Handbook for Preventive Water Treatment against Biological Problems

March 2006

Japan Waterworks Association

Handbook for Preventive Water Treatment against Biological Problems

* Original book (Japanese) is published by Japan Waterworks Association (JWWA), March 2006. This paper was translated by WaQuAC-NET members and WaQuAC-NET is responsible to this translation.

Contents

2.3.8 Genus *Dictyosphaerium*

2.3.9 Genus *Eudorina*

2.3.10 Genus *Gloeocystis*

2.3.11 Genus *Golenkinia*

2.3.12 Genus *Micractinium*

2.3.13 Genus *Oocystis*

2.3.14 Genus *Pandorina*

2.3.15 Genus *Pediastrum*

2.3.16 Genus *Quadrigula*

2.3.17 Genus *Scenedesmus*

2.3.18 Genus *Sphaerocystis*

2.3.19 Genus *Spirogyra*

2.3.20 Genus *Staurastrum*

2.3.21 Genus *Tetraedron*

2.3.22 Genus *Tetraspora*

2.3.23 Genus *Volvox*

2.4 CRYPTOPHYTES

2.4.1 Genus *Cryptomonas*

2.5 CHRYSOPHYTES

2.5.1 Genus *Mallomonas*

2.5.2 Genus *Pseudokephyrion*

2.5.3 Genus *Synura*

2.5.4 Genus *Uroglena*

2.6 DINOPHYTES

2.6.1 Genus *Glenodinium*

2.6.2 Genus *Peridinium*

2.7 EUGLENOPHYTES

2.7.1 Genus *Euglena*

2.7.2 Genus *Trachelomomus*

2.8 PORIFERA (Sponges)

2.8.1 Family Spongillidae

2.9 ASCHELMINTHES

2.9.1 Rotifera

2.9.2 Nematoda (Roundworms)

2.9.3 Gordioidea (Hairworms)

2.10 TENTACULATA

3.4.1 Critical value
3.4.2 Actual cases of found creature
4 Others

Chapter VI: Monitoring and cause survey of biological troubles
1. Procedure of monitoring and cause survey of biological troubles
2. Trouble on operation of facility
2.1 Trouble on coagulation and sedimentation
2.1.1 Monitoring
2.1.2 Cause survey
2.2 Filter clogging and passing through filter
2.2.1 Monitoring
2.2.2 Cause survey
2.2.3 Evaluation by size of trouble creature; obtaining equivalent sphere size
3. Trouble on quality of drinking water
3.1 Trouble on odor and taste
3.1.1 Monitoring
3.1.2 Cause survey
3.2 Trouble on turbidity
3.2.1 Monitoring
3.2.2 Cause survey
3.3 Colored water
3.3.1 Monitoring
3.3.2 Cause survey
3.4 Finding creature by human eyes
3.4.1 Monitoring
3.4.2 Cause survey
4 Others
5. Quantitative analysis of trouble creature; biological examination method
5.1 Quantitative analysis of trouble creature
5.1.1 Procedure of the method with standard counting plate
5.2 Sample preparation
5.2.1 Fixing
5.2.2 Dispersing cell
5.2.3 Pressurization
5.2.4 Dilution

5.2.5 Concentrating

Chapter VII: Countermeasures against biological problems

1. Selecting a countermeasure method against a biological trouble
2. Countermeasure at water source or for raw water
2.1 Reducing amount of trouble creature which come into raw water
2.2 Suppressing growth of trouble creature at water source
3. Countermeasure in treatment process
3.1 Case of rapid sand filtration
3.1.1 Countermeasure against creature contained in raw water
3.1.1.1 Countermeasure in between receiving well and sedimentation process
3.1.1.2 Countermeasure at filtration
3.1.2 Countermeasure against creature grown in treatment plant
3.2 Case of slow sand filtration
3.2.1 Countermeasure against organism contained in raw water
3.2.2 Countermeasure against organisms grown in treatment plant
3.3 Case of advanced water treatment
3.3.1 Biological treatment
3.3.2 Ozone treatment
3.3.3 Granular activated carbon
3.4 Case of only disinfection
4. Countermeasure in distribution process

Chapter VIII: Trouble by small animal and countermeasure

1. Small animal causing passing through filter
1.1 Nematoda
1.2 Larva of chironomidae
1.3 Gordioidea(Hairworm)
1.4 Asellus(Sow bug)
1.5 Others
2. Other trouble by small animal
2.1 Limnoperna
2.2 Fish egg(Silver bighead Hypophthalmichthys molitrix)

Chapter IX: Countermeasure against biological troubles in overseas

1. Manual of countermeasure against biological troubles by American Water Works

Chapter VII Countermeasures against biological problems

In this chapter, countermeasures against biological problem are shown with specific notation in each stage such as water source, treatment process and distribution. Countermeasures in water treatment process are shown in each method such as rapid sand filtration, slow sand filtration, advanced treatment and only disinfection method.

When biological problem is found by monitoring or survey of treatment trouble, some actions are necessary to avoid or control the trouble. Countermeasure should be chosen as the most efficient method in terms of cost and feasibility considering species of nuisance organisms, growth season, growing scale, condition of water source, facility and treatment method. For the serious case, several countermeasures are used in the same time.

1. Selecting a countermeasure method against biological problems

When a problem happens, it is considered what countermeasures are effective. Table VII-1-1 shows effectiveness of countermeasures against each problem. Figure VII-1-1 to VII-1-3 show flow diagram to choose countermeasure in each treatment method.

Most effective countermeasure is chosen by referring these table and figures. Evaluation of effectiveness of implemented countermeasure is necessary.

Grasping of level of problem and evaluation of effectiveness of countermeasures are done by setting appropriate checking parameters and points.

I

Table VII-1-1 List of countermeasures against biological problems

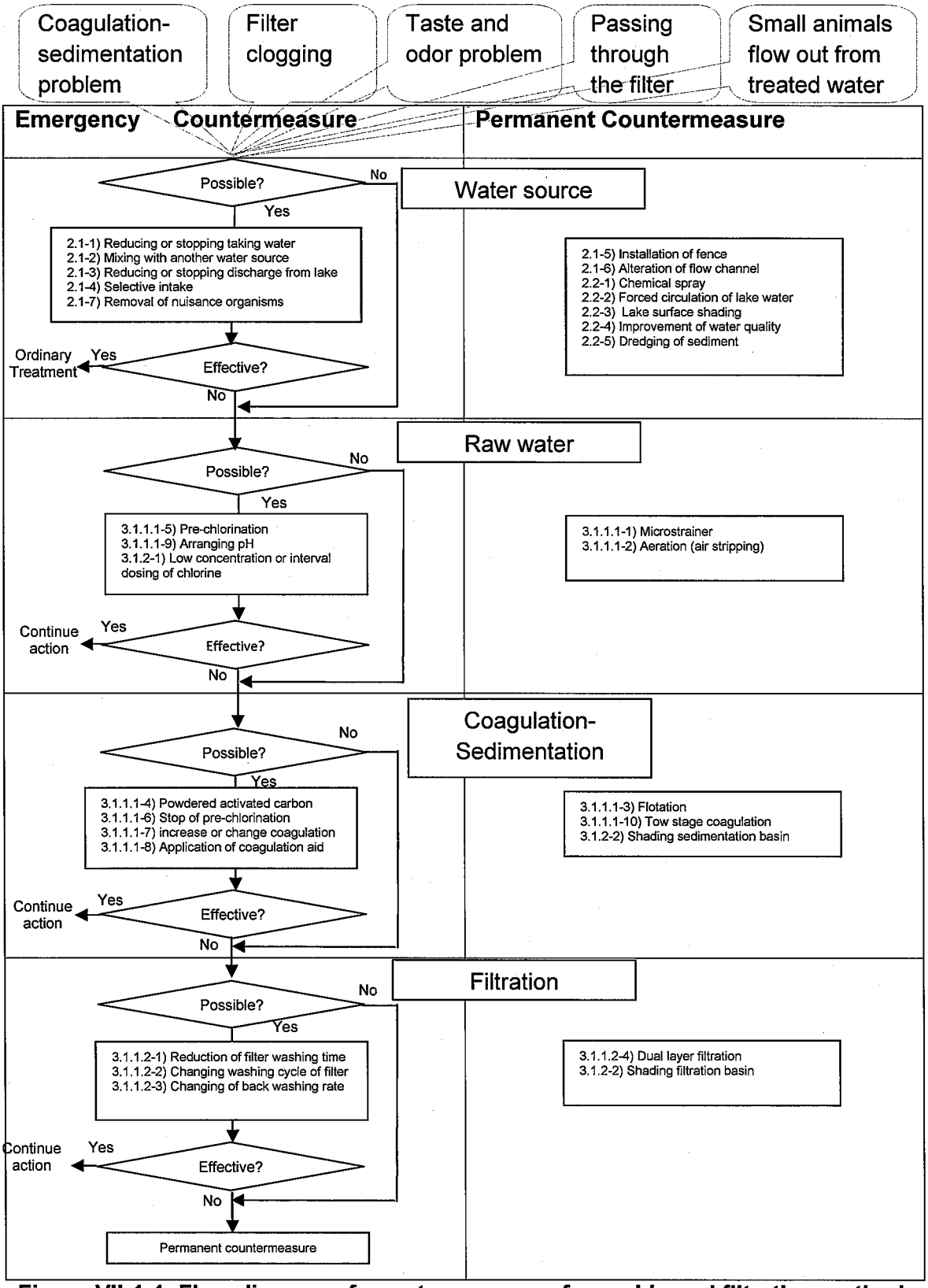


Figure VII-1-1 Flow diagram of countermeasures for rapid sand filtration method

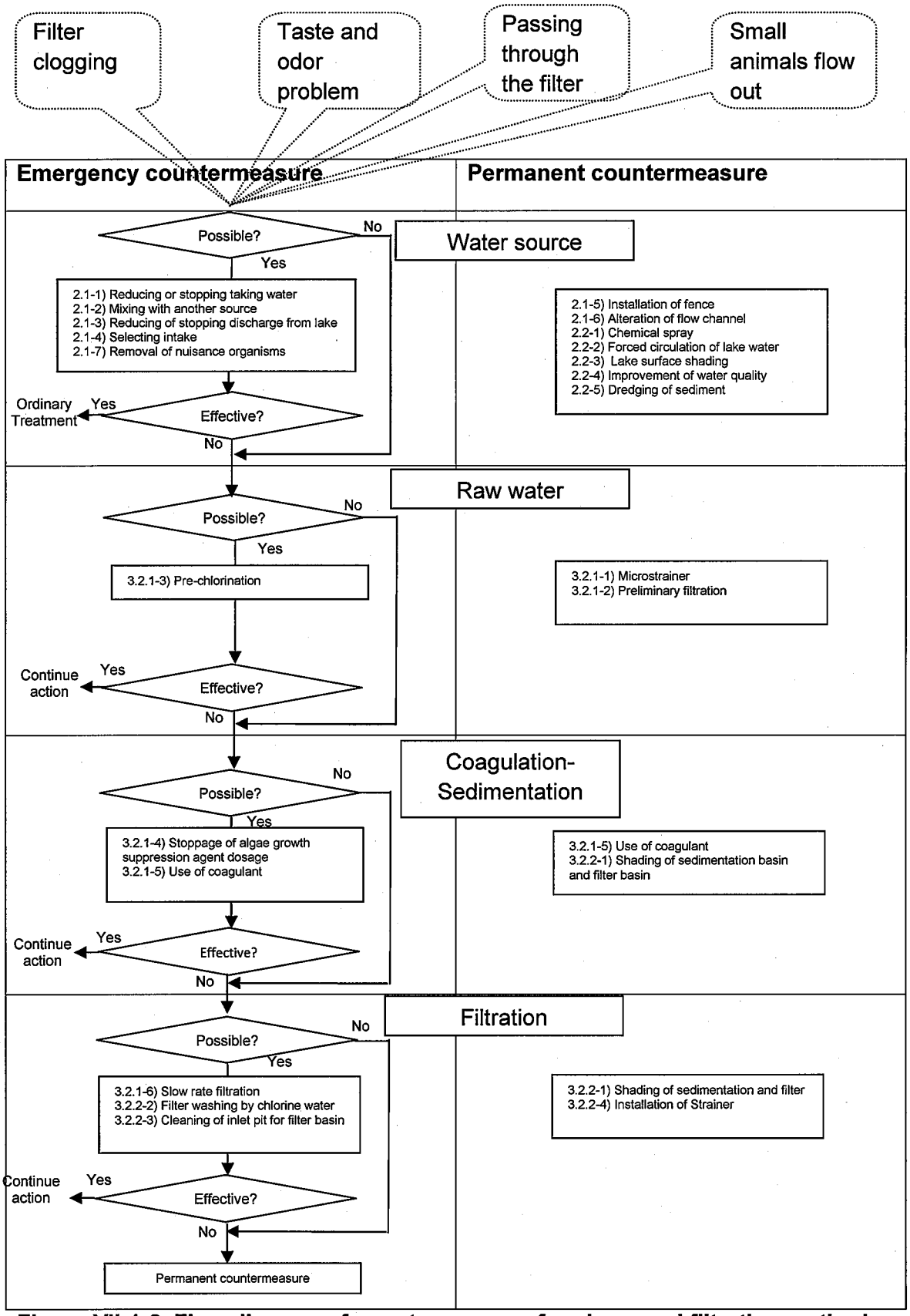


Figure VII-1-2 Flow diagram of countermeasure for slow sand filtration method

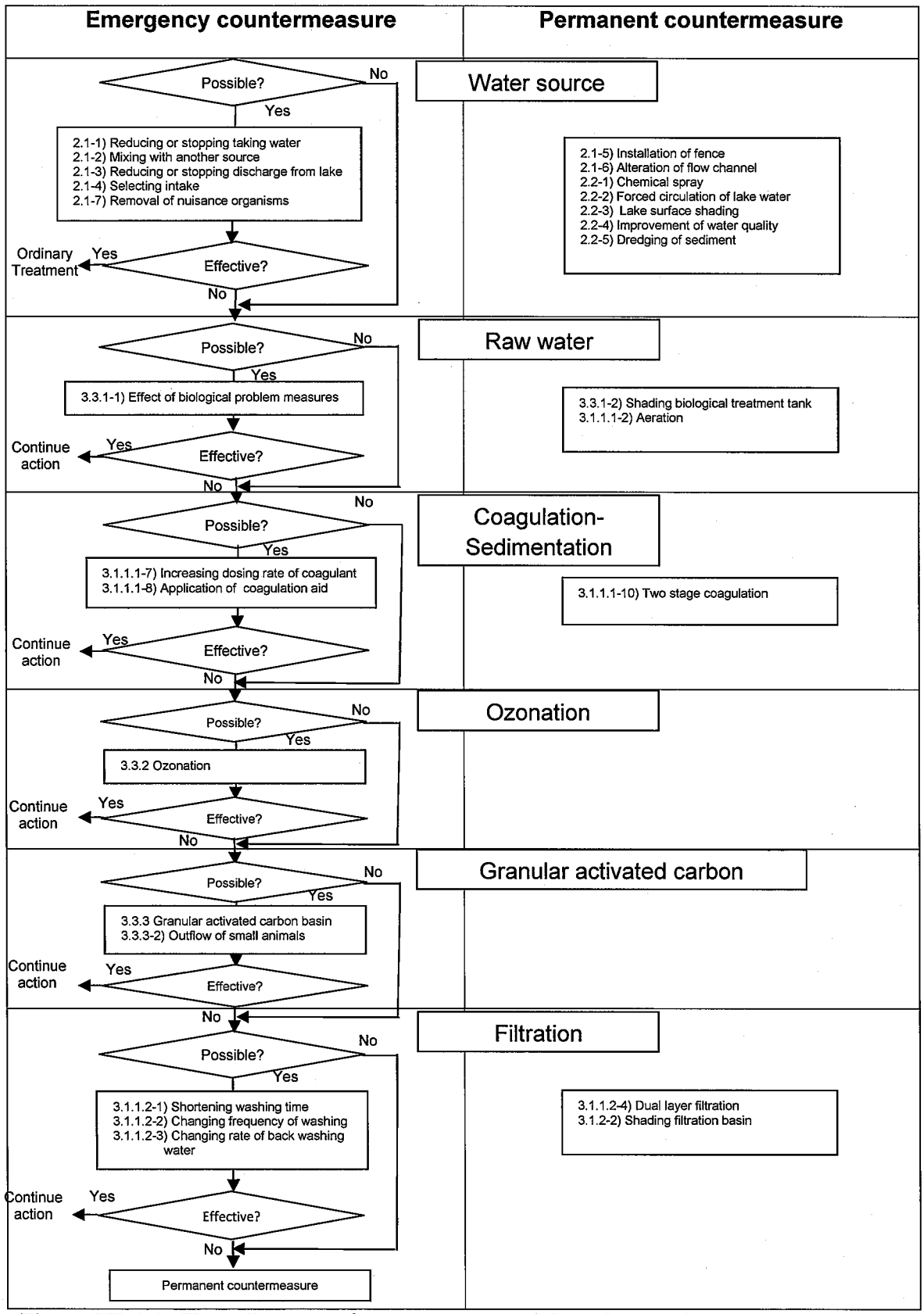


Figure VII-1-3 Flow diagram of countermeasure for advanced treatment method

Target			Action	Trouble							
				Coagulation, sedimentation	Filter clogging	Passing through filter	Odor, taste	Outflow	Turbidity	Color	Others
Water source	Intake		Reducing or stopping taking water	◎	◎	○	◎				
			Mixing with another water source	◎	◎	○	◎				
			Reducing or stopping discharge from lake	◎	◎	○	◎				
			Selective intake	◎	◎	○	◎				
	Lake		Installation of fence	○	△	△	△				
			Removal of nuisance organisms	○	○	○	○				
			Chemical spray	◎	◎	◎	◎				
			Forced circulation of lake water	○	△	△	△				
			Lake surfaces shading	○	○	○	○				
			Dredging of sediment	△	△	△	△				
	Water environment		Alteration of flow channel	○	○	○	○				
			Improvement of water quality	◎	◎	◎	◎				
Water treatment plant	Rapid sand filtration	Raw water	Microstrainer	△	○	△					
			Aeration (air stripping)				△				
		Coagulation, sedimentation	Flotation	○	△	△	△				
			Powdered activated carbon	△		△	◎				
			Improvement of coagulation treatment by pre-chlorination	△	△	△		△			
			Stop of pre-chlorination	△		△	△				
			Enhancing coagulation and using coagulation aid	○	○	○	△				
			pH decrease procedure at coagulation	○	○	○	△				
		Filtration	Two stage coagulation (re-coagulation)			○					
			Reducing washing time by strengthening surface washing		○						
			Change of washing cycle of filter		○						
			Change of back washing rate		○						○
			Dual layer filtration		○						
		Growth in facility	Low concentration or intermittent dossage of pre-chlorine		△	△					○
			Shading of sedimentation basin and filter basin		△	△					○
	Slow sand filtration	Raw water	Microstrainer		○						
			Primary filtration (coarse filtration)		○						
			Pre-chlorination		△	△					△
			Stoppage of algae growth suppression agent dosage		△		△				
		Coagulation, sedimentation	Use of coagulant		○						
		Filtration	Slow rate filtration		○	△	△				
		Growth in facility	Shading sedimentation basin and filter basin		△	△					○
			Filter washing by chlorine water					△			
			Cleaning of inlet pit for filter basin					○			
			Strainer					△			
	Advanced treatment	Raw water	Biological treatment	△			○				
			Aeration (air stripping)				△				
		Coagulation, sedimentation	Enhancing coagulation and using coagulation aid	○	○	○	△				
			Two stage coagulation (re-coagulation)			○					
		Ozonation	Ozonation				◎				
		GAC	Granular activated carbon treatment				◎				
		Filtration	Reducing washing time by strengthening surface washing		○						
			Change of back washing rate		○						○
			Change of washing cycle of filter and Slow rate filtration		○						
			Dual layer filtration		○						
		Growth in facility	Shading of biological treatment facility								◎
			Shortening washing cycle of GAC					◎			
			Cover of sedimentation basin and filter basin		△	△					○
Only disinfection		Intake	Pre-chlorination					○		○	○
			Washing intake well					○	○	○	○
Distribution facility		Distribution reservoir	Protection for insects at vent hole of reservoir					◎			
			Cleaning of facility					◎	○	○	◎
		Receiving tank	Cleaning of facility					◎	○	○	◎
			Prevention of algae film formation					◎	△	△	

◎: highly effective, ○: effective, △: conditionally effective

2. Countermeasures at water source (or for raw water)

If the trouble is caused by organisms in raw water, the most effective countermeasure is to reduce the number of nuisance organisms in raw water. There are basically two types of methods to reduce the number of organisms in raw water; emergency method and medium to long-term method. They are classified to the following.

a. Method to reduce the amount of nuisance organisms which come into raw water
b. Method to suppress the growth of nuisance organisms at water source

The following are options for **a.**

- to reduce or stop taking water
- to reduce the concentration of the organism in raw water by mixing with another water source
- to reduce or stop discharging water from the lake where the nuisance organism is present: change of water source
- to intake lake water selectively at the depth where the concentration of nuisance organisms is low
- to install fence to reduce the density of nuisance organisms
- to alter the flow channel of water source
- to remove nuisance organisms in the water source

The following are options for **b.**

- to apply chemicals to prevent the growth of nuisance organisms
- to physically circulate the water of lake
- to shade the surface of lake
- to improve water quality for preventing eutrophication
- to dredge bottom sediments

Effect of these measures above depend on "type of water source," "environmental conditions of water source," and "property of water source." For example, aeration is not effective if the depth of the lake is less than 10m, applying chemical and selective intake can be implemented if the reservoir is used only for the purpose of drinking water. Therefore, these measures should be determined considering the situation.

2.1 Procedure to reduce amount of nuisance organisms which come into raw water

1) Reducing or stopping taking water

This method is to decrease or to avoid the trouble by reducing or stopping taking water to the treatment plant

(1) Characteristics

a. Promptly effective

b. Countermeasures for emergency

(2) Remarks

a. This measure can be taken only in the case that it is possible to supply tap water from a treatment plant in another water source system.

b. It is necessary to optimize water treatment control against reduction of water taken.

(3) Effectiveness of measures against each problem

[Highly effective]: For coagulation inhibition, filter clogging, taste and odor problem,

[Effective]: For problem of passing through filter

[Case 2.1-1] Reducing water taken

In September 1979, the concentration of *Microcystis* increased in raw water, which originates from Lake Sagami, as high level as changing water color yellowish green. It resulted in high turbidity of filtered water nearly 2.0 degree because *Microcystis* were not removed sufficiently by common treatment. By elimination of pre-chlorination and employment of two stage coagulation, coagulation inhibition and problem of passing through filter were effectively improved. However, function of sludge treatment was affected because *Microcystis* concentrated in filtration basin flew into sludge thickener. To improve the efficiency of sludge treatment, water quantity taking from Lake Sagami was reduced up to 37% for one month.

2) Mixing with another water source

This method is to decrease the trouble by reducing concentration of nuisance organisms by means of mixing water which nuisance organisms are not present.

(1) Characteristics

a. Promptly effective

b. Countermeasures for emergency

(2) Remarks

This measure can be applied in the case that it is possible to take water from more than two water sources.

(3) Effectiveness of measures against each problem

[Highly effective]: For coagulation inhibition, filter clogging, taste and odor problem,

[Effective]: Problem of passing through filter

3) Reducing or stopping discharge from the lake

This method is to decrease or escape trouble by reducing concentration of nuisance organisms by means of reducing or stopping discharge from the lake. As a matter of course, this measure should be taken only under the condition that quantity of raw water is maintained from alternate water source, or tap water can be supplied from another distribution system when intake water is reduced.

(1) Characteristics

a. Promptly effective
b. Countermeasures for emergency

(2) Remarks

This measure can be utilized in only the case that it is possible to maintain quantity of supplying water from alternate water source when intake water is reduced.

(3) Effectiveness of measures against each problem

[Highly effective]: For coagulation inhibition, filter clogging, taste and odor problem,

[Effective]: For problem of passing through filer.

4) Selective intake

This method is to avoid the trouble by selectively taking water which nuisance organisms do not exist or present at low concentration by means of changing depth of water taken; for this purpose, intake tower which has multiple intakes at several depth is used. Phytoplankton which causes taste and odor problem or filter clogging generally grows in water between the surface and several meters depth: approximately twice as deep as the transparency of lake or reservoir. Though they are diffused by stirring effect of wind or temperature change, they exist more in the surface and less in the water lower than thermocline. Consequently, problem can be avoided when raw water is taken at the depth lower than thermocline. However, when plenty of water is taken from the middle layer, it is probable that surface water is taken as well. Additionally, it should be noted that the water of the bottom layer tends to be anaerobic and aggravated during the period of stagnation. In applying "selective intake" at multipurpose reservoir, it is also to be noted that

discharge of water lower than thermocline could affect fishery, rice farming, etc. due to its low water temperature.

(1) Characteristics

Promptly effective

(2) Remarks

a. It is required to investigate vertical distribution of both water temperature and nuisance organisms in the reservoir.
b. Considerations for agriculture and fishery are required when it is applied at multipurpose reservoirs.

(3) Effectiveness of measures against each problem

[Highly effective]: For coagulation inhibition, filter clogging, taste and odor problem,

[Effective]: For problem of passing through filter.

[Case 2.1-2] Selective intake-1

In the 1940s, selective intake was implemented against filter clogging of slow sand filtration basin, which was occurred by the growth of diatoms in the reservoir of Tokyo Metropolitan Waterworks. This was the case that "selective intake" was applied for the first time in Japan.

[Case 2.1-3] Selective intake-2

In the Yodo River System, selective intake was effectively implemented as the countermeasure against musty odor problem and filter clogging, which were caused by *Phormidium* and *Microcystis* respectively.

5) Installation of fence

This method is to reduce the intensity of nuisance organisms in raw water by blocking the move of organisms near the surface. The fence should be installed at the level between surface and 3~5m depth at the front of intake or outlet of the lake where nuisance organisms present.

(1) Characteristics

a. Especially it is effective for nuisance organisms of high buoyancy
b. Low maintenance cost

(2) Remarks

Effect cannot be expected for nuisance organisms which does not accumulate near the surface

(3) **Effectiveness of measures against each problem**

[Effective]: For coagulation inhibition,

[Conditionally effective]: For filter clogging, taste and odor problem, Passing through filter

[Case 2.1-4] Installation of fence

In 1979 at Lake Sagami in Kanagawa prefecture, to deal with excessive trouble caused by the growth of a large amount of *Microsystis*, a specific fence was installed in front of the intake. Change of water temperature, pH value, transparency, and concentration of *Microsystis* was observed between inside and outside of the fence. The number of *Microcystis* cells in raw water reduced to approximately one third of the initial value.

6) Alteration of flow channel

This method is to avoid taking water from the water source where nuisance organisms present, by means of alteration of flow channel. Moreover, efficient water operation is possible if the alteration can be employed selectively only when nuisance organisms are observed at high intensity. Alteration of flow channel requires large scale construction; it is not easily employed and it requires long time to be constructed. At the same time, there would be many problems to be solved if several municipalities or prefectures are located in the area of water source.

(1) Characteristics

Permanent countermeasure

(2) Remarks

a. A lot of cost and long period of time are needed for realization.
b. Collaboration with environmental administration or related organization is required.

(3) Effectiveness of measures against each problem

[Effective]: For taste and odor problem, filter clogging, coagulation inhibition, Passing through filter.

[Case 2.1-6] Alteration of flow channel

Kanamachi water treatment plant in Tokyo had received a lot of consumer complaints about musty odor since around 1972. It was investigated that the musty odor was caused by blue green algae grown in Saka River in the upper reaches of Edo River. A portion of the water of Saka River was treated by purification facility

and directly ran off the downstream of the intake through a canal constructed for this purpose. Raw water quality was remarkably improved by this strategy.

7) Removal of nuisance organisms

This method is to decrease the biological problem by collecting nuisance organisms in the water source using boat equipped with special device for removal. Collected organisms are to be separated, concentrated, and incinerated, etc. When this measure is taken for emergency, adequate removal performance for the growth rate of organism is required to reduce the concentration of the organisms to the safe level. This method is effective to use in the limited area where organisms are concentrated at high density by wind or water flow. Applying this method, improvement of water quality can be expected at the same time by preventing accumulation of nutrient in reservoir sediments.

(1) Characteristics

a. Immediate effect can be expected because nuisance organisms are directly removed in the target area.
b. Improvement of water quality also can be expected.

(2) Remarks

This method is more effective when it is implemented at the initial growth stage.

(3) Effectiveness of measures against each problem

[Effective]: For coagulation inhibition, filter clogging, taste and odor problem, passing through filter.

[Case 2.1-7] Nuisance organisms removal by aspiration

At Lake Kasumigaura in Ibaragi prefecture, nuisance organisms are removed using two types of boats equipped with aspiration device and centrifugation/pressure flotation/concentration/incineration devices.

2.2 Procedure to control the growth of nuisance organisms at water source

1) Chemical spray

Chemical spray is the procedure to control the growth of nuisance organisms by chemicals at the case such as the nuisance organisms' outbreak in reservoir/lake. The chemicals to use should satisfy the following conditions.

a. Cheap
b. Effective with small amount
c. Not harmful to humans and no damage on livestock, fish and agricultural

products.

d. Easy to handle and store

The chemicals usually used for water source are cupper sulfate and chlorine agents (liquefied chlorine, sodium hypochlorite, calcium hypochlorite).

Cupper sulfate is particularly effective to algae, and its effectiveness sustains longer. It is less dangerous than chlorine agents for handling, and easy to spray. But it also has disadvantages. The effect comes one or two days later. There is possibility to induce the growth of other algae which is tolerable to cupper. The mechanism of reduction of algae by cupper is considered that cupper blocks ability of photosynthesis. The necessary dosing rate of cupper sulfate depends on what species of organism is **(Table VII-2.2-1).** And the some factors should be taken into account for determination of dosing rate, e.g., temperature, amount of solar radiation, hardness, alkalinity and organic matters. Temperature and solar radiation enhance the capability of algicidal effect. On the other hand, hardness, alkalinity and organic matters reduce the effectiveness.

Chlorine agents are usually used for disinfection at the treatment process. Furthermore it is expected the effect on nuisance organisms. The chlorine mainly affects on cell membrane and enzyme. The necessary dosing amount varies by species of organism **(Table VII-2.2-1).**

It is calculated with the survey result of temperature and target algae distribution, and it is a value of multiplying total storage volume by dosing rate at the circulation season. If there is thermocline in stagnation period, it is calculated as a value of multiplying storage volume of upper layer of thermocline by dosing rate. In this case, the target organism must exist in upper layer.

The chemical spray is better to do at earlier stage of algae growth before problems occur. The chemical should be dosed all necessary amount at one time. And it has to be scattered uniformly in whole target water area (water mass).

There are three methods of spraying cupper sulfate, i.e., powder spray method, solution spray method, and continuous dissolving and spray method.

(Table VII-2.2-1) Standard dosing rate of disinfectant and algaecide

Organisms		$CuSO_4 \cdot 5H_2O$ (mg/L)	Cl_2 (mg/L)
Sulfur Bacteria	Beggiatoa	0.50	0.50
	Thiothrix		0.50~1.00
Iron Bacteria	Clonothrix	0.33~0.50	0.50
	Sphaerotilus	0.40	0.25
Eumycetes	Leptomitus	0.40	
	Saprolegnia	0.18	
Cyanophytes	Anabaena	0.12~0.48	0.50~1.00
(Blue-green algae)	Microcystis	0.12~1.00	1.00
	Aphanizomenon	0.12~0.50	0.50~1.00
	Oscillatoria	0.20~0.50	1.10
	Phormidium	0.70	3.00
Bacilariophy	Achnanthes	0.50	2.00~3.00
(Diatom)	Asterionella	0.12~0.20	0.50
	Attheya	0.20	
	Cyclotella	0.50	1.00
	Fragilaria	0.25	2.00
	Melosira	0.33	0.50~2.00
	Navicula	0.07	
	Nitzschia	0.50	
	Rhizosolenia	0.20~0.70	
	Stephanodiscus	0.25	
	Synedra	0.50~1.00	1.00
	Tabellaria	0.12~0.50	0.30~1.00
Chlorophytes	Ankistrodesmus	1.00	
(Green Algae)	Chlamydomonas	0.50	
	Closterium	0.17	
	Coccomyxa	2.50~3.00	
	Cosmarium	1.50~2.00	
	Palmella	0.50~1.00	2.50~3.00
	Scenedesmus	1.00	
	Sphaerocystis	0.25	
	Spirogyra	0.12~0.20	0.70~1.50
	Staurastrum	1.50	
	Tetraspora	0.30	1.00~1.50
	Ulothrix	0.20	
	Volvox	0.25	0.30~1.00
	Zygnema	0.50	
Chrysophytes	Dinobryon	2.50	0.30~1.00
	Mallomonas	0.50	
	Synura	0.12~0.25	0.30~1.00
	Uroglena	0.05~0.20	0.30~1.00
Dinophytes	Ceratium	0.33	0.30~1.00
	Peridinium	0.50~2.00	

The powder spray method is the procedure to spray powder or fine grain cupper sulfate by a power sprayer settled on boat. This method is easy for preparation and able to load the big quantity of chemicals. But the safety of worker is not fully secured. This method is impossible to do at rainy weather.

The solution spray method is the procedure to spray the cupper sulfate solution from the stern of the boat like a sprinkler. It needs the preparation time for dissolving crystalline cupper sulfate by hot water. The total quantity of prepared chemical is larger than the powder, therefore the smaller load capacity of boat results in the lower working efficiency.

The continuous dissolving and spray method is the procedure to spray the solution that is continuously prepared to dissolve clumpy or granular cupper sulfate in the dissolving tank on boat. It doesn't have the disadvantages which the former two procedures have, and has the good efficiency. However, due to difficulty of solving cupper sulfate, sometimes the unsolved particles go underwater without acting.

It is recommended that the spray method will be solution spray method or continuous dissolving and spray method because these methods are better for safety for workers and good for homogeneous spraying.

After spraying, the floating dead body of fish could be observed sometimes. It might make inhabitants living near the water body worry, and add rotten smell on water. Therefore, the daily observation is required for four or five days after spraying in order to carry away the dead bodies of fish for disposal.

Such chemical spray to reservoir which uses only for water supply is not a problem. On the other hand, in case of the reservoir used for multipurpose or case of natural lake, the effect on fishery or agriculture should be considered. The concentration of cupper sulfate must be controlled under 0.02mg/l that is the standard criterion for agricultural water in Japan.

(1) Characteristics

It is effective to the problem caused by algae

(2) Remarks

a. Chemical spray is effective at the time of beginning of nuisance organisms growth. After the growth occurs, the effect is not so significant.

b. The dose of chemical is calculated by the chemical tolerance of nuisance organisms and distribution extent.

(3) Effectiveness of measures against each problem

[Highly effective]: For problem of coagulating-sedimentation process, filter clogging, offensive taste and odor, passing through filter.

[Case 2.2-1] Cupper sulfate-1

It was a case of Togakushi treatment plant, which treated the water from Togakushi reservoir by slow sand filtration method. The diatoms growth occurred in water source, such as Asterionnella, Fragilaria, Melosira, etc. caused the filter clogging. It brought about the reduction of filter run time as only five or six days compared to usual runtime of more than 30 days. The cupper sulfate spray was effective and it reduced the problem of filter clogging. The fine crystalline cupper sulfate was scattered from a boat. The target water body was whole water because there was no thermocline identified.

[Case 2.2-2] Cupper sulfate-2

It was a case at Torihara reservoir that the growth of Microcystis had occurred since last half of 1960 and it was thought to cause coagulation inhibition. Therefore, the selective intake and cupper sulfate spray were done for reduction of Microcystis. In fact, it was 140,000 cell/ml of Microcystis concentration on 23th June, and it was 7,900 cell/ml after 8 hours of chemical spray, and then it became 240cell/L

2) Forced circulation of lake water

It was a procedure to circulate the lake water in stagnant period in order to send the nuisance organisms which is growing in the upper layer, to lower layer for the purpose of reducing growing speed. At the same time, the dissolved oxygen was sent to bottom sediment and it prevents the water quality from degradation caused by dissolving nutritional salts from bottom sediment.

The thermocline is formed in reservoir/lake from spring to autumn and the water become stagnant. It results in growth of phytoplankton at surface layer and decreasing concentration of dissolved oxygen. Especially in bottom layer, the oxygen concentration is nearly zero and it brings about the dissolution of manganese, iron, phosphate, etc. from sediment. The waterworks using reservoir water for source sometimes suffers from coloring trouble of iron or manganese and/or problem of algae which growth is enhanced by the eutrophication caused by dissolved nutrient like phosphate. These nuisance organisms' problems are solved by destruction of thermocline with successive water circulation.

There are three kinds of water circulation methods.

a. Whole layer circulation method; circulates the whole water body.

b. Deep layer aeration method; only circulates water in the lower layer of thermocline in order to prevent discharging low temperature water

c.Two-layer aeration method; circulation is operated separately in each layer.

These three methods are effective for improvement of water quality and prevention of

eutrophication but only 1) is effective for the algae control.

Whole layer circulation method is categorized in two types; intermittent aerohydraulic gun method and diffusing pipe method. The air introduced into lower layer by compressor moves upward and circulate the stagnant water for circulation.

The necessary capacity of circulation equipment and input energy (air volume) are calculated by the shape of target reservoir/lake.

It was reported that the circulation of water in stagnant period caused the decrease of biomass of algae and change of species. The mechanism has not been revealed completely but it is thought that the circulation improves the water quality by providing fresh air to anaerobic condition, and takes algae from surface to lower layer where the less amount of solar radiation disturbs the growth. It means the similar effect is not expected on the shallow lake of less than 5m depth, at which the algae can live whole layer because the ray of sun reaches the bottom. On the other hand, the deep reservoir/lake requires so huge amount of energy and large facilities that the realization is difficult even if it is ideally possible.

(1) Characteristics

a. It is effective on the problem caused by algae.

b. Improvement of water quality is expected.

(2) Remarks

a. The survey is required to know the trend of nuisance organism growth in water source.

b. The continuous operation is necessary during the stagnant period even if there is no problem.

(3) Effectiveness of measures against each problem

[Effective]: For coagulation-sedimentation process problem.

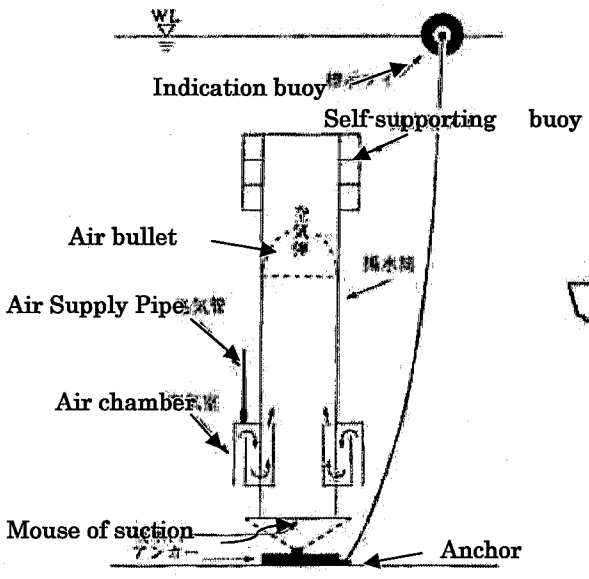
[Conditionally effective]: For filter clogging, offensive taste and odor, passing through filter.

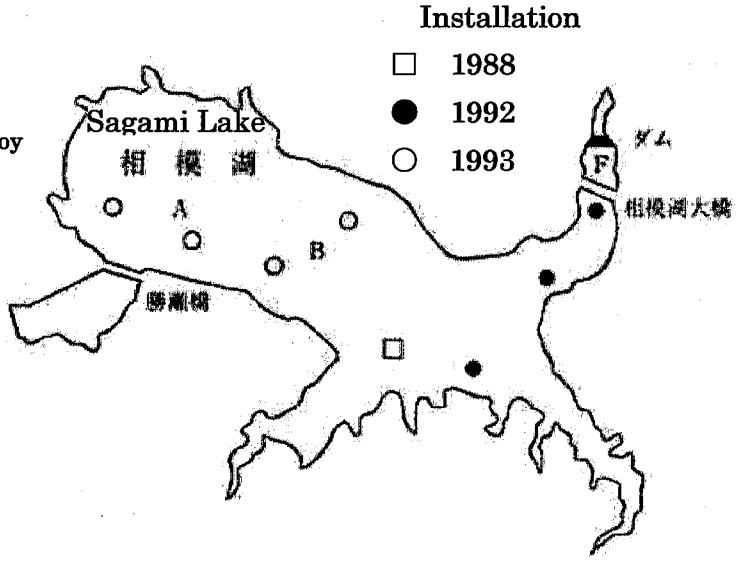
[Case study 2.2-3] Forced circulation-1

Sagamiko is a lake of water source and its total reservoir capacity is 63.2 million cubic meter. In 1979 from July to September, the growth of Microcystis occurred and it brought about the disturbance of treatment process. The fence was installed in front of outlet to prevent the discharge of algae bloom in 1981. Moreover, eight of the intermittent aerohydraulic guns were installed from 1982 to 1993. It was bundle type made of four tubes which were 500mm inside diameter, 12m length, FRP made. It had an air chamber at under part and was fixed by anchor to the lake bottom. The water intake of it was placed at 2m upside. **(FigureVII2.2-1)**

The location is shown in **FigureVII2.2-2**, and pumping discharge is 360~430 thousand

cubic meter per day. After installation, the thermocline was broken and quantity of Microcystis fell off. Accordingly, the problem in treatment process caused by Microcystis was solved, but the offensive taste and odor caused by Anabaena (blue-green algae) and filter clogging caused by diatom are still remaining.





FigureVII-2.2-1 Structure of aerohydraulic gun at Sagami Lake

FigureVII-2.2-2 Location of aerohydraulic guns in Sagami Lake

[Case 2.2-4] Forced circulation-2

This was a case of Sugawa reservoir that was a dam reservoir developed for drinking water use only in Nara City waterworks Bureau and total storage volume was 796,600m^3). Three intermittent aerohydraulic guns were installed in order to prevent the degradation of water quality by thermocline. The effect was examined by the comparison of water quality between before and after installation. The dissolved oxygen and amount of algae were unified in all layers, and concentration of dissolved manganese and ammonium at the bottom were controlled from spring to summer. The quality of raw water was improved due to prevention of thermocline creation.

[Case 2.2-5] Forced circulation-3

The Kumano reservoir in Hiroshima prefecture suffered from offensive taste and odor and filter clogging by flock carry-over from May to October in every year, so that the intermittent aerohydraulic guns were installed. The guns were operated from March to November. It resulted in all-layer unification of water temperature, concentration of dissolved oxygen and phytoplankton, e.g. the concentration of dissolved oxygen varied

only in a range from 90 to 100% at all layers. The concentration of organic nitrogen and nitrate nitrogen increased slightly but almost same at all layers. The concentration of ammonia nitrogen was under detectable limit. Total phosphate was reduced in a level of 1/4, and concentration of orthophosphoric acid phosphate became undetectable. The outbreak of *Synedra* and *Achnanthes* had been occurred every year but it was reduced after installation.

3) Lake surface shading

This procedure is to cover the surface of water body and cut the sunshine for controlling algae growth. The forced water circulation method described previously is not effective at the shallow lake of less than 5m depth, so Dr. Kojima had developed a new method applicable to shallow lake. Blue-green algae which causes many kinds of problems is disturbed its reproductively by shading because its photosynthesis ability is deteriorated by staying at dark place even temporally. For this reason, it is considered that the growth of blue-green algae is controllable by use of light shielding plates which float on a part of surface of lake, and by moving algae under the plates. The water in shallow lake moves by the wind and at the same time algae also moves with water, then the algae at bright place moves into the dark place under shading temporarily

As the result of experiment, the shading area must be about 30% of the lake surface area. It was reported that less area could not provide enough effect.

(1) Characteristics

a. It is effective to the problem caused by algae.

b. It is effective to the case of shallow lake.

(2) Remarks

The 30% of surface area should be covered, if not, there is no effect.

(3) Effectiveness of measures against each problem

[Effective]: For coagulation-sedimentation problem, filter clogging, offensive taste and odor, passing through filter.

[Case 2.2-6] Lake surface shading (experiment)

The effectiveness was examined by two irrigation ponds which have similar conditions like 3.3m depth and growth of Microcystis. The plastic plates of 20 by 20cm are set in a frame of 3 by 3 m. The plates were placed on the surface in movable style by wind. Only two months use in summer, the number of Microcystis in the shaded pond decreased dramatically. But, another pond without any measure had no change. The difference was not only algae amount, but also pH and transparency.

4) Improvement of water quality

It is the control method of the growth of nuisance organisms by taking measures to improve water quality of water source.

The growth of nuisance organisms is caused by the progression of eutrophication, so the taking measures for removing or reducing eutrophication source is the most reliable solution. However, the water quality improvement of the lake requires long period of time. And sometimes the catchment area is large beyond the administrative border. In such case there are so many problems to solve and which need the accommodation and adjustment among all stakeholders.

At the instant of March 2001, 180 local governments in Japan have established ordinances regarding drinking water source reservation in order to improve water quality of drinking water source such as river, lake, groundwater, etc.

To establish the practical measures for water quality improvement, information of basic conditions is essential for better understanding of environment of water source and pollution load, e.g., population of catchment area, land use, status of sewage system, distribution of factories and business establishment, etc.

The water quality of lake and reservoir depends on location, extent, depth, intake method, etc. and the water quality of inlet largely. Therefore the preservation of inlet water quality is the most effective procedure. The most important measure is taking action to reduce the nutrients (especially nitrogen and phosphorus) in inlet, which are causations of eutrophication.

If the limiting nutrient is identified as nitrogen or phosphorus, (limiting nutrient is necessary one for growth of organisms and it is short most in the lake/reservoir), the countermeasure is to reduce only the limiting nutrient. In case of Japan, the phosphorus limiting lake (phosphorus is short most) is predominant.

It is advisable that the process of reduction of nitrogen or phosphorus is 1) fix the target value of concentration of nitrogen or phosphorus in water source and inlet river, 2) make a plan for achievement of 1), and carry out 2) effectively. Measures of water quality improvement for the water source should be done with cooperation of all relevant authorities.

(1) Characteristics

It is enduring countermeasure.

(2) Remarks

a. It requires huge budget and long time.

b.It needs cooperation among relevant organizations, e.g., environmental authority.

(3) Effectiveness of measures against each problem

[Highly effective]: For coagulation-sedimentation process problem, filter clogging, offensive taste and odor, passing through filter.

[Case 2.3-1] Water quality improvement

Miyagi prefecture formulated the lake water quality improvement plan as the measures of water source conservation for the Kamabusa dam reservoir which was designated by the lake law. And they set the target value of phosphorous as 0.013mg/l in 1996. Various projects have been implemented for the achievement. The projects are as follows; 1) public sewage system development, 2) water quality improvement based on Lake Law, 3) conclusion of agreement about water quality preservation with developers of golf courses, 4) installation of small treatment facilities for non-fecal wastewater, 5) installation of livestock waste treatment facilities, 6) education and public awareness for countermeasures to domestic waste water. The waterworks covers some part of the budget of these projects.

5) Dredging of sediment

This procedure is to take the sediment away from lake for prevention of eutrophication and controlling the growth of nuisance organisms. Dredging is used for the purpose of not only controlling organisms but also inhibition of dissolution of iron or manganese, and maintaining water depth at certain level.

The other measure is to develop secondary weir at inlet, and remove the sediment at the weir periodically.

(1) Characteristics

It is effective to prevent the progression of eutrophication..

(2) Remarks

Removed sediment will create the problem of dumping.

(3) Effectiveness of measures against each problem

[Conditionally effective]: For coagulation-sedimentation process problem, filter clogging, offensive taste and odor, passing through filter

6) Other water quality improvement measures

Other water quality improvement measures are as follows, discharge of deep water of lake, sediment coating, sediment solidification, use of floating leaved plant like water hyacinth, use of lakefront zone plant like reed, purification of inflow water, use of coagulant to lake, etc.

3. Countermeasures in water treatment process.

Nuisance organisms cannot be reduced in the water source, or when biological problem was not improved even if some measures were carried out, some measures should be coped with in the process of water treatment. Generally, in case that biological problem is not serious, usual treatment process is used. For example, dose or stop pre-chlorine, change the point of chlorine dosing, enhance coagulation process, shorten the washing cycle of the filter. However, biological problem is serious or it occurs constantly, it is necessary to improve facility or increase water treatment process. For example, micro strainer, aeration, floatation, dosing of powdered activated carbon, adjustment of PH during the coagulation process, two stage coagulation, dual-layer filtration, activated carbon filtration, ozonation, etc. It is desirable to select optimal approach in reference to the actual case of countermeasure against biological problem, because these countermeasures against biological problem vary in effectiveness depend on species of nuisance organism, growing timing, growing size, existing water treatment plant and method of water treatment.

3.1 Case of rapid sand filtration

This section describes two cases of countermeasure against biological problem in water treatment plant which has rapid sand filtration system. One is "countermeasures against organisms contained in raw water", the other is" countermeasure against organisms grown in treatment plant." About taste and odor control, you can refer to "Guideline for control of taste and odor causing organisms"

3.1.1 Countermeasures against organisms contained in raw water

3.1.1.1 Countermeasures between receiving well and sedimentation process

1) Microstrainer

This method is to remove the nuisance organisms by a filter device which is called micro strainer and to avoid getting into trouble. Microstrainer can remove zooplankton, phytoplankton and microscopic material in raw water by stainless steel net attached on the circumference of the revolving drum mechanically. The mesh of the stainless steel net and size of device depend on the size and volume of targeted organisms. The removal effectiveness of this method is very good for large algae, for example, removal rate of the Fragilaria and *Asterionella* are over 95%, and removal rate of *Synedra* is over 80%.

(1) Characteristic

a. It is very effective to remove large organisms.

b. The device is compact and not so expensive, and also, it does not require human

work to maintain so much.

(2) Remarks

It is not effective to remove algae which make mucilage colony and small one.

(3) Effectiveness of measures against each problem

[Highly effective] : Foe filter clogging,

[Conditionally effective] : For problem on coagulation-sedimentation process, passing through filter.

[Case 3.1.1-1] : Removal of nuisance organisms by microstrainer.

In the water treatment plant which uses SAGAMI Lake water (in Kanagawa prefecture) as raw water, microstrainer was installed for removing nuisance organisms which caused filter clogging. And filter run time was improved from 24 hours to 82 hours. *Synedra* was removed over 85% in average by this method.

2) Aeration (Air stripping)

This method can reduce or avoid getting into trouble by blowing air into the raw water and releasing the taste and odor-causing substance to the air. There are a few actual cases. There is an example of aeration using the facility which installed for mixing the powdered activated carbon.

(1) Characteristic

It is very effective to remove highly-volatile material

(2) Remarks

Removal efficiency decrease when water temperature is low, because volatilization rate of the taste and odor-causing substance is related to water temperature.

(3) Effectiveness of measures against each problem

[Conditionally effective]: For problem on odor and taste

[Case 3.1.1-2]Countermeasure of odor and taste by aeration in the raw water

In the Mano Water Treatment Plant of Public Corporation Bureau, Otsu City, which takes raw water from north Biwa Lake, the fishy smell of *Uroglena americana* has reduced by

using aeration facility which was installed for mixing the powdered activated carbon originally.

3) Flotation

This method reduces or avoids getting into trouble by flotation of the flock which contains organisms causing biological problem with fine air bubble because it is difficult to remove the flock contains organisms by the sedimentation. Pressure flotation and natural flotation are adapted in water treatment process. New technology "foam separation" is recently being studied. Pressure flotation is also called "dissolved air flotation". At first air is dissolved with pressurization in water. Then, micro babble occurs when reducing the pressure. Micro babble sticks with flock. Finally the flock floats by force. Pressure floatation has three methods, whole raw water pressure floatation, part of raw water pressure flotation, circulation water pressure flotation. Circulation water pressure flotation is the best method in water treatment. There are three reasons. 1. it`s contains large amount of air. 2. There are a few broken flocks while contacting with bubble cluster. 3 It is easy to discharge sludge. Foam separation is a method to make flock adheres to air bubble by use of coagulant and casein which is protein substance and separate the raw water into a solid and liquid. Casein play as binder which can be air bubble adhere to flock, and promotes to make foam which is high degree of viscosity and stabilized.

(1) Characteristic

a. Algal is suitable for flotation, because it is lighter than suspended particle which contains clay.

b. Flotation can make separation far faster than sedimentation.

(2) Remarks

It is necessary to flocculate and make form adequately to do effective flotation.

(3) Effectiveness of measures against each problem

[Effective]: For trouble on coagulation-sedimentation process.

[Conditionally effective] : For filter clogging, trouble on odor and taste, passing through filter.

4) Powdered activated carbon

This method can reduce or avoid getting into trouble by powdered activated carbon which adsorbs the taste and odor-causing substance when trouble on odor and taste occurred. And powdered activated carbon absorbed taste and odor-causing substance is removed in the process of coagulation-sedimentation and filtration. It is necessary to increase dosage of coagulant in order to remove powdered activated carbon surely at coagulation-sedimentation basin and filtration. It is desirable to conduct experiments such as jar test and so on for deciding adequate coagulant dosage volume.

When a lot of taste and odor-causing substances exist inside of algae, It is better to stop the pre-chlorination and remove the algae by sedimentation (it means to remove taste and odor-causing substance too). This method can reduce the volume of powdered activated carbon. However, when there are a few taste and odor-causing substances in water source, or when it is difficult to remove nuisance organisms by sedimentation process, or when most of the taste and odor-causing substances dissolve to the water from algae body in the end of growth season, It may be effective to do the pre-chlorination and elute all taste and odor-causing substances into the water from algae body and then adsorb them by powder activated carbon. Since powdered activated carbon consumes chlorine, it is necessary to adjust the volume of chlorine dosage for keeping required residual chlorine in each treatment process. 1mg of the powdered activated carbon consumes 0.2-0.25mg chlorine (quoted from "Guideline for Waterworks technical Management" 344p, "Design Criteria for Waterworks Facilities" 289p).

When the problem of odor and taste become bigger or often happen, it is necessary to consider installing a tank for contacting powder activated carbon or facility of granular active carbon filtration.

Removal effectiveness of powdered activated carbon is influenced by many factors like kind and concentration of taste and odor-causing substances, raw material of powdered activated carbon, dosing ratio, mixing intensity, contact time, concentration of chlorine, existence or concentration of organic substances which are produced by algae, state of the taste and odor-causing substances, and water temperature.

Each factor is explained as below.

a. Kind of taste and odor-causing substance

Geosmin is easily adsorbed by powdered activated carbon in comparison with *2-MIB.*

b. Concentration of taste and odor-causing substance

Adsorptive capacity of powdered activated carbon is almost same in the range of

approximately 100 -500 ng/L of taste and odor-causing substance concentration.

c. Raw material of powdered activated carbon

Wood and coal are raw materials. And it is said that the former removes micro molecular weight substances easily, and the latter removes macro molecular weight substances. The molecular weight of *Geosmin* and *2-MIB* is 182 and 168 respectively. They are smaller than agrochemicals.

d. Contact time, mixing

It is necessary to mix well for adsorbing effectively, and it takes time until adsorption reaches equilibrium. When there is no contact tank of powdered activated carbon in water treatment plant, dose powdered activated carbon in some place where it is possible to mix well and contact for a long time.

e. Existence of chlorine or chloramine

Removal rate of powdered activated carbon drops when there is chlorine or chloramine in the water. Chloramine has impact on drop of removal rate more than chlorine. Furthermore, when there is chlorine in the water, adsorptive ability of powdered activated carbon for *2-MIB* drops more than *Geosmin*.

f. Existence of natural organic matter (NOM)

Adsorptive ability of powdered activated carbon for taste and odor- causing substance drops when there is a lot of NOM in the water, because they compete each other. Drop of adsorption ability by NOM affects *2-MIB* more than *Geosmin*.

g. Existence state of taste and odor-causing substances

Activated carbon can adsorb the taste and odor-causing substances which are dissolved in the water not inside of the body of algae. For removing taste and odor-causing substances which exist in the body of algae, it needs to elute them into the water by way that algae contact chlorine. When pre-chlorination is stopped and algae which contain taste and odor-causing substances remain in the settled water, intermediate chlorination must be stopped, because taste and odor-causing substances dissolve from algae body into the filtered water by intermediate chlorination.

h. Kinds of nuisance organisms and growth season

Removal effectiveness of only powdered activated carbon treatment may vary largely, because conditions are different depending on the kinds of nuisance organisms and the growth season or extinction season. The conditions are kinds and productive ability of

taste and odor-causing substance, ratio of inside and outside of algae body, removal efficiency of algae in the sedimentation process, fragility of cell and so on. In case of new installation of powdered activated carbon, waterworks bureau has to design it based on "the ministerial ordinance on technical criteria for water supply facilities".

(1) Characteristic

a. Running cost of powdered activated carbon is expensive, however construction cost is not so expensive.

b. There is no reaction product when mixing powdered activated carbon.

c. It is expected as assistant chemicals

(2) Remarks

a. It is necessary to figure out the ability of powdered activated carbon facility. And when concentration of nuisance organisms becomes over the capacity of facility, it must be considered to stop taking or reduce the water.

b. For effective removal, it is necessary to grasp whether taste and odor-causing substances exist inside or outside of nuisance organisms.

c. When dosing rate of powdered activated carbon is very high or sedimentation process does not work well, it is possible that powdered activated carbon leaks in to filtered water. Therefore, it may be needed to add coagulant more than before or upgrade to the two stage coagulation.

(3) Effectiveness of measures against each problem

[Highly effective]: For problem on odor and taste

[Conditionally effective] : For problem on coagulation-sedimentation process, passing thorough filter.

[Case 3.1.1-3] Powdered activated carbon treatment-1 (fishy smelling)

In case of Kyoto Waterworks and Sewerage Bureau, as countermeasures against fishy smell by *Uroglena* which was occurred in BIWA Lake, followings were implemented in the beginning time, 1) stop the pre-chlorination, 2) Increase coagulant, 3) Discharge returned water to sewer. When taste and odor became stronger, powdered activated carbon was used.

[Case 3.1.1-4] Powdered activated carbon treatment-2 (musty odor)

In the Otsu Enterprise Bureau, Shiga prefecture, 5-20mg/L concentration of powdered activated carbon was dosed as a measure against musty odor by *Anabaena (Geosmin)* which occurred in BIWA Lake.

[Case 3.1.1-5] Powdered activated carbon treatment-3 (parallel usage with pre-chlorination)

When *Phormidium* grew and musty odor (2-MIB) occurred in Kamafusa dam reservoir which was used as raw water of water supply, Moniwa water treatment plant of Sendai Waterworks Bureau carried out following measures, 1) *2-MIB* was dissolved from inside of algae by chlorination, 2) *2-MIB* was removed by adsorption of powdered activated carbon. After completion of the measures, it was confirmed that 50ng/L concentration of *2-MIB* in raw water could be treated until under 5ng/L of *2-MIB* in treated water. It is target value of water quality management in Sendai WWB.

5) Improvement of coagulation treatment by pre-chlorination

This treatment is dosing pre-chlorine to avoid or lessen biological problems through damaging the nuisance organisms and improving removal rate of coagulation. This pre-chlorination measure is expected to work effectively in combination with coagulation treatment.

Improving effectiveness of coagulation by pre-chlorination differs from kinds of nuisance organisms; this measure was confirmed to work effectively for *Bacilariophytes (diatoms)* such as *Aulacoseira* and *Synedra*. Because the damage by pre-chlorine to organisms depends on the concentration of residual chlorine and time goes-on, combination of pre-chlorine and two stages coagulation is more effective for the smaller organisms which may pass through the filters. However, there are some cases which pre-chlorination makes treatment worsen for such as taste and odor-causing organisms and *Microcystis colony* as described later.

(1) Characteristics

a. This is effective for organisms with low resistance to chlorine

b. This treatment works more effective when combined with two stage coagulation.

(2) Remarks

It is necessary to note that certain nuisance organisms may make situation worsen by pre-chlorination.

(3) Effectiveness of measures against each problem

[Conditionally effective]: For filter clogging, trouble on coagulation-sedimentation, passing through filter, flowing out into treated water.

[Case 3.1.1-6] Improvement of coagulation by pre-chlorination -1

In Tanigahara Water Treatment Plant of Kanagawa Waterworks Authority, removal rate of coagulation with or without pre-chlorination were experimented by jar-test and actual treatment facilities (horizontal-flow sedimentation basin) on 4 species of *Bacilariophytes (diatoms)* which grew in the Sagami Lake, its source water. In the result, it was found that pre-chlorination was effective for *Synedra urna* and *Synedra acus*. In terms of correlation between effectiveness and contact time with chlorine, removal rate of coagulation for *Synedra urna* can be higher when coagulant was dosed just after dose of pre-chlorine. And for *Synedra acus*, coagulant can work more effectively when dosed 35 minutes later than pre-chlorine dosage. Pre-chlorination for *Fragilaria* and *Melosira* cannot be confirmed on its effectiveness.

[Case 3.1.1-7] Improvement of coagulation by pre-chlorination -2

In Keage Treatment Plant of Kyoto City Waterworks and Sewarage Bureau, filter problem happened in early December of 1980, and *Daphnia* seemed to be the nuisance organism which grew and covered surface of the filter basin with more than 3 mm thickness. Therefore, dosing point of chlorine was changed from intermediate chlorination (the point before filtration) to pre-chlorination, and then it could resolve the filter clogging.

[Case 3.1.1-8] Improvement of coagulation by pre-chlorination-3

In Nishiya Water Treatment Plant of Yokohama Waterworks Bureau, filter clogging happened by *Asterilnella* grew in its source water, the Sagami Lake in early June 1996. The filter run time became 10 hours on average. Then dosing rate of polyaluminum chloride (PAC) was increased, and sodium hypochlorite with 0.3mg/l was additionally dosed at the raw water transmission channel (the point of 137 minutes long to reach the treatment plant). These countermeasures could improve the removal rate at the sedimentation basin from 50% to more than 80%.

[Case 3.1.1-9] Improvement of coagulation by pre-chlorination-4

In Hiroshima City Waterworks Bureau, kinds of coagulants and effectiveness on combination between each coagulant and pre-chlorination was examined as countermeasures against filter clogging caused by *Synedra acus*. In comparing removal rate of *Synedra acus,* average removal rate of separate dosage of aluminum sulfate was as low as about 60%. The one of separate dosage of PAC, combination of pre-chlorination + aluminum sulfate, and combination of pre-chlorination + PAC was

83%, 84% and 98%, respectively. In the result of survey on correlation between residual chlorine and removal rate using aluminum sulfate, it was confirmed that removal rate was stably high when concentration of residual chlorine at the outlet of sedimentation basin was more than 0.6mg/L.

[Case 3.1.1 - 10] Improvement of coagulation by pre-chlorination- 5

From July to August of 1966, in Kunijima Water Treatment Plant of Osaka City Waterworks Bureau, Picoplankton, minute phytoplankton, grew in the water source and caused malfunction of coagulation and filter-passing problem. Turbidity of the filtered water was normally less than 0.1 degree, but it exceeded 0.1degree after rapid growth of algae in the water source. In particular, the turbidity of the filtered water showed a daily trend to increase during night time and reached 0.27 degree at maximum. This was because the raw water which was taken from the intake point during the afternoon and early evening reached the water treatment plant at night. The major nuisance organisms causing higher turbidity of filtered water was *Synechococcus*, 14,000 cells/ml of which were roughly corresponded to 0.1 degree continuously.

As the countermeasure, dosing point of chlorine was changed from intermediate chlorination to pre-chlorination with 1.0 mg/L, dosing rate of aluminum sulfate was increased by about 10%, and pH value of coagulation was controlled; in result, turbidity of the filtered water could remain roughly less than 0.1 degree though concentration of nuisance organisms reached 380,000 cell/ml at maximum.

[Case 3.1.1 -11] Improvement of coagulation by pre-chlorination-6

In Kunijima Water Treatment Plant of Osaka City Waterworks Bureau, Chlorine is dosed usually by intermediate chlorination in order to reduce musty odor and trihalomethane (THM). When filter clogging happened, *Melosira* and *Cyclotella* of nuisance organisms were removed at the sedimentation basin more effectively by 0.5mg/L of pre-chlorination. However, the removal rate of another nuisance organism, *Synedra*, was not confirmed to change.

6) Stop of pre-chlorination (intermediate or post chlorination)

In water treatment plant which is usually operated with pre-chlorination, this measure is used for lessening or avoiding biological problems, which is stop of pre-chlorination and change to intermediate or post chlorination.

In the period of decline in growth of nuisance organisms which generate taste and odor-causing substances, most taste and odor-causing sybstances are discharged to the outside of the organisms. On the other hand, most taste and odors-causing

substances remain within the organisms in the early stage of growth of the nuisance organisms. In order to remove the eluted taste and odor-causing substances, adsorption treatment by activated carbon is necessary. However, when taste and odor-causing substances remained still within the organisms, it is effective to stop pre-chlorination and remove taste and odor-causing substances with the organisms themselves at sedimentation basin. So, depending on ratio between existences of the nuisance substances inside and outside of organisms, it is necessary to select the most appropriate combination of measures; stop of pre-chlorination, stop of pre-chlorination + adsorption treatment by activated carbon, or pre-chlorination + adsorption treatment by activated carbon. Moreover, the taste and odor-causing substances are also eluted by dosage of chlorine; therefore, when pre-chlorination is stopped, the nuisance organisms themselves can be removed at the sedimentation basin. However, the intermediate chlorination may make taste and odor-causing substances eluted from the organisms at the sedimentation basin. In this situation, it is necessary to stop also intermediate chlorination and operate treatment only by post chlorination.

In addition, if returned water is used as raw water which is sent back from supernatant of sludge chamber and back-wash water of filter basin to raw water, nuisance organisms and taste and odor-causing substances eluted in the return water should be monitored.

To understand whether the taste and odor-causing substances exist inside or outside of the organisms, commonly-used treatment is to compare 2 parameters; Concentration of taste and odor-causing substances (total) after chlorination, and the concentration of filtered water (dissolved) by paper filter with pore size around 1μm.

When *Microcystis* colonies exists in raw water, and if water treatment plant doses pre-chlorine and coagulant (first stage) at close point, pre-chlorination cause passing trough filter problem because the reaction times are different between collapse of the colonies by chlorine (more than 30 minutes) and coagulation reaction by coagulant (about 2 to 3 minutes), and the result is that *Microcystis* cells remain in the settled water. Therefore, treatment of *Microcystis colony* is that;

1) stop of pre-chlorination to keep the colonies as it is for removal at the sedimentation basin,

or 2) as described below, after dosage of pre-chlorine to decompose the colonies into cells at sedimentation basin, coagulant is dosed in two stages to coagulate the decomposed cells into micro-flocs so as to be removed at rapid filter basin. Also, when pre-chlorination was stopped for treatment of *Microcystis,* the colonies remained in the settled water can be decomposed at the filter basin by later intermediate chlorination, and pass through the filtration. Therefore, when *Microcystes* colony is found in the

settled water, it is needed to stop intermediate chlorination as well. Furthermore, in water treatment plants which use returned water as raw water from supernatant of sludge chambers or back-wash water of filtration basins, it is necessary to monitor concentration of *Microcystes* and its forms (colony or cells) in the returned water.

(1) Characteristics

a. This is effective in early stage of the taste and odor troubles particularly because most taste and odor-causing substaces exist within nuisance algae in early stage of their growth.

b. In case of passing through filter troubles by *Microcystes*, this treatment is more effective in the water treatment plants where pre-chlorine and coagulant are dosed at the almost same time.

(2) Remarks

a. In case of taste and odor trouble, it is important to understand whether the taste and odor-causing substances exist within the organisms or eluted outside of the organisms.

b. In case of use of returned water as raw water from sludge treatment process, it is necessary to monitor concentration of the nuisance organisms, their forms and behavior in the returned water.

(3) Effectiveness of measures against each problem

[Conditionally effective] : For coagulation-sedimentation trouble, passing trough filter trouble, taste and odor trouble

[Case 3.1.1-12] Stop of pre-chlorination-1 (measures against taste and odor trouble)

In Nishi Nagasawa Water Treatment Plant of Kanagawa Water Supply Authority, growth of *Anabaena* caused taste and odor trouble in Sagami Lake, the water source. To solve the problem, pre-chlorination was stopped, activated carbon was dosed and coagulant was increased, which could lead to avoid the trouble.

[Case 3.1.1-13] Case of stop of pre-chlorination-2 (measures against taste and odor trouble)

In a water treatment plant of Kawasaki Waterworks Bureau, passing through filter trouble happened caused by *Microcystes* grew in Sagami Lake, the water source. The *Microcystes* colonies were collapsed and decomposed into cells by pre-chlorination, which passed through the filtration and came to 1.4 degree of the filtered water at maximum. After stop of pre-chlorination, the removal rate at the sedimentation and the filtration was improved to around 80% from 50 % with pre-chlorination.

[Case 3.1.1-14] Case of stop of pre-chlorination 3 (measures against passing through filter trouble)

In Niwakubo Purification Plant of Osaka City Waterworks Bureau, stop of pre-chlorination (treatment by intermediate chlorination) was confirmed to be effective to reduce Microcystes's passing through filter.

7) Increase of dosing rate of coagulant or change of coagulant

This treatment is that the countermeasures such as increasing dosing rate of coagulant or changing coagulant can improve removal rate of nuisance organisms by coagulation-sedimentation process, and lessen or avoid biological problem happen at the later processes. It is popular to select aluminum sulfate (alum) or polyaluminum chloride (PAC) as coagulant. Depending on kinds of nuisance organisms, effectiveness of coagulation treatment may be improved by change or combined dosage of coagulants, or increase of dosing rate of coagulant. In order to remove nuisance organisms effectively at coagulation- sedimentation process, it is necessary to conduct jar-test and figure out the most appropriate and specific coagulant and dosing rate based on each parameter such as kind of nuisance organisms, pH value, water temperature.

As shown in Figure VII-3.1-3, although removal rate of *Synedra Acus* with normal dosing rate is low (around 50%), removal rate at sedimentation was improved (about 85%) by increasing dosing rate of coagulant (259mg/L).

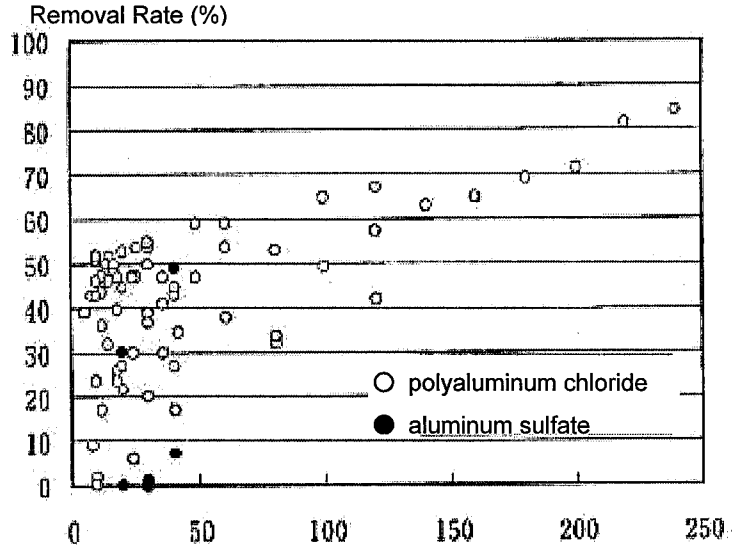


Figure VI 3.1-3 Removal rate of *Synedra Acus* by jar-test (Source; Yokohama Waterworks Bureau)

(1) Characteristics

a. Increasing of dosing rate of coagulant does not require any new facility. However, it is necessary to expand capacity of chemical dosage facility if required dosing rate

exceeds the designed maximum dosing rate.

b. Aluminum sulfate (alum) lowers pH value significantly, so this is effective when pH value of raw water is high.

c. polyaluminum chloride (PAC) is effective in case of low alkalinity and of low water temperature.

(2) Remarks

Increase of dosing rate of coagulant raises concentration of alum of the sludge and worsens dewater ability at sludge treatment.

(3) Effectiveness of measures against each problem

[Effective]: For coagulation-sedimentation treatment trouble, filter clogging trouble, passing

through filters trouble,

[Conditionally effective] : For taste and odor trouble

[Case 3.1.1-15] Increasing dosing rate of coagulant

In Osaka City Waterworks Bureau, sedimentation removal rate of clogging filter organisms such as *Synedra*, *Aulacoseira* and *Cyclotella* was verified by experiment in actual treatment plant and jar-test. Sedimentation removal rate was improved by increasing dosing rate of aluminum sulfate 10 – 20 mg/L more than optimum dosing rate calculated by turbidity. Also, removal rate was improved more by combination with breakpoint pre-chlorination.

8) Application of coagulation aid

This treatment is that adding coagulation aid in order to improve effectiveness of coagulation, lessen and avoid troubles when dosage of separate coagulant does not have good coagulation -sedimentation result. Coagulation aids are classified into 2 groups; coagulant aids for forming flocs and aids for adjusting pH. Here, coagulation aids for forming floc are described, and aids for adjusting pH are described later. Coagulation aids for forming floc are activated silica, sodium alginate, red-soil, bentonite, etc. In addition to these, there was a case that powdered activated carbon was used as coagulation aid to improve effectiveness of coagulation and sedimentation. There is another treatment to improve coagulation and sedimentation removal rate; dosing with pre-chlorination as described in above 5) Improvement of coagulation treatment by pre-chlorination.

(1) Characteristics

a. Usage of powdered activated carbon does not require equipping specific dosing facilities, which is different from other coagulation aids, and is expected to have

adsorption of taste and odor compounds.

(2) Remarks

a. It is necessary to watch carefully operation of sludge treatment because this treatment increases volume of sludge.

b. Effectiveness of the treatment depends on a great variety of water quality condition, therefore coagulants to be used and dosage rate should be confirmed by Jar-test etc..

(3) Effectiveness of measures against each problem

[Effective]: For coagulation-sedimentation treatment trouble, filter clogging trouble, passing through filters trouble,

[Conditionally effective] : For taste and odor trouble

[Case 3.1.1-16] Usage of coagulation aids (experiment)

Yokohama Waterworks Bureau conducted experiment on filter clogging organisms, *Synedra acus* and *Synedra ulna*, by jar-test to compare effectiveness of red-soil and bentonite as coagulation aids combining dosage with 2 kinds of coagulants, polyaluminum chloride (PAC) and aluminum sulfate, and got the result that red-soil was more effective than bentonite by coagulation and sedimentation removal rate with both coagulants.

[Case 3.1.1-17] Usage of powdered activated carbon as coagulation aid-1 [countermeasures against *Mycrocystis*]

In early September of 1995, Yanagasaki Water Treatment Plant of Otsu City Public Enterprise Bureau faced massive growth of *Mycrocystis* spp. in southern area of the Biwa Lake, the water source. Growth of *Mycrocystis* reached 300 colony/L in the raw water, caused malfunction of coagulation-sedimentation process, and was worried a rise in turbidity of the treated water. To solve the problem, powdered activated carbon was dosed with a range of 5-10mg/L, which improved the effectiveness of coagulation and sedimentation removal.

[Case 3.1.1-18] Usage of powdered activated carbon as coagulation aid-2 (countermeasures against *Dictyosphaerim*)

In Sagamihara Water Treatment Plant of Kanagawa Water Supply Authority, small organisms of around 1μ m big (estimated; *Dictyosphaerim sp.*) grew in the sludge chamber. And they were sent back to the raw water and caused a trouble of raising turbidity of the filtered water. As the measures, a) the time of drainage of sludge of sedimentation was shortened to reduce the volume of drainage of sludge so that out-flow of small-round green algae from the sludge chamber could be decreased, b)

washing water of the filter basins was diluted in order to reduce density of algae in the returned water, and c) powdered activated carbon was dosed as a coagulation aid. Dosage of 20mg/L of powdered activated carbon could be improved turbidity of the filtered water by about 90% at maximum.

9) pH decrease procedure at coagulation (Acid dosage)

This procedure is suitable for the case that bad coagulation occurs with high pH value of raw water due to carbon dioxide assimilation by algae. In order to adjust the pH value in the appropriate range, the acidic material like sulfuric acid or carbon dioxide gas is added. It reduces or removes the nuisance organisms because the organisms causing filter clogging or passing through filter could be removed by higher settling removal ratio. pH adjustment also increases the removal ratio of other turbid materials, and decreases the dosing rate of coagulant and concentration of aluminum in treated water as well.

The generally used aluminum-based coagulant is acidic, so it can be used excessively for the purpose of pH decrease. Aluminum sulfate is more effective than PAC for pH decrease.

(1) Characteristics

a. The removal ratio of other turbid materials will be improved.

b. Aluminum concentration in treated water will be decreased.

c. Effect on disinfection of chlorine will be improved.

(2) Remarks

a. Langelier's index drops too, and it might require the addition of alkaline agent at later process.

b. It increases the causticity, so the material of related facilities might be required to replace in some cases.

(3) Effectiveness of the measure against each problem

[Effective]: For the problem of coagulation-sedimentation process, filter clogging, andpassing through filter

[Conditionally effective]: For. offensive taste and odor

[Case 3.1.1-19] pH decrease procedure at coagulation-1

Yokohama Waterworks Bureau used concentrated sulfuric acid for pH control in the period of high pH from spring to autumn (pH of raw water; 7.0 to 8.6) at dam reservoir for water source. The target pH control range was 7.2 to 7.4, and it resulted in the improvement of removal ratio of algae, then the filter run time could be prolonged 10 hours more.

[Case 3.1.1-20] pH decrease procedure at coagulation-2

Kanagawa Water Supply Authority established pH control facilities using sulfuric acid in order to improve effect of coagulation and decrease of dosing rate of PAC, because they faced the coagulation problem caused by high pH (sometimes over 9 PH value) due to carbon dioxide assimilation of algae at riverbed of Sakawa River.

[Case 3.1.1-21] pH decrease procedure at coagulation-3

Kitakyushu City Waterworks Bureau had a problem of coagulation inhabitation and high concentration of aluminum in treated water because of high pH caused by organisms in Onga River. The pH decrease method by dosing carbon dioxide was taken. The problem seemed to be solved, and the coagulant dosage and sludge were decreased notably.

[Case 3.1.1-22] pH decrease procedure at coagulation-4

Osaka City Waterworks Bureau conducted an experimentation of coagulation-sedimentation removal ratio of *Microcystis* by jar test. It revealed that three kinds of coagulant; Aluminum sulfate, PAC and polyferric sulfate showed good performance under the condition of pH controlled less than 7.0. But the removal ratio of only aluminum sulfate was decreased less than 5.7 pH value. Without pH control, the dosing rate to obtain 90% removal was the smallest in aluminum sulfate 0.04mmolAL/L among above three coagulants.

10) Two stage coagulation (re-coagulation)

It is a procedure to add coagulant again after the process of coagulation-sedimentation in order to catch the remaining algae or turbid as micro flock at the filter basin. It is a countermeasure to pass though filter problem. The effectiveness of the procedure is proved for microalgae group, such as *Microcystis, Dictyosphaerium and Picoplankton.* Additionally, it is reported that exposure to light enhances the capture of Dictyosphaerium on flock at pre-chlorination. *Microcystis* generates coagulation inhibitor, and it decreases the effect of coagulation, especially in the case of simultaneous dosage of pre-chlorine and coagulant. So the following procedures are recommended.

1) Pre-chlorination is canceled for preventing collapse of cells. The cell will be removed at filter, or

2) Collapsed cell will be removed at filter after re-coagulation.

On the other hand, the enough contact time of chlorination before dosage of coagulant, increases the removal ratio at the first stage coagulation. Collapse ratio of *Microcystis* group depends on the species, e.g., *Microcystis aeruginosa* collapses 100% in 30

minutes contact, but M*icrocystis wesenbergii* collapses less than 50 % at 30 hours contact time. Generally, the high collapse ratio of *Microcystis* tends to cause serious passing through filter problem with pre-chlorination. The pre-chlorination is effective to *Dictyosphaerium* and *Picoplankton* because they are easy to be captured if damaged by chlorine. The dosage of coagulant at second stage is less. In case of PAC, usually it is around 5 to 10mg/L. If the coagulation is not successful at second stage, the capture ratio at filter is low. The coagulation reaction finishes quickly, so the immediate mixing after injection is important. A flush mixing apparatus and baffle are used for flush mixing, and use of diffuser is reported.

(1) Characteristics

a. It is so effective to the problem of pasing through filter of *Microcystis* for the treatment plant which dose pre-chlorine and coagulant at the same time.

b. Combination with chlorination enhances the effectiveness.

(2) Remarks

a. Flush mixing after dosage of coagulant is necessary.

b. Effect of combination with pre-chlorination depends on the target species.

(3) Effectiveness of the measure against each problem

[Effective]: Passing through filter

[Case 3.1.1-23] Two stage coagulation (Microcystis)-1

Tanigahara treatment plant in Kanagawa prefecture had been suffered by the problem of passing through filter caused by the *Microcystis* in every summer since 1978.

They dosed 12mg/IL PAC into settled water, and the filter water turbidity was decreased. The post-PAC dosing rate was effective in the range of 12 ~ 3 mg/L.

The rate of filter passing was 2.7% at 5mg/L PAC dosage and 0.8% at 12mg/L, although it was 47% in average without adding post-PAC.

[Case 3.1.1-24] Two stage coagulation (Dictyosphaerium)-2

It was a case of passing through filter by green algae at Tanigahara treatment plant in Kanagawa prefecture in June 1987. The removal rate was 48% at nighttime and 58% at daytime with 15 ~ 25mg/L PAC dosage. The number of algae was fluctuated sharply in a day. For this reason, *Dictyosphaerium* was considered that the exposure to light enhances its capture on flock under chlorine existence.

The post-PAC increased the removal rate such as 80% at nighttime and 90% at daytime, and turbidity in filtered water was undetectable at daytime and less than 1 degree at nighttime. There was no difference of removal rate with the difference of post-PAC concentration (5mlg/Land 10mg/L), and also the difference with the dosing rate of

pre-PAC (15, 20, 25mg/L).

[Case 3.1.1-25] Two stage coagulation (Picoplankton)-3

It was a case of Motojuku water treatment plant in Kiryu City, that was the problem of passing through filter by Picoplankton growth in a Kusaki Lake located at upper stream of water source of Watarase River in May 2000. It was proved that the increased pre-chlorine (from 0.7mg/L to 1.5mg/L) and dosage of post PAC(3.0mg/L) could control the effect at the concentration of a few ten thousand cell/ml of picoplankton.
It was shown that turbidity 0.1 degree was equivalent to about 4 thousand cell/ml.

[Case 3.1.1-26] Two stage coagulation-4

It was a case of passing through filter by *Microcystis* at a rapid sand filter of Nishinagasawa water treatment plant in Kanagagawa Prefecture.
Result of investigation and jar test proved follows. When chlorine and first stage coagulant dose in same time, the turbidity of filter water rose because the Microcystis single cell didn't absorbed in flock and passed through the filter. It happened by difference between collapsing period of *Microcystis* colony by chlorination (more than 30 minutes) and reaction time of coagulation (2 to 3 minutes).

3.1.1.2 Countermeasure at the filtration process

1) Reduction of filter washing time by strengthening surface washing

Usually, the filter clogging occurs near the surface layer only, so the sufficient surface washing and shorter backwashing time could secure the more supply water amount.

(1) Characteristics

a. This procedure requires only the change of operation of filter washing.
b. It is effective for emergency case.

(2) Remarks

The purpose of the procedure is saving washing water volume so that the increase of washing frequency due to reduction of washing time duration should be avoided.

(3) Effectiveness of the measure against each problem

[Effective]: For the problem of filter clogging.

[Case 3.1.1-27] Reduction of filter washing time by strengthening surface washing

It was a case of filter clogging by *Synedra acus* at Osaka City Waterworks Bureau. The sufficient surface of filter washing leaded shorter backwashing time because the trapped *Synedra* was released by less amount of backwashing water.

2) Change of washing cycle of filter

It is a procedure to wash a filter by less amount of water at higher frequency for preventing filter clogging. The longer surface washing of filter is recommended.

(1) Characteristics

a. This procedure only requires the change of operation of filter washing..

b. It is effective for emergency case.

(2) Remarks

It requires increase of amount of filter washing water, so the surplus of supply water is necessary.

(3) Effectiveness of measure against each problem

[Effective]: For the problem of filter clogging.

[Case 3.1.1-28] increased frequency of filter washing

It was a case of filter run time reduction caused by remaining turbid material of mixture of green algae *(Spirogyra)* and sludge at Kanamachi water treatment plant in Tokyo. The washing cycle reduced from 72 hours to 48 hours and backwashing rate was increased, and even the washing time was increased from 8 min. to 10 to 12 min. After taking these measures, the remaining material was decreased and the problem was solved mostly.

3) Change of back washing rate

This procedure is applicable to the severe filter clogging case caused by the abnormal accumulation of the flock on the surface of rapid sand filter and difficult to remove the flock by usual washing rate. In such case, the temporally increased filter washing rate could remove the accumulated flock and solve the problem.

(1) **Characteristics**

a. This procedure requires only the change of operation of filter washing..

b. It is effective for emergency case.

(2) Remarks

If the rate is increased too much, it results in the runoff of filter material.

(3) Effectiveness of the measure against each problem

[Effective]: For the problem of filter clogging, and abnormal appearance.

[Case] Please refer the case of 3.1.1-28

4) Dual-layer filtration

Filter clogging problem generally occurs due to unequally developed clogging in the surface layer of the filter. Therefore, as additional layer, to cover the larger grain size filter material on the single silica sand filter could reduce the concentrated clogging in surface layer and solve the problem. Anthracite is usually used as a material to place on upper layer, which is smokeless coal and lighter than silica sand, and the general effective size of grain for use is 0.9 to 1.4mm. The larger size filter material is effective for the larger size causative organism. It was reported that the 1.4mm anthracite was effective to *Sinedra acs* which was typical filter clogging organism. The general particle size of filter sand is 0.45 to 0.7mm for single layer filter, and the size of sand for dual-layer filter is 0.45 to 0.6mm.

(1) Characteristics

This procedure is effective to the bigger size filter clogging organisms.

(2) Remarks

The current condition of existing facilities should be studied carefully before the single layer sand will be changed to dual-layer filter.

(3) Effectiveness of the measure against each problem

[Effective]: For the problem of filter clogging.

[Case 3.1.1-29] dual-layer filter-1

Tanigahara water treatment plant in Kanagawa prefecture decided to introduce the dual-layer filter made with 1.4mm diameter anthracite as a countermeasure against filter clogging by *Sinedra acs*.

[Case 3.1.1-30] dual layer filter-2

It was a case of filter clogging at a treatment plant of Yokohama Waterworks Bureau caused by *Melosira* granulate *(Aulacoseira granulate)* in October 1985. The filter run time was decreased less than 20 hours from more than 90 hours. The increase of PAC dosing rate from 7mg/L to 17mg/L could not improve the condition. After covering anthracite (3 to 5cm) on existing filter media, the filter run time was improved and became more than 30 hours.

3.1.2 Countermeasures against organisms grown in the treatment plant

1) Low concentration or intermittent dosage of pre-chlorine

In case of certain period stoppage of pre-chlorine dosing for reduction of disinfection by product, sometimes algae growth in sedimentation basin causes another problem. This procedure is aimed to control the growth of algae in a basin and prevent a problem by adding pre-chlorine intermittently, or dosing very low concentration pre-chlorine.

(1) Characteristics

This procedure is not necessary to install new equipment.

(2) Remarks

The required concentration of chlorine for controlling algae growth depends on the conditions, such as water temperature, nutrient concentration, sunshine, etc. Particularly in the high temperature season, the surface water of sedimentation basin tends to grow stagnant and it may let the condition worse.

(3) Effectiveness of measures against each problem

[Effective]: For the problem of abnormal appearance.

[Conditionally effective]: The problem of filter clogging and Passing through filter.

2) Shading of sedimentation basin and filter basin

In case of certain period stoppage of pre-chlorination and intermediate chlorination, sometimes algae growth at sedimentation facilities such as incline plate or the wall of filter basin causes filter clogging, passing through filter and/or offensive taste and odor. This procedure is aimed to control the growth of algae and prevent a problem by shading the facilities. Algae grow easily in a sedimentation basin or filter basin located before a granular activated carbon treatment facility due to no chlorination usually. Because the algae need solar light for growth, the covering at opening of the facilities is effective. However, the large scale covering needs big amount of installation cost. The methods of shading are a) covering by light blocking materials like aluminum etc.

b) shading sheet, c) green color shading plate (filter), cheesecloth etc.

a. Covering

It has high light interception rate and the most effective, but the installation cost is high. It is generally used for the covering of large scale facilities for the purpose of antifreeze.

b. Shading sheet

The material is cheep, and the construction period is short.

c. Green color filter

Green color filter absorbs the light which is in a range of wavelength required for photosynthesis. The filter controls the growth of algae by blocking photosynthesis and its effect is high. It is transparent in certain degree so that the visual inspection of facilities is possible. In a similar way, the workability is improved under the covering which can absorb the light required for photosynthesis; wavelength near 660nm and 450nm selectively.

(1) Characteristics

a. This procedure does not require pre-chlorination, so it is better way to prevent the synthesis of disinfection by-product like trihalomethanes.

b. It is effective countermeasure against the algae growing at the facilities. .

(2) Remarks

a. The shading method is selected depending on the purpose. .

b. It is costly for the large scale facility.

(3) Effectiveness of measures against each problem

[Effective]: For the abnormal appearance.

[Conditionally effective]: For the problem of filter clogging and passing through filter.

[Case 3.1.2-1] Algae growth control by shading of sedimentation basin.

Toriyano Water Treatment Plant in Niigata city installed the shading sheet at sedimentation basin because the algae grew in a sedimentation basin and created problem after shifting to intermediate chlorination.

[Case 3.1.2-2] Prevent of algae growth by shading of sedimentation basin.

According to the survey result of Murano Water Treatment Plant in Osaka prefecture, green algae heavily grew on the incline plate under 0.3mg/L dosage of pre-chlorination, algae grew remarkably on the top of incline plate without shading regardless of pre-chlorination, and a lot of algae grew without pre-chlorination. However, in the case of the basin which whole surface was covered, there is only a little growth of algae, even though no dosage of pre-chlorine.

[Case 3.1.2-3] Measure against algae occurrence by shading of sedimentation basin and filter

Murano Water Treatment Plants in Osaka prefecture installed covering at inclined plate clarifier, and then surveyed necessity of covering of filter basins too. As the result, the number of organism in filter sand changed to 1/4 after covering sedimentation basin, 1/2 with covering filter basin and 1/10 with covering both of them. That is to say, the covering is more effective to install at the sedimentation basin than filter basin, and the covering both of them enhances the effect notably.

3.2 Case of slow sand filtration (SSF)

The most frequent biological problem occurs at slow sand filter is filter clogging, and secondly the offensive taste and odor, passing through filter. It was reported that floating *diatoms* such as *Asteriolnella, Synedra, Aulacoseira granulate, Fragilaria*, etc, didn't make serious filter clogging problem without the case of outbreak because they were floating near the surface of water at filter. The study of *Asterionella* showed the result that 10,000 cells/ml *Asterionella* didn't cause the filter clogging. However, if these

organisms are damaged by chlorination, it will accumulate on the filter sand and bring about the clogging. In case of the algae with agar-like film e.g. *Tetraspora lacusiris* growing on the surface of filter sand, it will cause filter clogging. On the other hand, it was reported that the filamentous algae e.g. *Melosira varians* on the surface of filter sand would reduce the rate of rise of head loss.

Slow sand filter is capable to remove materials which cause offensive taste and odor, but the excess load beyond capacity will make problem. In the sand layer of SSF, small animals; e.g. nematode, bloodworm, etc. are growing. These small animals potentially cause the problem of flow out into treated water. If the problem is not severe, the following measures are effective; scraping biofilm away, slow speed filtration, filter drain, cleaning of inlet pit for filter basin, etc. In the case of severe problem, following measures will be taken; pre-chlorination, coagulation-sedimentation treatment, filter layer cleaning by chlorine water. If the problem occurs constantly, the following measures will be required; microstrainer, primary filtration, shading of filter basin, installation of strainer. It is recommended that the selection of the most suitable procedure is important on the basis of past studies because the effect of countermeasure depends on the kind of nuisance organism, growing season and scale of growing. If the problem is so serious, the combination of measures is needed. SSF is a system to utilize the function of microbial community growing in sand layer for water purification, so the any damage on microbes in sand will be prevented in order to keep capacity of purification.

3.2.1 Countermeasure against organisms contained in raw water

1) Microstrainer

Please refer the description about microstrainer in chapter 3.1.

[Case 3.2.1-1] Installation of microstrainer at SSF

At the SSF treatment plant in Nagano prefecture, *Asterionera* growing in Togakushi reservoir which was a water source caused the filter clogging. One of countermeasure was spraying of cupper sulfate in the reservoir as before. Additionally, the other measure was taken, that was the installation of microstrainer in 1979. The removal capacity was high as 95% for 4 cells colony of *Asterionela*, however, low for small algae such as *Cyclonella, Oocystis*.

2) Primary filtration (Coarse filtration)

This method is installation of filter facility made of fine gravel before SSF, for the purpose of removal of nuisance organism in raw water.

The filter material is fine gravel with the size from 2 to 3 mm. The filtration method is upward flow method or downward flow method. Only a few cases have been done in Japan. There is a case of 260m/day of filtration rate in practice. However, it is thought that the effect is not same for different species, so the experiment is desirable for determination of facilities specification.

(1) Characteristics

It is more effective to the bigger size nuisance organisms.

(2) Remarks

The notable effect is not expected to smaller size nuisance organisms. .

(3) Effectiveness of the measure against each problem

[Highly effective]: For the filter clogging.

3) Pre-chlorination

Pre-chlorination to SSF is used for the purpose of improvement of organism removal ratio at sedimentation basin in the case of being with plain or chemical sedimentation basin, or controlling growth of organism in the facilities. Pre-chlorination has to be low concentration or intermittent use at SSF, because it damages the useful biota in the sand layer working for purification. Even the method using combined residual chlorine damages biofilm. Besides, the continuous pre-chlorination has the potential to enhance the growth of Tetraspora which has chlorine resistant agar-like material and create the filter clogging problem.

(1) Characteristics

a. It is effective to the organisms which results higher removal ratio by the damage of chlorination.

b. It is effective to control the growth of organism in the unfiltered water of the upper part of filter. .

(2) Remarks

a. The damage on biofilm should be prevented.

b. It has to be considered that the possibility of release of taste and odor-causing substance from the cell by chlorine attack.

c. The accumulation of damaged alga body on the surface of filter might increase clogging.

d. There is possibility of the outbreak of chlorine resistant algae.

(3) Effectiveness of the measure against each problem

[Conditionally effective]: the problem of filter clogging, passing through filter and others.

[Case 3.1.2-2] Control of passing through filter by intermittent dosage of pre-chlorination

At Kinuta water treatment plant in Tokyo, phytoflagellate such as Chlamydomonas and Synura grew in the filter basin and passed through the filter, and the turbidity of filtered water was increased. The pre-chlorination was done one time a week as a countermeasure, and it worked effectively for such purpose. The dosing rate of pre-chlorine was adjusted to detect only combined residual chlorine (0.3mg/L at a maximum) in order to minimize the adverse effect on the organisms in filter. During taking this measure, Tetraspora which is chlorine resistant grew on the surface of filter sand and head loss was increased a little.

4) Stoppage of algae growth suppression agent dosage

It is a procedure to reduce the offensive taste and odor and filter clogging by stoppage of algae growth suppression agent (chlorine agents etc.) at the SSF. Taste and odor-causing substance in the cell of algae is released by chlorine. Nakamoto reported that the stoppage of pre-chlorination diminished problem of offensive taste and odor and filter clogging problem. And also reported that, growth of Melosira varians which was diatoms growing in filaments on the surface of filter sand decreased the direct load of turbidity, and the filter clogging became better.

(1) Characteristics

It doesn't require any further cost.

(2) Remarks

If the raw water eutrophicates, the growth of algae in the filter basin will be significant and it will destroy the appearance, and it will be able to cause the filter clogging.

(3) Effectiveness of the measure against each problem

[Conditionally effective]: For the problem of filter clogging and offensive taste and odor.

[Case 3.1.2-3] Stoppage of pre-chlorination

At the SSF treatment plant in Ueda city, the pre-chlorine for the control of algae growth was stopped, and Melosira varians was transplanted willingly. It resulted in the improvement of the filtration condition. Originally, the filter run time had been only 2 or 3 days at the worst condition in summer, but after taking measures, the average run time was 14 to 15 days and 45 days at maximum. The Melosira varians was transplanted by bucket from other filter basin.

[Case 3.1.2-4] Stoppage of dosage of cupper chloride

At the Tanigahara water treatment plant in Kanagawa prefecture, Aulacoseira granulate

growing in water source; Tsukui Lake brought about the filter clogging at SSF. The cupper sulfate had been injected for the purpose of preventing bad appearance of attached algae. Once it was stopped, the problem of filter clogging by floating diatoms like Aulacoseira granulate was reduced.

5) Use of coagulant

It is a procedure for a SSF water treatment plant with plain sedimentation basin. The coagulant is dosed for the purpose of increase of removal rate of nuisance organisms for preventing the problem occurrence. The use of pre-chlorine at the same time is occasionally effective to the particular species, but it could damage useful organisms at the filter. In addition, the facilities for flash mix and flock formation are required to ensure the sufficient coagulating sedimentation treatment.

(1) Characteristics

This procedure increases the removal rate of turbid material as well, so that the filter run time will be improved.

(2) Remarks

If the carryover of flock occurs at sedimentation basin, .the clogging at the filter will be accelerated seriously.

(3) Effectiveness of the measure against each problem

[Highly effective]: For the problem of filter clogging.

[Case 3.1.2-5] Coagulant dosing

At the SSF water treatment plant with plain sedimentation basin in Yokosuka city, it was concerned the problem of filter clogging by *Fragilaria crotonensis* growing in the water source, and problem was diminished by the dosing of PAC20mg/L.

[Case 3.1.2-6] Coagulant dosing

At the Uegahara water treatment plant in Kobe city, the filter clogging occurred due to *Staurastrum dorsidentiferum* (530 cells/ml) likely, and the countermeasure of adding PAC at plain sedimentation basin succeeded.

6) Slow rate filtration

This is a countermeasure to filter clogging and offensive taste and odor by the slow rate filtration operation at the SSF. It is applicable to the case of having surplus capacity or alternative facilities, e.g. parallel establishment of rapid sand facility. However, the continuous operation of slow rate filtration possibly causes the bloom of algae in filter basin, and the algae will move to the lower sand layer at the time of water drain for the

renewal of filter surface. It will sometimes cause the passing through of organism to filter water shortly after operation restarted.

(1) Characteristics

a. This procedure needs only the change of operation.

b. It is an emergency countermeasure.

(2) Remarks

It is not expected the good effect to the problem caused by the growth of algae in the sedimentation basin.

(3) Effectiveness of the measure against each problem

[Highly effective]: For the problem of filter clogging

[Conditionally effective]: For passing through filter, Offensive taste and odor.

3.2.2 Countermeasure against organisms grown in water treatment plant

1) Shading of the sedimentation basin and filter basin

This method blocks the sunlight entering the sedimentation basin and filter for suppressing the breeding of obstacle algae. As a result, the outbreak of the obstacle is avoided or reduced.

Shading method is written in 3.1 Shading of sedimentation basin and filter basin in Case of rapid sand filtration.

(1) Characteristic

a. Biofilm in the slow sand filter does not have any bad influences, because the chemicals are not used.

(2) Remarks

Measures effect of the causative organisms except the algae is not expectable. But small animals which eat algae are controlled indirectly.

(3) Effectiveness of the measures against each problem

[Highly effective]: For other problems (abnormal outward appearance)

[Conditionally effective]: For filter clogging, Passing through filter

[Case 3.2.2-1] Shading of the slow sand filter-1

When Tokyo Metropolitan Waterworks Bureau used the agricultural shading net for shading slow sand filter which used river-bed water of Tama River as water source, algae growth was controlled and filter run time was extended.

And sludge amount was reduced and control effect of *Chironomidae* growth was assumed.

[Case 3.2.2-2] Shading of slow sand filter -2

For nuisance organisms have grown in Togakushi Reservoir, average run time of slow sand filter became 23.5 days in the Ojyo WTP in Nagano city WWB in 1977.
On the other hand, in Itsuna WTP using same water source, average run time of slow sand filter was 61 days in 1977. The filter had been covered because of heavy snow area. And then sunlight was also blocked. Therefore algae were controlled. That's why filter trouble didn't occur.

2) Filter washing by chlorine water

This is a method to reduce or avoid filter problems by washing the filter layer using chlorine water. Bacteria, algae and small animals live in sand layer of slow sand filter. They contribute to purify the water. Normally, colony of these organisms keeps balance of the number of kinds. However, when small animals such as midge, Nais varibilis and asellus grow massively by some reasons, problem of flow out from tap may occur. In this case, the problem may not be improved by only shaving the surface sand as usual. Washing by chlorine water method would be considered. It is a measure to give damage to nuisance organisms by contacting with chlorine water to sand layer for all day. When filter troubles occur in several filters, it is recommendable to implement the chlorine water contact method for each filter one by one after confirmed the function of washed filter, because it takes time to recover the function of biofilm.

(1) Characteristic

It is effective to the nuisance organisms which are weak to chlorine.

(2) Remarks

It is not effective so much to Nematode, because they have a tolerance to chlorine.

(3) Effectiveness of the measure against each problem

[Conditionally effective] : For flowing out from tap

[Case 3.2.2-3] Washing by chlorine water method -1 (Nais)

In the slow sand filter of Kitakyushu city WWB, Nais grew a lot. It was supposed that Nais would pass through from the filter. Therefore, the filter was washed by chlorine water. Nais were found in 2-5cm deep from surface of sand layer. The number of Nais was different among the filters from 18/m^2 to 1,900/m^2.
It was examined experimentally that CT value to kill Nais 180 (as 0.5mg/L of residual chlorine and 6 hours of contact time).

[Case 3.2.2-4] Washing by chlorine water-2

Nematoda, Nais, water flea and others grew so much in sand layer of slow

sand filter of WTP in M City WWB. As measures, the filter was washed by high chlorine concentration water. As a result, it was effective to Nais and water flea, but nematoda was not killed perfectly.
Washing by chlorine water kills useful organisms too. Therefore, M city WWB doesn't use this method now.

[Case 3.2.2-5] Washing by chlorine water-3 (Pandorina of green algae)
Algal smell TON(threshold odor number) 7 was examined in filtered water of slow sand filter in Kitahara WTP in Hiroshima WWB. Cause was pandorina, green algae which bred in the filter. Maximum 30,000/ml pandorinas appeared in the settled water. Maximum 1,000/ml pandorinas leaked out to the wash water drainage of filter. It was recognized that algal was killed by one-hour chlorine water contact under the condition that residual chlorine was more than 0.3 mg/l at the dosing point.

3) Cleaning of inlet pit for filter basin
When nuisance organisms breed in the adjustment well of slow sand filter, This is a method to reduce or avoid the trouble by cleaning the adjustment well.
When N*ematoda and Asellus* breed in the adjustment well of slow sand filter, it may cause trouble to flow out from tap. For preventing this trouble, staff has to check the existence of nuisance organisms in the adjustment well in the inspection time. When they exist, staff drains the water and cleans the well.

(1) Characteristic

a. This method is carried out by water utility itself and it is not required any special cost.

(2) Remarks
In the case that nuisance organisms breed in sand layer of filter too, it is necessary to increase the cleaning frequency of adjustment well or to carry out other measures to suppress the breeding in the sand layer at the same time.

(3) Effectiveness of the measure against each problem.
[Highly effective]: For problem of flowing out from tap

4) Installation of strainer
This is a method to install strainer for preventing the outflow of nuisance organisms to treated water. As a result, the trouble is reduced or prevented. It is necessary to select a suitable strainer. It has slit for catching the targeted small animals, let through the water well and is easy to maintain. As a measure against outflow problem, there is a case that the metal - honeycomb filter made in SUS 316 (mesh is 1mm around) was used. In general, it is said that metal-honeycomb filter is high opening rate and easy to clean.

(1)Characteristic

The outflow of nuisance organisms bigger than selected mesh size of strainer is prevented.

(2)Remarks

It is necessary to select a strainer which is easy to maintain when clogging.

(3)Effectiveness of the measures against each problem

[Conditionally effective] :For problem of out flow

3.3 Case of Advanced water treatment

Objectives of installing the advanced water treatment facilities are to remove odor matters, trihalomethane precursor and so on which cannot be removed by conventional method like coagulation-sedimentation process and filtration.

Advanced water treatment method consists of biological treatment, ozonation, activated carbon treatment, stripping (volatilization) treatment and so on.

It was introduced for measuring against odor and taste troubles in many cases of Japan.

As for the details about the advanced water treatment measures against "taste and odor" trouble, see "the guideline for measures against taste and odor water caused by creatures" (by JWWA).

Characteristics of effect of measures against biological problem by each advanced water treatment method and particular trouble of each advanced water treatment are written in this paragraph. In addition, measures against the problem of coagulation-sedimentation and rapid filtration facilities used together with advanced water treatment facilities, see **3.1 case of rapid filtration.**

3.3.1 Biological treatment

1) Effect of biological problem measures

Biological treatment is a method to improve water quality of raw water by removing organic matters using microorganisms in the water. It is often introduced for the purpose of removal of ammonium nitrogen mainly. It is recognized to be effective for decreasing the general bacteria and manganese, for stabilizing pH and for removing taste and odor-causing substances as well. The principle of biological treatment is to achieve the self-purification of the river in a short period by treatment plant system. The contact filter media which has several kinds is installed in the treatment tank and microorganisms grow in surface of the media. Raw water is cycled in the tank and contacted with microorganisms. And then the raw water is treated. Therefore, it is desirable that contact filter media has surface area as big as possible. Biological treatment is divided by contact methods as following; submerged bio-filter process

(honey comb method), rotating disk biological contact process, biological contact filtration process and so on.

(1)Characteristic

a. It is effective for taste and odor trouble

b. It is effective for improving raw water quality

(2)Remarks

Treatment effect reduces in the time that water temperature becomes low.

(3)Effectiveness of the measures against each problem

[Highly effective]: For taste and odor trouble

[Conditionally high]: For coagulation-sedimentation problem

[Case 3.3.1-1] Biological measure against taste and odor trouble -1 (submerged bio-filter process)

In case of kasumigaura WTP, Business Bureau, Ibaragi Prefecture, a biological treatment facility which has 13mm diameter honeycomb tube was Installed as pre-process of coagulation-sedimentation for the purpose of algae removal and measures against taste and odor problem. As the result, concentration of taste and odor matter has reduced about 65%.

[Case 3.3.1-2] Biological measure against taste and odor trouble -2 (submerged biofilter process: experiment plant)

In case of Niwakubo WTP, Department of Water Supply, Osaka Prefecture, A experimental plant was established. It was combined the conventional treatment system with the advanced treatment system like biological treatment which is a honey comb type, ozonation and granular activated carbon treatment for checking the effect of musty odor removal. This facility removed 41% of musty (2-MIB) in average. Removal rate was higher, when the concentration of 2-MIB is higher. When concentration was 219ng/L, removal rate was 54%. In this case, rate of 2-MIB inside algal was 26%. And on the experiment to add standard substances (all dissolved states), detention time was 74 minutes and 2-MIB was 200ng/L, removal rate was about 60%.

[Case 3.3.1-3]] Biological measures against taste and odor problem-3

(rotating disk biological contact process)

In case of Sebu WTP, Nakama Waterworkis Bureau,

The biological treatment system which was a rotating disk facility for solving the taste, odor and algae problems was installed. As the result, 30~40% of taste and odor was removed and then dosing rate of powder activated carbon and chlorine decreased at

the latter part of WTP.

Table III-33-1 Comparison among the biological treatment methods

Item	submerged bio-filter	rotating disk biological contact	biological contact filtration
Treatment method	The aggregate of honey comb tube is installed in the treatment tank. Surface of inside of tube is covered by biofilm. Raw water is circulated and contacted with the biofilm and treated. Energy of water circulation is supplied by aeration which makes dissolved oxygen.	the rotating disk in the tank is installed in the tank. the disk area of more than 40% is submerged in the water. raw water touches the biofilm on the disk and is purified. Dissolved oxygen is supplied for biofilm on the disk by touching the air.	Biofilm is growing on the surface of granular filter media which filled up in the tank. Raw water touches the biofilm by down-flow and is purified. A type that the air blows is always is sometimes used .
Structure of facilities	Treatment tank, honey comb tube, aeration facility for circulation, washing facility, sludge removal facility	Treatment tank, rotating disk, drive device, shed, Sludge removal facility	Treatment tank, Filter media, supporting material, water catchment facility, aeration facility, washing facility
Capacity	Detention time : About 2 hours	Detention time: About 2 hours	Filtration rate: More than 120m/d
Area required	0.015 ~ 0.020$m^2/m^3/d$	0.020 ~ 0.030$m^2/m^3/d$	About 0.010$m^2/m^3/d$
Depth of tank	5 ~ 7 m	3 ~ 4 m	4 ~ 5 m
Water loss	Negligible small	Negligible small	2 ~ 4 m
Aeration facility	Necessary for supplying oxygen and circulating the water.	Not necessary	Necessary
Washing facility	In the case of clogging, it is necessary	Not necessary	Necessary
Sludge removal facility	Often necessary	Often necessary	Not necessary
Maintenance	Easy	Very easy	Washing operation is necessary

[Case 3.3.1-4] Biological measures against taste and odor trouble -4

(biological contact filtration process)

In case of Zensyo WTP, Public Enterprise Bureau, Otsu City,

Biological contact filtration treatment which used ceramic porous media (particle size 3~5mm) before slow sand filter was carried out. It was operated with downflow treatment. As a result, About 70% removal of 2-MIB was confirmed. Moreover, in usage of powder activated carbon together, 81% of 2-MIB was removed in average (concentration of 2-MIB in raw water was 130ng/L in 1994 data)

2) Measure against the algae growth by shading the biological treatment tank.
When algae grow in the biological treatment tank, treatment function may change for the worth. When adherent algae such as the lump state of blue-green algae, filiform green algae and diatoms breed in the biological treatment facility, it becomes a cause of clogging, and also contact between biofilm and water was blocked. It has negative impact for treatment. In this case, the biological treatment can keep the function by shading the sunlight and controlling the algae growth in the tank. Method of the shading can be referred to **3.1 rapid sand filtration**.

[Case 3.3.1-5] Case of shading the biological treatment facility in submerged biofilter process
In case of Department of water Supply, Osaka Prefecture,
It was confirmed by the experiment that the shading the biological treatment tank prevents the decrease of treatment effectiveness and the clogging of filter media.

3.3.2 Ozone treatment

Ozone is strongly oxidative, so it is effective to reduce taste and odor substances. But, ozone treatment by-products are formed. It is required granular activated carbon process (by "ministerial ordinance for determining technical criteria for waterworks facilities). Actual ozonation facilities in Japan are shown table VII-3.3-2.

(1) Characteristics
It is effective to deal with the troubles on taste and odor.
(2) Remarks
It is required treating to ozone treatment by-products.
(3) Effectiveness of measures against each problem
[Highly effective]: For troubles on taste and odor.

[Case study 3.3.2-1] Measures against musty odor by ozonation
In case of Kashiwai Water Treatment Plant, Chiba Prefecture WWB,
Ozonation and activated carbon treatment process were introduced as measures

against musty odor. Decomposition rate of 2-MIB by ozonation was 60% in average at temperature 20℃and about 75% at 25℃.

3.3.3 Granular activated carbon treatment

1) Effects of granular activated carbon process

Activated carbon process is the way of removing impure substances using its adsorption capability. Both of the powdered activated carbon and the granular activated carbon are available to deal with troubles on taste and odor. About a powdered activated carbon process, refer to **3.1 Case of rapid sand filtration.**

Granular activated carbon adsorption basin is divided into 2 types, fixed bed and fluidized bed. In a fixed bed, there are few activated carbon leakages, so it is easy to operate. But it requires washing the bed regularly by clogging. In a fluidized bed, contact efficiency is high, although its operation is more difficult than a fixed bed's. Amount of adsorption to an activated carbon is limited. If an adsorption capability is lost, the activated carbon should be changed to new one. In contrast, a biological activated carbon treatment, which uses a biodegradation capability in an activated carbon treatment basin, can keep its effect for a longer time. The diameter of a granular activated carbon and a frequency of washing must be decided considering about each circumstances. In the case of installing a rapid sand filter after granular activated carbon process, it is effective to prevent for the outflow of small animals into purified water. This system however, increases a load of adsorption matter to activated carbon basin. Therefore, a duration time of an effective treatment becomes shorter than another system which has a rapid sand filter before a granular activated carbon process. Additionally, a poor coagulation-sedimentation process may facilitate clogging of activated carbon bed.

(1) Characteristics

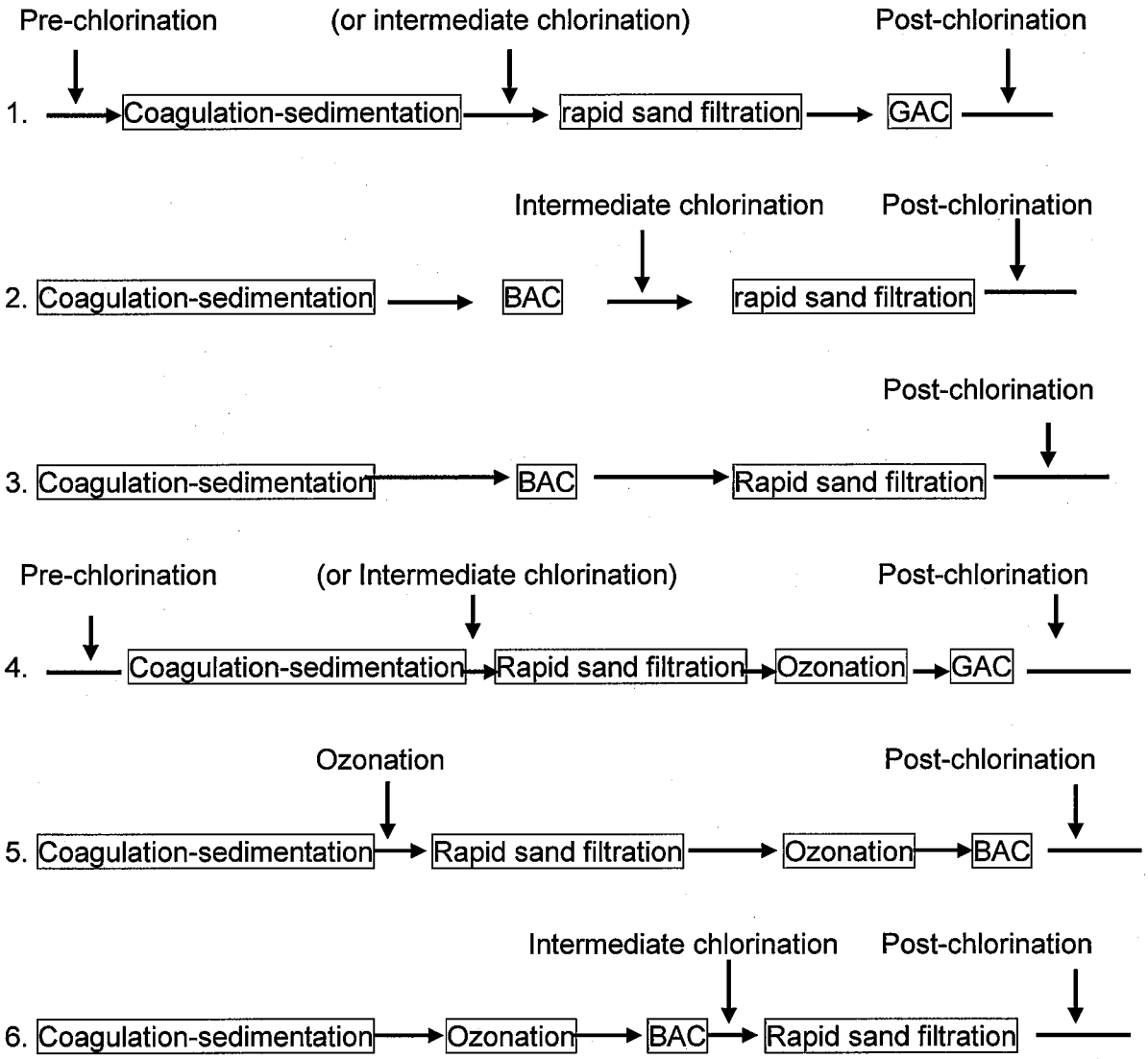
It is effective to deal with the troubles on odor and taste.

(2) Remaarks

It is necessary to pay attention to the outflow of small animals from the activated carbon treatment basin.

(3) Effectiveness of measures against each problem

[Highly effective]: For troubles on odor and taste



FigureVII-3.3-1 Granular Activated Carbon Treatment System (Actual Case)

2) Countermeasures against the outflow problem of small animals

In a granular activated carbon treatment basin, some small animals such as heterotrophic bacteria, nematodes, rotifers and oligochaetes, are growing and sometimes flowing out from the basin. Particularly, when granular activated carbon treatment is used jointly with ozonation, refractory organic matter is degraded to easily decomposable organic matter. So heterotrophic bacteria increase and it helps other small animals increase. If a rapid sand filter is set after the activated carbon treatment basin, small animals which flow out from the activated carbon treatment basin are removed in a rapid sand filter. But granular activated carbon treatment basin is a final process, small animals flow out into purified water. Influx of visible small animals into purified water loses comfort loses comfort in drinking water and loses reliability of water supply although it is no problem in hygiene. So countermeasures are necessary.

Several measures can be taken such as, setting a rapid sand filter after the granular activated carbon treatment, shortening washing cycle considering the growth period of small animals, backwashing with chlorine and changing the intensity of backwashing.

[Case study 3.3.3-1]

Countermeasures against the flowing out problem by shortening of the washing cycle -1

In a water treatment plant of Osaka WWB, some small aimals, such as nematodes and rotifers, flew out from the granular activated carbon treatment basin which have been set after the rapid sand filter. Considering the doubling time of small animals (table VII-3.3-4), the washing cycle of granular activated carbon treatment basin was changed from every 2 weeks into every 3 days. As a result, the amount of small animals which flew out decreased by half. In addition, it was confirmed that the washing out the small animals with an air wash(and backwash) was three times more effective than with a surface wash (and backwash).

Table VII-3.3-4 Doubling time of microorganisms and small animals

	Bacteria	Protozoa	Rotatoria	Oligochaeta	Small animals
Doubling time	33 minutes	5-10 hours	3 days	10 days	2-3 days

[Case study 3.3.3-2]

Countermeasures against the flowing out problem by shortening of the washing cycle -2

In case of the department of water, Osaka prefecture,

Small animals such as, Nematoda (length; 0.1~1mm), Rotoria (0.05mm), Mastigote (0.01mm) and Origocheata (1mm) flew out from the granular activated carbon treatment basin set after the rapid sand filter. It was confirmed that flowing out was prevented by washing cycle of every 3 days at the basin. Additionally, the effect of the prevention for flowing out was more improved by using both of the backwash and the air wash.

[Case study 3.3.3-3]

Successful example for the rapid sand filter after the granular activated carbon treatment

In case of Kanamach Water Treatment Plant of Tokyo Metropolitan Government WWB, some small animals such as Rotoria, Nematoda and Gastrotrichia appeared in water purified in the granular activated carbon, whose number was average 6.3~7.6 organisms/L. But they were removed effectively in the rapid sand filter after the granular activated carbon treatment.

(Water treatment process: Coagulation-sedimentation → Ozonation → Granular activated carbon (GAC) adsorption → Rapid sand filtration → Disinfection)

3.4 Case of only disinfection

This section describes countermeasures against biological problems which occur in water treatment plant adopting a method of only disinfection. As water source of the water treatment plant which consists of only disinfection system, clean water like groundwater or river-bed water is generally used. However, organism such as *Asellus* which is peculiar to groundwater grows and it occasionally flows out into treated water. And also, terrestrial organisms sometimes are going into the shallow wells or river-bed water, and they may cause the problem of outflow into tap water. When outflow of nuisance organisms is caused by organisms related to groundwater, it is good to install the device of coarse filter such as microstrainer. However, when nuisance organism is terrestrial one and it cannot deny a possibility of protozoan pathogen such as cryptosporidium, it is necessary to establish appropriate treatment facilities (coagulation-sedimentation + sand filtration, membrane filtration and so on). Organisms related to groundwater have generally no eyes. Even if they have, these are red color (in Japan). Sometimes living organisms are observed in the tap water with following conditions; organisms have the tolerant to chlorine or concentration of chlorine is low in the treated water, or chlorine contact time is short. And coloration problem may occur due to growth of iron bacteria in the water treatment plant which has only disinfection facility. It is thought that the coloration problem occurs quite often according to the many cases of inquiries to JWWA. However there are extremely a few reports as document.

[Case 3.4-1] Countermeasure against the coloration problem by iron bacteria-1

In Ikuta Water Treatment Plant of Kawasaki City Waterworks Bureau, coloration problem occurred due to the growth of iron bacteria, *Clonothrix putealis* in the boreholes of water source. It was found out that cause of the problem was exfoliation and outflow of iron bacteria that grew inside pipe of raw water transmission. Therefore, the following countermeasure was taken; chlorine water was filled up in the transmission pipe and contacted for 24 hours and then it was drained (washed). Above treatment (washing) was repeated by four times. As a result, the amount of outflow of the iron bacteria was decreased sharply. Next year, the same problem occurred again, therefore above countermeasure was increased and implemented by once a month, 12 times a year in total. After that, the problem was avoided. Continuously, as a permanent measure, sodium hypochlorite facility was equipped and sodium hypochlorite is dosed regularly.

The monitoring of raw water which checks samples caught by plankton net is conducted every 24 hours and it is confirmed whether sample is abnormal or not. The plankton net made by cloth was damaged easily, thus a net made by stainless steel (special order) was used.

[Case 3.4-2] Countermeasure against the coloration problem by iron bacteria-2

In Saitama City Waterworks Bureau, coloration problem was caused by iron bacteria which occurred in a well of water source. *Leptothrix, Gallionella, Crenothrix, Sphaerotilus* as species of iron bacteria were confirmed in raw water and treated water. As countermeasure, drainage from a fire hydrant and dosing of sodium metaphosphate were conducted in the transmission pipe. After that, it was cleared that a cause of the problem was iron bacteria which occurred in the well of water source. Therefore, in addition, dosage of chlorine to raw transmission pipe, increase of volume of chorine at mixing tank, and installation of special filtration device were conducted. After that, the problem was avoided.

[Case 3.4-3] Countermeasure against the outflow problem of *Sphaerotilus*

In Kawasaki City Waterworks Bureau, *Sphaerotilus* grew in the well of water source. And *Sphaerotilus* flew out into tap water. *Sphaerotilus* is also called "mizuwata", and it is a bacterium which grows and consists of cluster as gathering grayish white filiform colony in the water area existing abundant of organic matter. It was assumed that the growth of *Sphaerotilus* in the well was caused by the change of groundwater quality. It became suitable one for habitat condition for *Sphaerotilus* because groundwater had been contaminated by organic matter increased more than the purification ability of aerobe in the soil. It was that the increased organic matter by the domestic wastewater was not diluted without recharging water from surface by water shortage for a long time. As a countermeasure, highly concentrated chlorination water was contacted in a few days, after clearing well, regulating reservoir and clear water reservoir which was confirmed existence of *Sphaerotilus*.

4. Countermeasure in distribution process - Countermeasure against biological problems which occurs in distribution reservoir (regulating reservoir) and water receiving tank -

In distribution reservoir and water receiving tank, some substances such as very small suspended solid which flew out from water treatment plant, small organisms damaged by chlorine, and insects entered from vent hole, sink and accumulate as sediment. These sediments may cause the outflow problem. And also the outflow problem was

caused by propagation of bacteria in the sediments. Furthermore propagation of *Protozoan and Nematodes* which eat bacteria may cause outflow problem. In addition, *Midge imago* which entered distribution reservoir lays eggs and larva which was hatched may cause the outflow problem. And like a hairworm, organisms getting away from the host insect body which entered reservoir may cause the outflow problem as well. Basic countermeasures are periodical checking and cleaning of inside of reservoir, and prevention of entering insects from vent hole. In case of outdoor water tank that light can penetrate the wall of the tank, alga film develops on the inside wall. Then bacteria, fungi, and moreover small animals such as *Protozoan, Nematodes and Midge* may propagate in the alga film. These may cause the outflow problem. Therefore countermeasures such as shading of wall of tank are required.

1) Protection for insects at vent hole of reservoir

Some cases are reported; one case is that midge which entered from vent hole of reservoir laid eggs and hatched larvae flew out from tap. Another case is that animals such as bird, rat, cat, dog and snake entered from vent hole of receiving water tank and then they clogged service pipes. In order to prevent entering animals, putting net to vent hole and periodical check of damage is necessary.

2) Cleaning of distribution reservoir (regulating reservoir) and water receiving tank

It is necessary to check the dist that reservoirs are divided into more than 2 systems in order to clean them without cutting off water supply. When cleaning the reservoirs, footwear and tools of staff should be ribution reservoir (adjustment tank) and water receiving tank regularly, and when sediments increase in the reservoir and tanks, it must be cleaned. It is desirable disinfected well and it is important to consider the prevention of pollution during the cleaning.

[Case 4-1] Growth of small animals such as *Nematodes* in the reservoir

In the water treatment plant of which water source is groundwater from deep well and has pre-chlorination, coagulation-sedimentation and rapid filtration for iron and manganese removal, white spongiform colony inhabited by *Nematodes, Rotifer* and *Water mite* was confirmed at the bottom of distribution reservoir. As a result of investigation, it was assumed that bacteria increased at the sediments which remained for insufficient cleaning, and then *Protozoans and Nematodes* eat that bacteria and propagated.

3) Prevention of algae film formation in the water receiving tank

Algae having tolerance to chlorine may grow on the inner wall of water tank which was made by FRP (Fiberglass Reinforced Plastic) and which light can penetrate installed on the ground. Then small organisms such as bacteria, fungi, furthermore, *Protozoans, Nematodes* and *Midges* may inhabit in the algae film. These small organisms occasionally causes problems due to exfoliation and flow out from the water tank. These algae film itself also sometimes exfoliate and flow out. There are many kind of form of algae film, such as film, granular and eel head. Algae film consists of algae such as *Oscillatoria*, *Phormidium, Lyngbya, Chroococcus* as *Cyanobacteria*, and *Achnanthes, Nitzschia* as *Diatoms,* and *Gloeocystis* as *Chlorophyceae*. The well grown algae film is difficult to disinfect and remove it under normal residual chlorine concentration. Therefore washing by human power is required. As radical measures, to change wall of tank to the materials which can prevent penetrating sunlight, or to implement some countermeasures to prevent sunlight penetrating are needed. According to the report of investigation of nineties water receiving tanks which installed on high-rise buildings such as apartments and office buildings in Kanagawa prefecture, growth of algae was confirmed in 27 % of FRP water tanks installed outdoor. And also, it was a report that adhesions of micro-organisms as cluster with being form of mat or semi-spherical, such as C*yanobacteria, Diatoms,* fungi, bacteria, and small animals such as *Nematodes* and *Midges* were confirmed in the water receiving tanks which installed on high-rise buildings in jurisdiction of Honjo public health center, Tokyo.