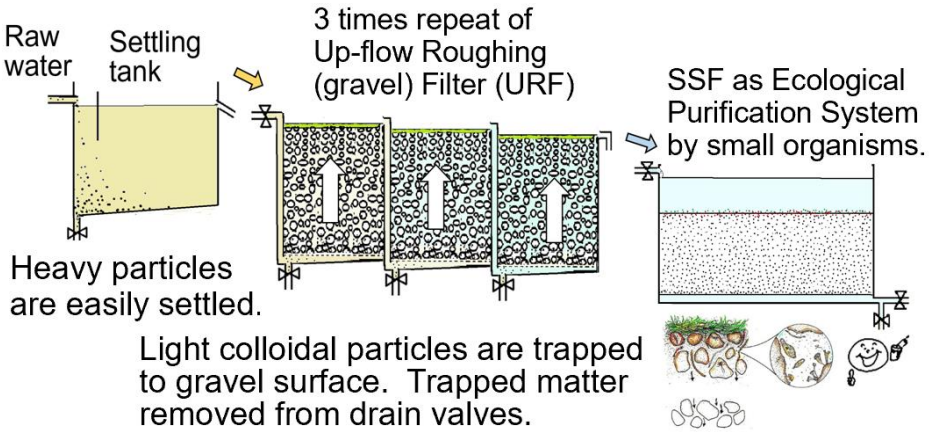
Rapid Sand Filter



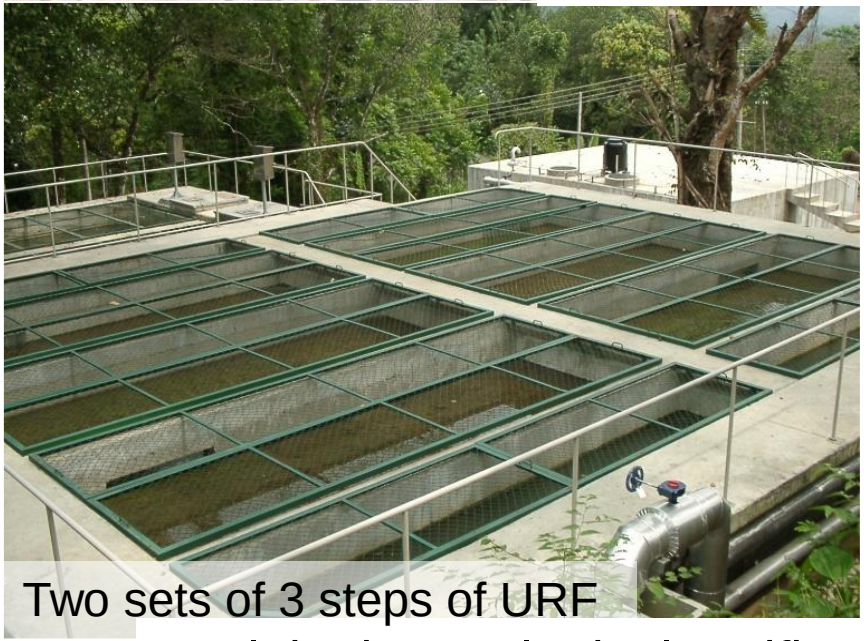
Shift to non-detectable.
Are these really acceptable?



I advised new Water Purification plant to a national hospital, Sri Lanka by EPS in 2001.



Turbid reduction by Settling tank and URF without chemicals.


Two sets of 3 steps of URF

Explain the ecological purification mechanism of chemical free system.
Manager said "Conventional is a commercial filter. This is a natural filter".

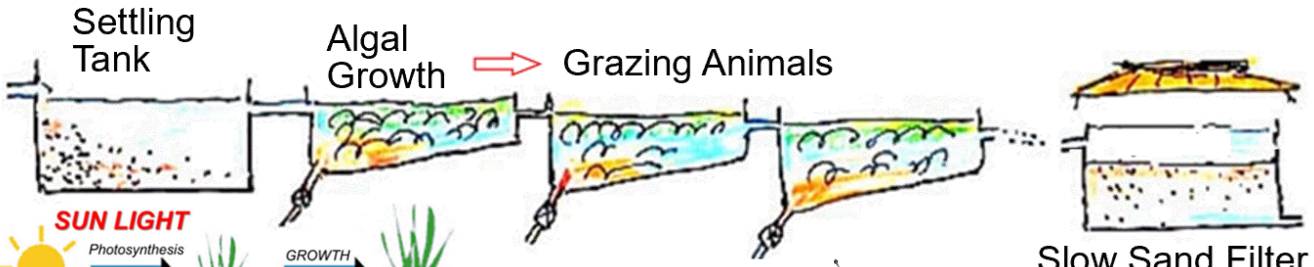
Yamaha provided Safe Water to Villagers as Social Contribution in Indonesia in 2001.

Villager maintains over 10 years by themselves.

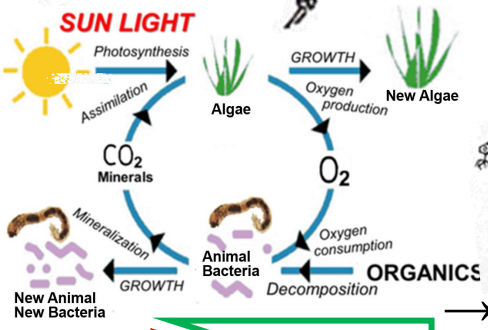
Public tap system

Tap keeper collects money of filling the bottle for the maintenance cost of the plant.

Two bottles of 20liters per 1 family. This water is used for drinking and cooking only. This water is not used for bath and washing hands. Diarrhea and eye sickness are disappeared.



YAMAHA clean water system to the world.



Food Chain

Acceptable Risk

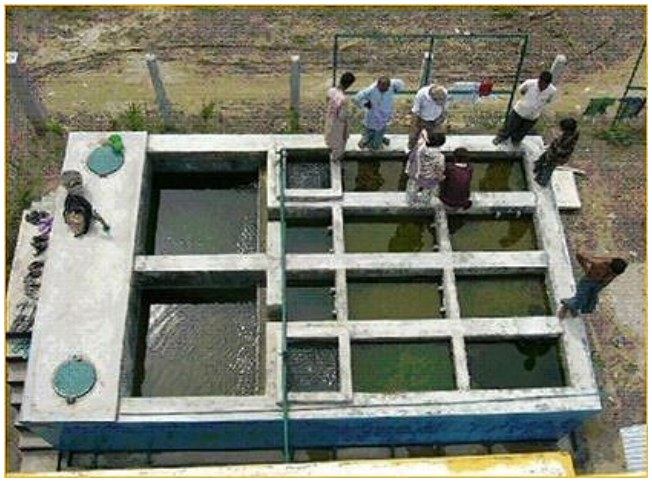
→Health village

→Sanitary sense and its level are distributed to the villagers.

→This acts to protect against sickness.

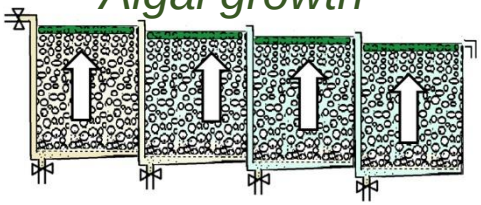
EPS for safe drinking water in arsenate contaminated Bangladesh in 2004.

Surface water is polluted and ground water is contaminated with arsenate in Bangladesh.

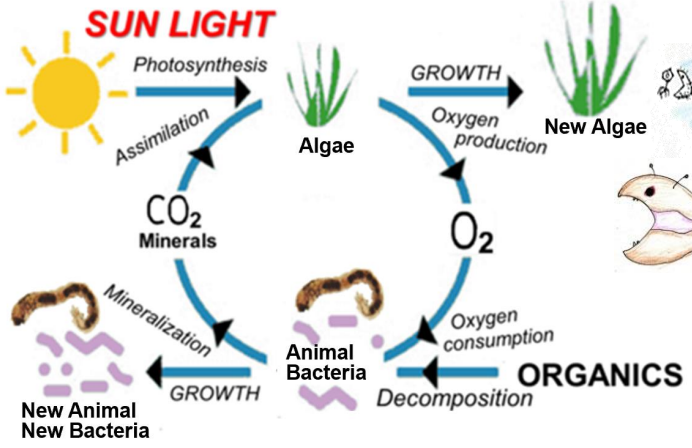


Local staffs of Asia Arsenate Network understood the EPS mechanism.

Algal growth



Repeat URF to decompose herbicide.



Mr Mizan sent me photos. They made new EPS in Sylet, Bangladesh by themselves, by UNICEF fund.

Complete decomposition (mineralization) in the faecal pellet.

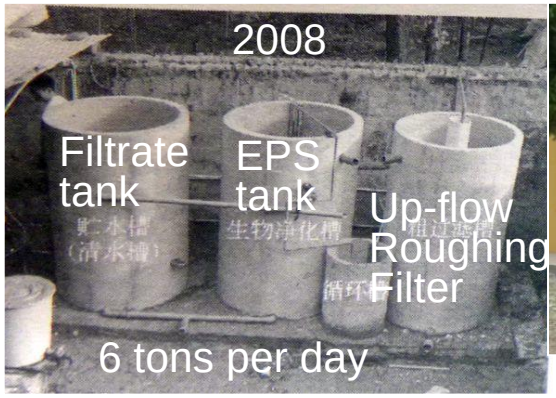
Anaerobic condition in fecal pellet.

Mr. Jin Shengzhe, translator of Chinese version of Japanese EPS manual, made three EPS plants in China in 2008 after the great earthquake.

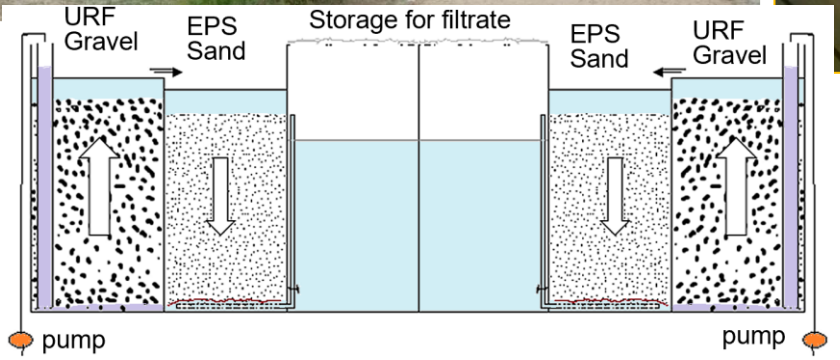
Aug. 2005.

May 2009.

2008 Huo Dai Shan, Shenqiu county, Henan province, made contaminated groundwater safe to drink under the guidance of Jin Shengzhe. Since then, water purification systems have been constructed in over 40 locations.



Mr. Jin said that there is a saying in China, “Accumulate virtue 積善積徳."



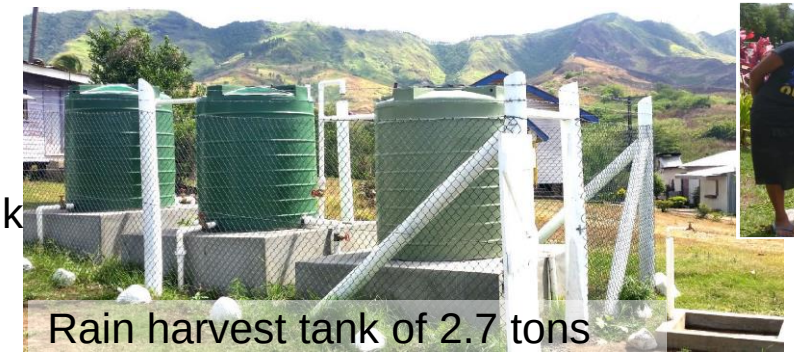
May 2016.

Mr. Vishwa Jeet from Fiji learned EPS from JICA training in Okinawa in 2011.

2011.8.Miyakojima Island

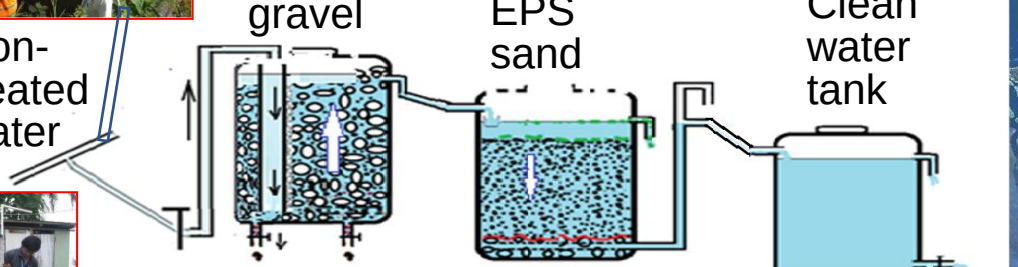
Jan. 2013. Project opening seminar on Safe drinking water for all villagers by EPS in Fiji.

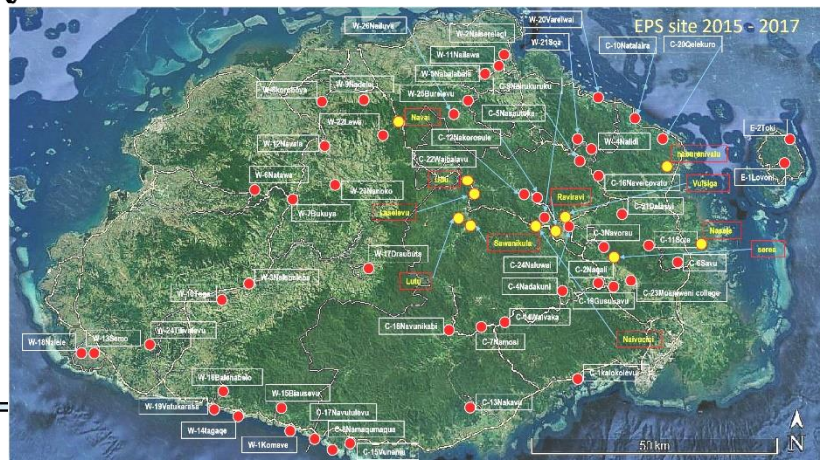
Present storage tank



Rain harvest tank of 2.7 tons

Non-treated water





EPS plants were completed from 2014 to 2018（4 years).

I contributed as short term expert (2 times of 1 month per year).

Cava ceremony

I cannot say chlorinated water.

Public taps

Reduce the risk

From 2006 to Samoa JICA Okinawa project :

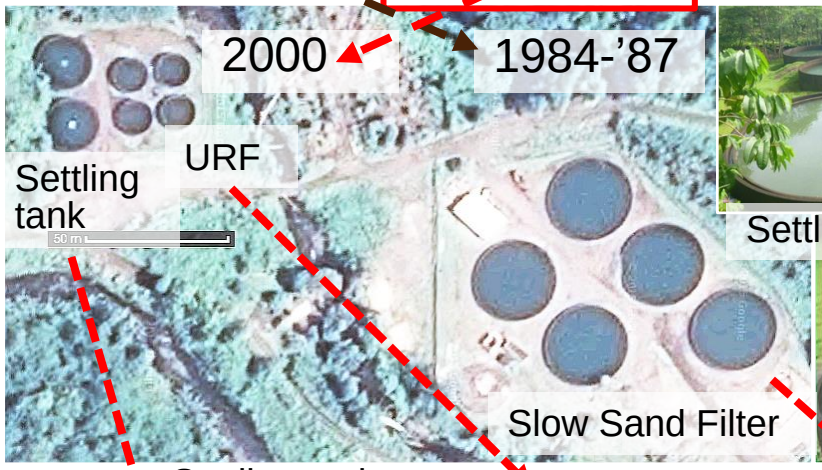
Increase biological activity and help improve maintenance and management.

1984-’87 SSF by Germany

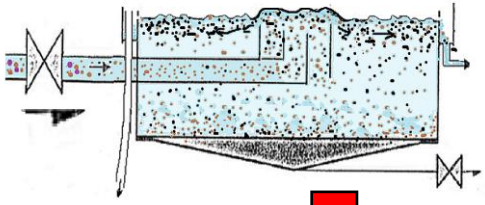
2000 Settling and URF b Germany

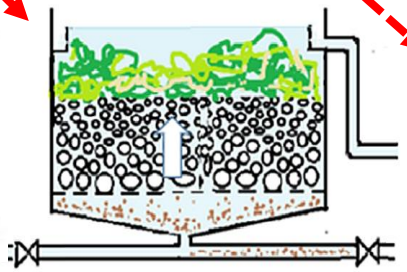
2006～JICA Miyakojima

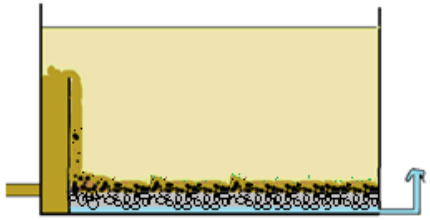
2010～JICA Miyakojima⇒All Okinawa Advice EPS, Water system

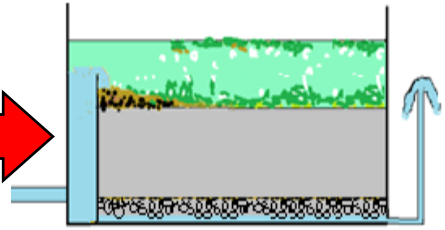


Settling tank



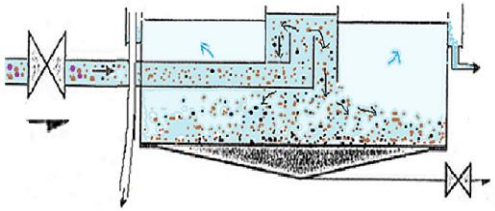




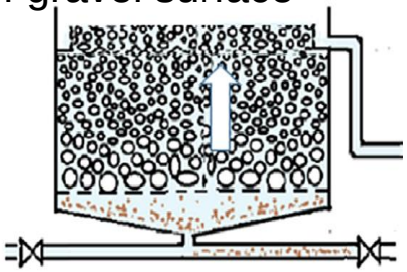


Deep water depth ⇒put sand ⇒shallow depth ⇒increase algal growth ⇒increase EPS function

Reduce inflow ⇒Easy to settling

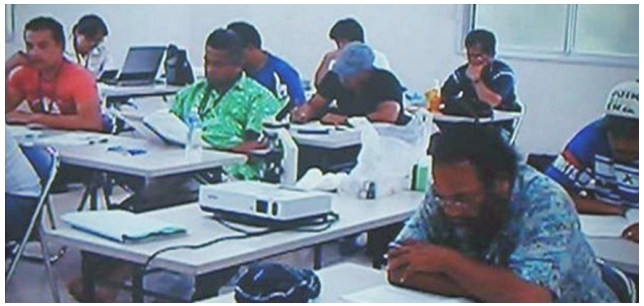


Put more gravel ⇒Increase area of gravel surface



Samoa Water Authority began to make EPS plant for villager by themselves from Nov. 2019.

I started JICA training on EPS in Okinawa from 2006.



At the end of the six-week JICA training in Okinawa (September 1, 2010), Ms. Marista from the Solomon Islands, gave a speech of thanks on behalf of the trainees.

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.

International Course on Slow Sand Filter in Okinawa, in 2010 by JICA – YouTube / 6:08

https://www.youtube.com/watch?v=c3mVIbmFPqA&t=138s

You can deepen your understanding through outdoor experience rather than classroom lectures.