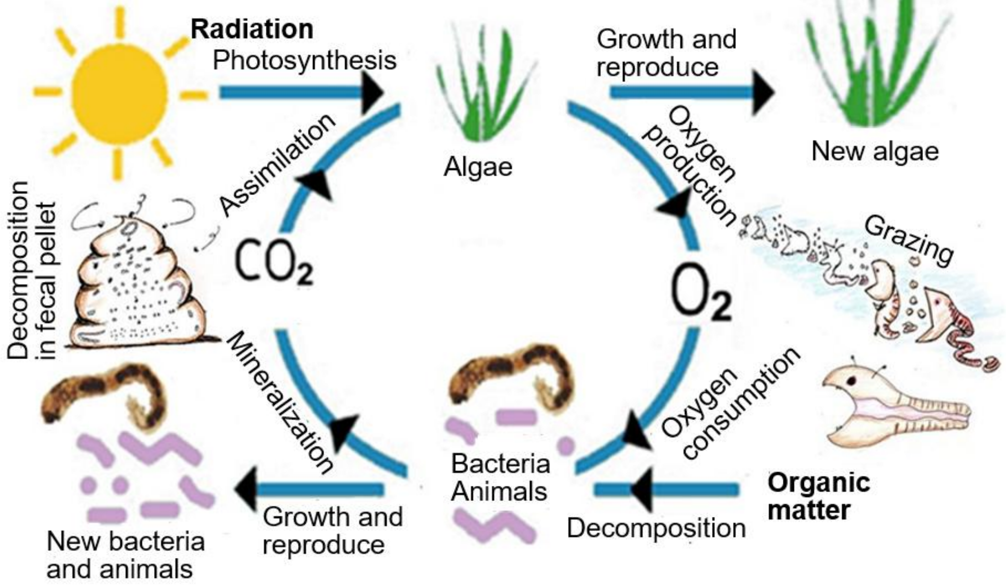
④ Food Chain is Key.

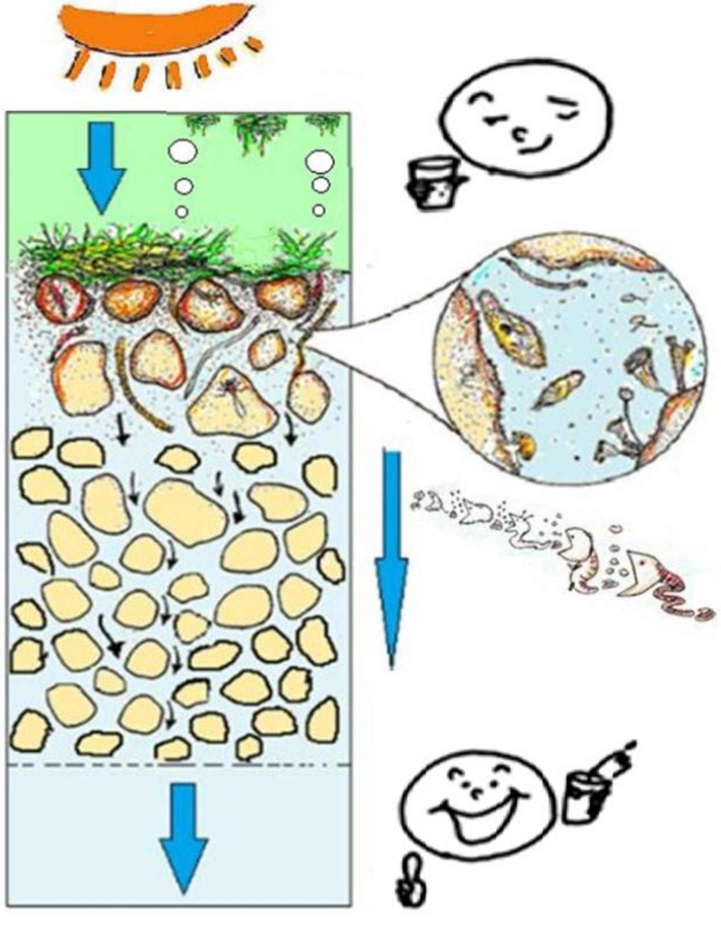


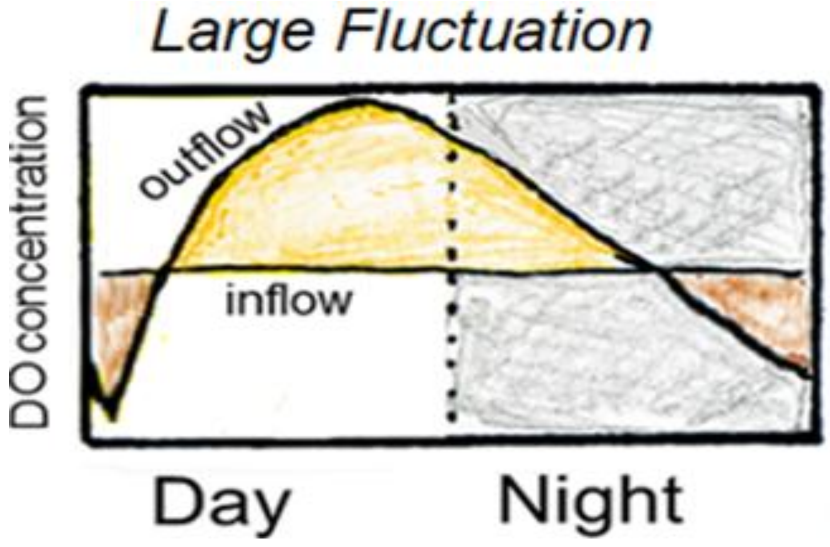
Visit Someya WTP Along Water line and biological activity.

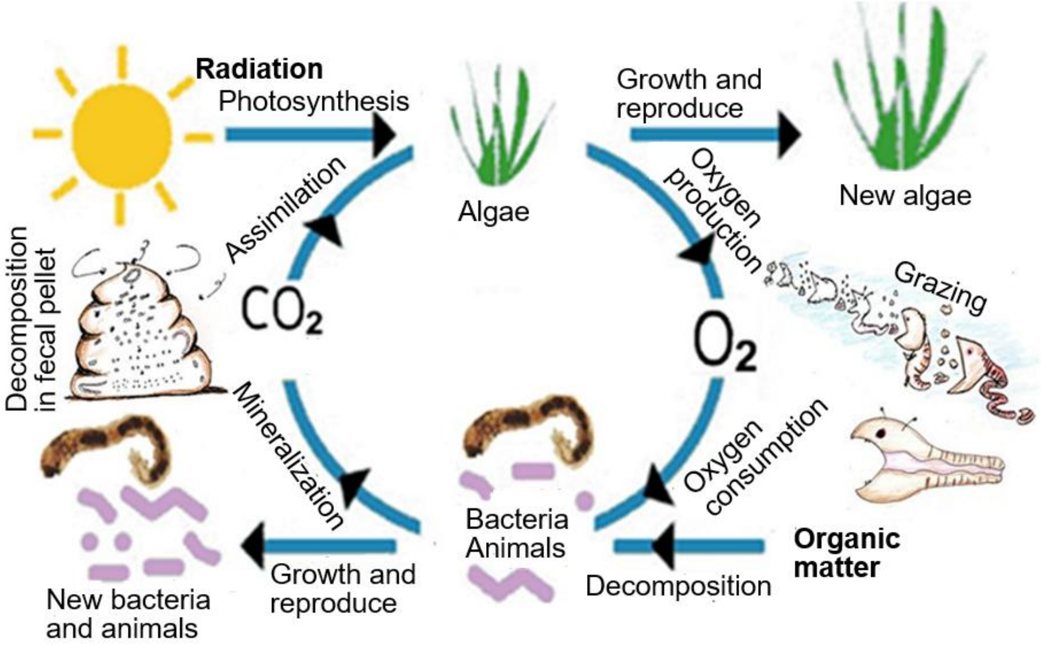
4 min. 31 sec.

https://www.youtube.com/watch?v=0KZq3dpORps

Aerobic condition is essential.







https://www.youtube.com/watch?v=pBmHoxOqi1U&t=3s

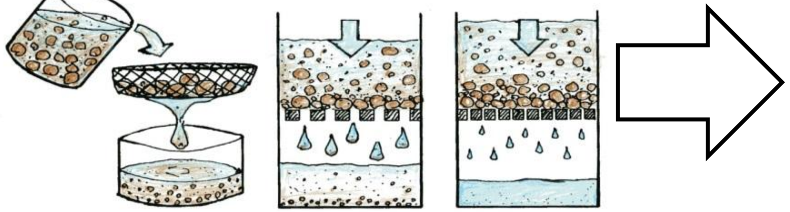
THIS is FOOD CHAIN.

This is a summary of the open lecture at UCL and Univ. Glasgow, in May, 2011.

The first use of slow sand filter for the public supply of drinking water began in 1804 in Paisley, Scotland. The present vertical type of slow sand filter was devised by James Simpson in 1829 after his 2,000 miles inspection trip all over the Britain. This filter provided safe drinking water, free of pathogens to residents in London. This **vertical** type of filter spread round the world and was known as the “English Filter”. Slow sand filter has been believed that it was a **mechanical filter with fine sand under slow current**. However, the major contribution of the purification of the impurities is the **food chain** in this system. The word of “**slow**” was “**gentle for organisms**”. Recently, the English filter of “**Slow Sand Filter**” has been recognized as “**Ecological Purification System**” in Japan.

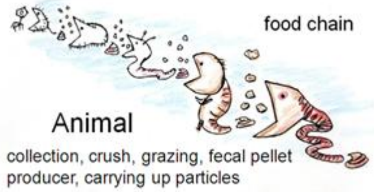
*Slow Sand Filter → Biological Filter → **Ecological Purification System***

English Filter : Mechanical filter



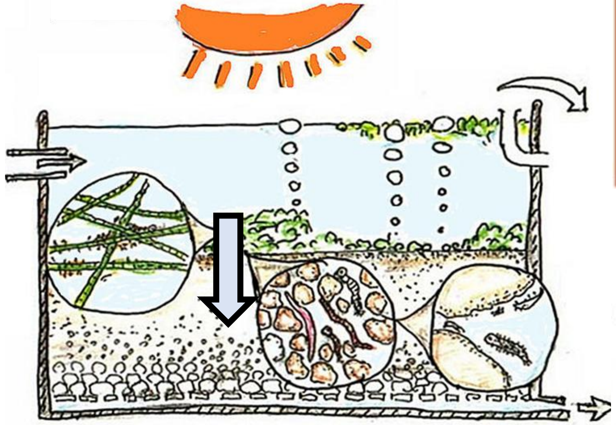
New Concept and New Name

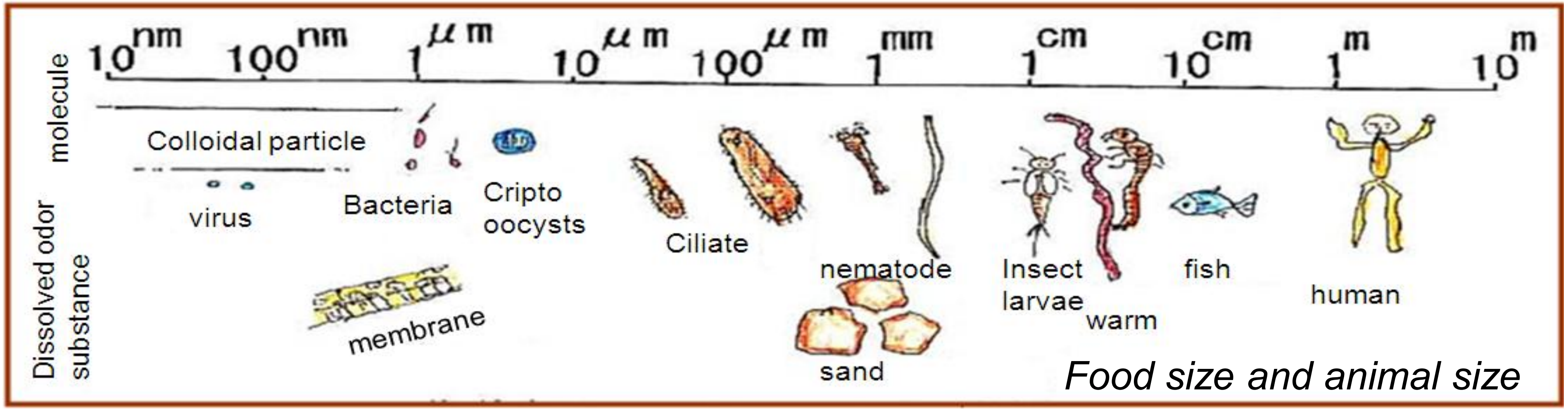
Short time work



Long term action

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



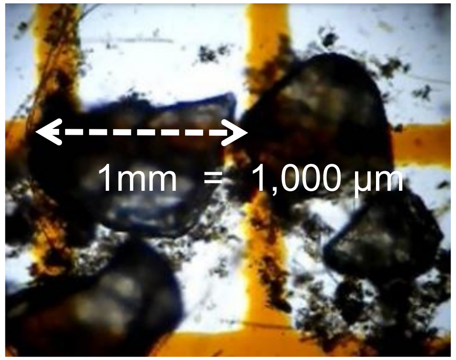


Food size and animal size

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.

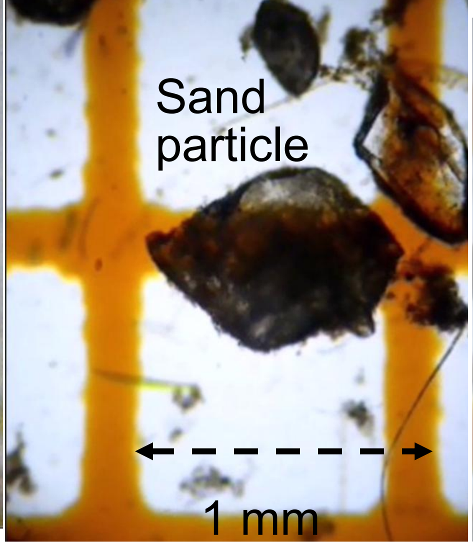


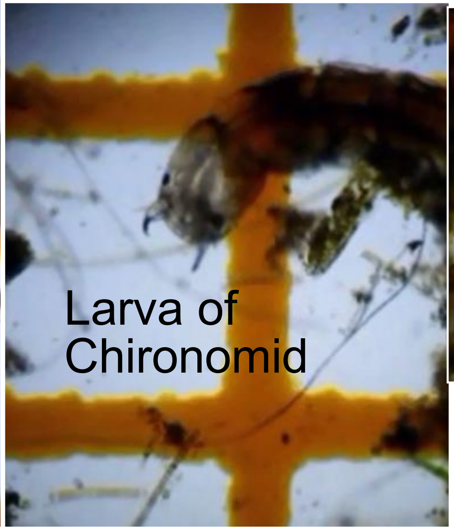
Long term action

Complete decomposition (mineralization) in the faecal pellet.

Anaerobic condition inside of fecal pellet.

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



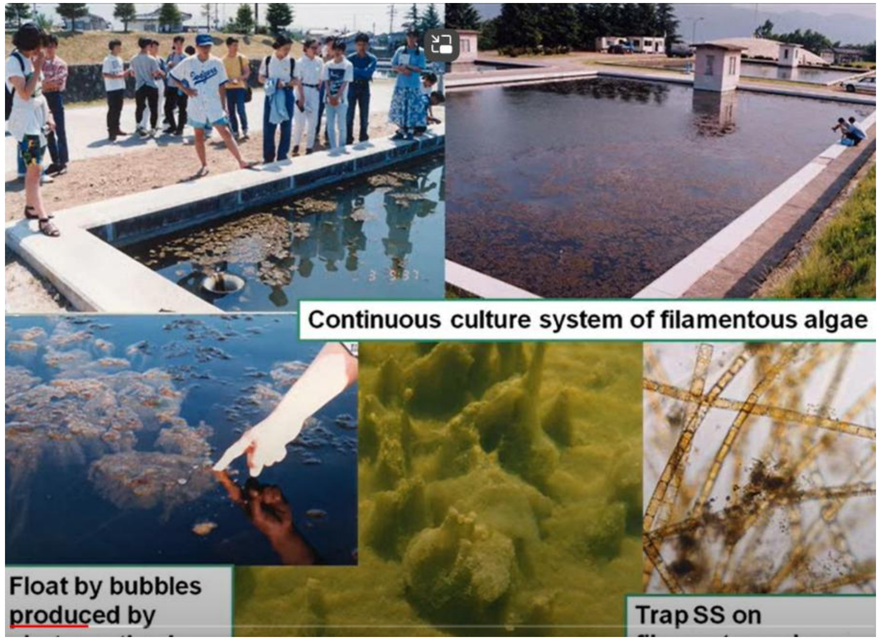


Fecal pellet of Chironomid larva

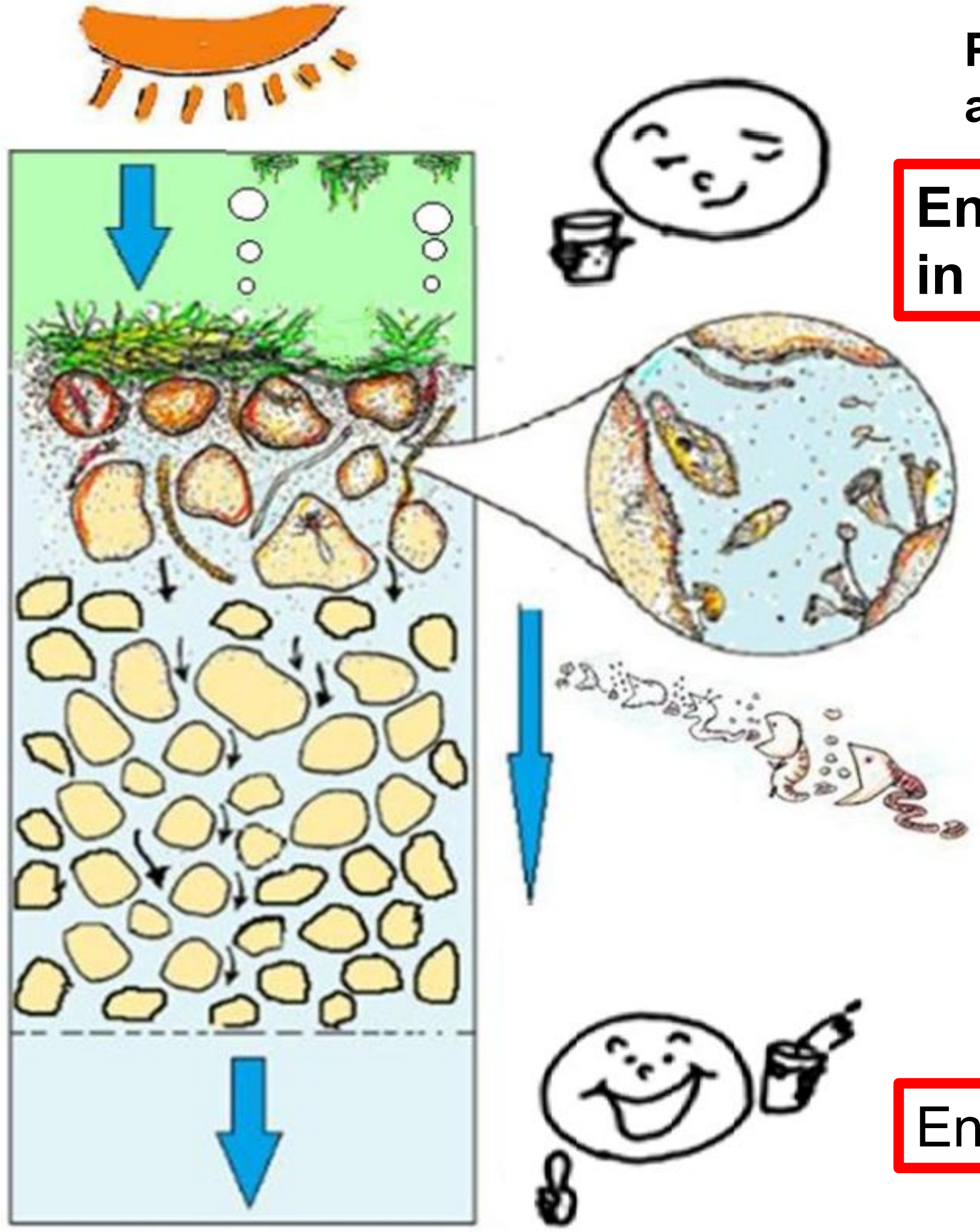
Slow sand filter is real ecological purification system. Food chain is the key. It's an ecological purification system. / 5:22

https://www.youtube.com/watch?v=pBmHoxOqi1U&t=3s

Detail of Ecological Purification System for safe drinking water / 6:23



https://www.youtube.com/watch?v=Pk_JNC6RTyo



Passing time during biological active layer is very short.

English standard filter rate 4.8m/d (20 cm/h) in supernatant water.

Purification is done during the passing time of **1 to 2 minutes** through biological active layer.

Purification time is very short near the surface.

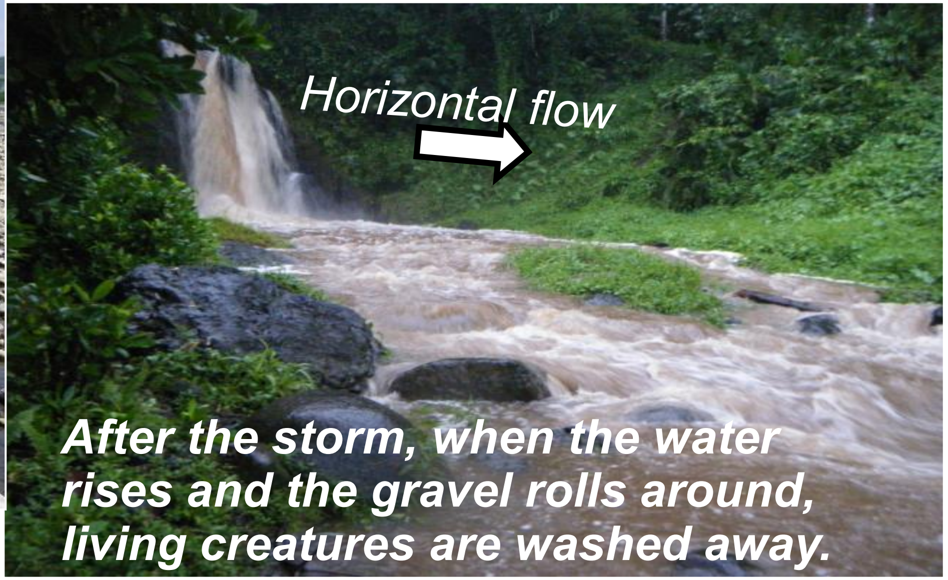
Guarantee and insurance layer for emergency

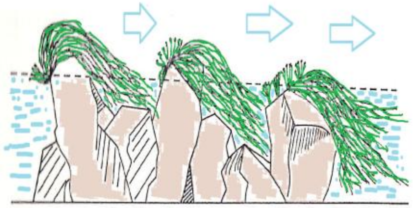
When the porosity is 50% in sand layer, filter rate becomes double. 9.6m/d (40 cm/h)

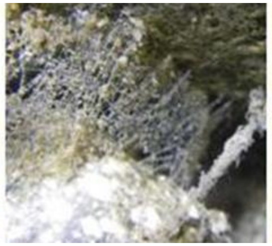
English standard filter rate 4.8m/d (20 cm/h)

Where is clear water?

Sand, stone and soil are not moved.

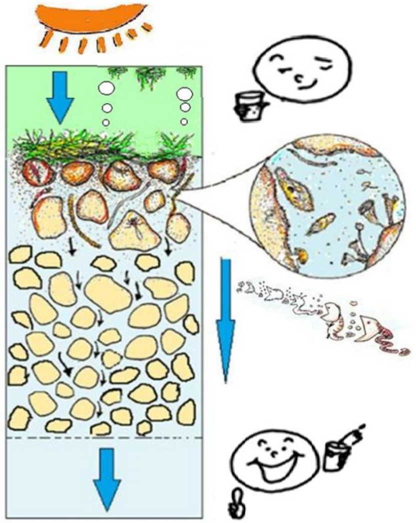






Small animals on the surface of rocks collect turbid matters.

Sand and stone are not moved.



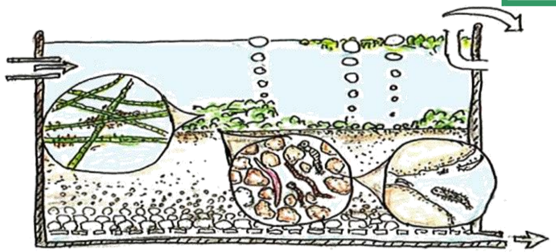
Spring water is always clear.

vertical current.

Gentle for small organisms is the key to make **clean water**.

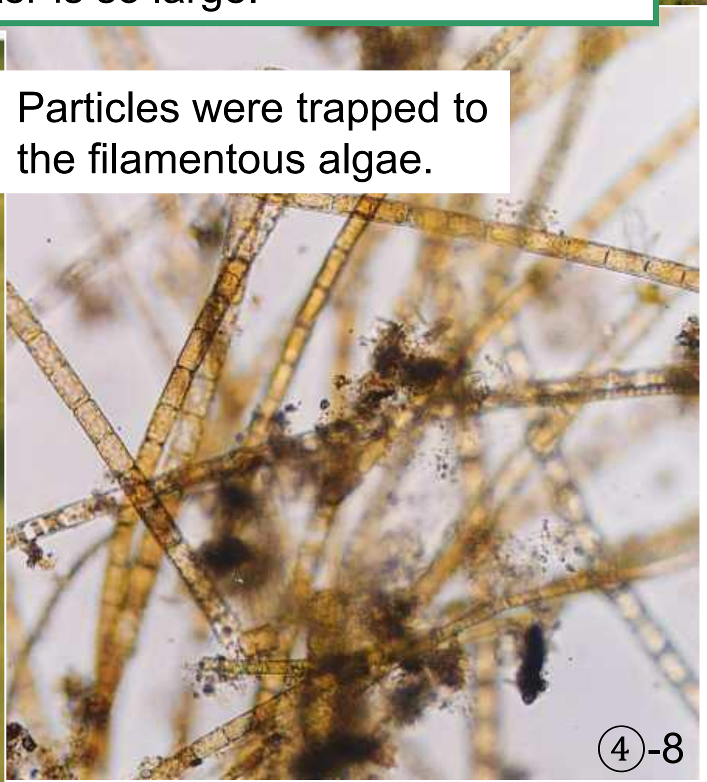
I noticed the Continuous Culture system of filamentous diatom

SSF Capacity to make safe drinking water is so large.

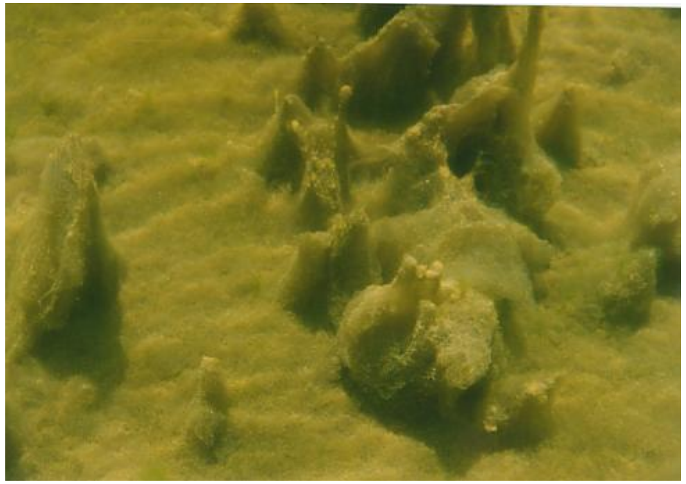


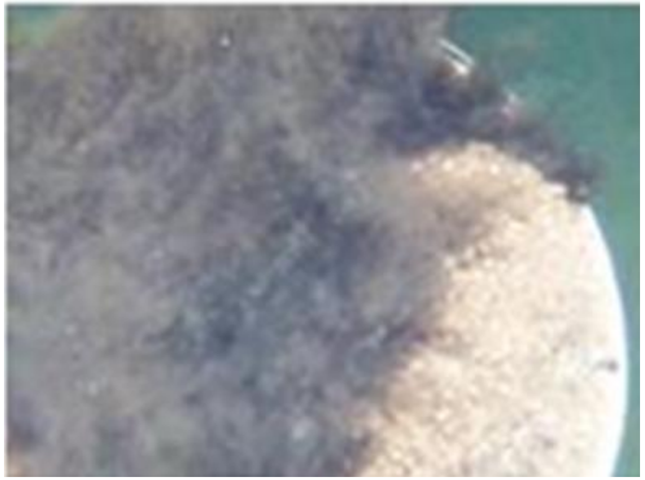
Algal mat lifts by oxygen bubbles produced by photosynthesis.

Particles were trapped to the filamentous algae.



There is a thin **slimy (gelatinous) mat** known as the *Schmutzdecke*, or filter skin on the surface of the sand layer in many textbooks. *This explanation is not correct.*

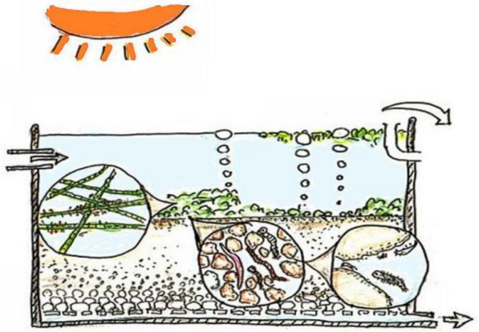


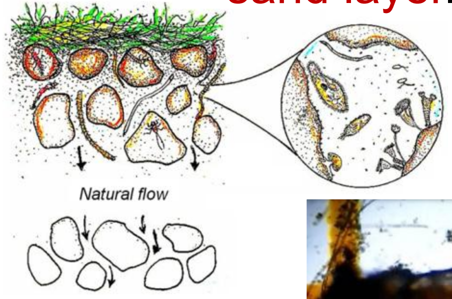


On the surface of sand layer, there is a **soft mat like light feather** mat. Filamentous algal mat is just lay down.

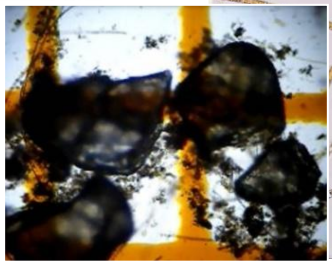
On the shallow bottom, filamentous algae grow well.

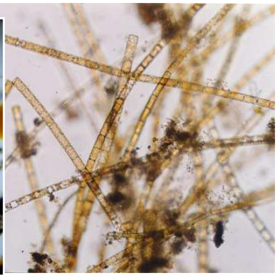
Sand is clear at the site **in water**. When we pull up this mat from the bottom to surface and in air, sand turns dirty color. A large amount of trapped SS among filamentous algal mat drops into sand layer.

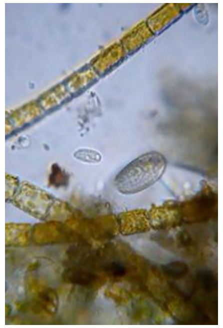




Algae are the best food for animal.







Filamentous diatom is a **pioneer plant in cold water**.

Opflow: American Water Works Association 1993.7.

I made algal mat sampler without any damage of sand filter during the filter run.

Opflow
ISSN 0149-8029
Vol. 19 No. 7 July 1993
A monthly publication of the American Water Works Association

Schmutzdecke Sampler Reduces Filter Bed Damage

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Shinshu University
Ueda, Japan

A schmutzdecke is a sticky algal mat cultivated on the fine sand surface of a slow sand filter. The schmutzdecke is valuable because it acts to remove turbidity without chemical coagulation. The algae prevents the filter from becoming clogged by trapping suspended matter and producing oxygen to promote decomposition activity on the surface sand. When a schmutzdecke is properly maintained, it acts as an "automatic purifier." For a schmutzdecke to form, flow rates must be kept very low.

Operators frequently have difficulty checking the condition of the schmutzdecke while the slow sand filter is being operated. The device described in this article allows samples to be drawn so that the schmutzdecke can be easily analyzed without any damage to the sand surface during operation of the filter.

Sampler Components

The schmutzdecke sampler shown in Figure 1 was assembled from the parts listed in the box below. Figure 2 (page 4) shows a schematic view of the sampler.

The total costs of all components was estimated to be about $100, primarily for the hand pump and acrylic tube. Several hours were required to construct the sampler.

Building the Sampler

The schmutzdecke sampler can be constructed by following the steps listed below.

1. To construct the ring weight, drill an inner hole 1.4 in. (35.7 mm) in diameter in the 2.75-in. × 2-in. (70-mm × 50-mm) brass rod. Drill two holes through the ring weight for screws to secure the acrylic tube. Form the 0.3-in. (8-mm) edge on the bottom of the ring weight.

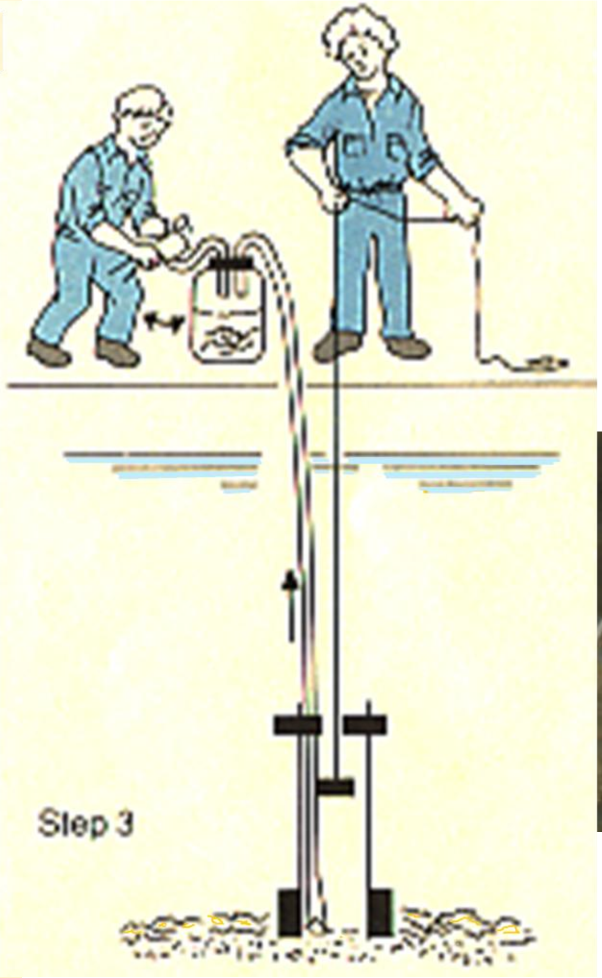
Figure 1 The schmutzdecke sampler

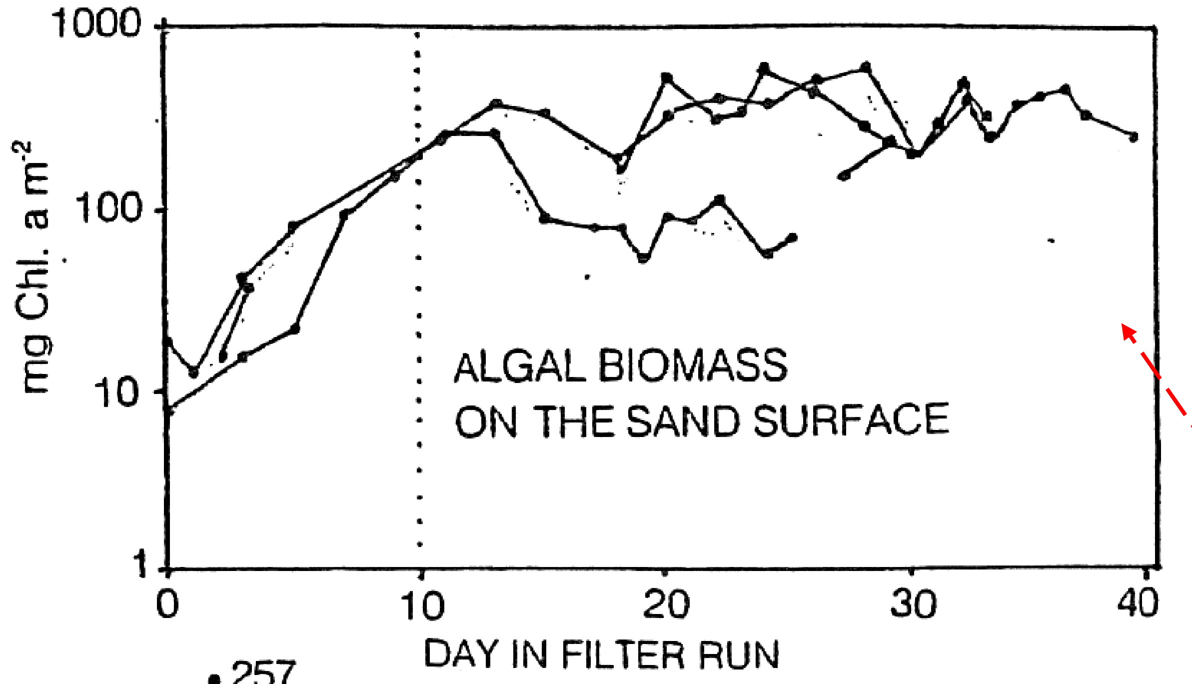
2. Drill a hole in the inner hammer rod for the hanger string.
3. In the stopper rod, drill 0.18-in. (4.5-mm) diameter holes in the center for

(continued on page 4)

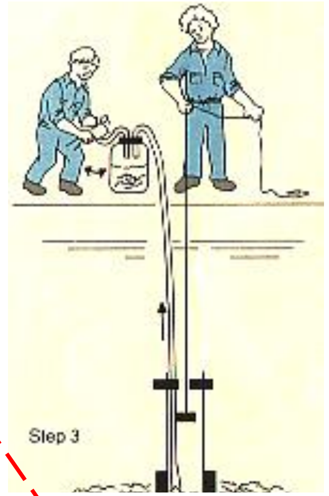
Materials and Costs of the Schmutzdecke Sampler

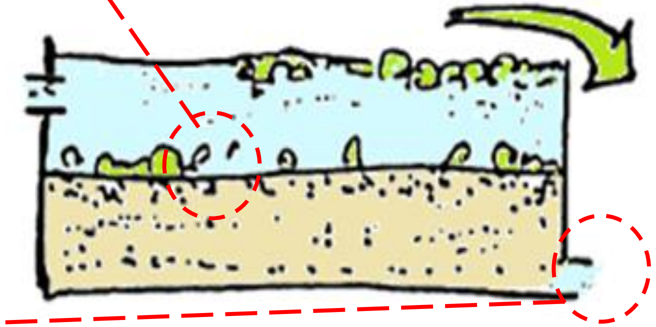
Item	Purpose	Cost
one brass rod, 2.75 in. × 2 in. (70 mm × 50 mm)	ring weight	$ 1.50
one brass rod, 0.6 in. × 0.9 in. (15 mm × 22 mm)	inner hammer rod	.15

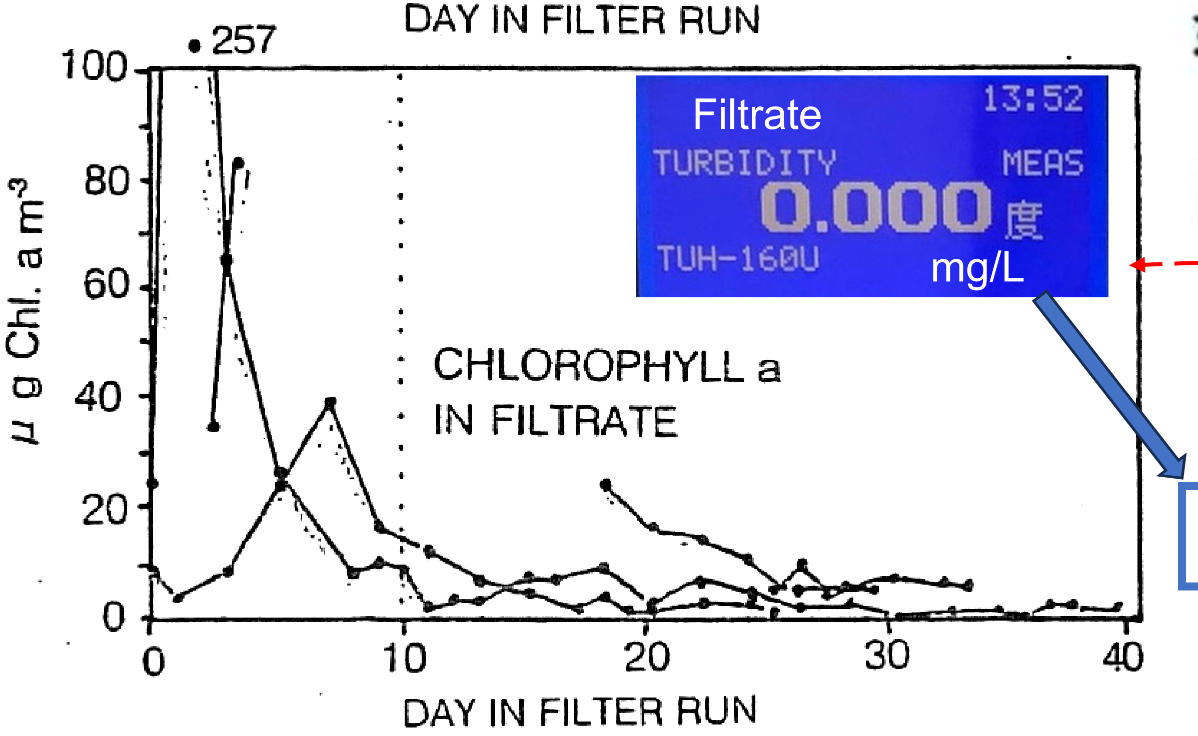




Algae grow well in summer. Continuous culture system of filamentous algae becomes after 10 days.







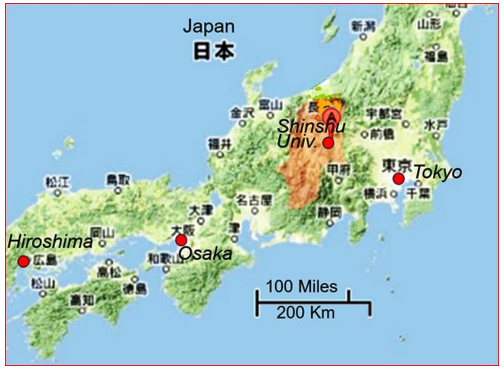
Filtrate water became clear water in 10 days. Grazing animal community grew well within 10 days.

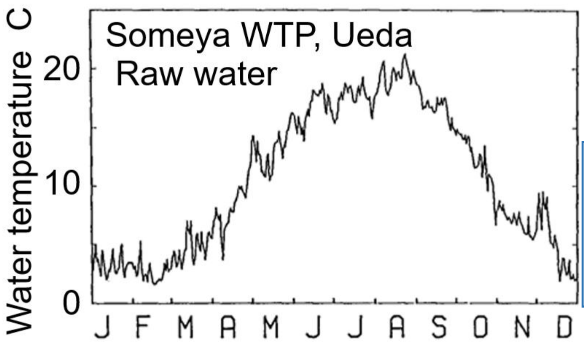
*Japanese standard of filtrate is **2 degrees (mg/L).***

Super clean filtrate.

In summer, scrapping of surface mud is not necessary.

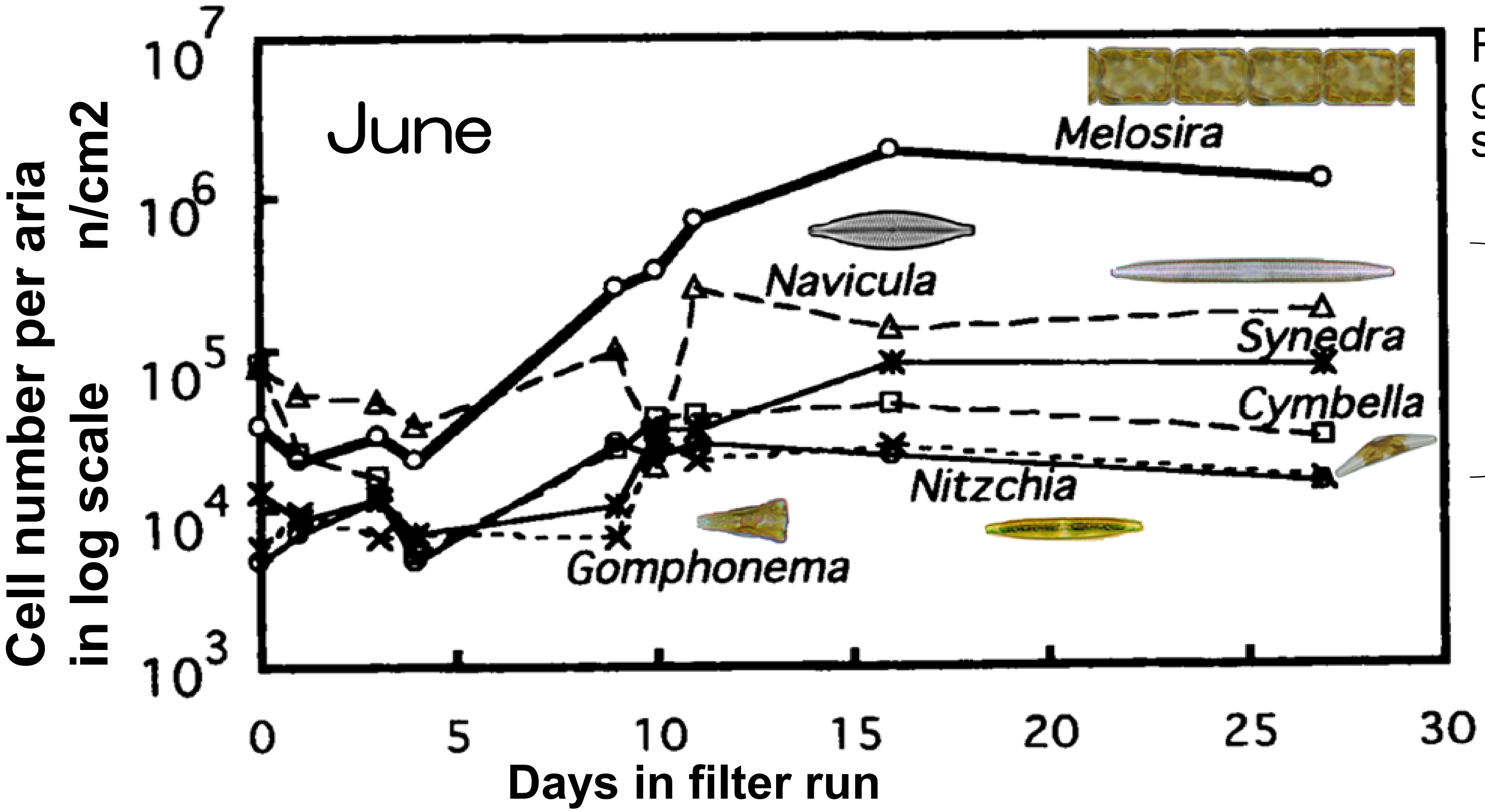
Development of algae on the sand bed during filter run in June in Ueda, Japan.





Seasonal change of temperature

My city (Ueda, Nagano, Japan) is located in cool region in Japan.



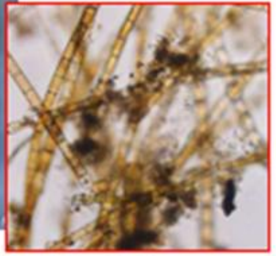
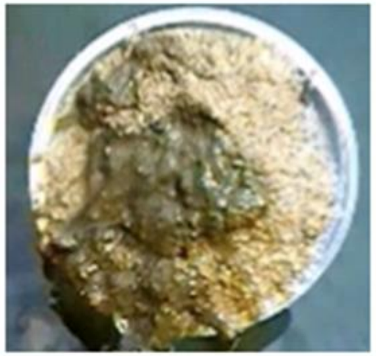
Filamentous algae grow well on the sand filter bed.

From a river

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

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

Melosira became dominates in cool water where grazing activity of animals is weak.

Lift up in air.

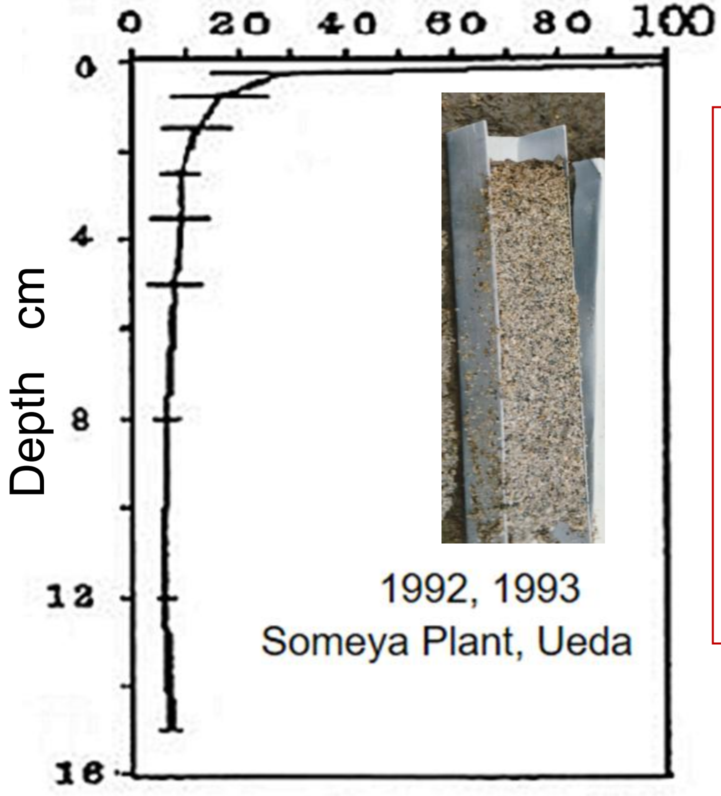
Algal mat on the sand surface in water.

Sand beneath the surface in water is clean.
When the supernatant water drain off, the trapped SS releases and drops into sand layer.


Dirty Suspended matter is only near the surface.

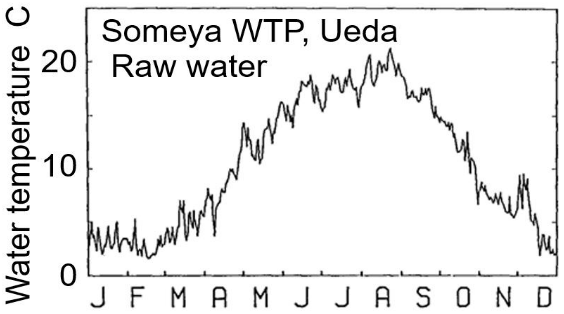

At scraping time, we took sand sample.

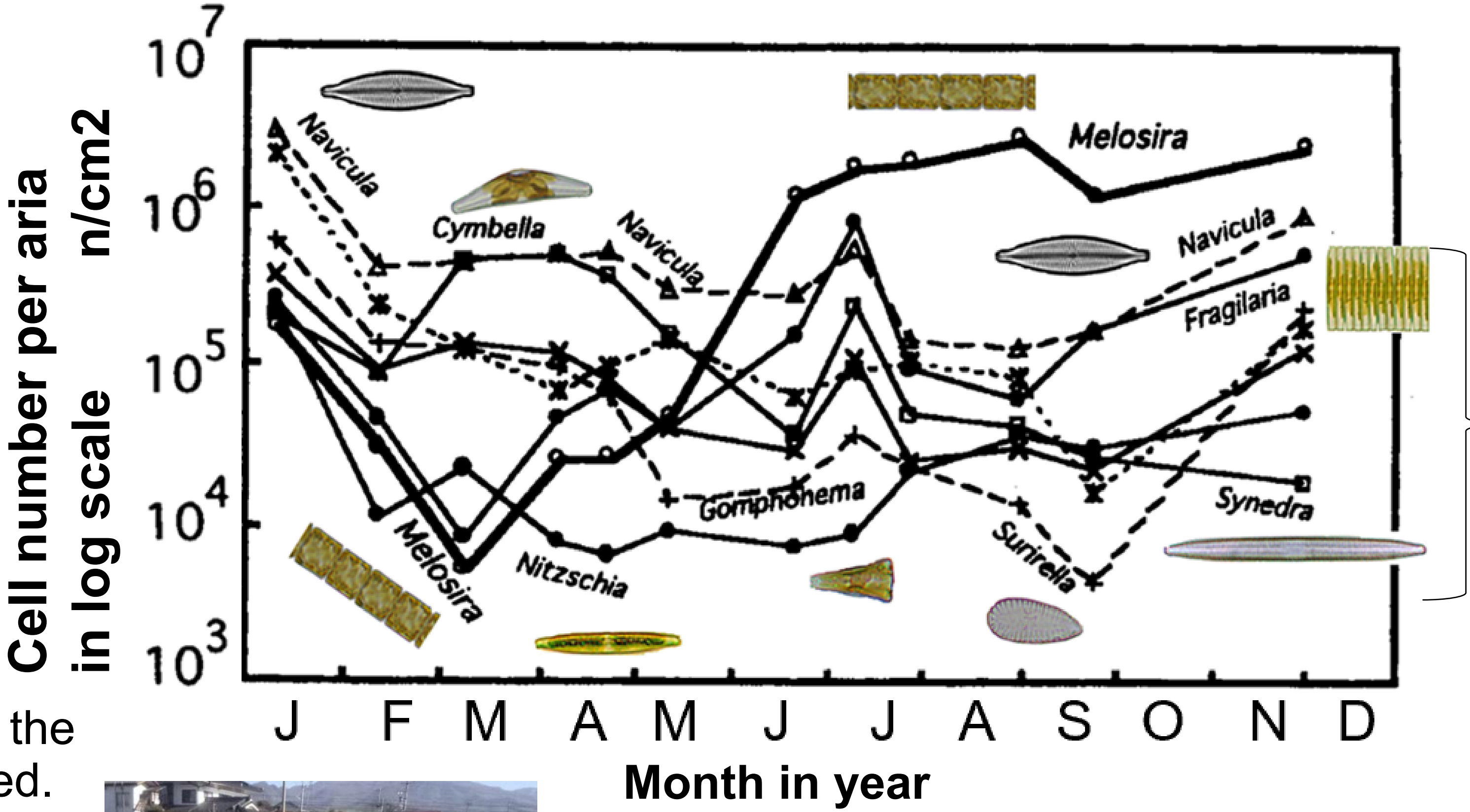
Suspended Solid in washed sand.



Dirty matter in sand layer is only near the surface where biological activity is high. Deeper sand layer is clear.

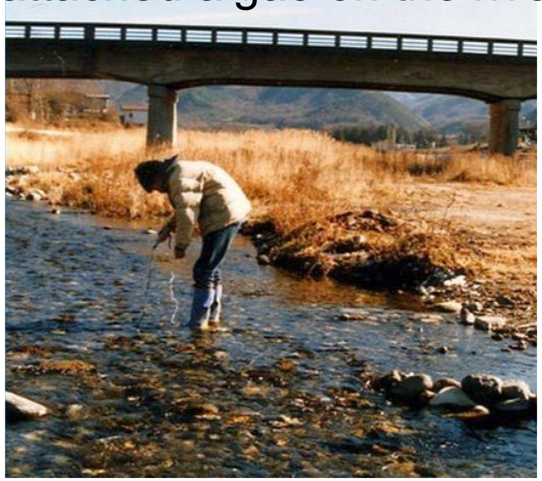
Seasonal changes of the algal mat after 10 days of filtration run.





From a river

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



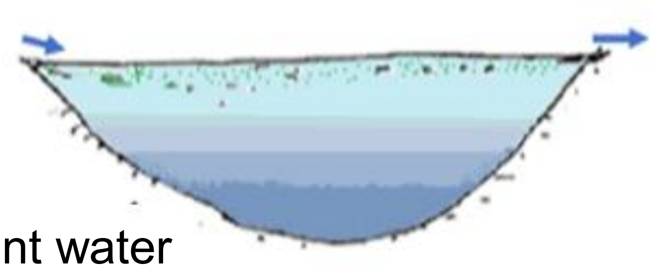
Weak biological activity in cold water.

When the amount of solar radiation increased and the water temperature increased, the filamentous diatom of *Melosira* became dominant until December.

Different type of algae grow in different environment.

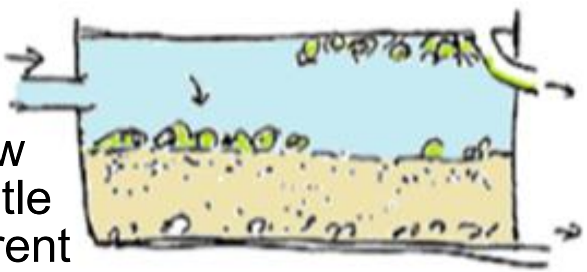
In Slow Sand Filter pond, there is down ward current from surface.
Filamentous form of algae can grow on the sand bed.

Pond, lake and ocean

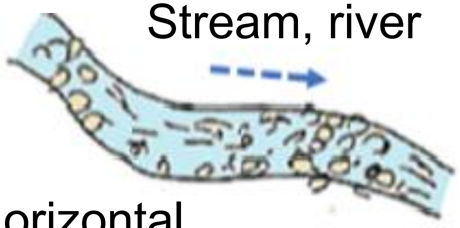


Stagnant water

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

Try to accelerate algal growth in winter.

Algal growth made delicious tap water.

I thought that the nutrient concentration in rivers in Ueda city was poor than in London.

Even in winter, the diatom *Melosira grew* well in London, UK.

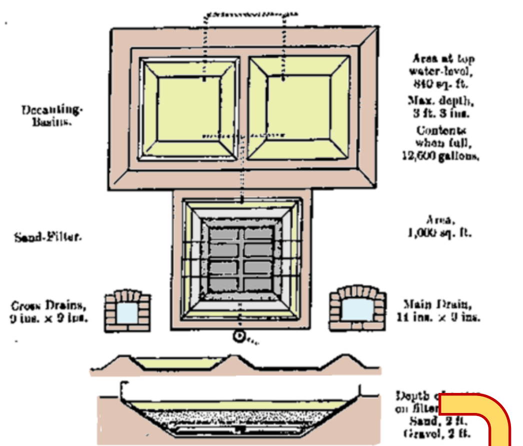


Fig. 28. James Simpson's Experimental Filter of 1827–1828

I thought the nutrient concentration was too low.

38 cm Water
61 cm Sand
61 cm Gravel

I put nutrient to the filter pond in cold winter.

But no growth of algae in the filter pond.

When I put nutrient to the floating bottle in winter, algae grew even in cold condition in Ueda.

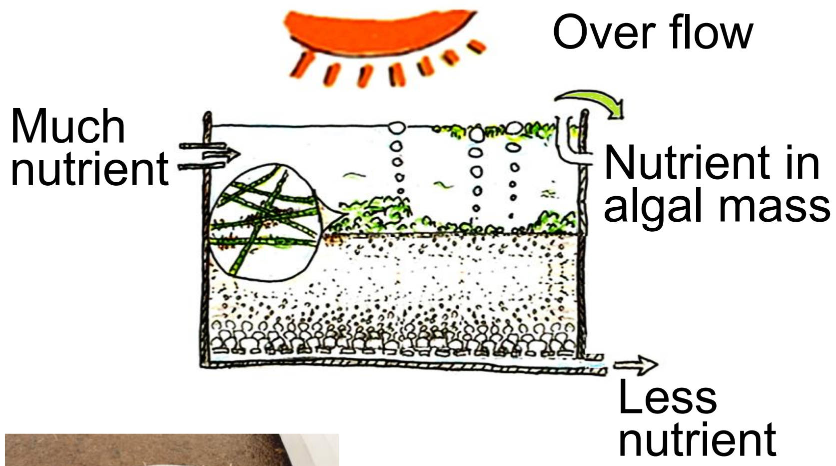
In March when snow melt period, algae did not grow in the filter pond.

Algae grew well in shallow water in the flood plain.

Algae grew well in a shallow model.

I found **shallow depth** was the key of growth of algae than nutrient.

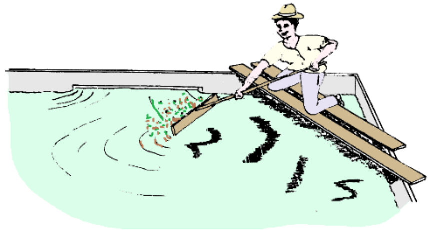
Continuous algal culture system is a nutrient reducing system.



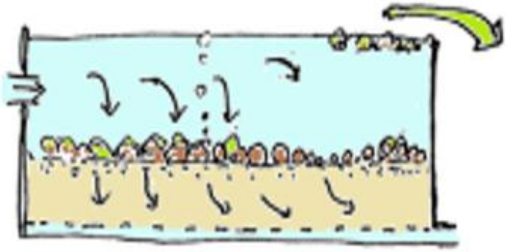
Harvest experiment was done.

Average daily harvest during 11 days in July

Wet matter	173 g/m2
Dry matter	25.9 g/m2
Organic matter	7.81 g/m2
Nitrogen	373 mg/m2
Phosphorous	32 mg/m2

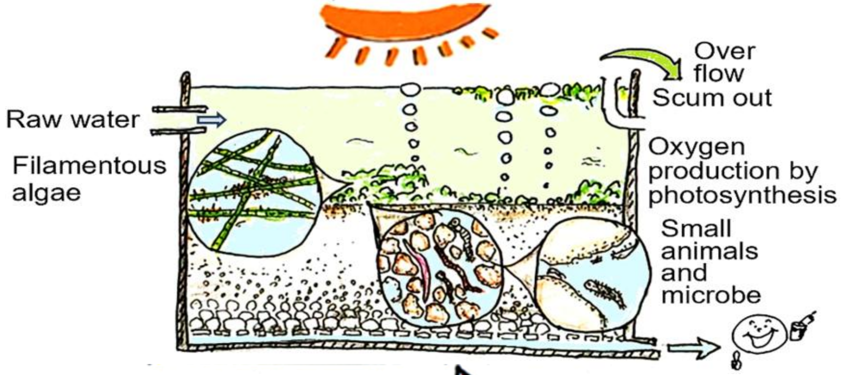


Nutrient reduction from inflow water to filtrate by algal growth.



Nutrient removal as
Nitrogen 4.6 %
Phosphorous 27%

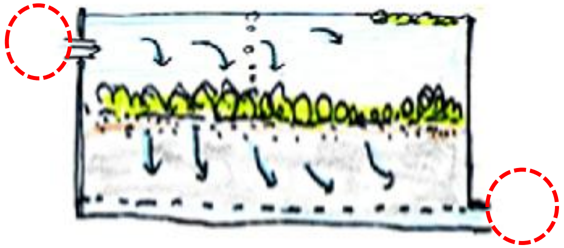
Aerobic condition is essential for biological activity.



$$CO_2 + H_2O \rightleftarrows CH_2O + O_2$$

Algal photosynthesis accelerates purification process.

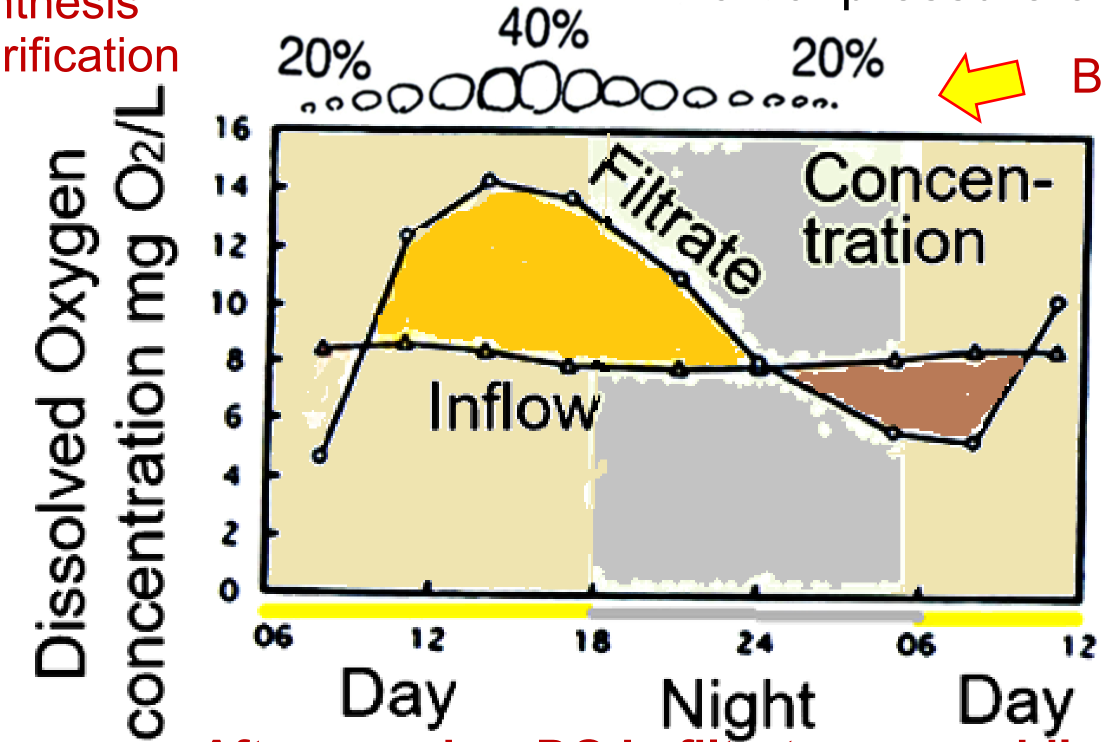
There is down ward current.



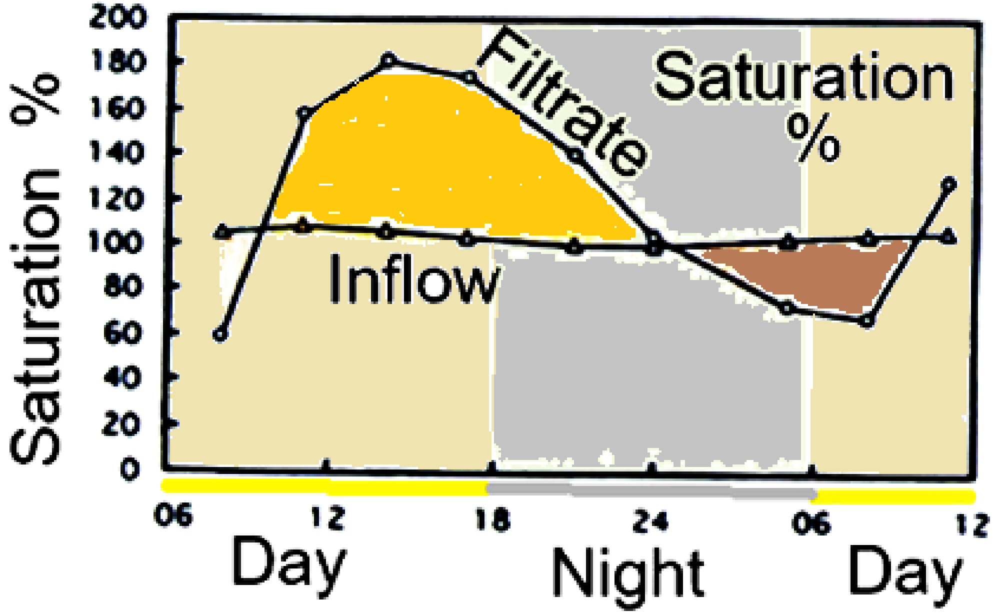
Diurnal change of dissolved oxygen (DO) was measured.

Partial pressure of oxygen in bubbles was also measured.

Bubbles keep aerobic condition after sunset.



After sun rise, DO in filtrate was rapidly increased.



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

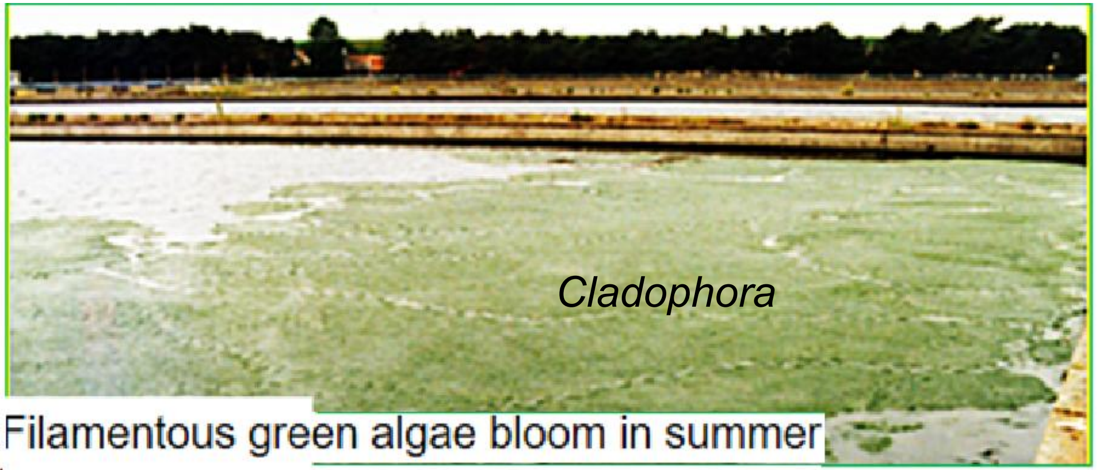
I investigated the seasonal change of algae in Thames filters in London from 1994 to 1996, **30 years ago**.

Nutrient rich water

Biological roughing filter without chemical.

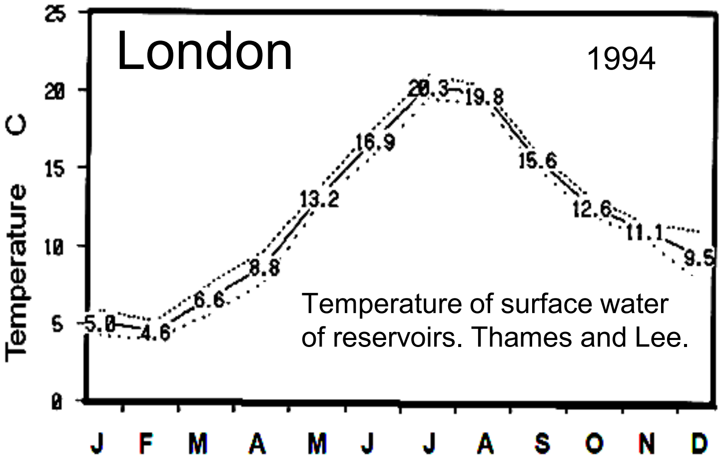
100mx35m
32 Filters

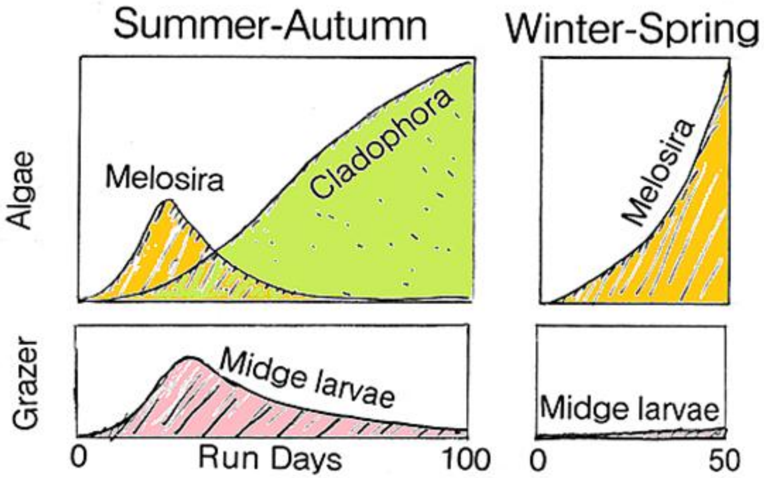
Ashford Common WTP, Thames Water



Filamentous green algae bloom in summer

Filamentous diatom in winter

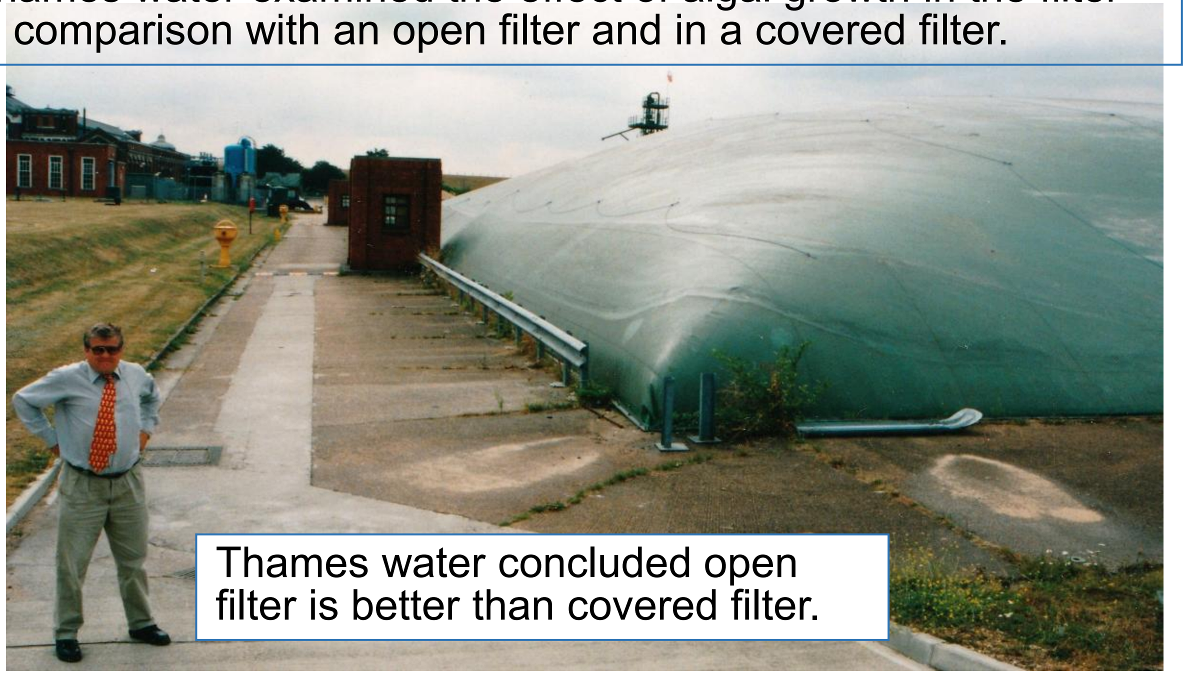




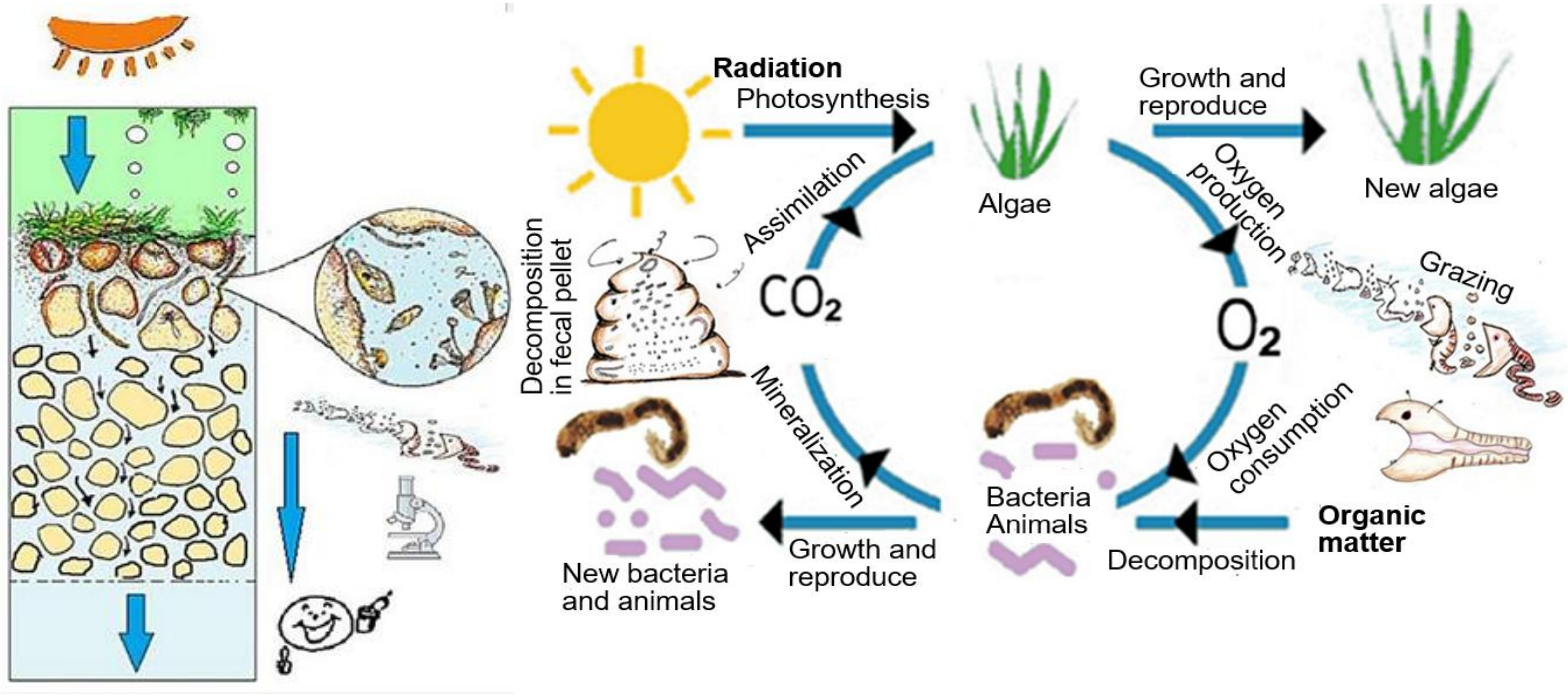
Diatom to Green algae in summer is due to grazing activity.

The Thames Water Company had a hard time removing the massive proliferation of filamentous green algae. They called it **blanket weed**.

Thames water examined the effect of algal growth in the filter in comparison with an open filter and in a covered filter.



Thames water concluded open filter is better than covered filter.



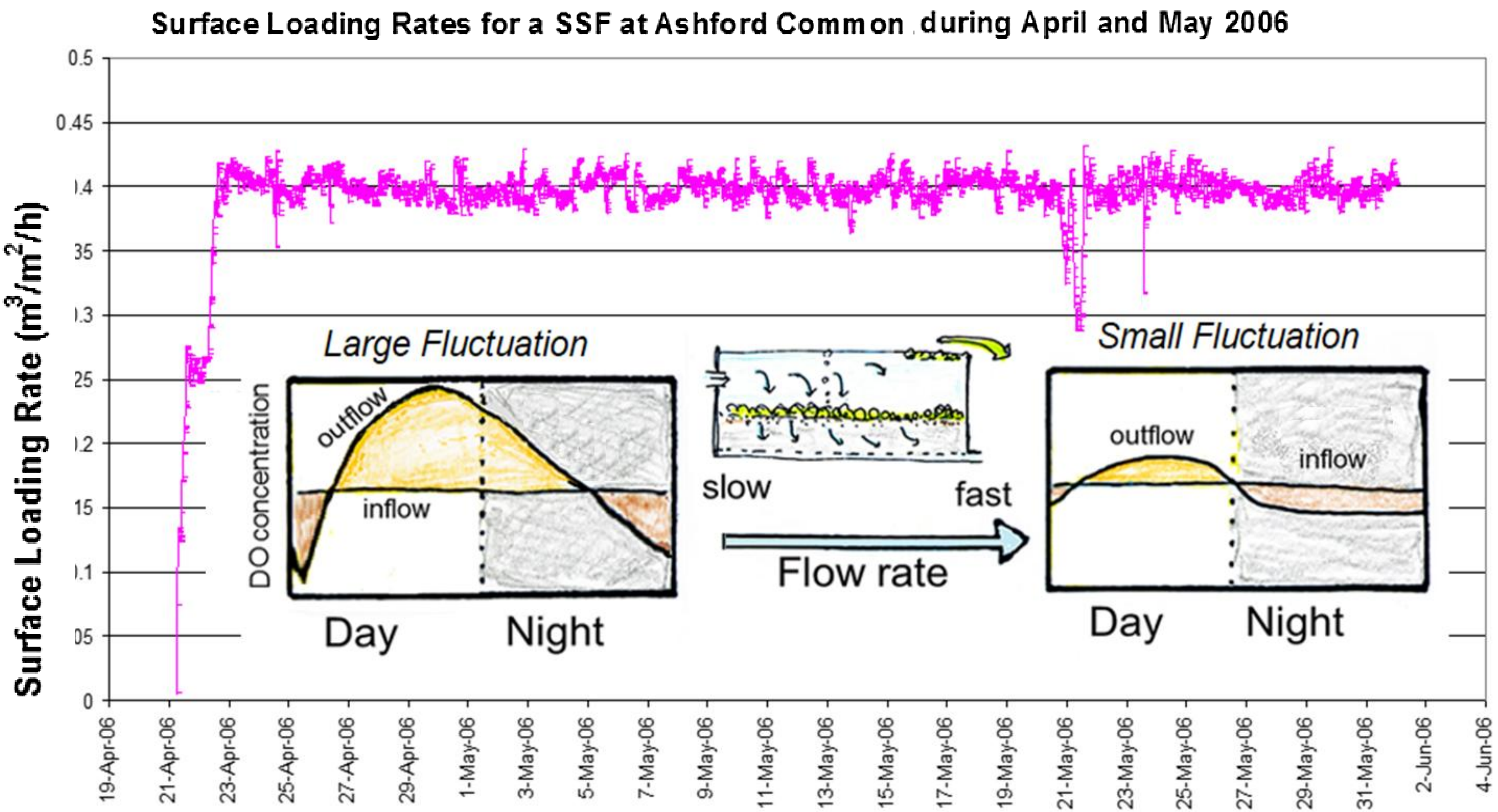
After the experiment, they confirmed "algal growth contributed better condition for biological purification process".

Algae produce oxygen through photosynthesis, and **the presence of dissolved oxygen creates an environment in which heterotrophic organisms can thrive without worry.**

Slow does not refer to speed, but to being **gentle to the organisms**.

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

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



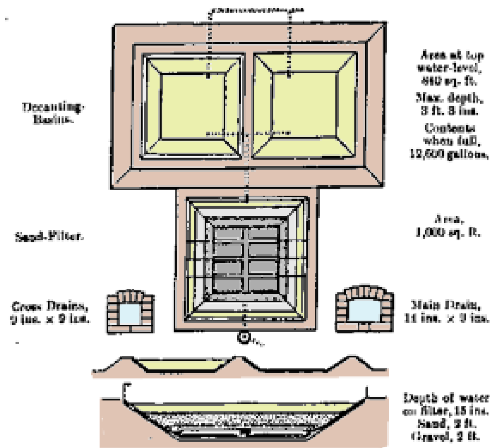


FIG. 28. JAMES SIMPSON'S EXPERIMENTAL FILTER OF 1827–1828

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

38cm water depth

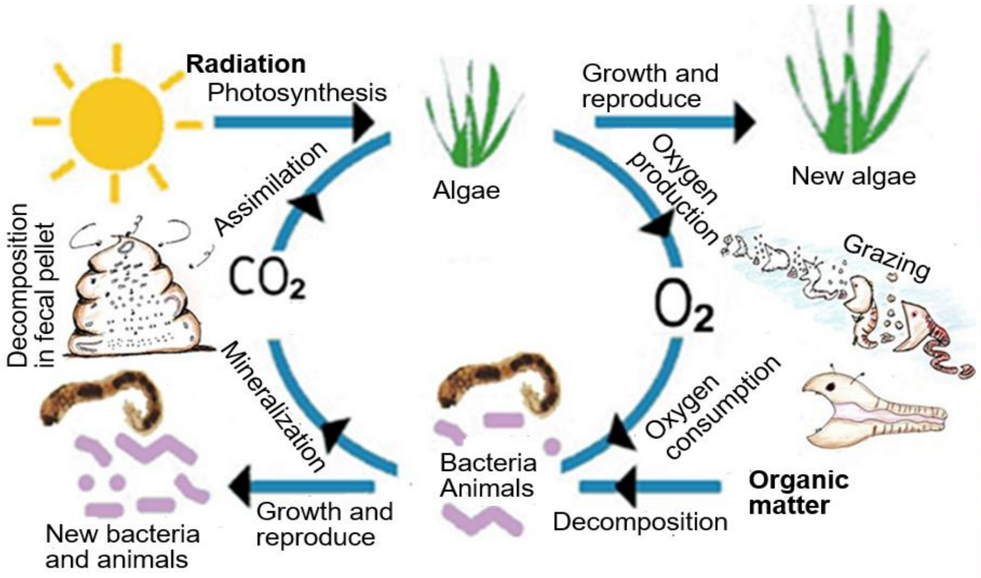
200yrs ago

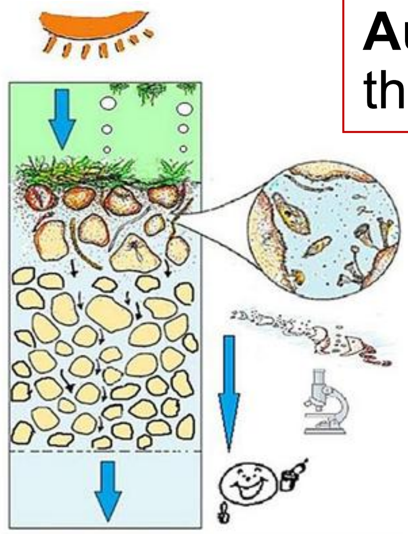
➡ ***4.8 m/d (20 cm/h)***
World wide English Standard Filter rate

➡ The filter rate of **9.6m/d(0.4m/h)** is adopted in Thames filter plants in London to escape oxygen drop in filtrate during the night time, in 2006.

⬇

Thames Water's asset standard says we can operate up to **12m/d(0.5 m/h)**, in 2025.





My first visit to Thames Water Company was on **August 19th in 1992**. I explained my study on the **role of algae in SSF system** in Ueda.

I explained the biological activity using DO changes in the filters.

Ashford Common WTP

Slow sand filtration is a purification process that relies on the efforts of a biological community. **Algae produce oxygen** through photosynthesis, and **the presence of dissolved oxygen creates an environment in which heterotrophic organisms can thrive without worry.** Slow does not refer to speed, but to being gentle to the organisms.

Idea of EPS spreads from Japan to the world.

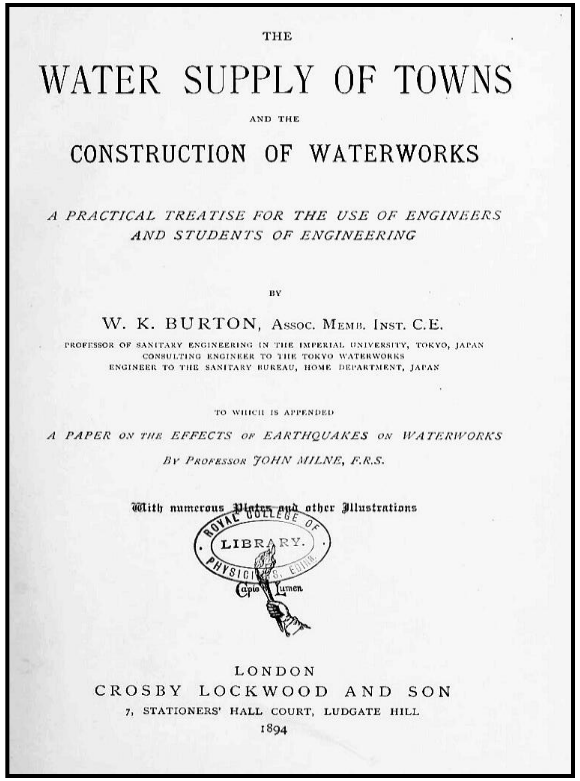
About higher flow rate asked by N. Nakamoto

Michael Chipps Principal Research Scientist
2025/03/18

Since your visit (Aug. 19th 1992) we have added DO and turbidity monitoring on the outlet of all SSFs. Thames Water's asset standard says we can operate up to **0.5 m/h(12m/d)**, but in reality, we are usually in region of 0.25 to 0.35 m/h, but we can reach 0.4 m/h occasionally if we have to. We do have keep a careful eye on dissolved oxygen (DO).

W. K. Burton published "**The Water Supply of Towns and the Construction of Waterworks**" in **1894** in London.

https://wellcomecollection.org/works/da2p35kj/items



THE

WATER SUPPLY OF TOWNS

AND THE

CONSTRUCTION OF WATERWORKS

A PRACTICAL TREATISE FOR THE USE OF ENGINEERS AND STUDENTS OF ENGINEERING

BY

W. K. BURTON, Assoc. Memb. Inst. C.E.

PROFESSOR OF SANITARY ENGINEERING IN THE IMPERIAL UNIVERSITY, TOKYO, JAPAN
CONSULTING ENGINEER TO THE TOKYO WATERWORKS
ENGINEER TO THE SANITARY BUREAU, HOME DEPARTMENT, JAPAN

TO WHICH IS APPENDED

A PAPER ON THE EFFECTS OF EARTHQUAKES ON WATERWORKS

By Professor JOHN MILNE, F.R.S.

With numerous Plates and other Illustrations

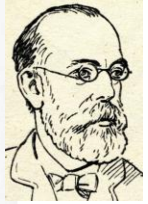
LONDON
CROSBY LOCKWOOD AND SON
7, STATIONERS' HALL COURT, LUDGATE HILL
1894

On p94

practice. Dr. Koch, the eminent bacteriologist, has (the writer understands) come to the conclusion that a filtering speed should never exceed $7\frac{3}{4}$ feet in twenty-four hours. It seems unlikely that any such hard-and-fast rule can hold good for all cases,* for there can be no doubt that the efficiency of filtration varies with many circumstances—with the purity or the reverse of the water, for example; with the nature of the sand; and with the temperature.

* A series of experiments, both biological and chemical, carried on in connection with the Osaka (Japan) waterworks, gave very different results from this.

It has recently been discovered, at the Berlin waterworks, that covered filters are much less efficient than open.



Dr. R. Koch neve exceed 7 ¾ feet in 24 hrs. = **2.27 m/d**

Osaka(Japan) wks gave very different results from this.
➪**faster rate?**

Berlin wks discovered that covered filters are much less efficient than open.
➪**Open is better.**

On p95

On the other hand, the much higher velocities—16 feet in twenty-four hours or even more—adopted by some English engineers, are undoubtedly too high.

It is with some diffidence that the writer states the conclusion he has come to—namely, that a *maximum filtering speed of 10 feet in twenty-four hours is quite permissible* in the case of water already fairly good. That is to say, with arrangements properly

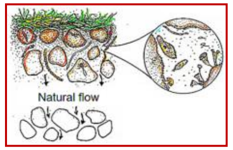
English engineers adopted more 16 feet in 24 hrs. = **over 4.88 m/d**

Burton : max 10 feet in 24 hrs. = **max 3 m/d**

At that time in **1894**, he believed that purification was done by **slow speed with fine sand**.

This means **mechanical filtration**.

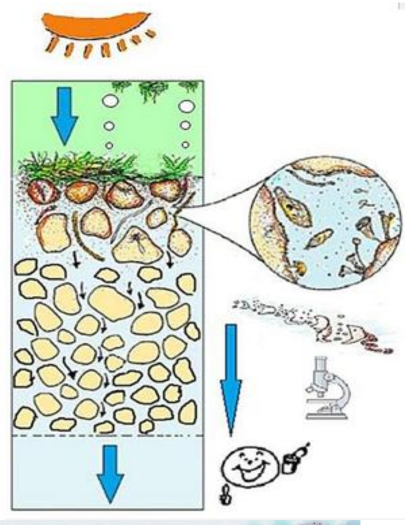
Present Thames wks adopts **12 m/d.**



This is depended on **Ecological Purification System**.

Don’t remove biological active layer.

Slow sand filtration is a nature based chemical free process for purifying water by removing contaminants through biological and physical processes using fine sand.



In case of dry skimming to scrape upper dirty sand layer, this treatment is the removing biological active layer. It takes time to develop biological active layer.

https://www.thameswater.co.uk/about-us/innovation/sandscape-project

Thames Water tests new robotic underwater technologies designed to simplify and speed up the cleaning and maintenance of slow sand filtration methods used in the water treatment process.