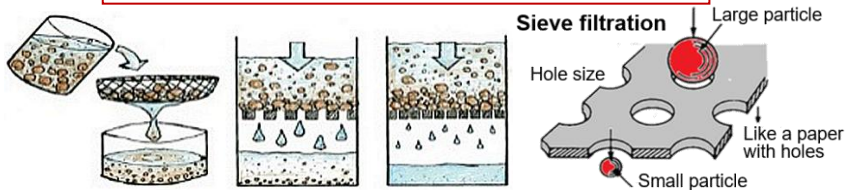


② Quest for Pure Water : Food chain is key.

SSF was **misunderstood** under the name.

Image of **Slow Sand Filter**



200 years have passed, since SSF was developed to supply clean water to **urban** areas in **London, UK**.

Contents:

① Introduction : EPS

② Quest for Pure Water :
Food Chain is key.

③ Chemical free URF
and EPS.

④ From Miyako Island
to Samoa

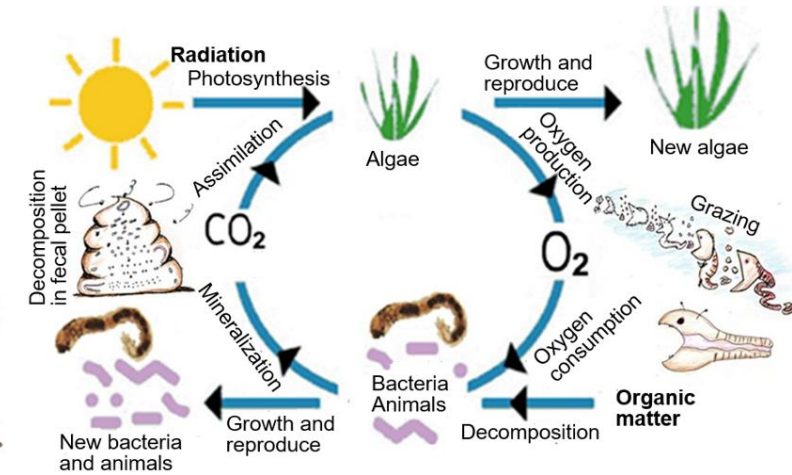
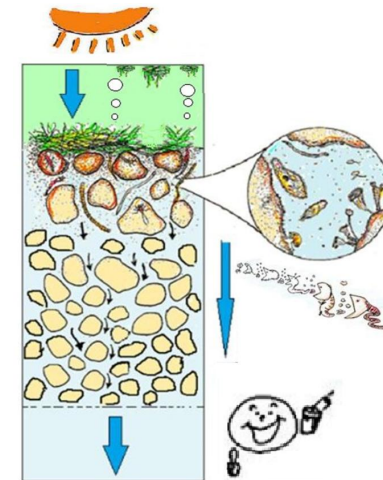
⑤ From Okinawa to Fiji

⑥ EPS as Social Contribution

⑦ EPS trial in Malaysia and Guyana

⑧ EPS in Sri Lanka and Pakistan

⑨ EPS: Trust Our Sense



**Algae and microorganisms are
the key to purification.**



SSF is to make
**artificial spring
water** by
biological
community.

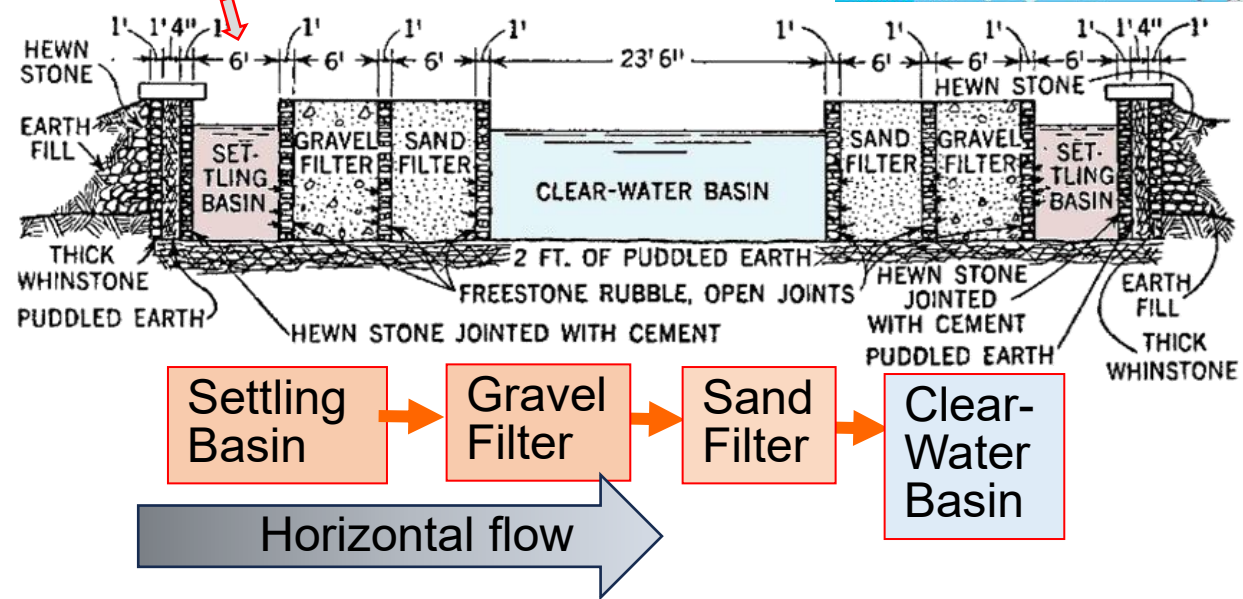
Quest for Pure Water, Origin of Public Water Supply

During the Age of Discovery, the textile industry developed.

In 1804, in Paisley, a suburb of Glasgow, Scotland, John Gibb created an artificial spring in a riverbed to wash away dye from dyed fabric.

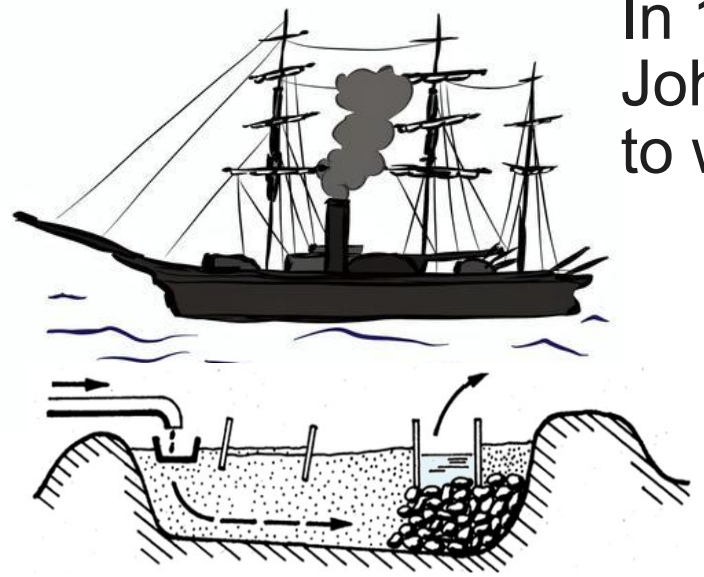
He created an artificially clean spring water by horizontally through gravel and sand tanks.

Surface water from the Clyde river.



Gibb had water left over from his factory work, so he put it in barrels and sold it around the city by horse-drawn cart.

This is the origin of public water supply systems.

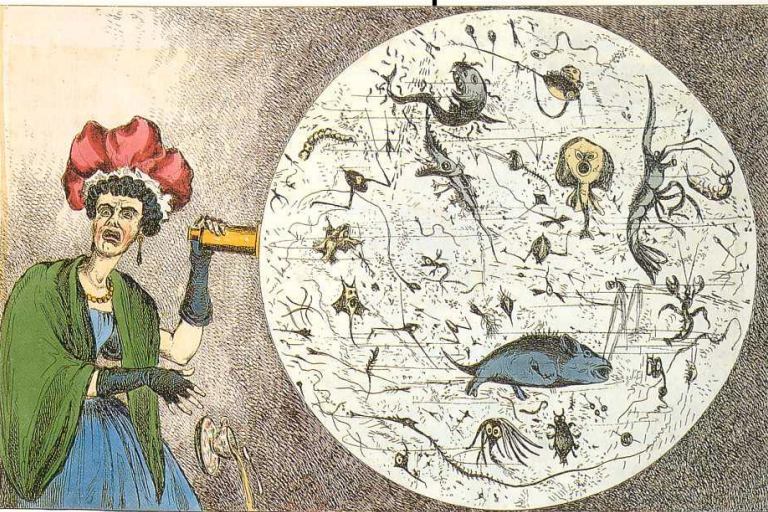


During the Industrial Revolution, people concentrated in cities, and urban rivers became polluted.

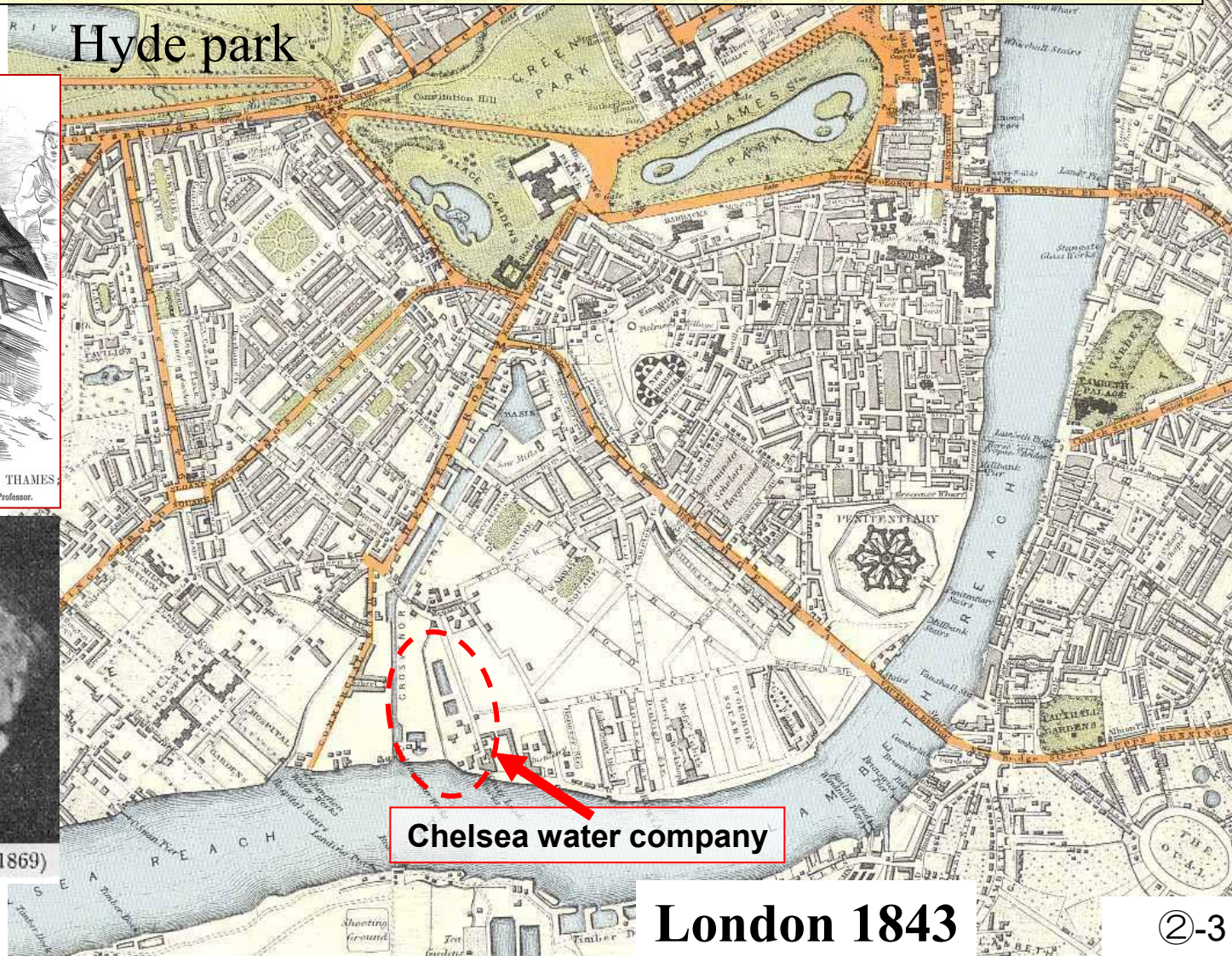
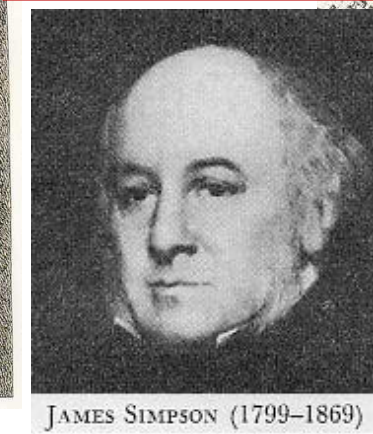
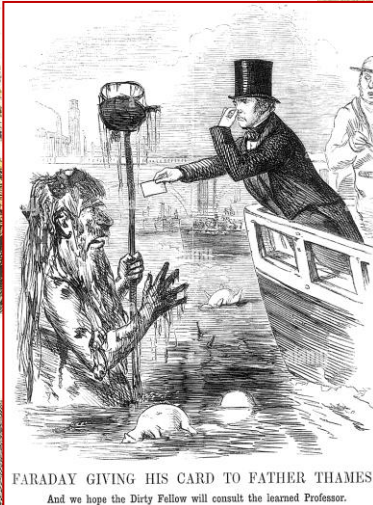
1832: Sewage was spilling into the Thames.



1828 : Monster Soup



James Simpson (1799-1869) was 24 years old (1823) when he joined his father's Chelsea Water Company and made a "2,000 miles tour of inspection" around England. This became known as the **Quest for Pure Water**.



← Polluted Thames water
James Simpson
Settling basins **28 yrs old**

Experiment filter 1827-1829

Sand filter

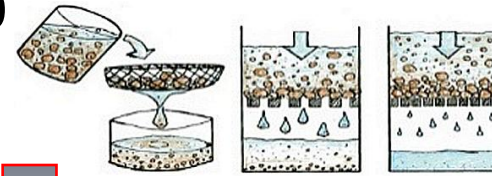
Filter rate

2-3 m/d (10cm/h)

38 cm Water depth

61 cm Sand depth

61 cm Gravel depth



The sand doesn't move.

Downward

30 yrs old

The practical filter was completed in 1829.

About 100mx40m

No detailed drawings of practical one-acre filter remain.

In 1838, James Simpson pointed out that slow sand filtration had greater removal capacity than mechanical filtration.

39 yrs old

Did Simpson feel that biological activity was involved?



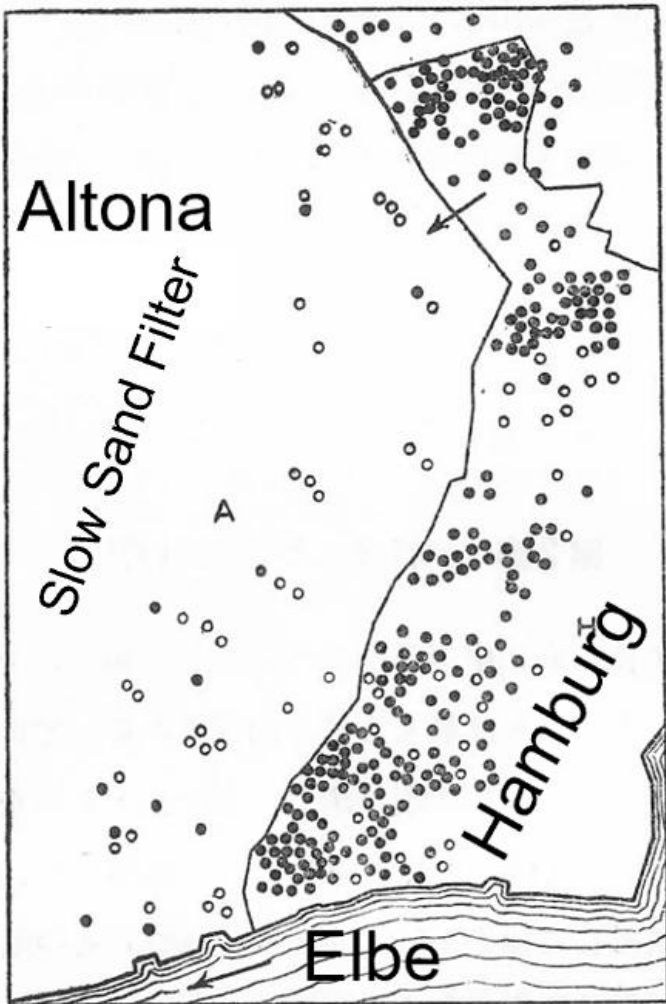
Chelsea Water Company Practical Filter worked during 1829 to 1856.

Slow Sand Filter

Settling basin

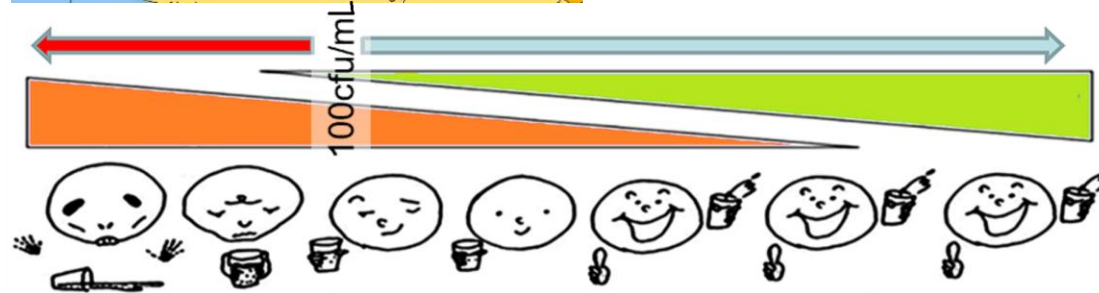
Even the polluted water of the River Thames could be made free of pathogens by using slow sand filtration (SSF). Then, SSF spread around the world as **English filter**.

We (Thames Water) will be reporting our findings over the next 3 years and hope to have an **event in 2029 to celebrate 200 years** since James Simpson's English Filter was established at Chelsea Water Works. (2025/06/17)



The **clear proof of the filtration** was provided in **1892**. This was **134 years ago**. **Hamburg** suffered from a cholera epidemic that infected and caused more than 7,500 deaths, while **Altona** was few.

Dr. **Robert Koch** tested the bacteria in the water with slow sand filtration. 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**.*

It was found that SSF could eliminate pathogens under the acceptable level.

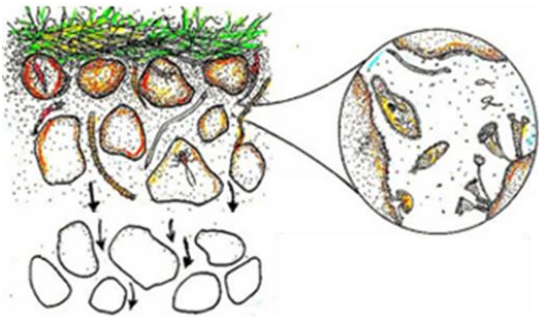
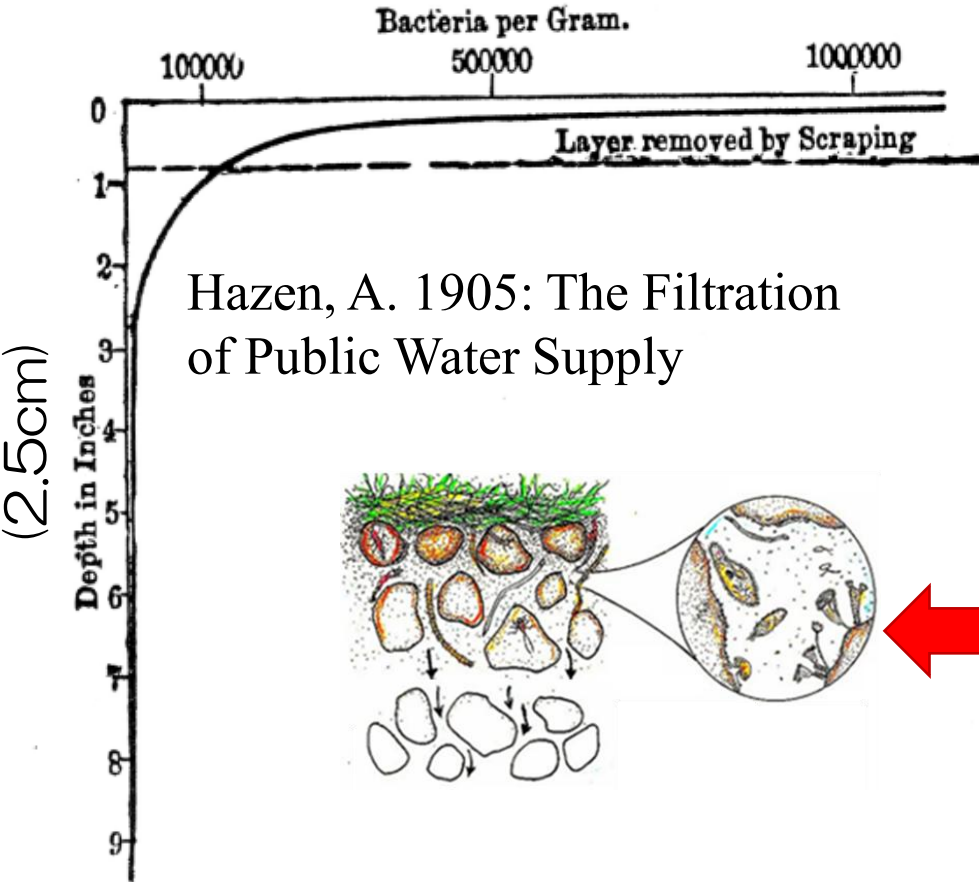
Based on this fact, people came to recognize SSF as an absolutely safe process.



*They believed SSF was **mechanical reduction of impurity by slow filtration with fine sand**.*

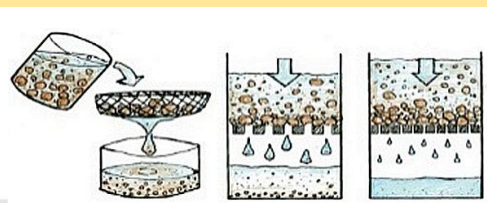


In 1838, James Simpson pointed out that SSF had greater removal capacity than mechanical filtration.

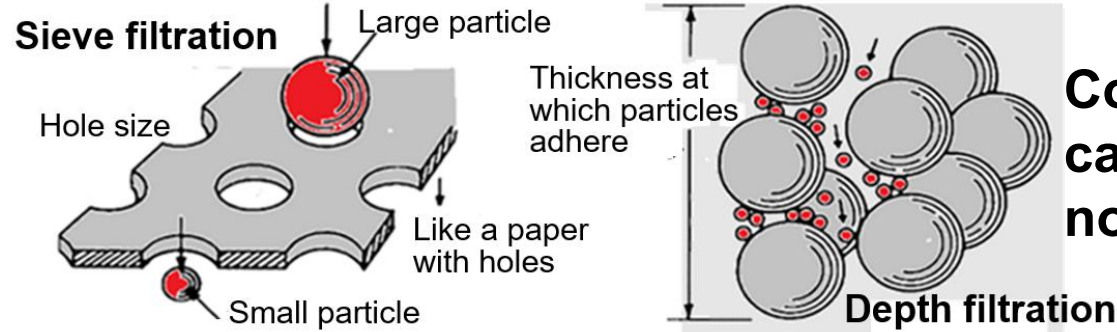


55 years after Simpson's findings, in 1893, a report from a water purification plant in **Berlin** stated that only the upper part of the sand layer was polluted. **The erosion was deep in winter and shallow in summer. However, algae were in bloom in summer. When comparing open and covered filtration ponds and investigating bacterial removal for 20 years, the open filtration ponds had a better removal rate. The report said that this may have been something special.**

The report said that **temperature and solar radiation** are related, that **biological phenomena** are involved, **but that mechanical removal is the greater factor.**

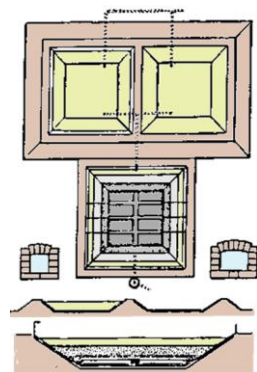


He was exactly as Simpson had described "slow sand filtration."

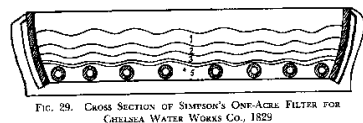


Considering the size of the pathogens, their removal cannot be explained by the size or gaps in the sand, nor by mechanical sieving or filtering through the sand.

Experiment filter
1827-1829



Practical Filter
1829



Germ free filtrate

SSF removed pathogens from the polluted water of the Thames, making it safe to drink.

Open Filtrate Basin

The filtrate storage basin was open because the pathogens had already been removed.

1832:
Richmond,
Virginia,
USA

From 1872: Poughkeepsie Filter plant,
NY

Sand filter

Filtrate basin

Open basin

May 1997



1891: Ilion, NY.

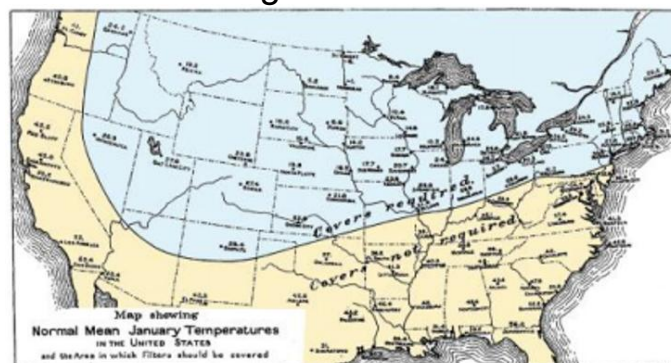
Filtrate basin



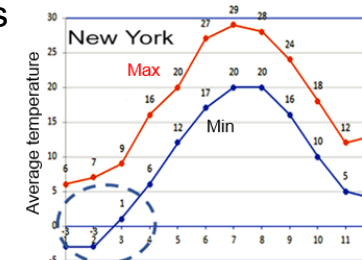
Covered basin in 1997



The average temperature in January is below 0 degrees.

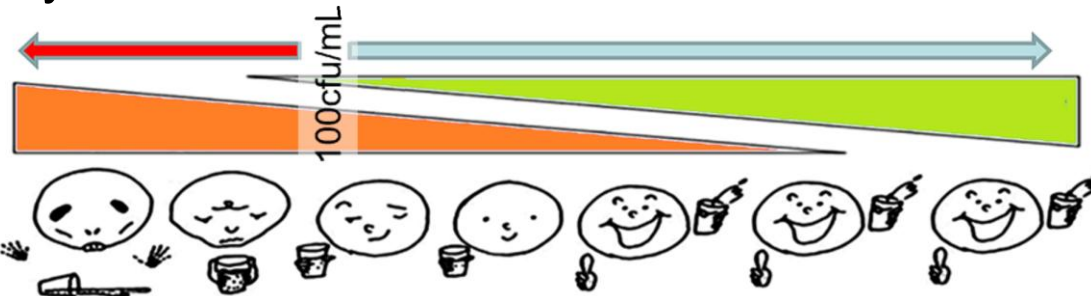


In the United States, it is recommended to cover filter ponds and filtrate basins to prevent freezing.



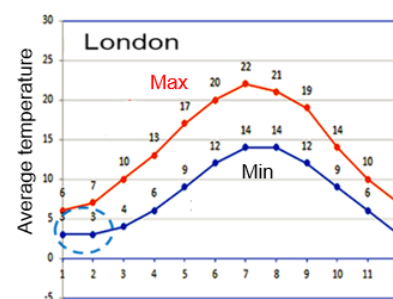
New York gets very cold in the winter and hot in the summer.

Normally, even if we are exposed to small number of pathogens, humans have a strong immune system and are fine.

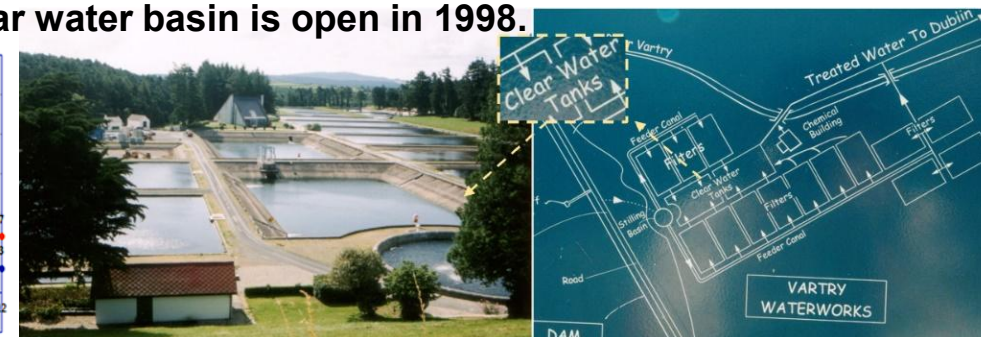


Vartry Water works, Dublin, Irlanda, from 1860s.

Clear water basin is open in 1998.



London doesn't get very cold even in winter.





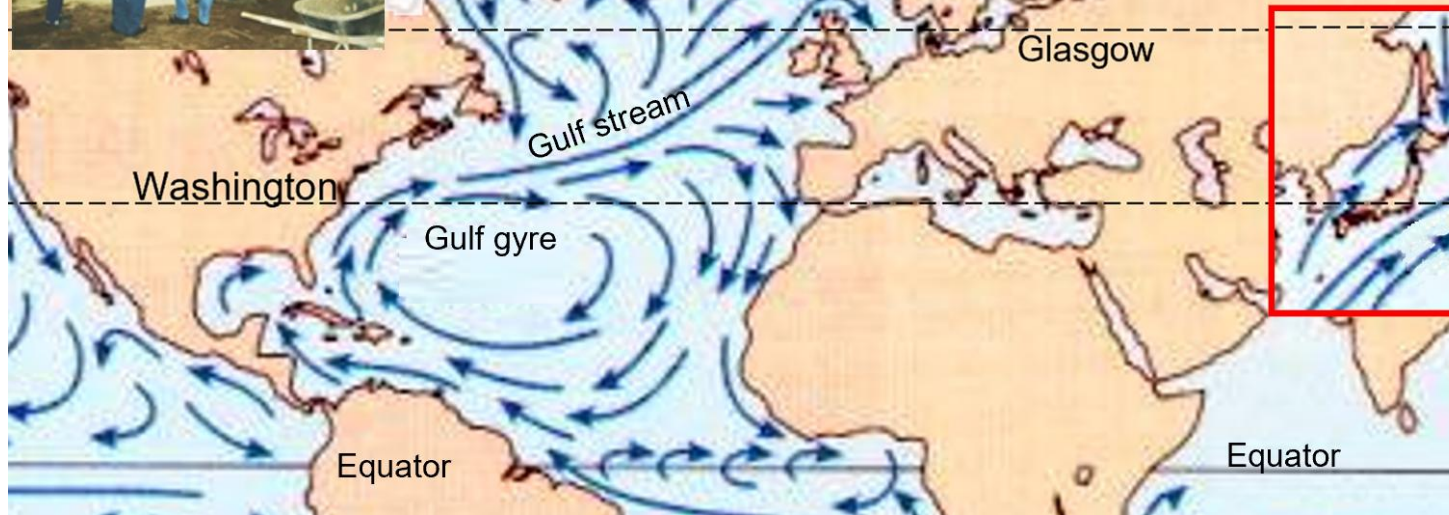
Covered filter,
Albany, NY, US



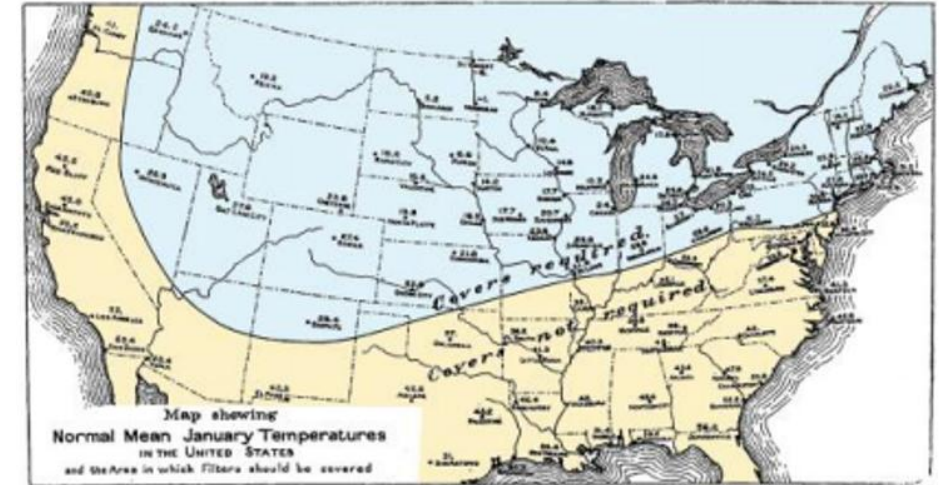
Winter
Thames
Filter



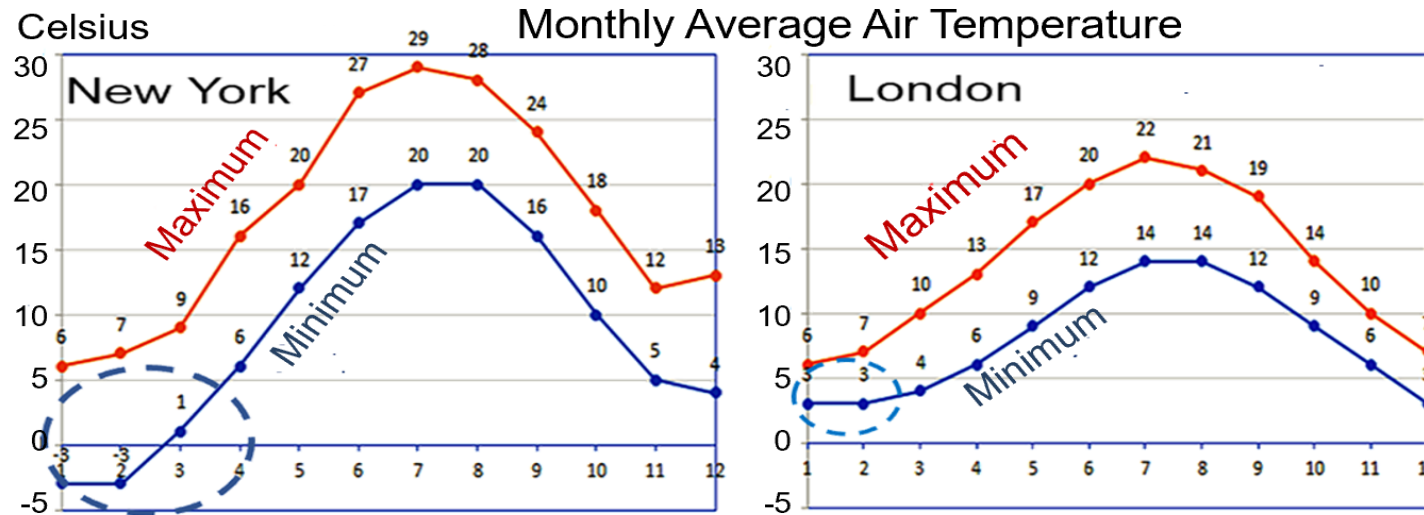
February
Glasgow



The average temperature in January is below 0°C. Covered filter was required.



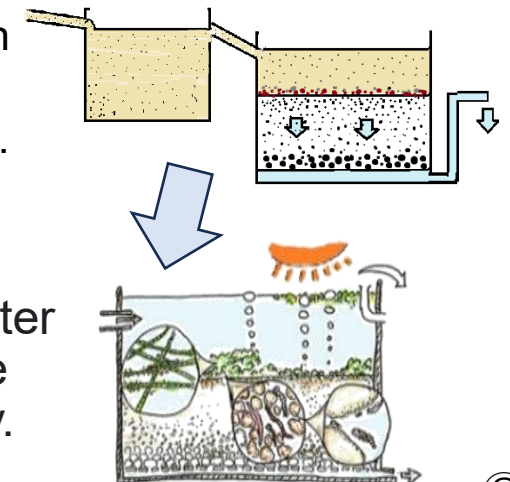
Winter temperatures in North America were cold and biological activity was weak. And the viscosity of water was high in winter.



New York has cold winter and hot summers.

London is not cold even in winter due to the warm current.

The turbidity of rivers in the continental plain is fine and difficult to sink.



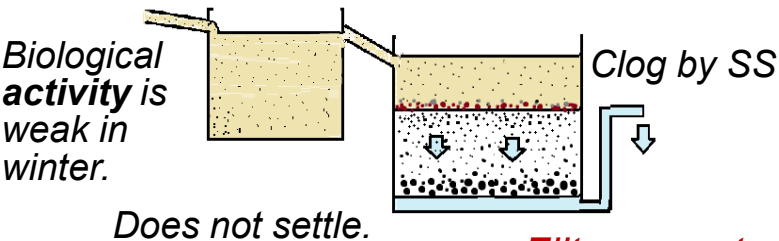
Safe drinking water was made by the biological activity.

Non-polluted river in new continent: poor food for small organisms
 1882: NJ, USA, Coagulation treatment : Origin of Rapid sand filter
 1910: NJ, USA, Chlorine treatment Completion of **American Filter**

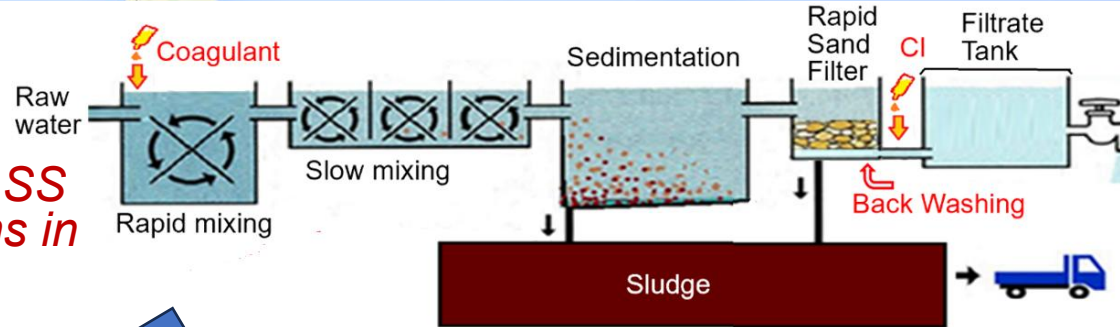
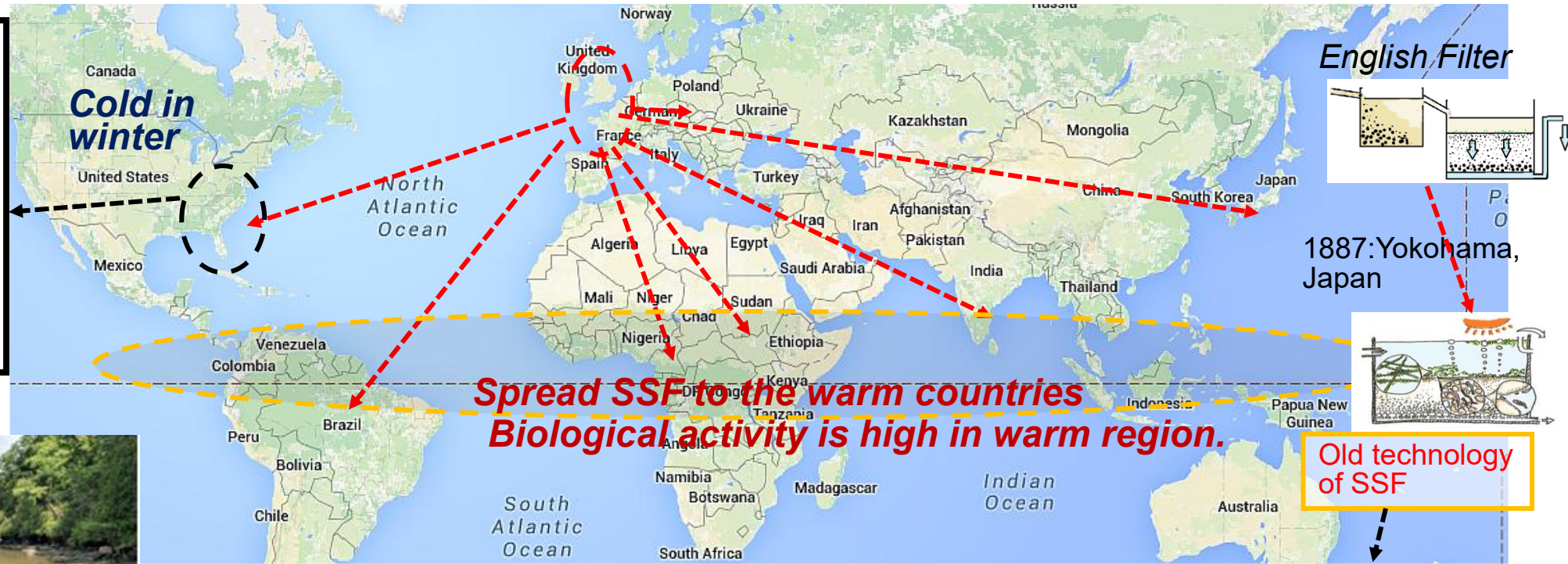
Fine much suspended solid



Non-polluted water contains fine SS and poor food for small organisms in continent rivers in USA.



Filter easy to brock by suspended solid.



New Technology

Rapid Sand Filter is chemical treatment.

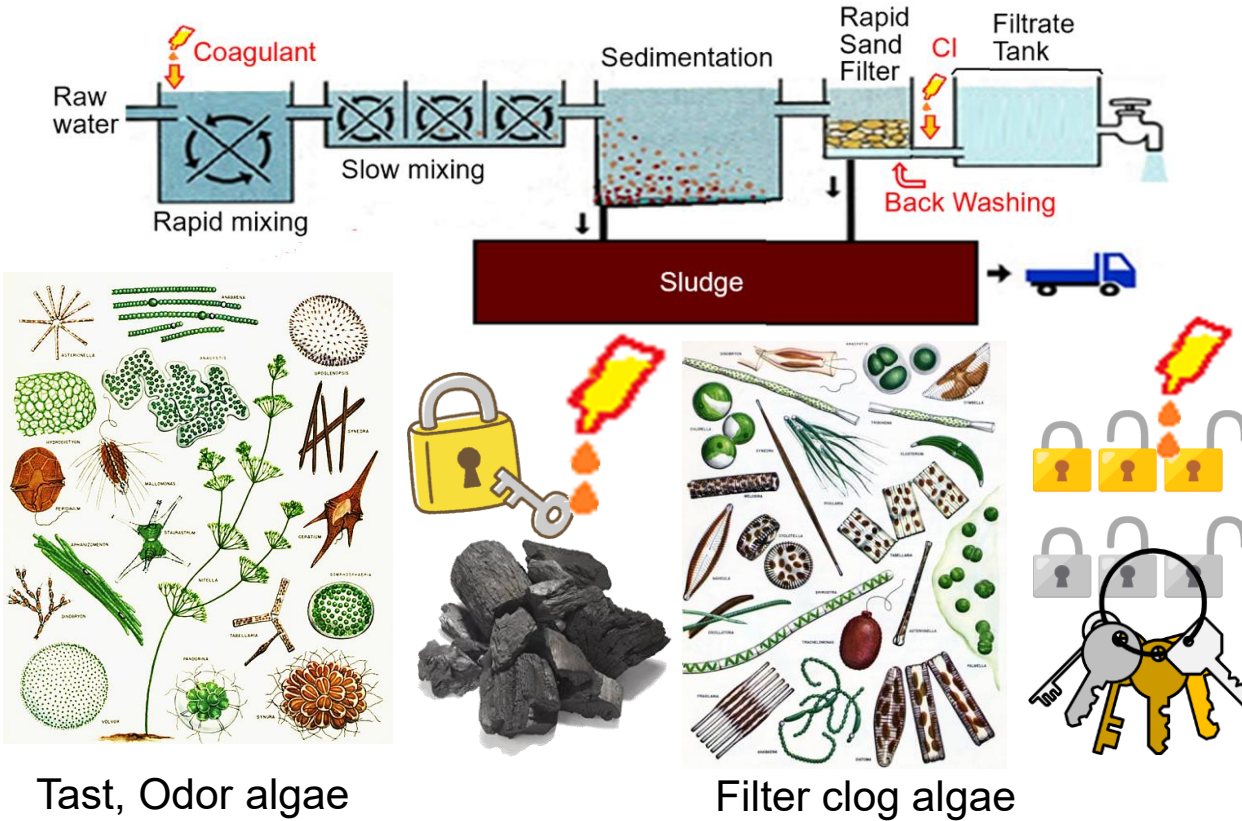
People loves new technology.



This is American Commercial Filter.

RSF spread to the world.

From Rapid Sand Filter to a Safe Purification Method **without chemicals**: Rediscovery of Slow Sand Filter.

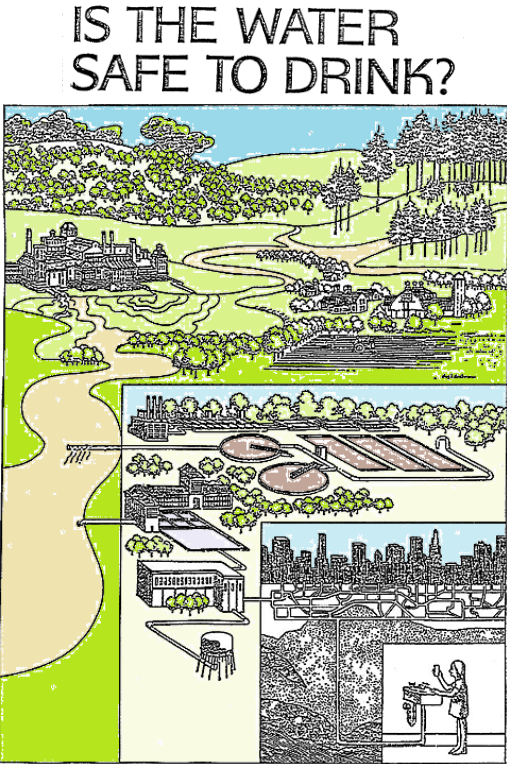


Tast, Odor algae

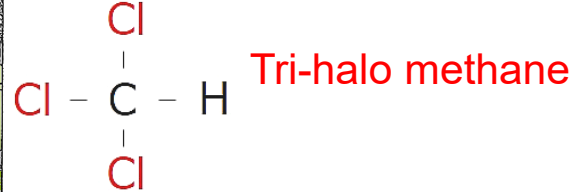
Filter clog algae

Algaecide is common practice in rapid sand filtration.

In 1962, R. Carson published Silent Spring. It warned that the pesticide DDT was causing biological condensation, killing not only insects but also other unexpected organisms. It warned of the dangers of chlorinated compounds.



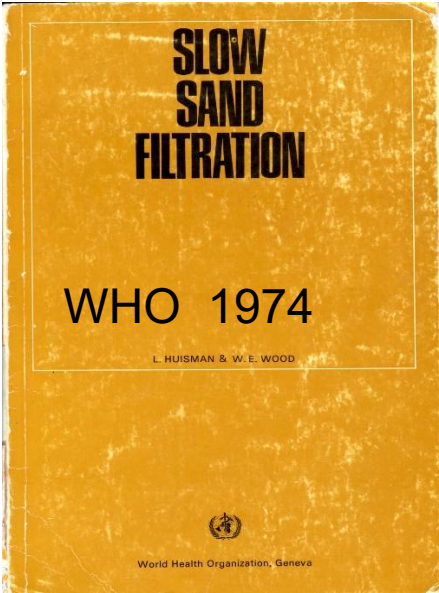
Robert H. Harris and others
Consumer Report, June, 1974.



They point out the risk of carcinogens in chemically treated tap water, the risk of asbestos pipes, etc.

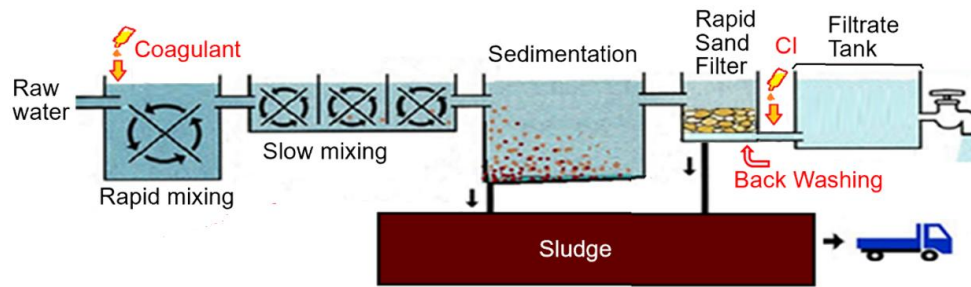


Slow Sand Filtration:
a safe chemical-free
purification method,
by Huisman and
Wood, 1974



A large-scale outbreak of diarrhea caused by Crypto zoa that had passed through rapid sand filtration.

Rediscovery of slow sand filtration without backwashing



In April 1993, an outbreak of diarrhea caused by Cryptozoa occurred in Milwaukee, USA, affecting 400,000 people. Rapid sand filtration was carried out through the backwash process.



Backwashing lets everything pass through.

Rapid sand filtration is recognized as a completely defective process.



The dormant protozoa have a thick shell and cannot be killed by chlorine, so they pass through the rapid sand filter.

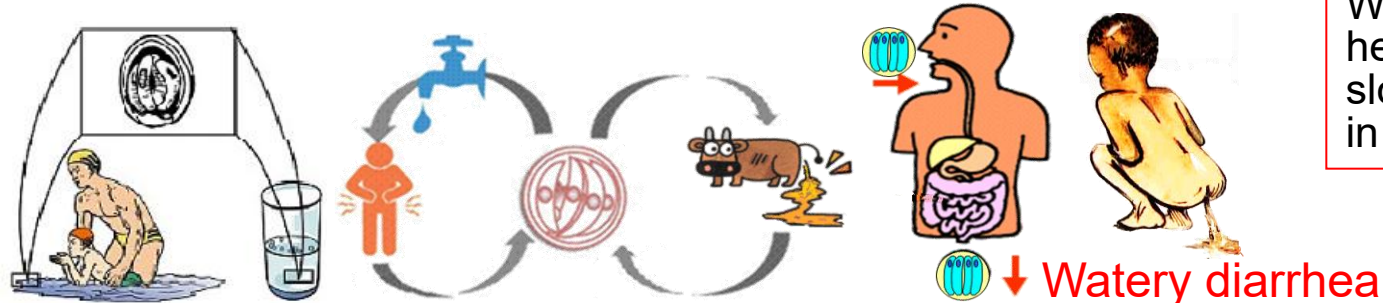
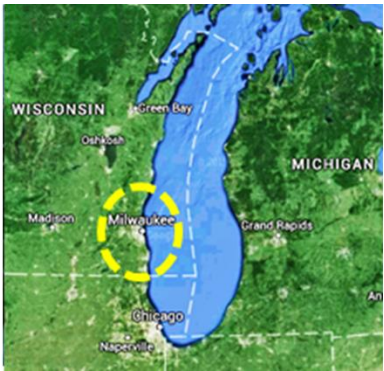
In September 1994, the American Water Works Association held a workshop on slow sand filtration in Salem, Oregon.

Refocus, Rediscovery, Timeless Technology for Modern Application.

However, people loves New Technology.

June 1996: Mass diarrhea in Ogoe, Saitama Prefecture

Japan recommended membrane treatment.



Only mammals with long intestines get diarrhea.

JournalAWWA
Volume 88, Issue 12 December 1996
Pages 8-8

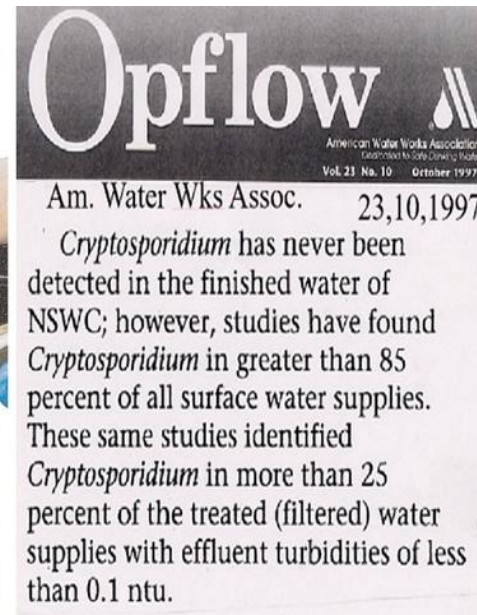
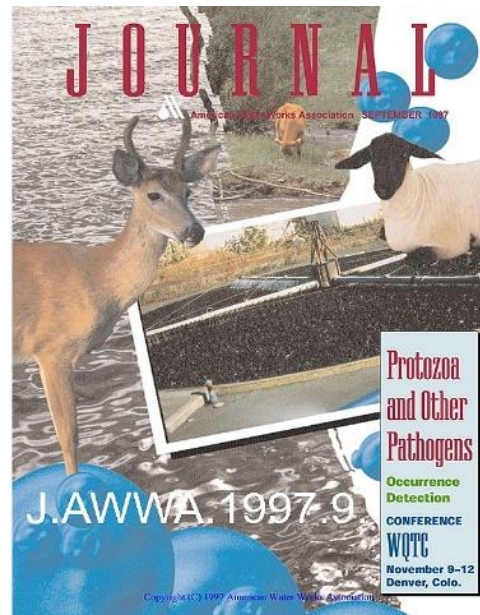
Acceptable Microbial Risk

Charles N. Haas

JournalAWWA
Volume 89, Issue 12 December 1997
Pages 14-15

Slow Sand Filtration: Still a Timeless Technology Under the New Regs?

Stephen A. Tanner



Crypto-protozoa are detected in more than 85% of surface water, but no crypto-
protozoa are detected in treated water.

So Many Oocysts are detected everywhere, but there are almost no diarrheal infections.

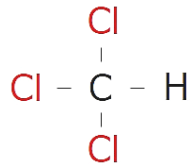
*What is real risk?
What is more safe
treatment?*



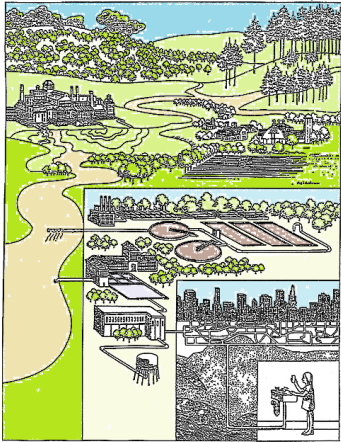
With slow sand filtration, they can trust that it will be absolutely safe even if it is contaminated with crypto-
protozoa. SSF plant was constructed in 1997 at
Central Bridge, NY, USA.

IS THE WATER SAFE TO DRINK?

Harris Report 1974



Robert H. Harris and others 1974 pointed out the risk of formation of tri-halo-methane by chemical addition of chlorine.

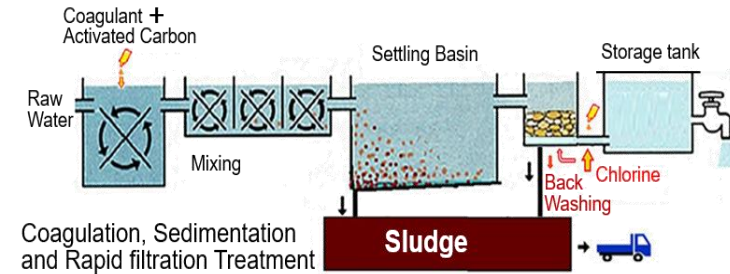


Winnipeg, Canada

Northern Pike in Canadian brown stream. Brown water is originated from peat land.



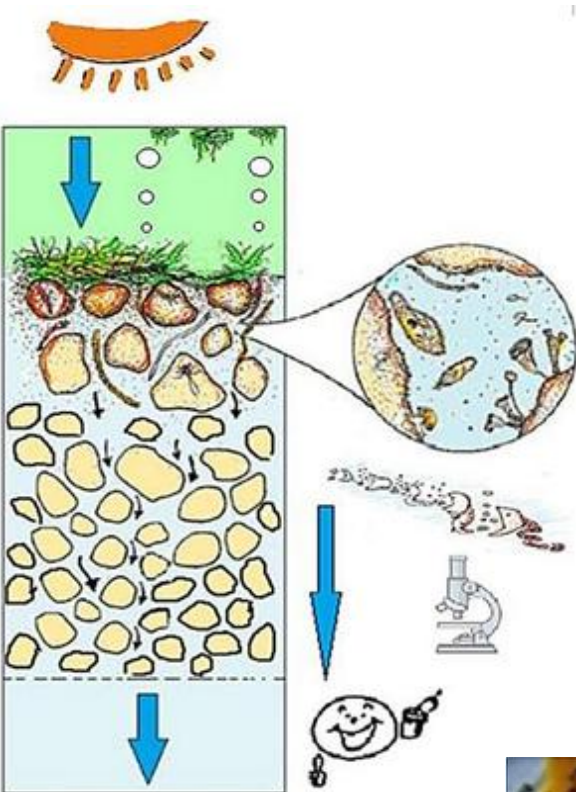
Water color is brown in the filter pond in Edinburgh in Scotland. Raw water comes from peat land.



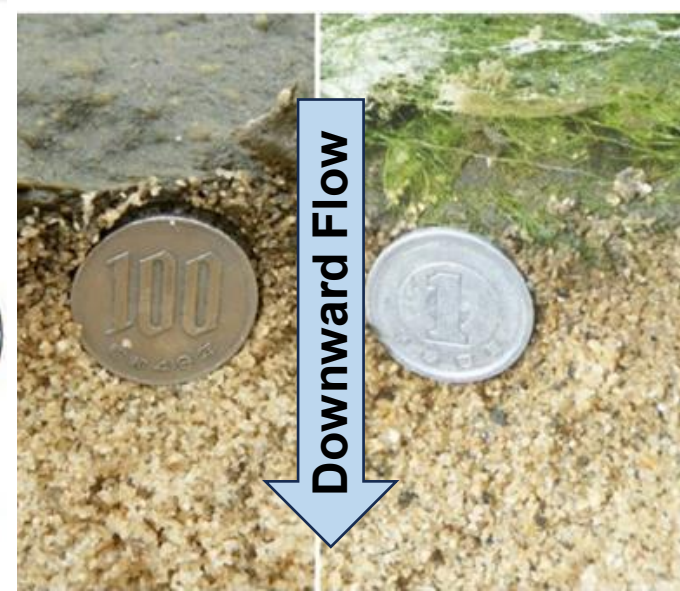
Brown water is not good. This idea came from chemical treatment. Rapid Sand Filter produces Cancer Risk by chlorine addition.



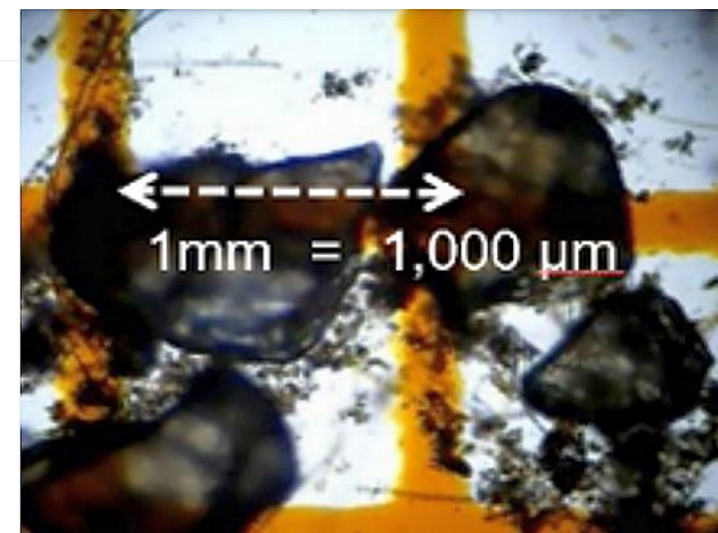
Vartry Waterworks, Dublin, Ireland. I could see brown water in open clear water tank. The filtrate water tank is not covered. They have served from 1860s.



Artificial delicious spring water

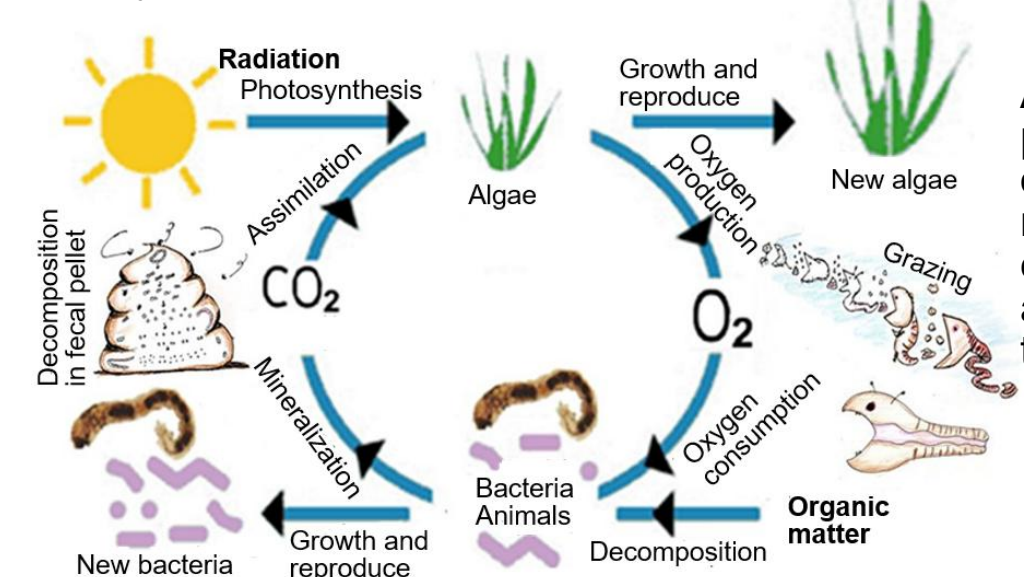


Gentle for small organisms.
The sand does not move even when the flow rate changes.



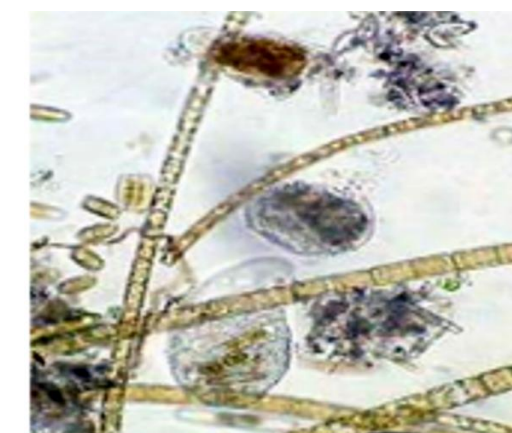
Organisms smaller than the size of sand are active here.

Photosynthesis is dependent on the amount of **solar radiation**.



Algae produce oxygen, making it easier for animals to thrive.

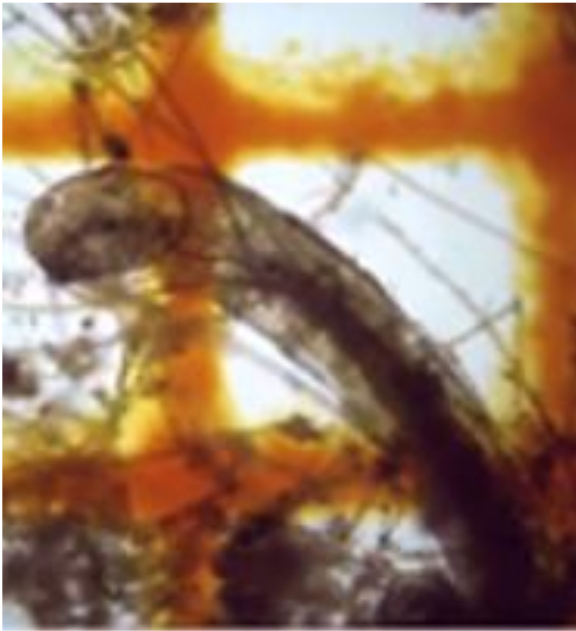
The activity of microorganisms and animals is related to **temperature**.



Hungry microscopic animals will eat anything.

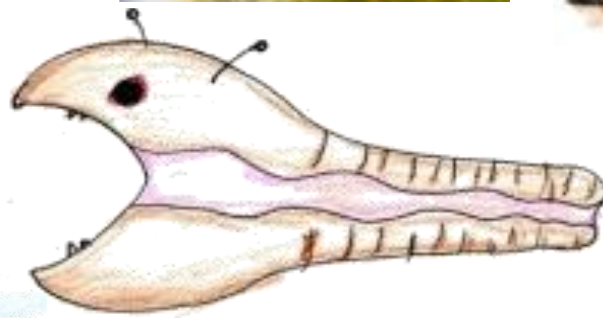
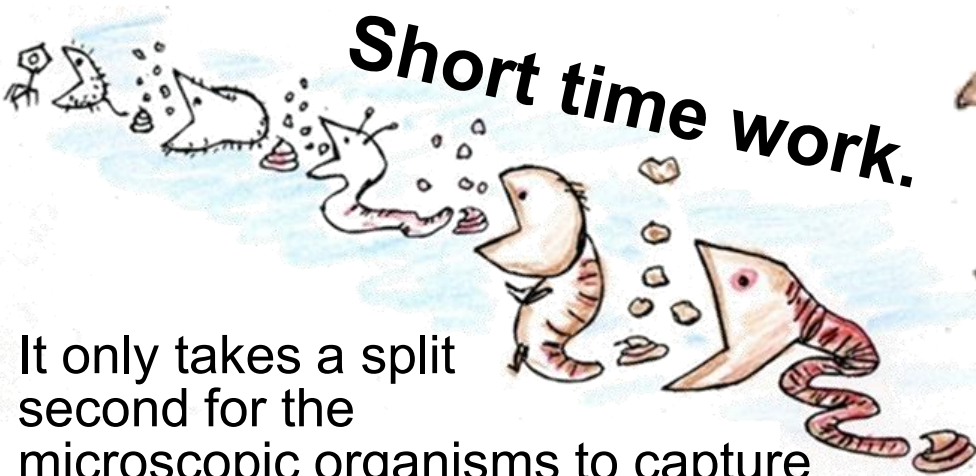
slow → **Gentle for any organisms.**

Hungry animals move around in search of food and will trap and eat anything.



Short time work.

It only takes a split second for the microscopic organisms to capture food and any suspended matter.



The food that is eaten passes through the intestinal tract in a short time and is immediately excreted as feces.

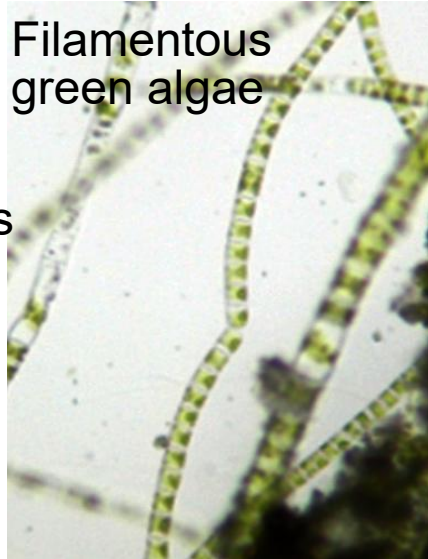
Long-term action.

Decomposition takes place over a long period of time within the feces. Fermentation progresses in the anaerobic environment with a lack of oxygen, breaking down large molecules into smaller molecules.

When observed under a microscope, algae and other tiny organisms.



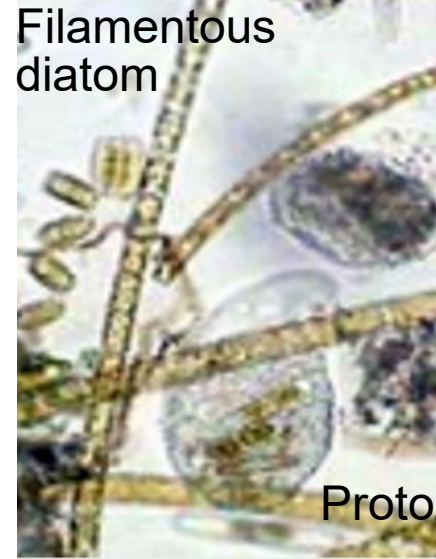
Tiny organisms



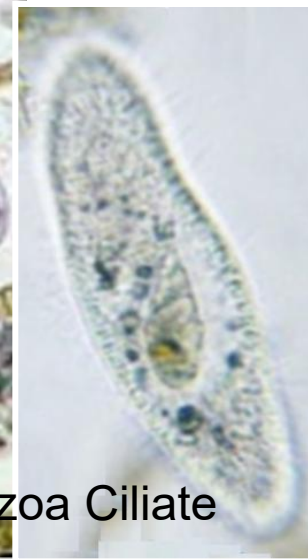
Filamentous green algae



Protozoa Vorticella



Filamentous diatom



Protozoa Ciliate



Oligochaeta



Nematoda



Rotifer



Chironomid larvae



Carnivorous dragonfly nymph

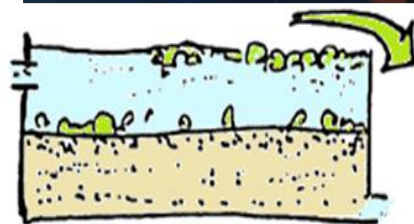


The snail eats green algae.



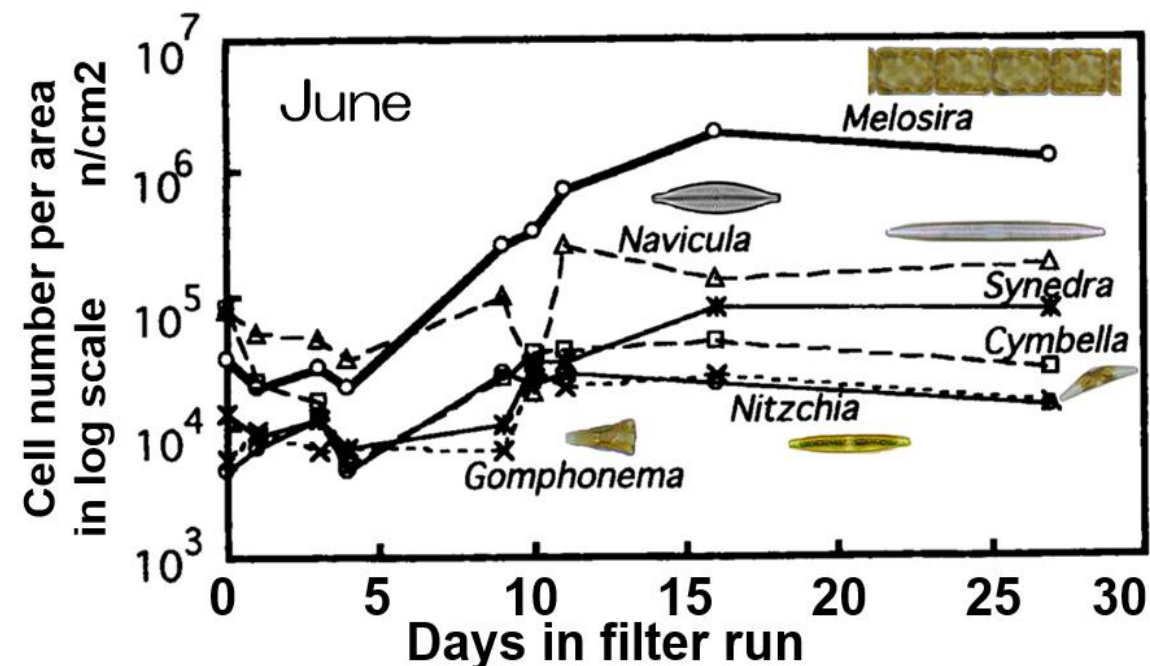
There are clams in the sand layer.

In slow sand filters, the **food chain** is the key to purification - eating and being eaten.



I was impressed the continuous culture system of filamentous algae in the slow sand filter pond.

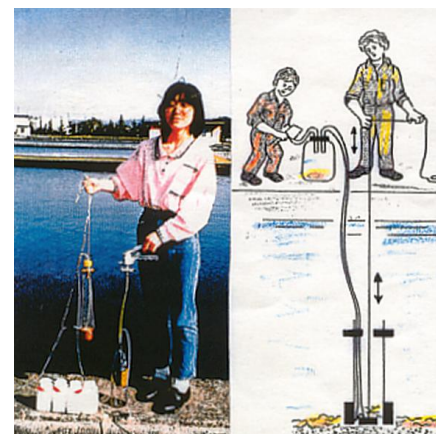
I checked the development of algae on the sand bed during filter run in June.



Grew on the filter



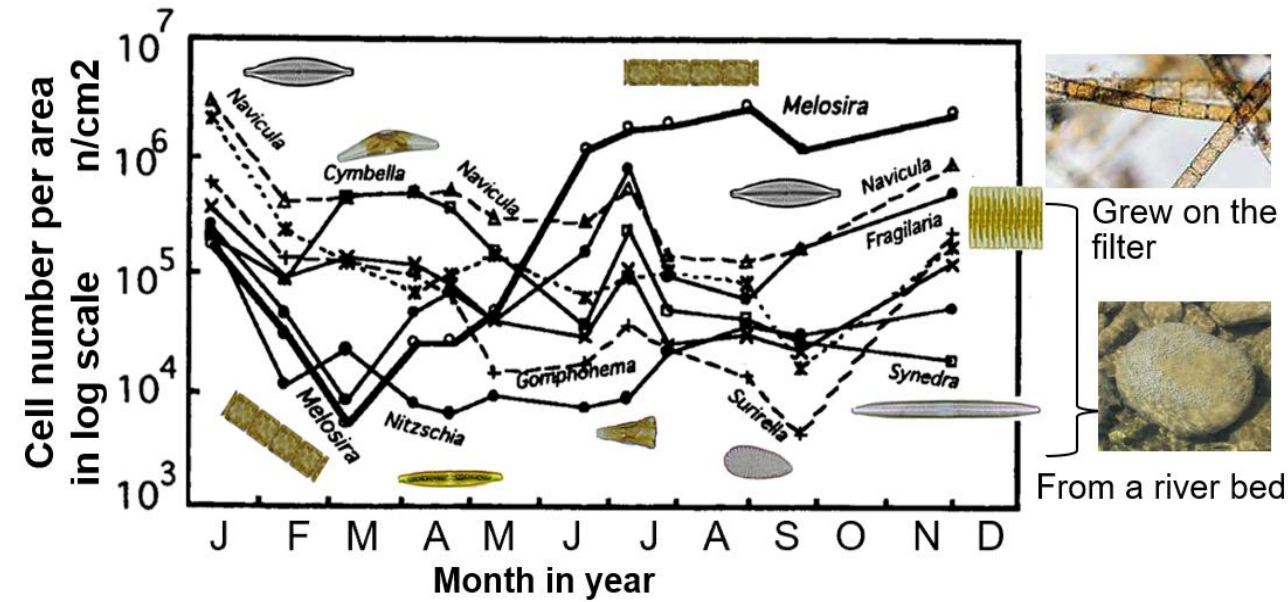
From a river bed



In June, algae first appear on the sand surface are the same as attached algae (periphyton) on the rock of riverbeds.

When the filtration continued, filamentous diatom of *Melosira* became dominant.

Seasonal changes of the algal mat after 10 days of filter run.

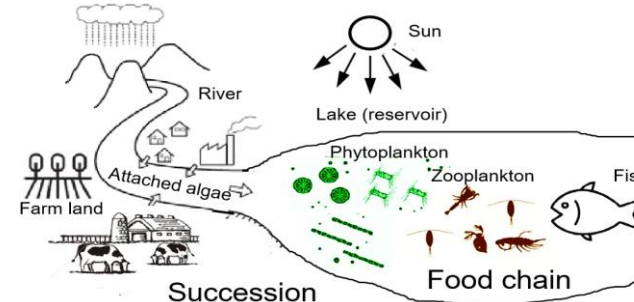
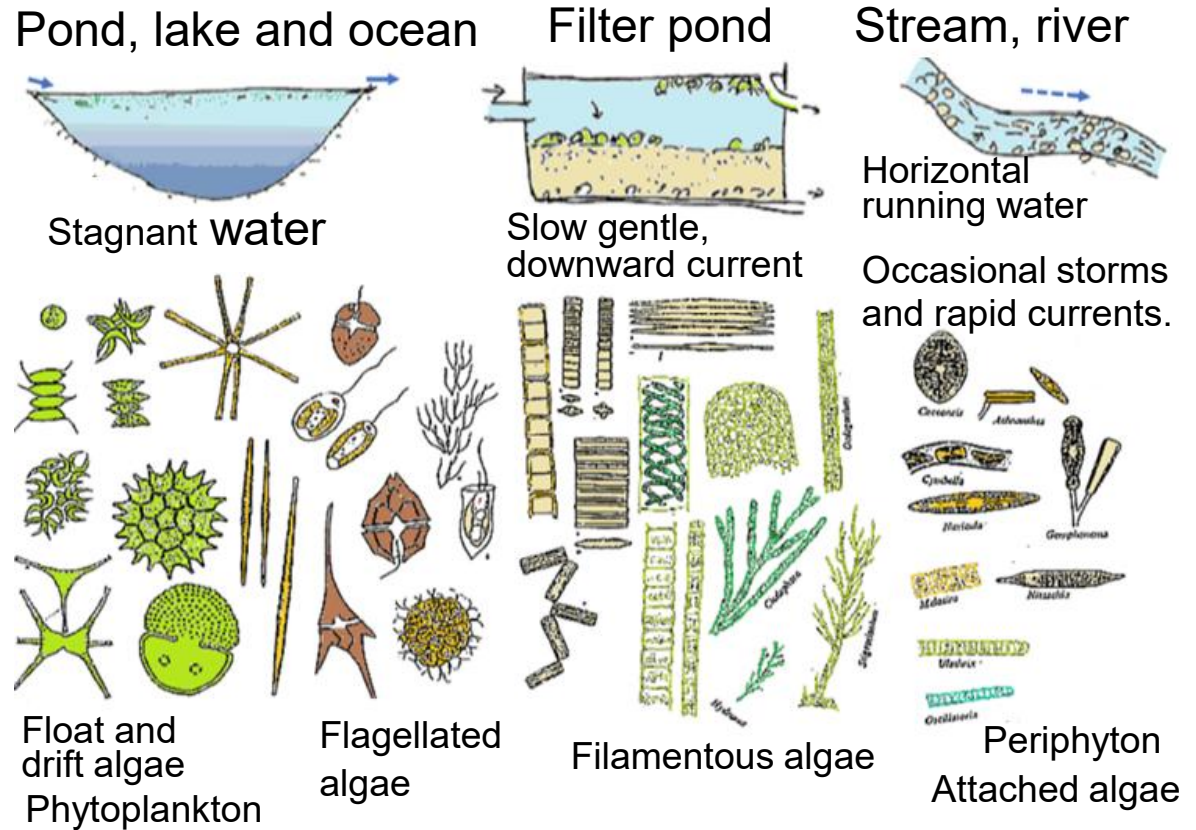


In winter, it was the same as the attached algae on the riverbed.

When the amount of **solar radiation** increased and the **water temperature** increased (during the active biological period), the **filamentous diatom of *Melosira*** became dominant until December in Ueda, Japan.

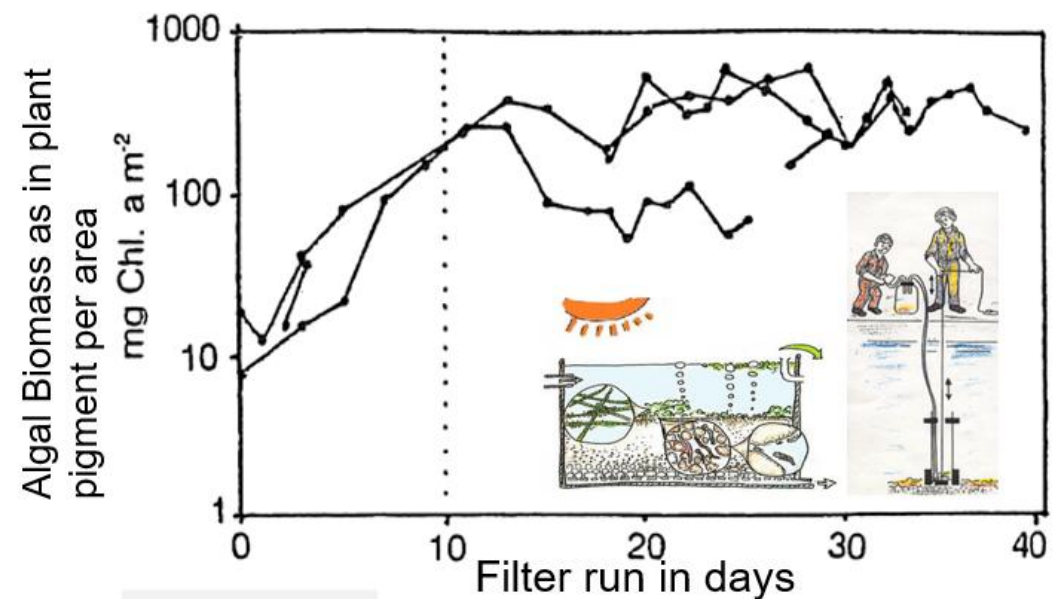


Different seasons and environments lead to the growth of different types of algae suited to those specific conditions.



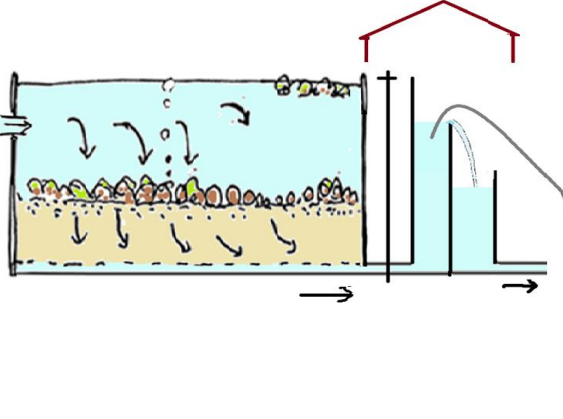
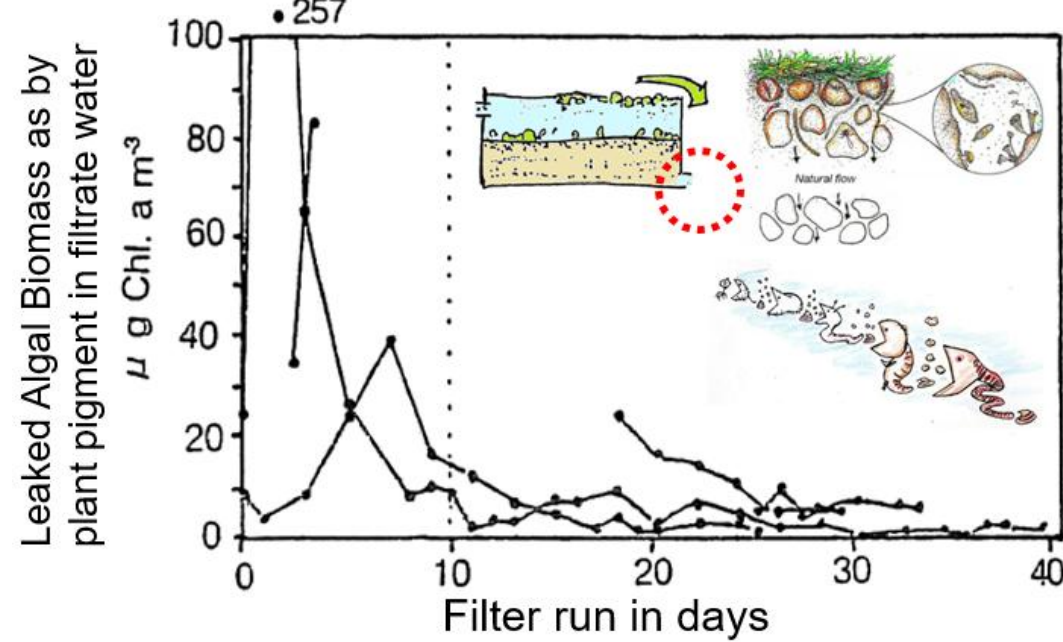
Organisms suited to the new environment emerge. The rise and fall of life. Food chains. Ecological succession. Living things strive to survive. Always Hungry !

Development of algal mat after scrape sand surface.

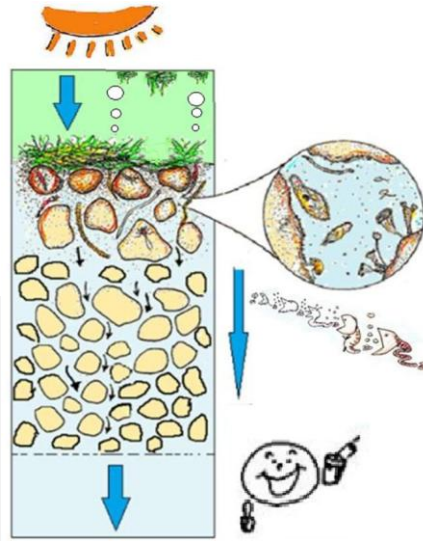


In Ueda City, algae growth in the filtration ponds is remarkable during the summer. Once filtration resumes after the sand surface has been scraped, algae proliferate vigorously; within about ten days, the ponds come to resemble a continuous culture system for filamentous algae.

After scrape, changes of leaked matter in filtrate.

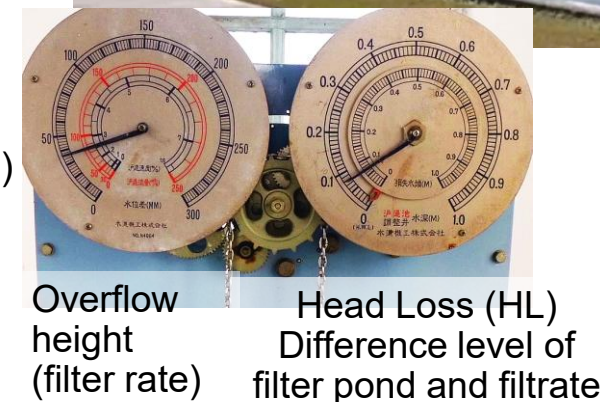
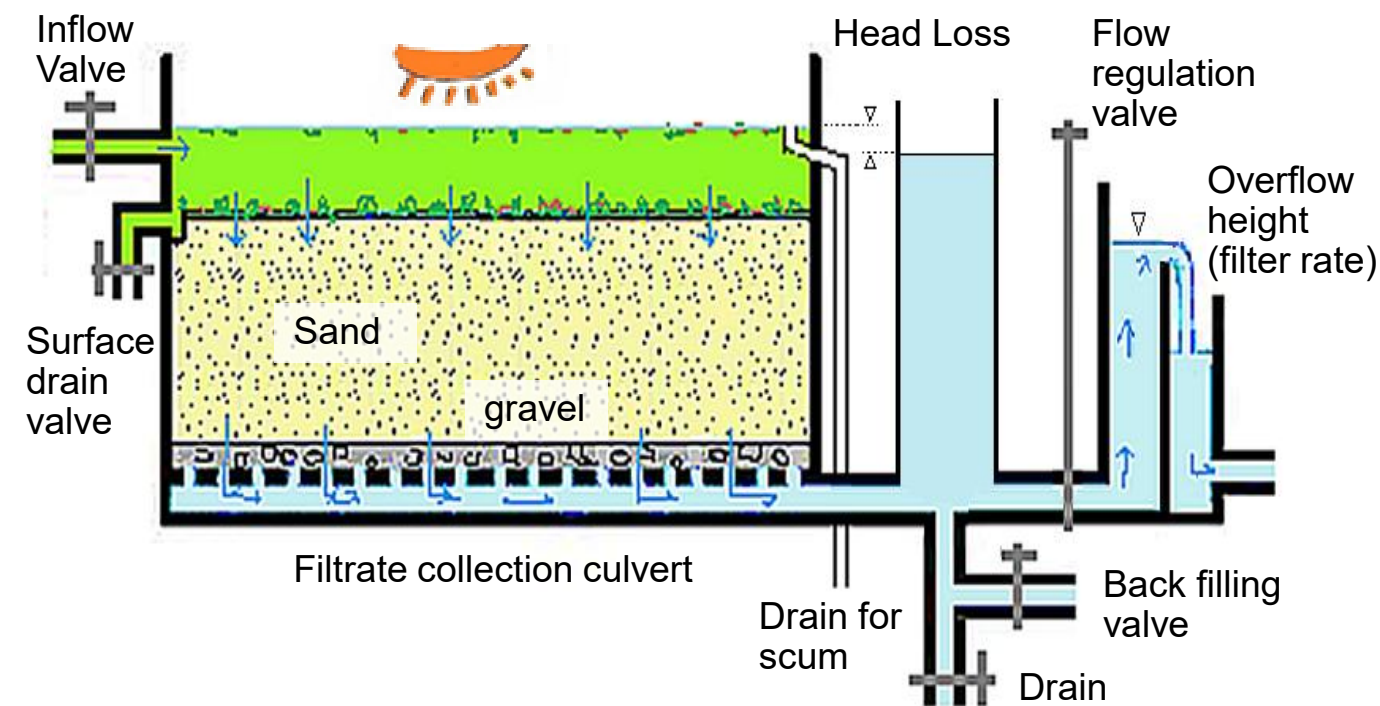


After approximately 10 days, the filtrate became "super clean," with a turbidity of 0.000 mg/L.

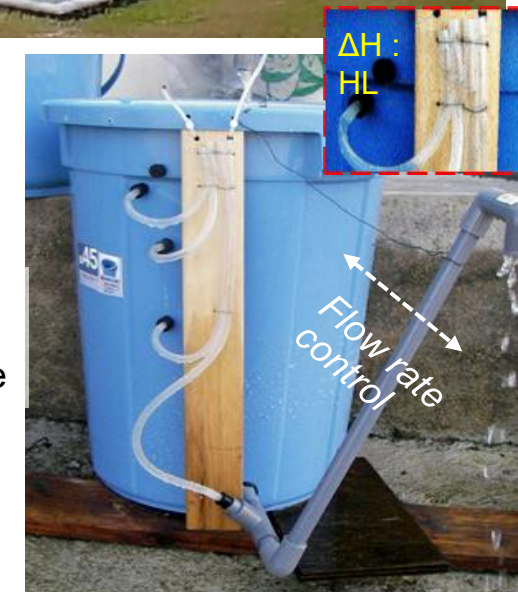


filtrate turbidity 0.000 mg/L.

Filter resistance expresses as a head loss (HL) between the water level difference of filter pond and filtrate. However, this head loss is proportional to flow rate.



The measured apparent head loss (HL) does not directly represent the filtration resistance.



HL is proportional to flow rate.

Although the Japanese manual provides no explanation, filtration resistance is evaluated using NHL internationally.

The measured apparent head loss (HL) does not directly represent the filtration resistance.
 ⇒ Calculate to Normalized Head Loss (NHL) under Standard Flow Rate (20 cm/h or 8 m/d).

NHL(Normalized Head Loss): H_n (cm)

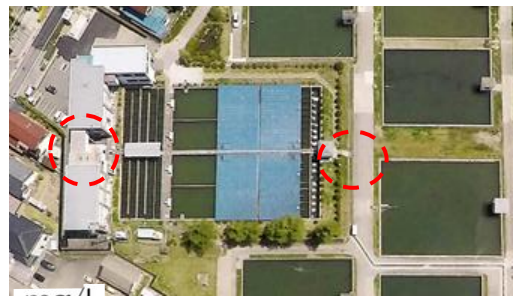
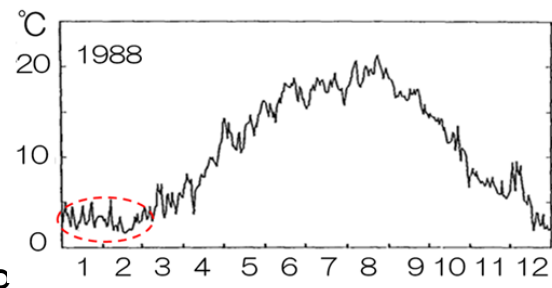
$$H_n = (H \times V_n) \div V$$

Measured apparent HL : H (cm)

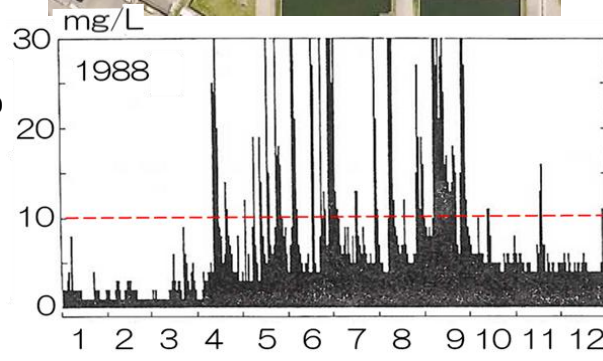
Standard flow rate : V_n (20 cm/h or 4.8 m/d)

Measured flow rate : V (cm/h or m/d)

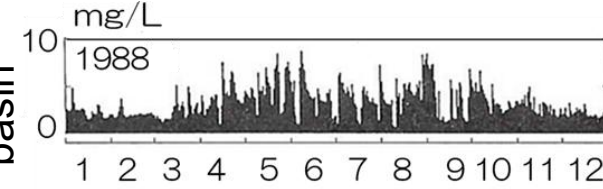
Water temperature of receiving well in 1988



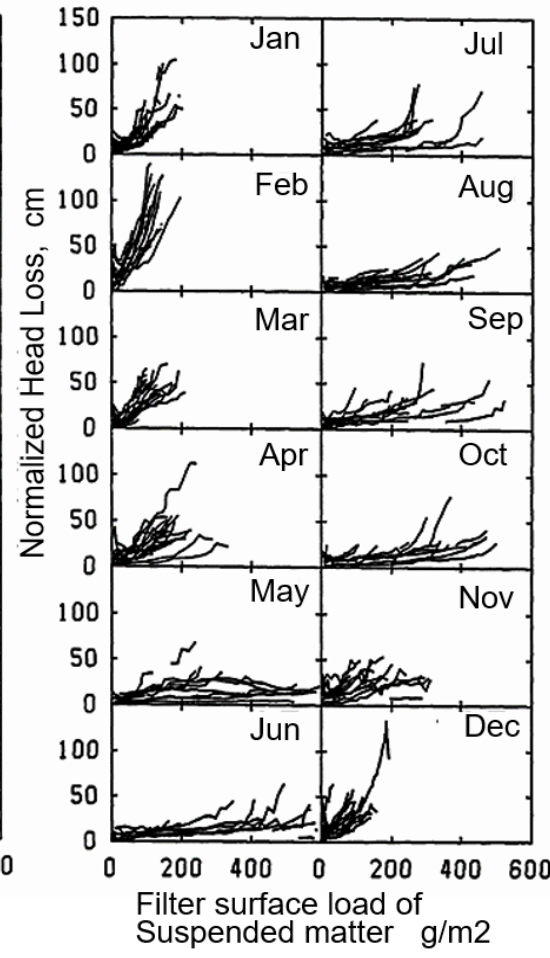
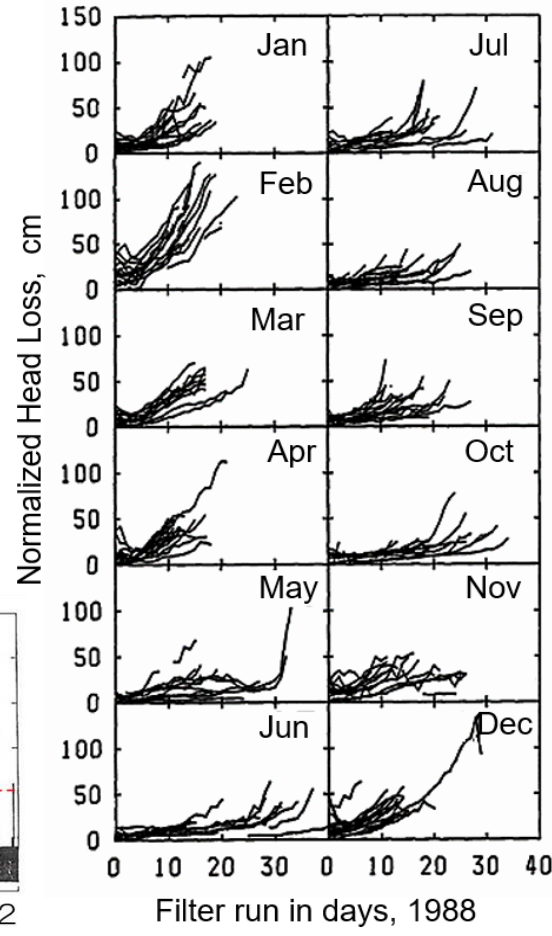
Turbidity of receiving well



Turbidity after settling basin



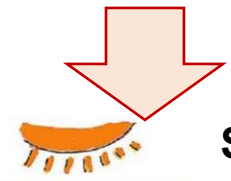
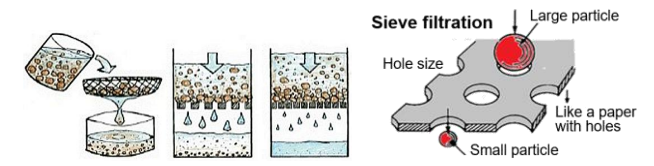
During periods of low water temperature, rainfall is scarce, and river water remains clear; turbidity is low at this time. However, as solar radiation increases and water temperatures rise, rainfall occurs in the mountains, leading to higher turbidity. This turbidity settles effectively in the sedimentation basin.



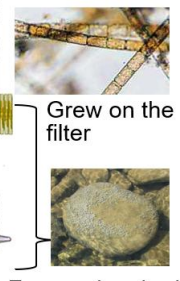
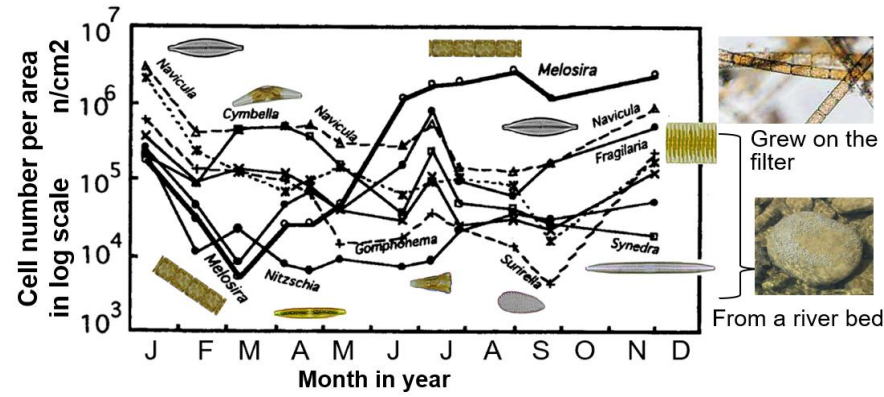
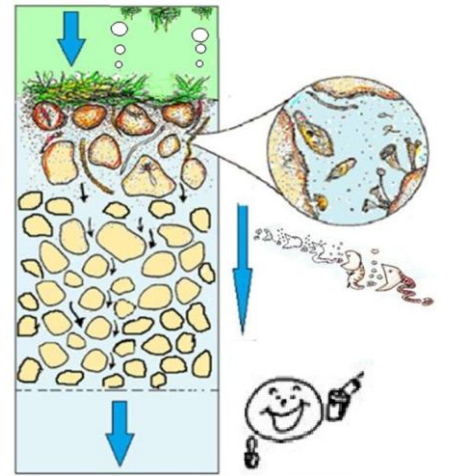
Filtration resistance (NHL) did not increase during periods of low water temperature. **High viscosity of water and week biological activity.**

NHL did not rise when filamentous algae proliferated in the filtration basin from May.

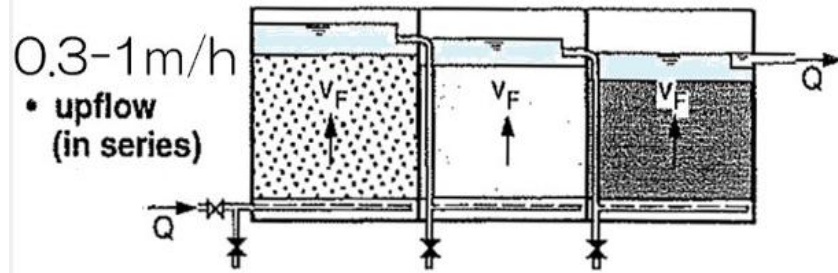
Although inflow turbidity increased in the summer, NHL did not increase.



SSF is real EPS.



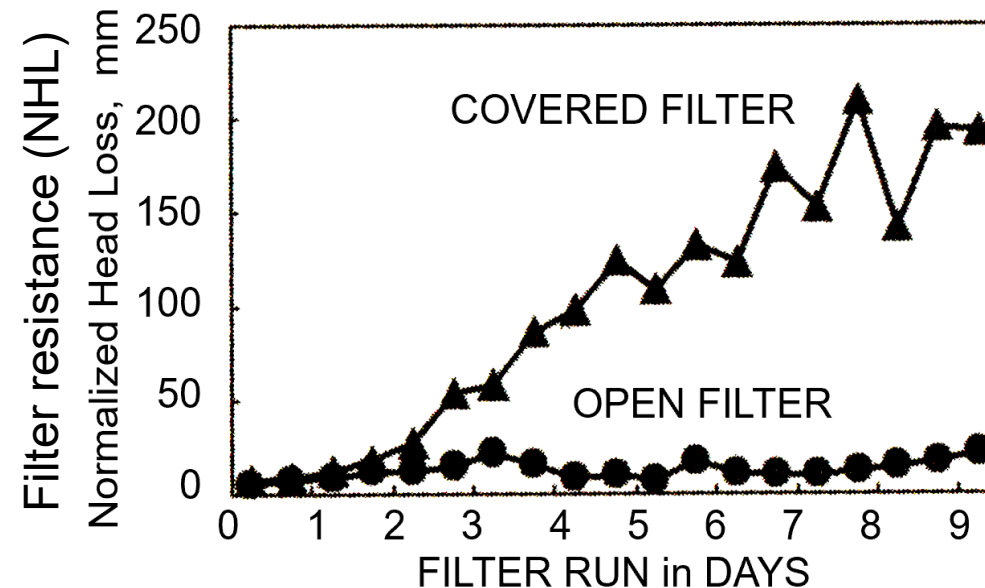
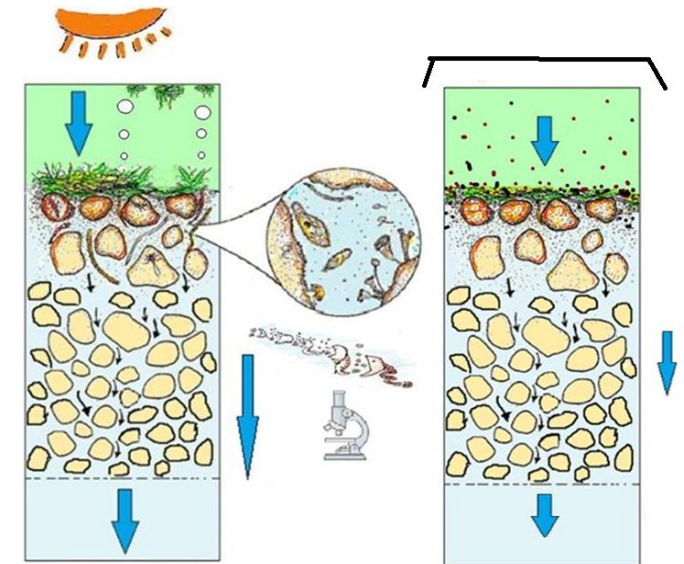
I examined the performance of **URF** to eliminate SS from an irrigation canal water in Ueda, Japan with my students,



Algae produce oxygen and be food for animals. Small animals move around for food in URF and SSF.



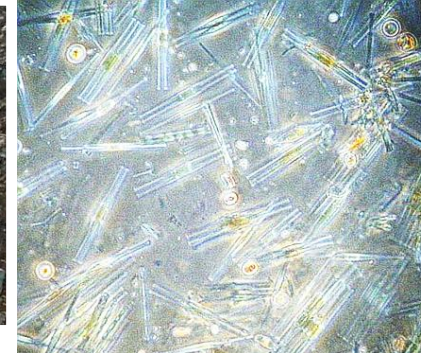
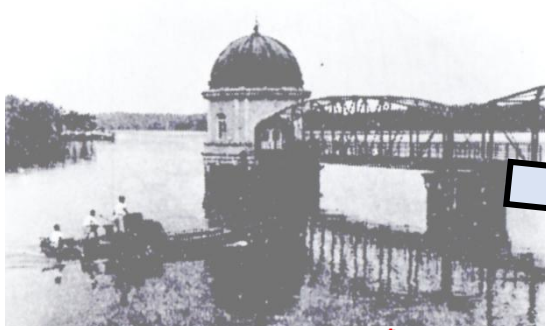
I checked the effect of **open** and **covered** filters.



The resistance of Covered filter increased almost every day.

But filter resistance (NHL) of Open filter was almost constant.

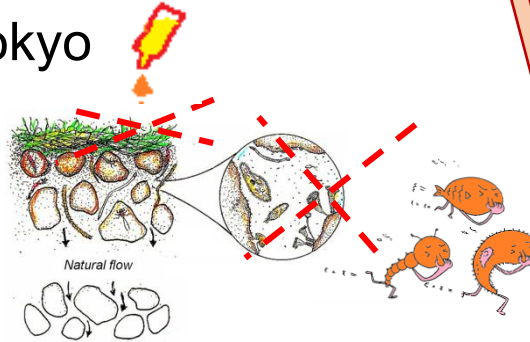
The biological community reduced the filter resistance.



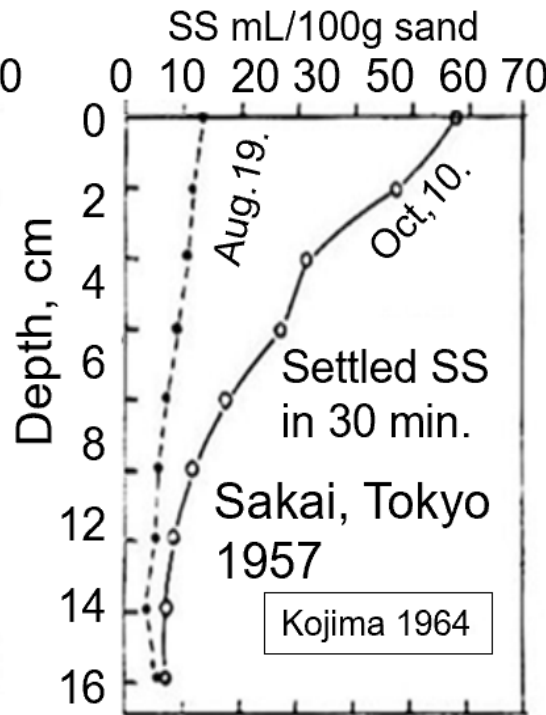
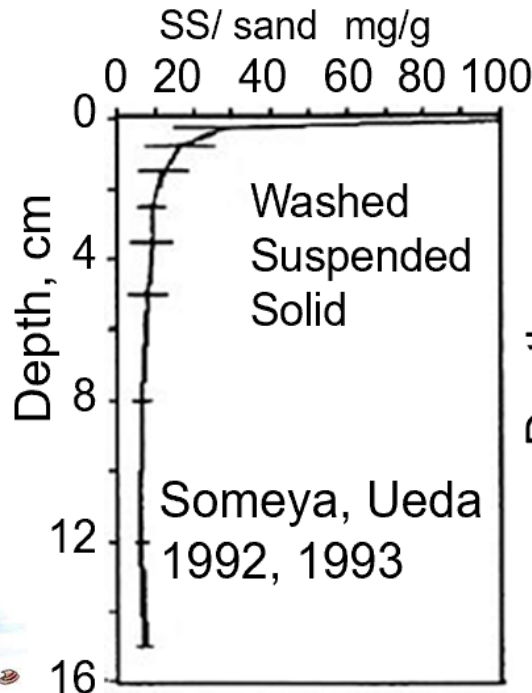
Sakai, Tokyo

Phytoplankton from the reservoir accumulates on the filter pond. Algae do not grow on the filter bed.

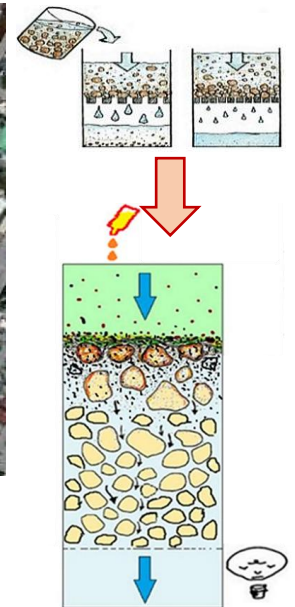
Put algicide (CuSO_4) into reservoir from 1928 until present.



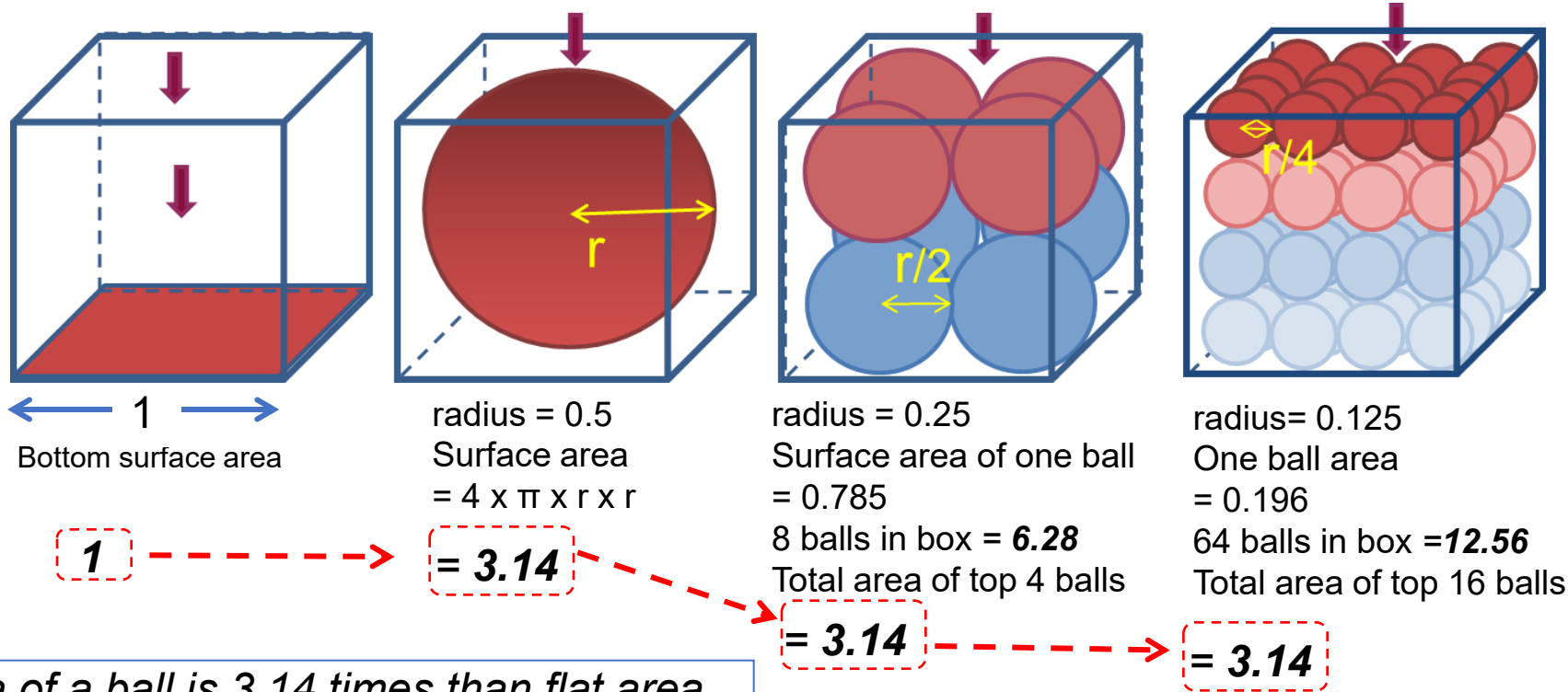
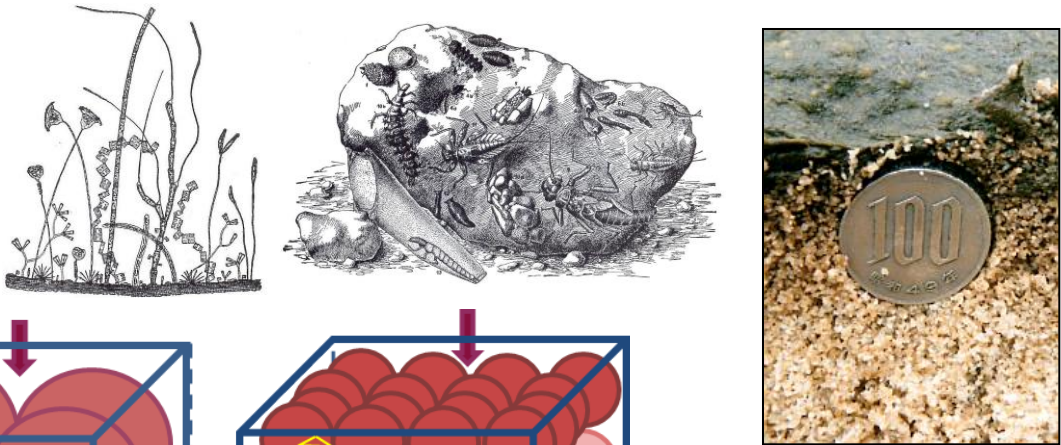
Microscopic organisms react sensitively to even minute amounts of toxic substances. The sand passes through without removing any dirt or dissolved substances.



They misunderstood the real purification mechanism of EPS.



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**.



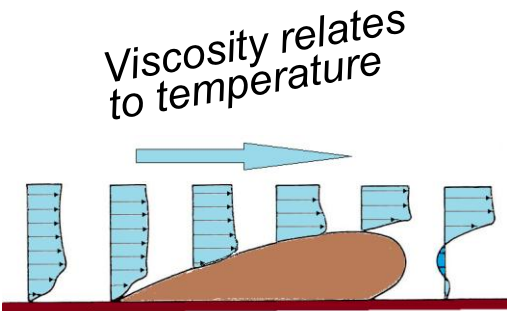
Too small particle becomes a flat surface.

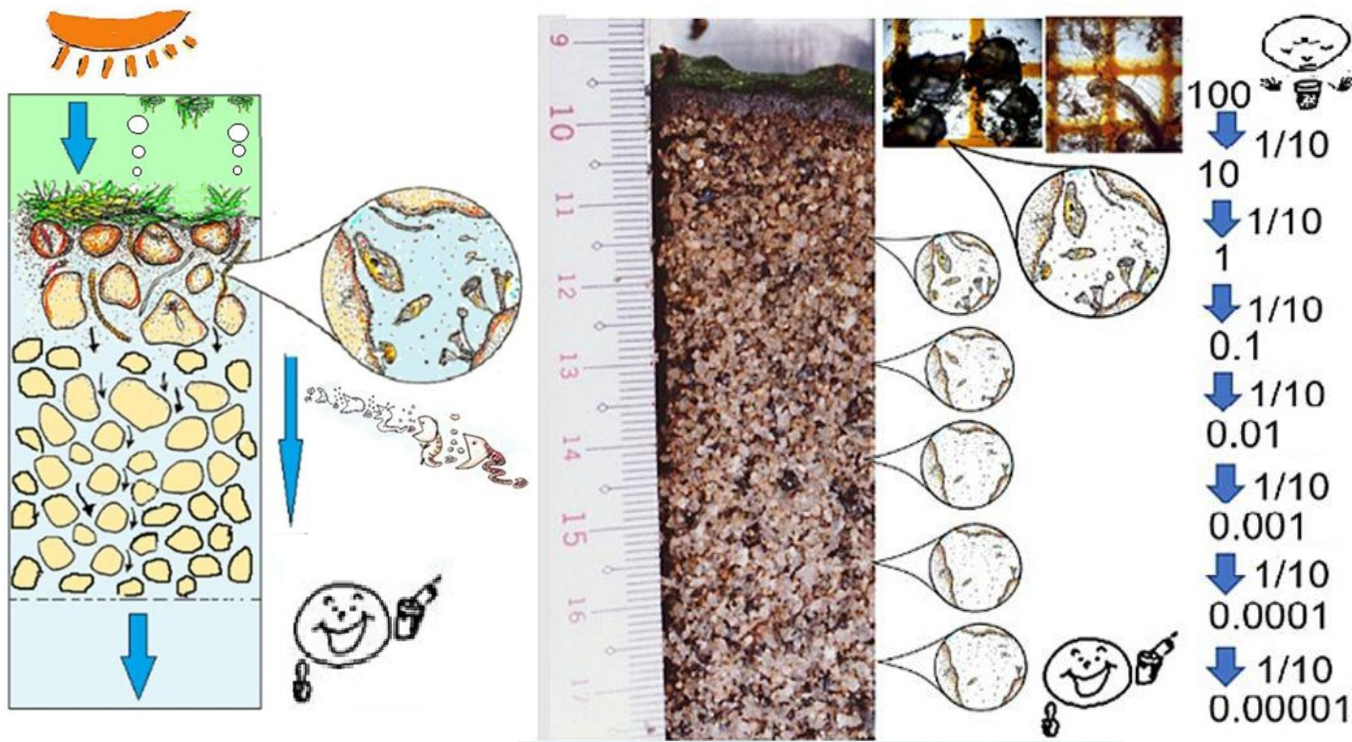
Surface area of a ball is 3.14 times than flat area.

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.





Don't remove biological active layer. Scraping the sand surface removes the biological community. It is best to avoid scraping whenever possible.



Thames Water has begun trials using a device resembling an underwater vacuum cleaner to remove the layer of debris accumulating on the sand surface of filtration beds, without draining the water.

Chironomid is not same as Mosquito.

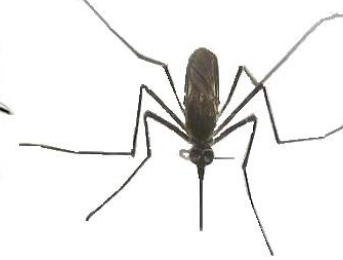
Chironomid

Non-biting
Mosquito



Mosquito

Biting Mosquito (Female)



Both Midges of
Chironomid and
Mosquito swarm
for mating.

Midge swarming



**Mosquito larvae
live in stagnant
environments.**

**The mosquito larvae
float on the water
surface, drifting with
their tails up. Their
tails act as
respiratory organs,
and they bring them
to the surface to
breathe.**

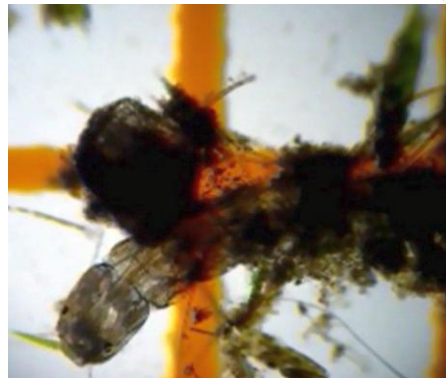
Troublesome Nuisance Insects

Vending
Machine

Lake and Pond

Roughing filter

Ecological System under
slow water current

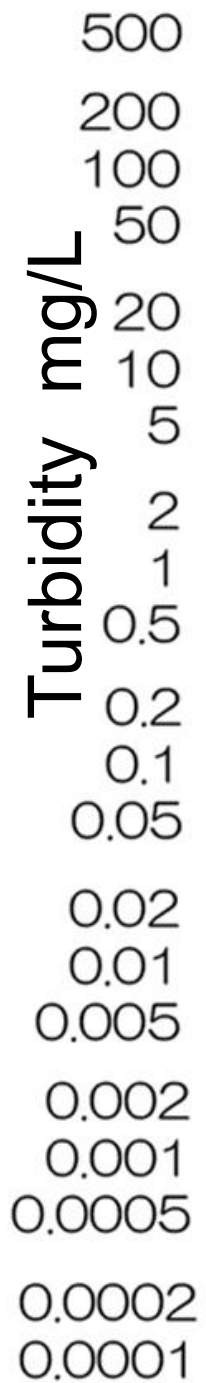


**Chironomid larvae:
making nest at the bottom**



Chironomid larvae are active on the muddy surface, sandy surface, and upper part of the sand layer. These environments with currents have dissolved oxygen.

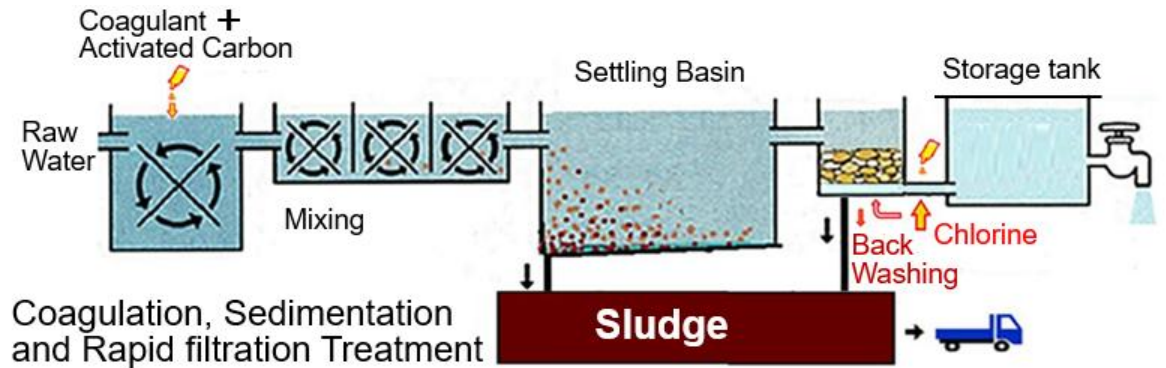
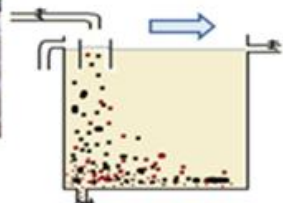
Turbidity mg/L



Storm event



Major turbid matter in mountain stream is easily set within several hours.



Coagulant + Chlorine
Rapid Sand Filter

SS passes by
backwash.

2 degrees
Jap. standard

After Crypto
outbreak.

Recommended
to 0.1 degrees



Chlorination
is essential.



This is a
commercial
filter.



Purified
by small
organisms

Natural
spring



Super clean
and delicious.



Artificial Natural spring water

