Water Supply Facilities Maintenance Manual

2006

Chapter 7. Water Treatment Facilities

Chapter 13. Water Quality Management

（The Excerpt）

Ministry of Health, Labour and Welfare

Chapter 7. Water Treatment Facilities

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This manual consists of extracts from Chapter 7. Water Treatment Facilities, and Chapter 13. Water Quality Management of “Water Supply Facilities Maintenance Manual 2006 [Japan Water Works Association]”
The numbering of Figures and Tables in the extracts is identical to that in the original manual.

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7. Water Treatment Facilities

7.1. General

7.1.1. Principal Matters

1. Importance of water treatment facilities

Water treatment facilities are those which produce safe tap water to be comfortably used in conformity with the water quality standards. In case the facilities are not adequately operated and maintained, proper quantity and quality of treated water cannot be obtained, which, as a result, causes serious influence to the entire operation of the water supply facilities.

2. Water treatment methods suitable for raw water quality

The method of water treatment, the components of water treatment facilities, their size etc. are to be determined by the condition of water sources, raw water quality and the output of treated water. To always carry out reliable water treatment, suitable maintenance of the facilities, including their improvement according to the need, shall be undertaken with original and innovative ideas based on the understanding of their design concept.

Methods of water treatment are largely classified into (1) a method only with disinfection; (2) a slow sand filtration method; (3) a rapid sand filtration method; (4) a membrane filtration method. In addition, an advanced treatment process and other methods may be added as needed as per raw water quality. Selection criteria of respective water treatment methods in consideration of raw water quality are presented in Table 7.1.1.

1) Method only with disinfection

This method is applied to a source of groundwater, a spring or a mountain stream with particularly good quality throughout the year. Since the treatment process is simple, their operation and maintenance are easy.

However, in case the raw water is contaminated with such chlorine resistant pathogenic organisms as cryptosporidium, the slow sand filtration method, the rapid sand filtration method, membrane filtration method etc. shall be used as the cryptosporidium cannot be inactivated by chlorination. Its basic process flow is presented in Figure 7.1.1.

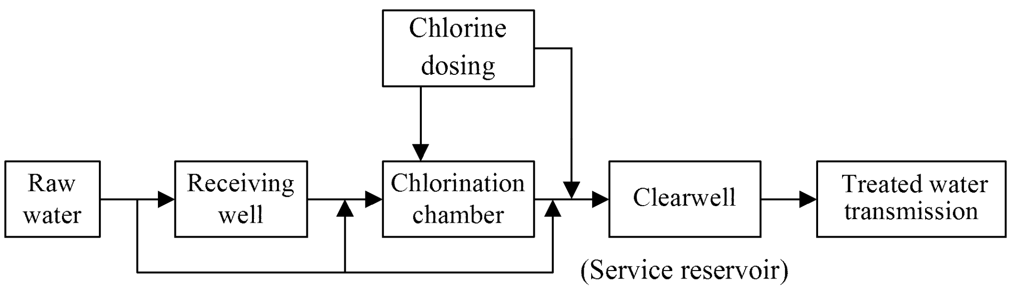


Figure 7.1.1 Method only with disinfection

Table 7.1.1 Selection criteria of water treatment methods

<table>
<tr><th>Treatment method</th><th colspan="2">Objective substances to be removed</th><th>Removal method (principal treatment facility)</th></tr>
<tr><td>Method only with chlorination</td><td colspan="2">Generally, in case water source is groundwater etc. with particularly good water quality, raw water, compatible to water quality standards only with chlorination, is the object.</td><td>Chlorination</td></tr>
<tr><td>Slow sand filtration method</td><td colspan="2">In general, in case raw water quality is good with low stable turbidity. Annual av. turbidity< 10 units.

Biochemical oxygen demand (BOD) < 2 mg/L

Annual average turbidity<10 units</td><td>(Annual maximum turbidity < 10 units)
……Slow sand filtration
(Annual maximum turbidity < 10 ~ 30 units)
……Plain sedimentation + slow sand filtration
(Annual maximum turbidity > 30 units)
……Sedimentation basin, for which chemical treatment can be applied + slow sand filtration</td></tr>
<tr><td>Rapid sand filtration</td><td colspan="2">For raw water other than the above. However, raw water, for which another treatment method and an advanced treatment method are not needed.</td><td>Coagulation basin (rapid mixer + flocculation basin) + sedimentation basin + rapid sand filter

Suspended solid contact clarifier + rapid sand filter</td></tr>
<tr><td>Membrane filtration method</td><td colspan="2">(do)</td><td>In some cases, it is advantageous to remove suspended matters and dissolved substances to certain degree in advance
(Pretreatment)+membrane filtration facilities</td></tr>
<tr><td rowspan="15">Other treatment method and advanced water treatment</td><td colspan="2">pH control</td><td>Alkali treatment, acid treatment</td></tr>
<tr><td colspan="2">Erosive free carbonate</td><td>Aeration, alkali treatment</td></tr>
<tr><td colspan="2">Fluorides</td><td>Coagulation and sedimentation, activated alumina method, bone char method, electrolysis method</td></tr>
<tr><td colspan="2">Color</td><td>Coagulation and sedimentation, activated carbon adsorption, ozonation</td></tr>
<tr><td rowspan="3">Trihalomethanes</td><td>Removal of trihalomethane precursors</td><td>Coagulation and sedimentation, algae control, ozonation, activated carbon adsorption (powder, granular), ion exchange, biological treatment</td></tr>
<tr><td>Reduction in formation of trihalomethanes</td><td>Conversion from pre-chlorination to intermediate chlorination and post-chlorination, ozonation, chlorine dioxide treatment, chloramines treatment, ion exchange</td></tr>
<tr><td>Removal of trihalomethanes</td><td>Activated carbon adsorption (powder, granular)</td></tr>
<tr><td colspan="2">Trichloroethylene etc.</td><td>Activated carbon adsorption (powder, granular), aeration, ozonation</td></tr>
<tr><td colspan="2">Anionic surfactants</td><td>Activated carbon adsorption (powder, granular), biological activated carbon (BAC) treatment, biological treatment, ozonation,</td></tr>
<tr><td colspan="2">Taste and odor</td><td>Aeration, chlorination, activated carbon adsorption (powder, granular), BAC treatment, biological treatment, algae control</td></tr>
<tr><td colspan="2">Ammoniac nitrogen</td><td>Break point chlorination, biological treatment</td></tr>
<tr><td colspan="2">Nitrate nitrogen</td><td>Ion exchange, reverse osmosis membrane filtration, electrodialysis</td></tr>
<tr><td colspan="2">Agricultural chemicals</td><td>Activated carbon adsorption (powder, granular), chlorination, ozonation, aeration, reverse osmosis membrane filtration</td></tr>
<tr><td colspan="2">Oils</td><td>Activated carbon adsorption (powder), ozonation, oil mat, oil fence</td></tr>
</table>

2) Slow sand filtration method

This method is in general employed in case the raw water is good and stable in quality with low turbidity. Water is filtered through a relatively fine sand layer at 4 to 5 m/day of filtration rate. Suspended matters are trapped and dissolved substances are removed by oxidization and biodegradation on colonies of microorganisms which grow on the surface and inside of the sand layer.

What is more, as a measure against cryptosporidium, the filtration rate is to be maintained lower than about 5 m/day and rapid change in the rate shall be avoided. Its basic process flow is presented in Figure 7.1.2.

Depending on raw water quality, there is a case to install a plain sedimentation basin. In some small scale water treatment plants, the process of turbidity removal is changed over to a membrane filtration method at the occasion of replacement of their facilities.

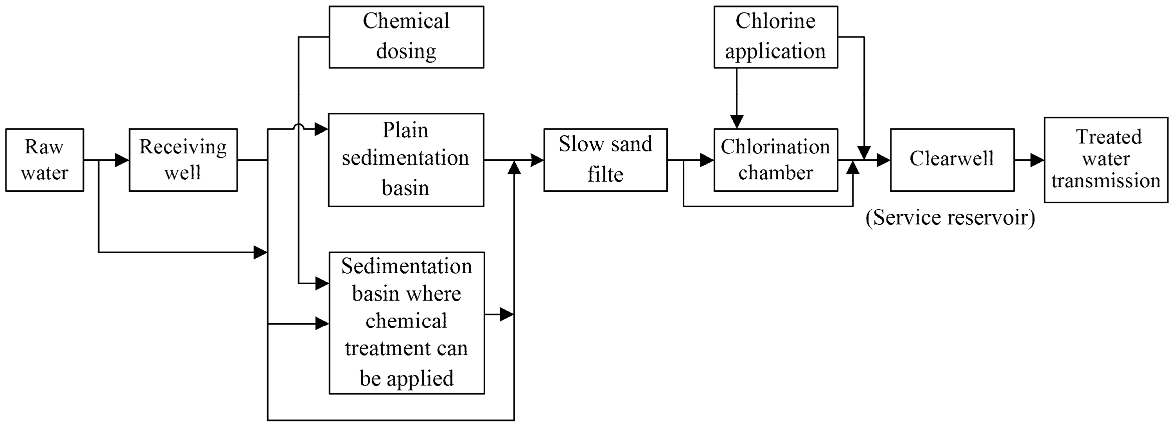


Figure 7.1.2 Slow sand filtration method

3) Rapid sand filtration method

This method is applied in the cases of raw water quality for which the slow sand filtration method is not applicable, the limited site area, and a large quantity of water to be treated. Its main components are chemical sedimentation (flocculation and sedimentation) and rapid sand filtration.

Sand coarser than the one for the slow sand filter is used for the rapid sand filter, and its standard filtration rate is 120~150 m/day. Its treatment train consists of dosing of coagulant, preliminary coagulation of such suspended matters as clayish materials, bacteria, algae etc. into flocs, sedimentation and filtration. This method can deal with raw water of high turbidity.

Since quality of preliminary treatment is extremely important for secure removal of turbidity matters and cryptosporidium, performance of pretreatment before the filtration process is extremely important, minute attention for operation and maintenance in regard to the optimum dose of coagulants and so forth based on the result of a jar test etc. is needed (See 7.3.2 Coagulants). Its basic process flow is presented in Figure 7.1.3.

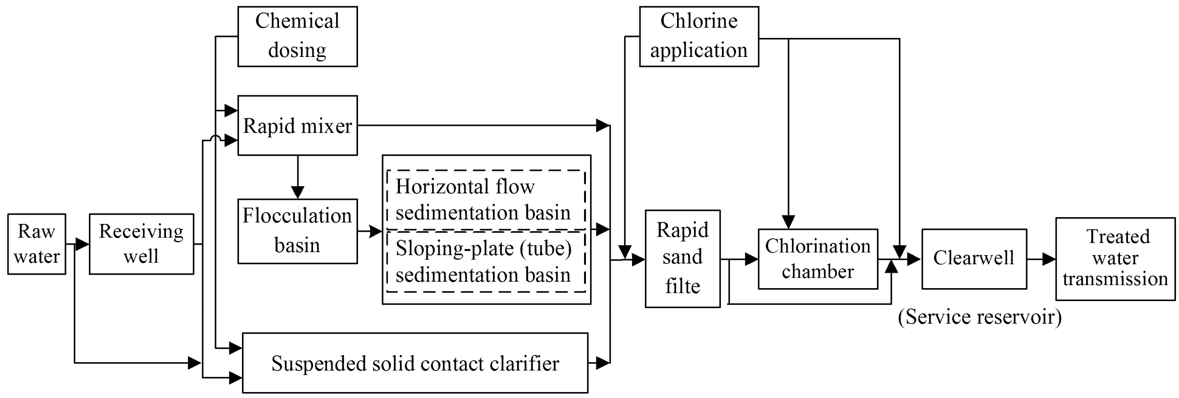


Figure 7.1.3 Rapid filtration method

4) Membrane filtration method

This method is generally used to physically remove suspended matters, colloids, bacteria, cryptosporidium etc. in raw water applying organic or inorganic membranes for microfiltration (MF membrane) , ultra-filtration (UF membrane) etc. in accordance with their pore sizes. Although they can deal with a wide range of raw water quality, understanding of raw water quality is essential because the type of the membrane or the treatment process with its combination is determined by the objective matters to be removed.

Although, in addition to routine inspections, chemical cleaning of the membrane every several months and replacement of the membrane every several years are required, operation and maintenance of membrane filtration is in general easy since the number of treatment processes is small; there are few moving components; and automation and remote control of the system are applicable.

Besides, more and more membrane filtration systems have been employed with such a backdrop as the problem of difficult acquisition of a lot for a water treatment plant, scarce trained technical personnel to be secured for water utilities etc.

Meanwhile, the reverse osmosis (RO) membrane has widely been in use for seawater desalination.

A basic process train is shown in Figure 7.1.4.

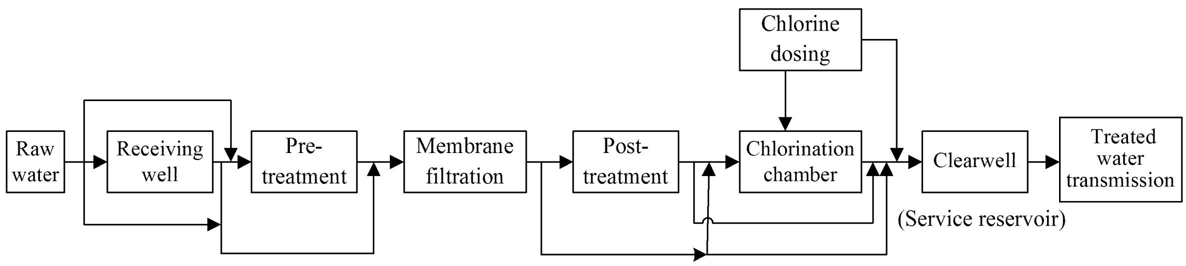


Figure 7.1.4 Membrane filtration method

5) Advanced water treatment methods and other treatment methods

Advanced water treatment stands for activated carbon adsorption, ozonation, biological treatment etc. aiming to treat odor causing matters, trihalomethane precursors, color, ammoniac nitrogen, anionic surfactants and so forth, which cannot sufficiently be removed by the ordinary means of water treatment.

Besides, as other water treatment methods, there are pre-chlorination, aeration, alkaline agent treatment etc. which treat a large amount of iron, manganese, corrosive free carbonate and so on contained in raw water.

3. Necessity of chlorination

Although there are many water treatment methods, disinfection by a chlorine agent is a must even in case any of such treatment methods are used. The reasons are that it is difficult to completely remove bacteria in raw water by sedimentation and filtration; that there is a hygienic need to insure the safety of tap water by retaining disinfecting capability of water itself also in the water transmission and distribution systems and so on. For such reasons, chlorination of treated water is obligated under Article 22 of the Water Supply Law and Item 3, Article 17 of the Enforcement Regulations of the Law so that residual free chlorine in water is to be maintained at 0.1 mg/L or more (in the case of combined residual chlorine: 0.4 mg/L) at the tap.

Although the chlorine agents can keep disinfection ability for a long time, disinfection shall properly be undertaken in adequate consideration of the palatability of water and the production of such disinfection byproducts as trihalomethanes etc. (See 7.9 Disinfection Equipment).

4. Necessity of wastewater treatment

The drainage of wastewater generated from water treatment processes is regulated by such related laws as Water Pollution Prevention Law etc.

Efforts shall be made to utilize the sludge cake produced from wastewater treatment for a supplemental material for agricultural and horticultural earth. The Law for treatment and cleaning of wastes (1980 Law No. 137) shall be abided by when treating or disposing the cake by reclamation etc. (See 7.18 Wastewater treatment facilities).

5. Management of facilities with the emphasis on the entire system of water treatment

When operating and maintaining water treatment facilities, it is important not only to make these respective facilities to properly function but render the entire water treatment facilities to work as an organic and unified system. Besides, even if the condition of water treatment such as the deterioration in raw water quality and at an emergency changes to certain extent, it is required to operate and maintain the facilities while dealing with such changes with an adequate margin.

For that aim, it is important to adequately grasp the condition of water sources, treated water transmission and distribution systems, water service systems etc. and at the same time to operate and maintain water treatment facilities while keeping close communication among offices in charge of such facilities.

A common flow chart of a water treatment plant by the rapid filtration method is presented in Figure 7.1.5.

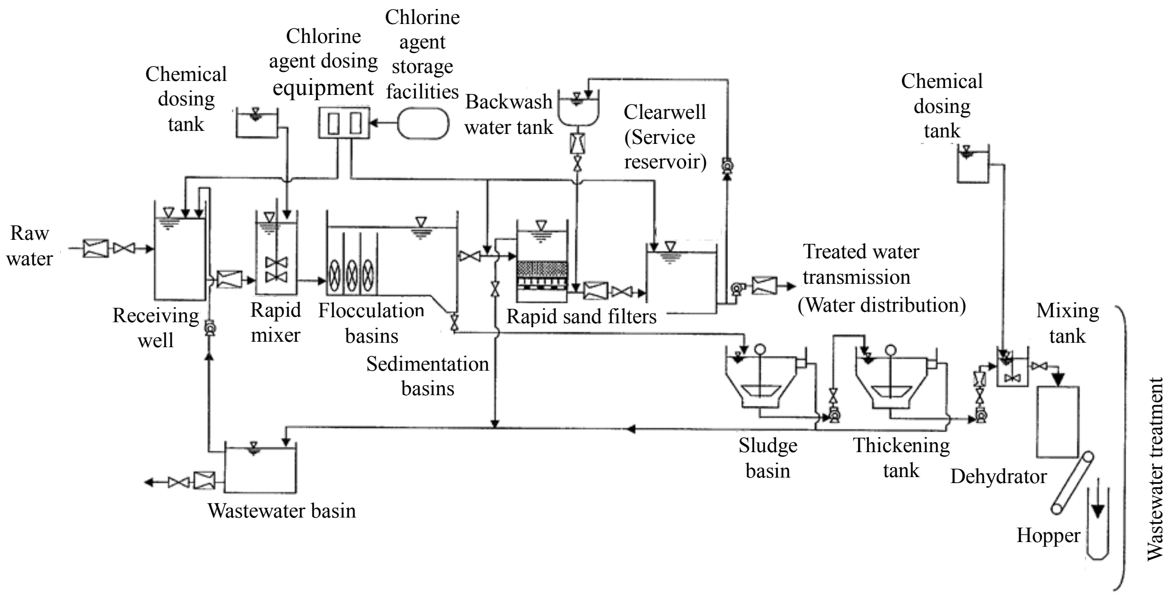


Figure 7.1.5 Common flow chart of a water treatment plant (Rapid sand filtration method)

6. New trend of water treatment

The issue related to water treatment is the measures against byproducts of chlorine agents and ozone, such chlorine resistant protozoa as cryptosporidium, trace organic matters including agricultural chemicals and odor causing materials.

1) Disinfection byproducts

Disinfection byproducts include many species such as trihalomethanes, which are produced by reaction between organic matters of humic substances etc. and chlorine during chlorination, and it is pointed out that some of them are carcinogenic.

As measures for reducing disinfection byproducts, there are intermediate chlorination, powdered or granular activated carbon (GAC) adsorption, a combination of ozonation and GAC adsorption or ozonation and biological activated carbon (BAC) treatment and so on.

Although ozonation exerts strong oxidation effect, ozonation produces bromic acid in case raw water contains bromic ions. As the quantity of bromic acid formation is proportional to the dissolved concentration of ozone, it is needed to control excessive formation of bromic acid due to excessive ozonation based on understanding of the optimum dosing rate of ozone through testing etc.

2) Cryptosporidium

Cryptosporidium is a protozoan belonging to sporozoea, and a pathogenic microorganism, which infects humans and domestic animals.

If taken through the mouth, it mainly infects in enterons causing diarrhea and stomachache. It exists as an oocyst outside its host in the size of 4 to 6 μm or so, and resistant to chlorine. As such, as it cannot be inactivated by ordinary chlorination, such measure as turbidity control of filtrate etc. is required.

At a water treatment plant, for which water source there is a possibility of contamination with cryptosporidium, water treatment by slow sand filtration method, rapid sand filtration method, membrane filtration method etc. is an obligation. Additionally, it is obligated that thorough improvement of water treatment operation and facilities shall be implemented so that the turbidity of filtrate is maintained less than 0.1 turbidity units by means of continuous monitoring of turbidity at the effluent of filters.

What is more, UV radiation and ozonation are considered effective for inactivation of cryptosporidium.

3) Trace organic matters

Problematic trace organic matters are various substances including trichloroethylene, tetrachloroethylene, 1,4-dioxane etc. used as solvent and a cleaning agent at dry cleaning shops or semiconductor factories, agricultural chemicals etc. Methods of their treatment include stripping, powdered activated carbon or granular carbon adsorption etc.

Particularly important matters in maintaining these facilities are to precisely understand the characteristics of the raw water, to conduct thorough daily water quality control including prediction of seasonal changes etc., and to reflect result of such observation to the condition for water treatment operation. Likewise, manuals etc. shall be provided so that sudden changes in water quality can be dealt with as required.

7. Automation and safety of the system

For the application of automation, it is important to make respective processes to hold such a function as feedback, feed-forward, failsafe, foolproof etc. so that the system can be operated precisely and safely even at an emergency of a serious failure.

8. Energy saving and cost related to operation of water treatment facilities

1) Energy saving

To make energy consumption of electric power etc. as small as possible, it is essential to establish a policy for reduction in power consumption and execute it such as control of delivery pressure of pumps for treated water transmission and distribution in consideration of energy saving, introduction of energy saving equipment, implementation of measures for the improvement of power factor compatible with the status of respective facilities, setting of appropriate temperature for air-conditioning and so forth including careful daily handling.

2) Recycling

As recycling in water treatment facilities, there is effective utilization of abstracted raw water. In this concept, process water such as cooling water for equipment and treated water generated from a wastewater treatment facility is not discharged to public water body or sewers but reused.

Nonetheless, if the quality of reused water is bad, the quality of raw water becomes deteriorated as a result, which causes a problem for water treatment. Therefore, necessary measures shall be taken so that any trouble is not to be brought about in treated water or water treatment processes.

3) Total cost

Emphasizing on the life cycle, efforts shall be made to properly operate and maintain water treatment facilities. Furthermore, aiming at environmental preservation measures, energy saving, saving of resources, and reduction in manpower, efficient operation and management as whole facilities shall be aimed.

7.1.2. Rational management of facilities

Rational management of water treatment facilities does not denote management only depending on experience and hunch, but stands for the one in that effectively using statistical and mathematical prediction, analysis, optimization method etc., management goals are forecast and determined. Such management goals shall be reevaluated and adjusted.

The following merits can be expected by rational management:

① The present status can quantitatively be grasped, which can be used for future forecast and planning of facility improvement.

② Management goals etc. for operation can logically be established.

③ Automatic control by computer can easily be made.

④ Implementation of energy saving, saving of resources, reduction in manpower etc. can become possible, which will result in cost saving.

⑤ The method of management is standardized, and failures will be reduced.

As a result, water volume control, water quality management, chemical handling, and facility maintenance can be optimized.

7.1.3. Evaluation and diagnosis of functions

1. Significance of total evaluation and diagnosis of water treatment facilities

A water treatment plant is a synthetic system consisting of civil and architectural structures, mechanical and electric equipment, instrumental equipment, chemical apparatus, office buildings etc. Given this, synthetic evaluation and diagnosis are important to secure the reliability of water treatment facilities as a comprehensive system.

Points of attention for evaluation and diagnosis in relation to respective facilities including civil structures are given below:

1) Civil structures

Important elements of evaluation and diagnosis of civil structures are the following items:

① Whether or not the water level at each civil structure shall properly be secured so that it can adequately deal with head loss needed for each process.

② Whether or not reliable water treatment can be secured even in the case of shutdown of part of facilities due to changes in raw water quality or treatment flow. For example, whether or not the capacity or output of the sedimentation basin, filter, backwash water retaining pond, chemical tank etc. are adequately secured.

2) Mechanical and electrical equipment

Important factors related to evaluation and diagnosis of the mechanical and electrical equipment are the following items:

① Whether or not backup function at the time of inspection or power failure is provided such as two-way power receiving, duplicated power wiring, installation of in-house power generation and so forth.

② Whether or not the capacity of facilities is adequate. To how much extent the standby units are provided.

③ Whether or not safety or protection devices to indicate “stop”, “warning” or “illustration” are installed to enhance the safety.

3) Instrumental equipment

Since instrumental equipment works to smoothly organize monitoring and control of facilities, important elements of its evaluation and diagnosis are the following items:

① To what extent monitoring, control, and processing of information become available by means of instrumentation throughout the entire water treatment plant.

② Whether or not instrumental equipment for chemical dosing, filter backwashing etc. are working precisely and smoothly.

③ Can the instrumental equipment safely and quickly work at an emergency and the time of an accident?

④ Whether or not safety measures are provided so that the function of the entire facilities is not halted even in the case of shutdown by means of duplication of the instrumentation system.

4) Chemical dosing equipment

Safety, accuracy etc. are particularly important for chemical dosing equipment, so the following are pointed out as the factors for evaluation and diagnosis:

① As for chemical dosing, is safety secured for the entire system including security provisions?

② Can dosing of all the chemicals be carried out precisely and smoothly?

③ Can the capacity of feeders of chemicals always deal with the ranges of dosage at the maximum through minimum?

④ Are spare units of feeders secured?

⑤ To what extent of deterioration in raw water quality can the chemical dosing equipment deal with?

⑥ Can all the routes of chemical dosing piping be switched or washed?

2. Function evaluation and diagnosis for each unit process

It is also important to carry out function evaluation and diagnosis of water treatment facilities independently for each of unit processes of rapid mix, flocculation, sedimentation, filtration etc.

The causes of decline in the performance of unit processes are divided into four categories by causes, and methods of diagnosis on the respective causes are presented as follows:

1) Design factors

These factors are brought about by the gaps between the condition at the times of design and construction of facilities and the one at present. It can be known from the result of examination and diagnosis whether or not the validity of conditions at the time of design is still maintained.

2) Operating and maintenance factors

Although temporary decline in performance is often caused by improper adjustment of facilities, the validity of operating procedures can be judged from the diagnosis.

3) Age-related factors

These factors are related to age-related deterioration of superannuation of facilities etc. Information for judgment can be obtained from the diagnosis if partially refurbishment or total replacement of facilities is needed.

4) External factors

Deterioration in raw water quality, changes in production volume etc. are the main external factors. They are concerned with function evaluation of the system as a whole.

In Figure 7.1.6 obstacles in rapid sand filters are classified, and it is illustrated how the situation of deterioration in functions is related to the above-mentioned four factors:

To evaluate and diagnose the functions of the unit processes in this method, it is needed that the checklist of facilities shall be enriched, and a diagnosis manual shall be provided.

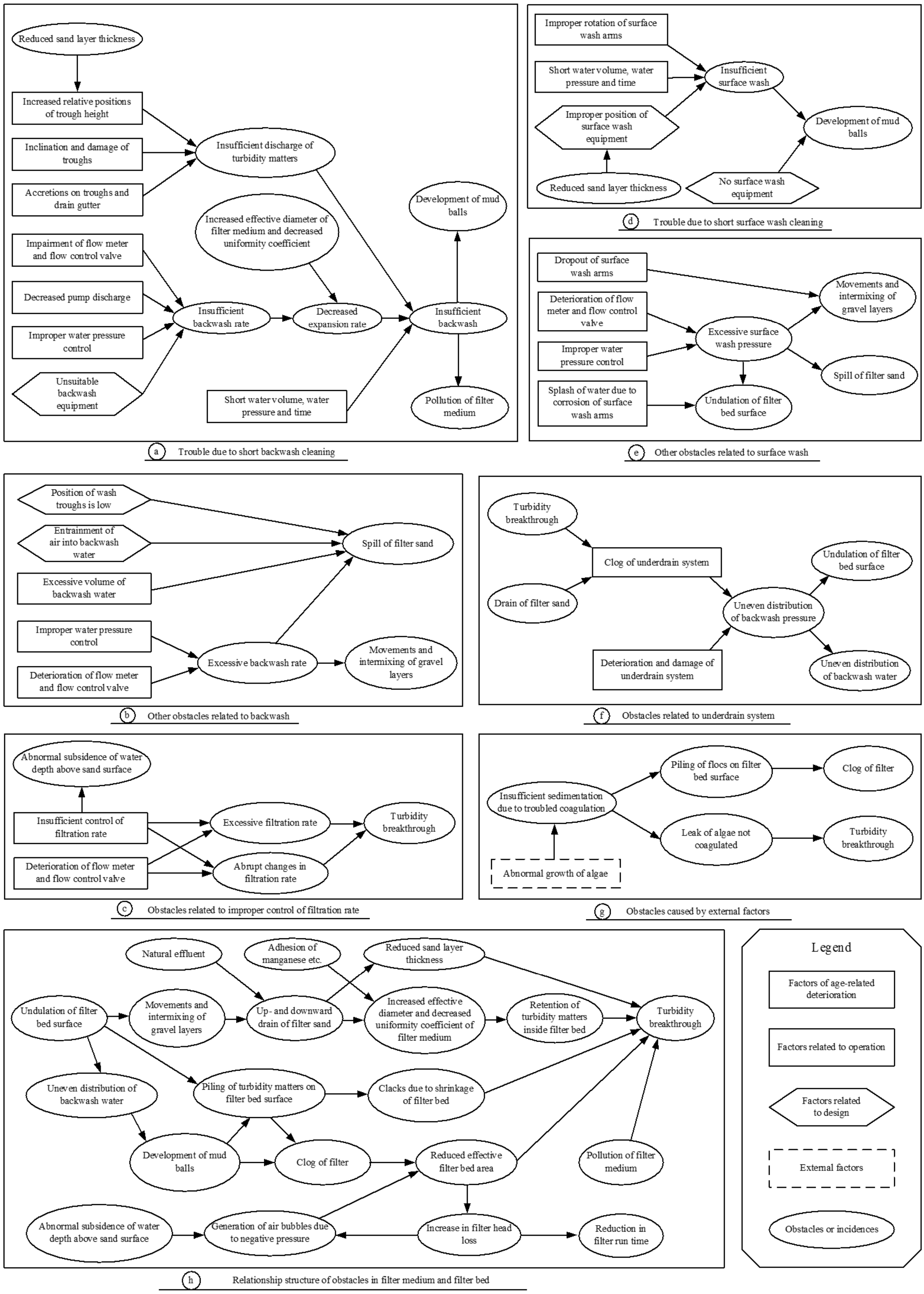


Figure 7.1.6 Schematic of relationship structure of decline in functions of rapid sand filters

7.1.4. Operation

1. Operation and management

The objects of operation and control in the water treatment plant are each facility and equipment. It is determined by the manner how to manage such a control target as the plant output, water quality, facilities, chemicals etc. whether or not the plant is efficiently and economically operated as a system.

1) Control of water volume

Water volume control in a water treatment plant stands for measuring water volume at each treatment process in respect to the target volume to be treated and controlling facilities and equipment so that the water volume is to fit the target value based on their comparison.

① The volumes of raw water and treated water are to be determined based on the water service volume. Therefore, they shall adequately be fit to the latter, which shall daily be predicted.

② Although the raw water volume is determined based on the water treatment volume, in case the filter backwash water and effluent from wastewater treatment are returned to the plant head and reused, the volume of such water shall be accounted for.

③ The treatment volume shall be determined based on not only the water service volume but the volumes for process water, utility uses etc.

- The process water includes cleaning water for sedimentation basins, filter backwash water or sand cleaning water, water for chemical dilution, pressurized injection water for chlorine dosing, cooling water for equipment, lubricant water for rotating parts of equipment, water for water quality testing, cleaning water for facilities etc..
- Utility use water includes water service in the plant premises, plant c leasing water etc.
- To properly manage water volumes at respective steps of water treatment, it is needed for flow meters etc. are always functioning precisely and data from them are accurately indicated and recorded.
- The record of water volumes shall be classified, stored and processed statistically.

2) Control of water quality

Water quality control is essential to produce tap water which is hygienically safe and can comfortably be used as in conformity with the water quality standards. Water quality shall be tested at each treatment process; its result shall be compared with the standards or the management goals; it shall be confirmed for conformity with the standards; the water quality data shall be classified and analyzed; and its result shall be reflected to improve water treatment processes.

3) Upkeep of facilities

Upkeep of facilities means to patrol and inspect the condition of facilities, equipment, apparatus etc.; carry out maintenance and repair finding defective points in an early stage; supply fuel, oils, reagents etc. so as to keep the facilities to always work smoothly. Additionally, patrol and inspection are needed to maintain hygienic environment of the water treatment facilities and prevent accident of workers and visitors.

4) Management of chemicals

Management of chemicals shall be undertaken in that they shall be ordered based on a demand and supply plan for chemicals used in the water treatment plant; that they are stored and adjusted after examination of their quality or standards and quantity; that dosing rate and quantity of chemicals are determined based on the treatment quantity and water quality; and that chemicals are dosed accordingly. “Chemicals” here denote coagulants, coagulant aides, acid and alkaline agents, chlorine agents, powdered activated carbon (PAC) and so forth.

(1) Proper inventory control and securement of safety at the time of receiving

As the quantity of chemicals to be used is determined by the raw water quality and its volume, inventory control shall be undertaken in adequate consideration of such annual demand pattern as seasonal and monthly changes in water quality and volume etc., occurrence of typhoons, the supply system of suppliers and so forth.

What is more, when receiving chemicals, handling shall be carried out, first of all, considering safety lest accidents would occur. Safety of workplace shall be secured so that no chemicals shall spatter.

(2) Inspection of quality and quantity

When receiving chemicals, their quality and quantity shall be inspected, confirmed and recorded so that proper inventory and quality control are to be conducted.

2. Appropriate labor saving in the water treatment plant

In a water treatment plant, instrumentation is employed to the highest degree among the entire water supply facilities, and labor saving is advanced as a result of firmly established centralized operation and control. In the course of employing automation and unmanned operation and management system, facilities and equipment shall be prepared so that water service would not be adversely affected even at the time of an accident.

1) Automation

The magnitude of automation or labor-saving of a water treatment plant shall carefully be determined in adequate consideration of such sorts of conditions as the location of the water treatment plant in question, the situation of water source, characteristics and status of the change in raw water quality, the method of water treatment, the complexity of water distribution etc.

2) Unmanned operation

To introduce unmanned operation to a water treatment plant, reliability and safety shall be established with the adequate provision of preventive measures against intrusion from outside, preparation of remote monitoring and control, establishment of manning at the side to remotely monitor and so on.

Besides, it is needed to examine a management system for patrol and inspection of unmanned facilities and dealing with emergency cases of accidents or failures. The management system shall be in conformity with the size and characteristics of the facilities and equipment.

3. Time lag of water treatment processes

Although, in case raw water quality changes, the dosing rate of chemicals is paced, its effect can only be specifically detected with a certain time lag due to reaction time, time required for sample water to travel to water quality analysis equipment and so forth. It is important to shorten the time lag as much as possible; quickly confirm the result; and precisely control chemical dosing.

The methods to shorten the time lag include proper layout of water quality testing apparatuses, reduction in travel time of sampled water and so on.

As automatic chemical dosing methods, there are the feedback control, the feed-forward control etc. Reduction in the time lag is important even in case these methods are employed.

4. Water treatment in the case of low water temperature (Annotation omitted)

5. Measures for high turbidity raw water

Since, in case raw water is river water, high turbidity directly affects the performance of water treatment at the time of a flood etc., measures against it is needed. As the characteristics of turbidity matter at the time when the turbidity is rising are different from those when it is falling, treatability of water largely differs from each other.

1) Gathering of information and understanding of the situation of turbidity

Efforts shall be made to gather meteorological information, and always grasp the situation of raw water turbidity. It is effective to install water testing apparatus for continuously measuring and recording raw water turbidity.

Since the changes in raw water turbidity can be predicted if the condition of turbidity further upstream of raw water abstraction is known, there are examples in which measures are undertaken in the following methods:

① Sending a staff member to upstream of the intake point, and letting him to test the water quality, the test result is transmitted to the water treatment plant by telephone or radio.

② Inquiry is made by telephone to a water treatment plant situated upstream about the results of water quality testing.

③ Equipment is installed to directly take testing results, via a communication circuit, made by raw water quality testing apparatus at a water treatment plant situated upstream. Secondly, if the water treatment plant situated upstream is one of other utility, such a measure would be made on an agreement to be concluded with the above utility.

Although it is difficult to determine the pattern of high turbidity at the time of flood since condition of rainfall is different at each time of rain. It can be predicted to certain extent by means of making a database from the changes of high turbidity data in the past.

2) Dosing of an alkaline agent or replacement of the coagulant with another one

In conjunction with the condition of turbidity, dosing of an alkaline agent or replacement of the coagulant with another one or change in its dosing rate is needed as follows:

When the river flow is increasing due to rainfalls etc., alkalinity tends to rise temporarily, and then falls. In this case, application of such alkaline agent as sodium hydroxide is needed to maintain the proper range of coagulation.

In case alum is normally used as coagulant with provision of polyaluminum chloride dosing equipment, the change over to the latter is a way to cope with high turbidity. Polyaluminum chloride is generally useful for water with high turbidity, low alkalinity and a low temperature.

On the other hand, turbidity particles become extremely small when turbidity of raw water is falling resulting in difficulty in settling. In this case, more coagulant is needed than at the time of its rise. Therefore, the dosing rate of coagulant suitable to the current condition needs to be determined by means of jar tests.

3) Measure to cope with high turbidity by cutting peaking time

In case there is spare capacity in the output of water treatment facilities and the storage volume of service reservoirs, one measure is to cut the peak of high turbidity by curtailing water intake partially or completely temporarily when raw water turbidity is high, and intake quantity is restored to the normal level after turbidity has declined to certain extent.

In the case of a relatively small water treatment plant, intake of raw water with high turbidity can be curtailed by provision of a raw water retaining pond with capacity of one day’s water production.

If peak cut is possible, as the quantity of turbidity matters to be taken into the water treatment plant can be reduced, dosing quantity of such chemicals as coagulants can be decreased resulting in the abatement of load on the wastewater treatment process. Outline of peak cut is presented in Figure 7.1.7.

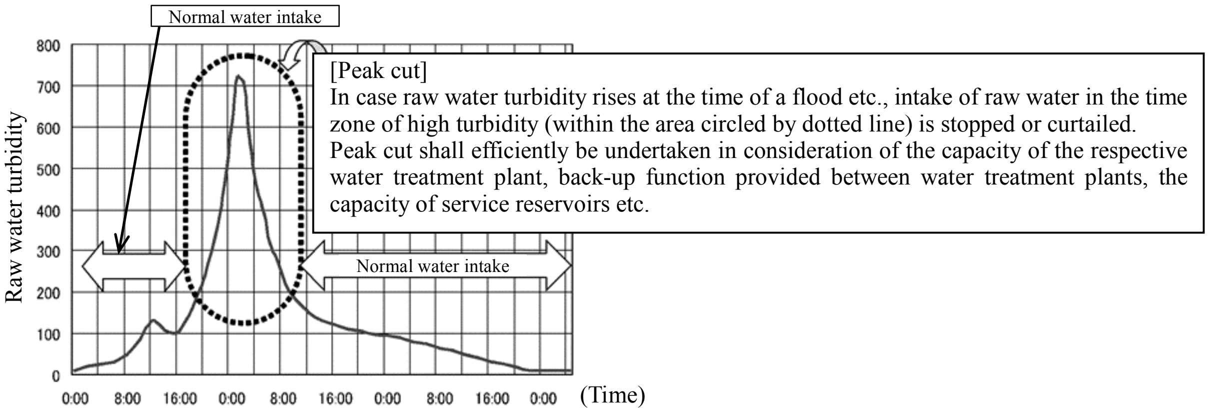


Figure 7.1.7 Outline of peak cut

4) Operational strengthening of wastewater treatment

Scores times of turbidity matter flows into the water treatment facilities compared with the normal times at the time of taw water high turbidity. Therefore, water treatment operation will be seriously hindered unless desludging from sedimentation basins and wastewater treatment are operated smoothly.

Although wastewater treatment facilities are generally designed with a certain margin, enhanced (or prolonged) operation is often required at the time of high turbidity.

6. Optimum sampling location for water quality analysis

1) Sampling locations required for management of normal water treatment processes

① The location of sampling, which can represent the outcome of treatment still in progress are the points where chemicals are fully mixed and their effects can be observed in the flocculation basin; and the settled water effluent channel, filtered water channel, outlet of the clearwell etc. where the result of treatment can be confirmed.

② As the measure against cryptosporidium, the water turbidity at the outlet of the filter needs to be maintained at less than 0.1 turbidity units. As such, a sampling tap shall be fit on the outlet pipe of the filter, and turbidity is monitored with sample water from it.

③ A location where there is no stagnation; there is no influence of sediments; and there is standard flow velocity.

④ In case the water treatment processes are divided into independent systems, it is desirable for sampling points to be set at each system.

For day-to-day management of water treatment processes, continuous analysis by water quality analysis instruments is desirable.

2) Location for installation of water quality analysis instruments

Water quality analysis instruments shall be installed where there are less vibration, an impact, dust, humidity, corrosive gases (chlorine, ozone etc.) etc. and is not exposed to direct sunlight and rain.

There are two ways of installing water quality analysis instruments: (1) the localized type: Instruments are installed close to the sampling point; (2) the centrally concentrated type: Water samples are conveyed from sampling points to a remote laboratory etc. where they are intensively tested.

(1) Localized setting type

Since time lag of measurement data is small; especially, reliable and secure control can be made for control of chemical dosing, it is suitable in case hourly changes of raw water quality are large.

(2) Centrally concentrated type

The environment of installing instruments is good, and their inspection and upkeep can be carried out intensively. However, in case the sample transmission pipe is too thin or too thick, change in water quality (especially, ammoniac nitrogen, turbidity etc.), clogging or breakage of pipe, failure of pumps and so forth may cause a trouble in measurement at times.

Cleaning of sampling pipe is important to prevent change in water quality in the pipe, and clogging due to scaling in the pipe. Cleaning is in general carried out by pressurized water or sodium hypochlorite or making a sponge ball to travel in the pipe and so on. Cleaning shall be implemented as required according to the situation of stains.

7. Shutdown and restart of the water treatment plant

The water treatment plant may be partially or entirely shut down during construction or service work in the plant, and restarted after it. Principal points of attention, among many other things, for shutting down and restarting the plant are the following:

① In case a large quantity of water is discharged to outside of a water treatment plant, sufficient advance consultation with the administrator of the area to which water is discharged shall be made.

② Inspection, upkeep, cleaning, repair etc. of facilities and equipment, which cannot be executed at normal times, shall be implemented utilizing the downtime according to a work plan to be provided in advance.

③ The inside of feeders and piping shall sufficiently be washed by water etc. and then water in them shall be drained so that used chemicals would not remain.

④ In case electrical equipment is shut down for a long time, measures for damp-proofing, drying etc. shall be implemented since there is possibility of reduction in insulation.

⑤ In case the sedimentation basin is shut down, caution shall be paid to the putrefaction of water in the basin, obnoxious odor due to the growth of algae etc.

⑥ If the water level in the sloping-plate (tube) sedimentation basin is rapidly lowered, the device may be broken due to the weight of sludge deposited on the device. As such, the water level shall gradually be lowered; or lowered while washing the sludge away.

⑦ In case the slow sand filter is shut down for a certain period of time, skimming of sand bed shall be carried out, and operation shall be resumed after adequate cure.

⑧ In case the rapid sand filter is shut down for a short period (up to two to three weeks) of time, it is good practice to retain water above sand surface to prevent exfoliation of manganese from sand grains due to drying. Likewise, in the case of a long downtime, since microorganisms grow in the filter bed causing an adverse effect as a result of anaerobic status in the bed and so forth, it is needed to dewater the bed after its cleaning. When restating, the filter shall sufficiently be cleaned.

⑨ When biological treatment facility or biological activated carbon adsorption facility is restarted, attention shall be paid to the condition of organisms; and time required for running-in before restart needs to be accounted for.

⑩ When resuming, exhaust of air from respective pipes, and filling-up of water in them shall be confirmed. After extended period of downtime, prior oiling and watering and test running are needed to prevent an accident due to lack of lubrication of machinery and lack of shaft seal water of the pump when they are restarted.

7.1.5. Upkeep and management

1. Inspection standards of respective facilities

To prevent troubles of water treatment facilities in advance, effective patrol, inspection and upkeep shall be implemented; safety and credibility of respective facilities shall be secured so that reliable operation can be continued.

2. Precautionary preservation and posterior preservation

Precautionary preservation denotes that inspection and replacement of spare parts for every fixed cycle or certain runtime to prevent trouble of equipment etc. in advance.

To establish the method of precautionary preservation, the durability etc. of respective parts which comprise the equipment and apparatuses shall precisely be grasped. To this end, it is essential that not only the existing data but the data which have been accumulated through inspection and upkeep be analyzed and their results be utilized for enhancement of precautionary preservation.

Posterior preservation stands for the method to repair after damage is brought about; a system to do repair as quickly as possible shall be established.

As for procurement and repair of materials and spare parts at an emergency, the system of supply and its contact address shall be grasped in advance.

3. Replacement of existing facilities

There are many cases of replacing water treatment facilities from the need for measures to overcome their aging, enhance earthquake resistance, deal with deterioration in raw water quality and so forth. When replacing the facilities, it is important that a replacement plan has been established, and the harmony between existing facilities and the new one has been aimed.

1) Replacement plan

When proceeding on the replacement plan, the following items shall clearly be identified:

① Purpose (need) of replacement

② Scope of replacement

③ Soundness and reliability of the type (or model) of replaced facilities

④ Durability of replaced facilities

⑤ Compatibility with the design concept of the existing facilities

⑥ Yearly work schedule and funding plan for replacement

⑦ Securement of backup capacity during implementation of replacement

2) Harmony with existing facilities

When replacing water treatment facilities, the work is carried out while demolishing part of existing facilities in many cases. Therefore, as the replacement work is executed close to the existing facilities, it is needed that the work is undertaken with adequate consideration to that the function of existing facilities is not affected.

4. Measures for reform and augmentation

In case reform or strengthening of existing facilities is needed, it is important to secure space for installing the new components of the facilities, and to devise hydraulic integrity of the new and existing facilities.

In case such a new treatment process as advanced water treatment facilities are introduced, since space for such facilities shall be secured, and head loss for such facilities hydraulically increases, measures against them are needed.

7.1.6. Risk management

When operating and maintaining water treatment facilities, attention shall be paid to measures against such risks as an earthquake, flood, draught, lightning, power failure, fire, accident of leak of chemicals etc, damage of equipment, erroneous handling of apparatuses, aging of facilities, human casualties, accident of water pollution, deterioration of raw water quality, intrusion from outside etc.

1. Risk management in consideration of characteristics of the water treatment plant

The contents of risks related to the water treatment plant are different depending on characteristics of the region where it is situated. For example, a region where earthquake and lightning frequently occur, and the other one where there are few of them; a region where raw water quality is bad and the other where it is good; or whether or not a region is situated in a cold zone and so on. So, risk management in a water treatment plant in adequate consideration of characteristics of the region is needed.

Moreover, the contents of risks related to the water treatment plant are different depending on its own characteristics. For instance, since there are such differences as the size of the plant, priority, the magnitude of aging, whether or not water can be conveyed by gravity, if there is a system of mutual supply of raw water or treated water and so forth, such characteristics need to be taken into consideration.

2. Measures against power failure

There are power failures due to earthquake, storm and flood damage, snow damage, fire etc.; power failures due to maintenance work of power transmission circuits and equipment; unexpected power failure caused by small animals and so on.

As method of securement of power among measures against power failure, there are installation of emergency and common use in-house generators, and two-way power receiving.

It is needed to estimate the damage to be caused by power failure based on the environment surrounding the water treatment plant, its size, priority etc.; to compile measures against the above risks; and, comparing them, to implement a measure.

3. Measures against the risk of deterioration of raw water quality

1) Understanding of present status of raw water quality and its future prediction.

To deal with the deterioration in raw water quality, while precisely understanding the present status, prediction shall be made to what extent the deterioration progresses in future, and what water quality items would especially become problematic, and measures shall be implemented based on it.

2) Promotion of preservation of water source quality

As measures for preservation of water source quality, there are preservation of such a water source area as rivers, lakes, impounding reservoirs etc., preservation measures in lakes and impounding reservoirs, and preservation of groundwater.

Since these preservation measures are often undertaken by organizations related to environment, such measures need to be carried out in close coordination with those related organizations.

3) Securement of alternative water sources

In case water source(s), of which quality is better than the existing one, can reliably be secured in future as well, and its water can be treated by the normal means, conversion of water source to the latter needs to be considered.

4) Investigation of the introduction of advanced water treatment

In case preservation of water source quality is critical, and acquisition of alternative water sources is difficult, the introduction of advanced water treatment shall be investigated.

When examining the introduction of advanced water treatment, the optimum method of treatment, which fully exerts removal capability for the objective water quality items, shall be chosen also in consideration of economic advantage.

In this case, the judgment at which step of the coagulation, sedimentation, and filtration processes, and in what combination the biological treatment, biological activated carbon adsorption, ozonation etc. is very important. Decision shall be made fully in consideration of the characteristics of raw water quality and the nature of the water treatment plant in question.

4. Measures against the risk of intrusion from outside, terrorism etc.

As risks by intrusion from outside, terrorism etc, the deeds of polluting water sources, intruding into the water treatment plant to contaminate water there, vandalism and so forht are considered. Such measures against the risk as enhancement of monitoring of water sources, intensification of guard of water treatment facilities, and establishment of protection shall be planned, and, at the same time, water quality management by means of bioassay etc. needs to be thoroughly implemented.

Additionally, complete management of visitors and contractors, who commute to the facilities, is important. As a measure to prevent throwing of foreign matters from outside, the water treatment would be covered with a roof.

5. Other risk management

1) Measures against natural disasters

To secure safety against natural disasters and prevent accidents before they occur, it is needed to carry out various measures through day-to-day operation and maintenance.

(1) Measures at the time of a flood and a heavy rain

In case earth and debris deposited in drainage pipes in the water treatment plant at the time of a heavy rain, water cannot fully be drained. So there is a risk of damage from inundation. As a measure against it, periodic cleaning of drainage pipes, and test running of pumps are needed. Besides, if the premises of the water treatment plant is low, there is such a risk that muddy water may flow into the premises due to flooding of a river or a heavy rain, and water treatment becomes impossible.

Especially, although the piping gallery of the filters, the clearwell, the entrance to a pump room are in general situated a step higher, their entrances shall be walled up to make them water-tight; or sand bags shall always be prepared so that the entrances can be sealed by the sand bags.

Likewise, it is also important to place electrical and instrumentation apparatuses at a location where there is no risk of inundation, or implement protection measures against inundation.

2) Measures against accidents and fire

(2) Measures against accidents of the leak of chemicals

As a lot of chemicals are used in the water treatment plant, leak accidents, for which attention shall specially be paid, are of chlorine agents, acid and alkaline agents. Patrol and inspection of reserve tanks, liquid retaining walls, drainage pits, piping and feeders shall be carried out so that the safety is to be confirmed in the normal times.

Furthermore, to prevent accidents related to chlorine before they occur, it is needed that its handling shall be conducted very carefully, and that the neutralization and emergency shutdown equipment needs to adequately be patrolled and inspected so that they can normally function.

(3) Fire control

If the fire alarm is erroneously activated frequently, the alarm may be neglected or its switch may be turned off, which may bring about an event, which cannot be recovered. Given this the alarm shall regularly be tested, and needs to quickly be repaired when erroneous activation occurs. What is more, workers etc. engaged in construction sites in the water treatment plant shall be instructed to strictly handle fire.

(4) Safety measures against accidents resulting in human casualties

Accidents related to human casualties occurring in the water treatment plant happen in many cases when staff or plant operator and personnel related construction work are careless, or engaged in work without adequate safety measures.

In normal times education and training shall be implemented; necessary safety measures shall be provided; and such safety control as wearing safety suits and posting of a warning board at dangerous points shall strictly be carried out.

7.1.7. Environmental and other measures

1. Compiling and preservation of documents and drawings

To properly operate and maintain complex and diverse water treatment facilities, and quickly deal with accidents and disasters, it is important to precisely understand the location, structure, functions, material, date of construction, situation of improvement and replacement of the facilities and equipment and their history.

Documents and drawings to be compiled and preserved at the water treatment plant are as follows:

① Documents and drawings related to lots (cadastral maps, surveyed maps, acreage maps, as built drawings)

② Completion drawings of structures, pipelines, architectures, machinery, electrical equipment, communication equipment etc., and application drawings which were submitted to concerned organizations

③ Test reports and handling instructions of respective equipment

④ Documents obligated by laws

⑤ Drawings which are specially recognized as necessary by the technical administrator of the water utility.

Drawings especially important for operation of the water treatment plant are the layout plan of the plant, pipe laying drawing in the plant, drawing of chemical dosing piping, drawing of valve open-close positions, wiring diagram, hydraulic profile, other as-built drawings, related materials etc. In this connection, changes are made in the drawings as a result of improvement or repair, revisions shall immediately be made so that the present status can always be grasped by these drawings and so on.

2. Management system of the water treatment plant

The management system of the water treatment plant is in general largely divided into two: the department in charge of the operation of facilities, and another one in charge of maintenance.

The operation department consists of operators responsible for the operation of water treatment facilities and technical staff in charge of planning of water control, and management of facilities in many cases. Since the water treatment plant is generally run continuously 24 hours, a shift work system is usually employed.

The maintenance department fittingly performs inspection and upkeep so that the plant can always exert functions in an optimum way, and, at the same time, carries out repair etc. of facilities and equipment as required.

The management of the water treatment plant consists of thorough safety control and hygienic management, provision and enhancement of operation manuals and inspection standards, measures against deterioration of raw water quality, plan for dealing with such emergency as an accident, a disaster etc., coaching and rearing of technical staff, measures for new issues etc.

3. Environmental measures in the water treatment plant

Environmental issues related to the water treatment plant and measures against them are as follows:

(1) Noise and vibration emitting from machinery

Measures shall be implemented after the noise and vibration are studied in detail through actual measurement. As measures against noise, there are application of sound absorber inside the building, double-paned windows, installation of shrouding at the boundary with the neighboring lot, and planting of leafy trees to be considered.

As measures for vibration, such vibro-isolating material as rubber or spring shall effectively be used in the base of machinery. Against vibration, which is transmitted through pipe etc., the use of expansion and contraction joints is effective.

(2) Odor and dust generated from sludge cake produced at the water treatment plant

Installation of a shelter, setting a shielding wall against noise and dust at the boundary with the neighbor, provision of a buffer zone and so forth shall be implemented.

(3) Noise, vibration and dust generated by construction work in the plant

Guidance to contractors shall strictly be given; heavy machinery with low noise and vibration shall be employed; and cleaning and sprinkling of water in and around the plant premises and so on shall be implemented.

(4) Cleaning of the plant premises and its surroundings

Efforts shall be made to beatify the plant premises and its surroundings by cleaning and weeding so that there are no fallen leaves and weeds. In summer, attention shall be paid to remove hairy caterpillars so as not to trouble residents living in the neighborhood and pedestrians.

(5) Damage to agricultural crops caused by lighting at night

At the water treatment plant surrounded by agricultural land, attention shall be paid on the direction and intensity of lighting so that the growth of vegetables and rice plants are not affected.

(6) Plan for tree planting in the water treatment plant

When planting trees, tree species, which would cause adverse effects to the crops, shall be avoided.

7.2. Receiving well

7.2.1. General

The receiving well is a facility to stabilize the fluctuating water level; measure the volume of raw water; and control the volume.

Besides, the receiving well is also used as the point at which coagulants, chlorine agents for water treatment, PAC, acid and alkaline agents at the time of abnormal raw water quality are dosed.

7.2.2. Receiving well

1. Water volume management

Since the raw water volume is the base for properly carrying out water volume management, chemical dosing control etc. in the water treatment processes, it shall accurately be measured and controlled.

To this end, the water level shall precisely be measured and controlled so that the difference between the receiving volume and the treatment volume does not abruptly become large.

In case water is received from many water sources, the raw water shall be measured for each source, and the respective proportions shall be grasped. Such operation is needed to properly carry out water volume management, chemical dosing etc. in case water quality is different from source to source; same concept applies to the case of receiving return water from filter backwash.

2. Water quality control

Since the receiving well is the point where raw water primarily arrives, raw water quality shall accurately be grasped so as to properly carry out water treatment. Therefore, water sampling shall be taken where no influence of chemical dosing etc. is.

Secondly, to quickly deal with the changes in raw water quality, it is important to convey the information on water quality at the intake point by means of frequent communication with the water treatment plant.

For preparing for pollution of raw water by poisons etc., water quality shall continuously be monitored by means of an aquarium using fish etc. In this case, although it is ideal to do such monitoring at the intake point, in case the raw water transmission is performed by an open channel, monitoring shall again be carried out at the receiving well.

3. Daily inspection

To maintain functions of level gauges, flow meters, water quality testing instruments, flow control valves, sampling pumps etc., they shall properly be inspected and kept up. Furthermore, to secure the retention time of the receiving well, the volume of deposited mud shall suitably be measured and it shall be cleaned. Especially, as in case normal treatment water volume is significantly smaller than the design volume, attention shall be paid since mud and shells are easily deposited.

Contents and cycle of daily inspection, periodic inspection and detailed inspection are shown in Table 7.2.1.

Table 7.2.1 Examples of points of inspection of equipment in receiving well

Facility	Daily inspection		Periodic inspection		Detailed inspection (upkeep)	
Receiving Well	Cycle	Inspection contents	Cycle	Inspection contents	Cycle	Inspection contents
	As needed	1.To confirm raw water volume	1 year	1.Status of function of valves	5 years	1.Disinfection of receiving well
	As needed	2.To confirm water level in receiving well	1 year	2.To check clacks and deterioration of concrete	3 to 5 years	2.Repainting of steel parts
	As needed	3.To confirm quality of raw water (turbidity, pH, alkalinity etc.)	1 year	3.To check leakage		
			1 year	4.To check condition of paint on steel parts		
				Inspection and upkeep of level gauge, flow meter, water quality testing instruments etc. Inspection and upkeep of flow control valves, sampling pumps etc.		

7.3. Dosing equipment for coagulation chemicals

7.3.1. General

In the rapid sand filtration method, even though the raw water turbidity is low, treatment shall inevitably be conducted properly with a coagulant to adequately remove colloids and other suspended matters including cryptosporidium.

In the mean time, even in the slow sand filtration method, as the filter is clogged when the raw water turbidity become higher than 30 turbidity units, treatment by coagulation and sedimentation is required.

Coagulation chemicals for water supply are largely divided into coagulants, pH control agents (acid and alkaline agents), and coagulant aids.

Coagulants are used to make suspended materials in raw water coagulated as flocs, which easily settle and readily trapped in the filter. Aluminum sulfate for water supply (another name: alum. Hereinafter, aluminum sulfate), polyaluminum chloride for water supply (another name: basic aluminum chloride for water supply. Hereinafter, polyaluminum chloride), iron family coagulants and polymer coagulants are available.

Acid agents are used when pH of raw water is too high, and there are concentrated sulfuric acid for water supply (Hereinafter, concentrated sulfuric acid), liquefied carbon dioxide (another name: liquefied carbonic acid gas. Hereinafter, carbonic acid gas), and hydrochloric acid.

Alkaline agents are used when alkalinity is insufficient, and sodium hydroxide for water supply (another name: caustic soda. Hereinafter, sodium hydroxide), calcium hydroxide for water supply (another name: slaked lime for water supply. Hereinafter, slaked lime), sodium carbonate for water supply (another name: soda ash for water supply) are in use.

Coagulant aids are used together with a coagulant to enhance the effect of flocculation, sedimentation and filtration, and there are activated silica, sodium alginate for water supply (Hereinafter, sodium alginate) etc,

Chemicals to be used shall be selected in consideration of not only fully confirming their treatment effects, and no negative influence to water quality by their dosing, but also their easy handling.

Since many of the chemicals are strongly acidic or alkaline, at the time of their receiving, storage, dissolution, dilution, mixing, conveyance etc. and inspection and upkeep of their respective steps of handling and equipment, caution suitable for respective chemicals and their characteristics is required.

As to handling of chemicals, safety and hygienic attention is especially needed.

Coagulant dosing equipment consists of instrumentation facility, dosing control apparatus, acceptance facility, storage facility etc., and shall properly be operated so as to be able to precisely follow the changes in raw water quality.

For dosing of coagulant chemicals, it is important to maintain the optimum dosing rate and quantity for the volume and quality of raw water, and it is essential for the instrumentation apparatus to be able to precisely measure them.

The dosing point for the coagulant shall be at a point right before rapid mix, and it is important to uniformly disperse the coagulant and adequately mix it. pH control agent (acid or alkaline agent) for maintaining pH at optimum range shall be dosed upstream of the dosing point for the coagulant, and the method of mixing is same as that for the coagulant.

7.3.2. Coagulants

Since the effects of a coagulant are different depending on raw water quality, water temperature etc., it is important for the effects of iron, manganese, algae, turbidity, water temperature or powdered activated carbon (PAC) to be examined at respective water treatment plants. To make the coagulant to fully exert its effects, it is important that the most suitable coagulant for the purpose of water treatment shall be chosen, and that pH control, adjustment of mixing condition shall be accurately be carried out. When dosing it, operation and maintenance shall be undertaken based on adequate understanding of its quality, characteristics etc.

1. Type

1) Aluminum sulfate

Aluminum sulfate is supplied in a liquid form or a solid form, and its use in the form of liquid constitutes in a large majority of cases. The solid form of aluminum sulfate is used in 5 to 10 percent solution.

Although, as coagulation characteristics, aluminum sulfate is effective for almost all turbidity matters, a coagulant aid is needed when water temperature is low since flocculation becomes inefficient.

Moreover, as the dosing rate increases at the time of high turbidity, the use of an alkaline agent may be needed.

Regarding its storage in solution, caution shall be paid as it may separate from the solution depending on concentration and liquid temperature.

2) Polyaluminum chloride

Polyaluminum chloride is the most stable in the status of 10 to 11 percent concentration as converted to aluminum oxide, so suitable for storage and dosing.

If diluted, its solution becomes turbid as a result of hydrolysis, which may cause adverse effects on piping etc. Besides, as it may change in quality depending on the period of storage, attention shall be paid. Likewise, since, if it is mixed with other chemical, white sediments are generated, which cause reduction in coagulation ability and clogging of piping, the common use of the piping with different chemicals shall be avoided.

3) Iron family coagulants

As the iron family coagulants, there are ferric chlorides etc. Although, as its characteristics and a merit, its pH range suitable for coagulation is wide, and its flocs easily settle, its acidity is strong and highly corrosive, so the materials to come into contact with it are limited. It is cautioned that if it is dosed excessively, iron will remain in water and water is colored.

Ferric chlorides separate from their solution when the liquid temperature is -10 to -15 degrees C.

4) Polymer coagulants

The concentration of residual acrylamide monomer is regulated to be less than 0.00005mg/L.

2. Dosing rate

Since the dosing rate of the coagulant differs depending on the condition of raw water quality, and the difference in sedimentation basins, filters etc., it shall be determined in adequate consideration of such conditions.

When determining the dosing rate, the basic operation is a jar test using the raw water to be treated, and the dosing rate shall synthetically be judged in consideration of the test result, the status of the actual facilities, and the trend of the change in raw water quality.

Although the jar test is to regularly be conducted, it shall quickly be performed at the time of rapid change in raw water quality so as to monitor the condition of flocculation and sedimentation and confirm if coagulation, sedimentation and filtration processes are appropriate.

[Reference 7.2] Jar test

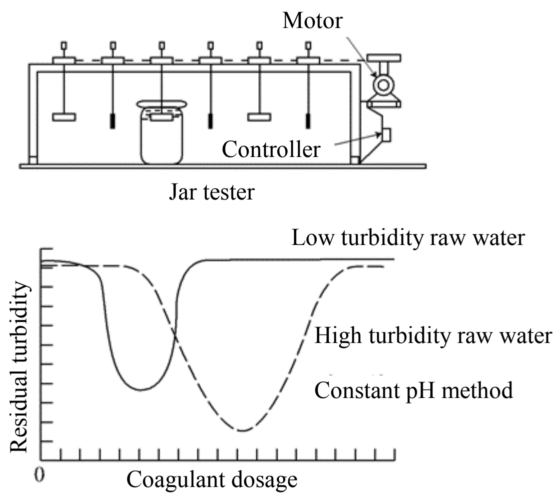
Jar tests are conducted using a jar tester. Filling respective beakers with 1 liter each of raw water, the peripheral speed of the rotator blade is set at 40 cm/s.

Then, coagulant is rapidly dosed in stepwise different dosages to the respective beakers; rapid mix is given for 1 min., and slow stirring is given at the peripheral speed at 15 cm/s for 10 min. After leaving the beakers at rest for 10 min., 500 mm liters of supernatant is quietly taken by a siphon or decanting (The peripheral speed, time for mixing and leaving at rest and the quantity of sample are tentative standards.). During these periods of time, formation of flocs and their settling shall be observed.

Turbidity, pH, alkalinity etc. of the sample shall be tested, the results of flocculation and settling shall synthetically be judged, and the optimum dosage is to be determined.

In case no good results of coagulation are obtained, tests shall be repeated by changing dosing rates of the coagulant, and furthermore using an acid or alkaline agent or a coagulant aid together with the coagulant.

The coagulant to be used for jar tests shall be prepared using the coagulant to be actually applied. If solution of 1 w/v % is made, adding 1 mm liter of the solution to 1 liter of raw water, the dosing rate of 10 mg/liter can conveniently be set. Moreover, diluted solution of polyaluminum chloride becomes clouded over time because of hydrolysis. In case such solution is used for a jar test, correct judgment of coagulation effect cannot be made.



Reference Figure 7.2.1 Jar test

(Norihito Tambo: New System Civil Engineering – 88 Water Supply, Gihodo Shuppan)

3. Factors affecting coagulation

As factors which affect coagulation, mixing, pH, alkalinity, water temperature etc. act in a complicated manner strongly affecting the dosing rate of the coagulant.

1) Mixing

There are rapid mix, which rapidly disperses a coagulant, makes colloidal particles bound together, and forms micro flocs; and slow mix, which makes micro flocs to collide each other, flocculate and grow larger.

In case the intensity of rapid mix is insufficient or its time is too short, flocculation will become insufficient as raw water, coagulant and alkaline agent do not mix uniformly.

Slow mix needs to be given at a magnitude of intensity not to break flocs.

2) pH

pH is an important factor for the process of coagulation. Therefore, in case pH of raw water is too high or too low, pH shall be adjusted by acid or alkaline agent so that it becomes in the optimum range.

3) Alkalinity

Alkalinity is an important factor which gives influence to the effect of coagulation. To form good flocs, it is desirable for alkalinity to be higher than 20 mg/L or so after dosing of coagulant.

In case alkalinity is low, as the buffer action is weak, dosing of an alkaline agent is needed to maintain proper alkalinity.

For instance, in case 20 mg/L or so of alkalinity is left after dosing of proper quantity of coagulant according to the turbidity of raw water, only the application of coagulant will suffice. However, an alkaline agent needs to be dosed at the times of high turbidity due to rainfall, and low alkalinity in a thaw season.

4) Water temperature

Water temperature is an important factor which influences coagulation reaction, growth of flocs, sedimentation and separation. Growth of flocs is brought forward when the temperature is high whereas it is retarded when it is low. Given this, in case the coagulation process is done by aluminum sulfate, as the formation of flocs becomes markedly bad if the water temperature is lower than ten degrees C., such a measure is needed as the application of a coagulant aid or conversion of the coagulant from aluminum sulfate to polyaluminum chloride and so forth.

4. Measures against changes in raw water

1) Measures at the time of high turbidity

When raw water turbidity is rapidly rising at the time of a typhoon or a heavy rain, there may be some cases in which the method to determine the proper coagulant dosage by jar tests cannot catch up with such a change. For that reason, it is desirable to conduct jar tests using river bed mud or clay in normal times, and examine the selection of coagulants, the needs for alkaline agents and the use of coagulant aids, and determine the range of the dosage of chemicals in advance.

2) Measures when algae grow

If a lot of algae are contained in raw water, filters clog in a short period of time in the case of the diatom; and algae may break through the filter in the case of the blue-green algae. In both cases, since inadequate coagulation is the cause, proper dosage rate (or slightly more than normal) of coagulant shall be selected, and adequate consideration shall be made for pH and alkalinity.

3) Measures against high color and organic matters

In case color by humic substances is high, high dose of coagulant or treatment on the acidic side using an acid agent raise the removal effect in many cases.

4) Measures against returned wastewater in the plant

Since the returned water from backwash water and wastewater treatment facilities influence the coagulation process, adequate consideration shall be made to the dose of coagulant etc.

5. Special coagulation process

1) Microfloc process (direct filtration)

In this method, in case raw water with stable low turbidity is treated, reducing the coagulant dosage at 50 to 60 percent of the normal dosage, and applying rapid mix for relatively short period of time, uniform small flocs with a diameter of scores µm or less are formed. These flocs are directly introduced on to filters and filtered without settling at the sedimentation basin.

2) Two-step coagulation process (post-coagulation process)

In this method, the coagulant is again dosed to water which has been coagulated and settled as usual. In case, due to trouble in the coagulation process because of plankton, algae break through the filter resulting in rise in filtrate turbidity, coagulant is again dosed to settled water and the water is filtered.

7.3.3. Acid agents

In case raw water pH becomes too high due to biological photosynthesis, and in another case alkalinity of raw water is high as a result of the reduction in the natural flow, flocculation become insufficient. Besides, in case an aluminum family coagulant is in use, it may liquate resulting in a rise in aluminum concentration in treated water. To remedy it, pH control shall be conducted so as to keep pH in the optimum range.

1. Types

1) Concentrated sulfuric acid

The concentration of concentrated sulfuric acid used as the acid agent is 93 percent or more in accordance with the standards of JWWA K 134-2005 Sulfuric Acid for Water Supply. Concerning its handling, as it violently reacts with water and generates heat, its dilution in the water treatment plant shall be avoided. Additionally, if it comes in contact with the human body, sulfuric acid takes moisture from the body and generate a lot of heat resulting in fierce chemical burn, it shall be handled paying adequate attention with its sufficient knowledge.

2) Carbon acid gas

Carbon acid gas is a colorless and odorless gas and weighs 1.5 times the air. Although it is incombustible, it gives adverse effect to a human body if its concentration in air becomes high. Thus such attention as ventilation shall be paid in its handling.

3) Hydrochloric acid

Hydrochloric acid is incombustible and colorless or light yellowish liquid, and possesses the nature to emit smoke in concentration of 25 percent or more and strong irritant odor. If it comes in contact with a human body, it causes inflammation in the skin and mucous membranes. Since its handling as the acid agent is difficult, examples of its use are extremely few.

2. Dosing rate

It is desirable for the acid agent to apply the value obtained in advance by an experiment on the raw water as the object of treatment. Since it reduces alkalinity depending on its type, its type to be used needs to be selected in accordance with the nature of raw water. The rate of reduction in alkalinity when dosing an acid agent at 1 mg/L is presented in Table 7.3.3.

Table 7.3.3 Reduction in alkalinity by dosing acid at 1 mg/L

Type		Reduced alkalinity (mg/L)
Sulfuric acid	(H_2SO_4 0.1%)	1.0
Hydrochloric acid	(HCl 0.1%)	0.58
Carbon acid gas	(Co_2 99.5%)	None

7.3.4. Alkaline agents

An alkaline agent is used to supplement alkalinity, which has become short as a result of insufficient alkalinity or dosing of a coagulant, so as to adjust pH and alkalinity in their optimum range.

1. Types

1) Sodium hydroxide

Although sodium hydroxide is received at the water treatment plant with the concentration of 45 percent for the convenience of handling, it needs to be diluted to 20 to 25 percent when it is stored because it separates from the solution if the liquid temperature becomes below 10 degrees C.

Since it rapidly generates heat when it is mixed with water at the time of dilution, water shall first be poured in the dilution tank and sodium hydroxide shall slowly be added. What is more, since it is a hazardous substance, and strongly corrosive, special care shall be taken for its handling, and goggles, rubber gloves etc. shall be worn.

2) Calcium hydroxide

As the method of dosing of calcium hydroxide, there are three types of dosing, i.e., in its powder, its slurry (concentration: 10 to 20 percent) and its solution. It is cautioned that dosing in powder becomes unstable in constant quantity feeding and uneven in dilution in water.

For slurry dosing, there is possibility of scaling in pumps and pipes, and for undiluted calcium hydroxide to deposit at the point of dosing. In the method to dose in solution, since the supernatant of perfect solution is used, the same handling of dosing as sodium hydroxide is possible. However, it is a demerit that the solution tank becomes big as its solubility in water is small.

3) Sodium carbonate

As the method of dosing of sodium carbonate, there are dosing in its powder, and its slurry. To use it after dissolving its powder in water, sufficient dissolution is needed, and scale and insoluble matter need to be removed.

2. Dosing rate

To obtain good performance of coagulation and sedimentation, alkalinity becomes an important factor.

Coagulants reduce alkalinity at the rate as shown in Table 7.3.5 depending on their type.

Table 7.3.5 Change in alkalinity when dosing 1 mg/L of chemicals for water treatment

Product name		Alkalinity	
	Conversion	Increase	Decrease
Aluminum sulfate	(As Al_2O_3: liquid 7%)	—	0.21
; $Al_2O_3(SO_4)_3 \cdot 18H_2O$	(As Al_2O_3: liquid 8%)	—	0.24
	(As Al_2O_3: solid 15%)	—	0.45
Polyaluminum chloride	(As Al_2O_3: liquid 8%)	—	0.15
Chlorine	—	—	1.41
Sodium hydroxide	45%	0.56	—
	20%	0.25	—
Calcium hydroxide ; $Ca(OH)_2$ (slaked lime)	(As CaO: 72%)	1.29	—
Sodium carbonate ; Na_2CO_3 (soda ash)	99%	0.93	—

The dosing rate of alkaline agent is computed by the following formula using the values in Table 7.3.5:

$$W = [(A_2 + K \times R) - A_1] \div F$$

W : Dosing rate of alkaline agent (mg/L)

A_1: Alkalinity in raw water (mg/L)

A_2: Alkalinity to be left in water after treatment (mg/L)

K : Value of coagulant used in Table 7.3.5

R : Dosing rate of coagulant (mg/L)

F : Value of alkaline agent used in Table 7.3.5

Furthermore, attention needs to be paid since alkalinity changes not only by the coagulant but also by pre-chlorination.

7.3.5. Coagulant aids

The coagulant aid is added together with the coagulant so as to form heavy and tough flocs and improve settling and separation ability and filterability of flocs in case sufficient treatment effect cannot be achieved only by the coagulant.

1. Types

1) Activated silica

Activated silica is produced neutralizing part of alkalinity of sodium silicate with an acid or salt, and then it is matured for some time for activation. Activation needs to be made each time it is used. Although coagulation effect is improved by the use of activated silica, attention needs to be paid as head loss in the filter becomes large.

2) Sodium alginate

Sodium alginate is a natural polymer, and its effects are to facilitate coagulation and flocculation, enhance settlability, and prevent breakthrough of turbidity in the filter.

2. Dosing rate

The effect of coagulant aid depends on the type of the coagulant, its dosing rate, raw water quality etc. When determining the dosing rate of coagulant aid and the timing of dosing, it is essential to conduct jar tests.

Activated silica is to be dosed as at the rate of 1 to 5 mg/L as SiO_2; and sodium alginate is to be applied at the rate range of 0.2 to 2 mg/L.

7.3.6. Receiving of chemicals

Since the purpose of the receiving equipment is quality control and store management of chemicals for water supply, proper confirmation of the quality and accurate measurement are needed.

① At the time of receiving chemicals, it shall be confirmed that their quantity and quality are in conformity with the contract; the date and time of receipt, names of chemicals, quantity received and quality are to be recorded and stored for the required time.

② Suppliers shall be requested to submit a quality analysis table of chemicals for each receipt.

③ It is desirable to test specific gravity, temperature etc. of liquid chemicals (aluminum sulfate, polyaluminum chloride, sodium hydroxide etc.) each time of their receipt; and confirm their concentration and the existence of foreign matters in them.

④ At their receipt, chemicals supplied in bags, boxes, cans etc. shall be checked by their numbers; liquid and powdered chemicals delivered in the tank-truck and truck shall be confirmed based on inspection by the liquid level of the receiving tank, quantity measured by an integrating flow meter, or the weight measured by a truck scale.

⑤ At the time of receipt of chemicals, workers engaged in receiving shall wear goggles, rubber gloves etc. to secure their safety. Additionally, a manual for securing the safety of work shall be prepared.

7.3.7. Storage of chemicals

1. Inventory control of chemicals

① In case receiving liquid chemicals at a storage tank from a tank-truck, attention shall be paid to setting of chocks, engagement and disengagement of connecting pipes and hoses, and a leak of liquid. In case a leak of liquid occurs, it is to temporarily be kept inside the retaining wall, and proper neutralization shall be carried out.

② As the level gauge in the storage tank is important for operation and inventory control, it shall be confirmed that the gauge is accurately working.

③ Since liquid aluminum sulfate separates if its concentration (converted to aluminum oxide) of higher than 9 percent or so even in the normal temperature, the concentration shall carefully be watched. Even the concentration is less than 9 percent, the store room shall be heated, or the storage tank shall be warmed.

④ Attention shall be paid when polyaluminum chloride is stored for longer than 6 months because of stability of its quality.

⑤ In case sodium hydroxide is purchased and stored in the concentration of 45 percent solution, it needs to be diluted to 20 to 25 percent or so since its crystal separates if the liquid temperature becomes lower than 5 to 10 degrees C. Since it reacts with water generating heat, water shall first be poured in the dilution tank, and sodium hydroxide is to slowly be added to the water, but not vice versa.

Moreover, as it deteriorates absorbing carbon dioxide in the air if it stored for a long time, it shall be kept air-tight as much as possible.

⑥ Since concentrated sulfuric acid facilitates corrosion of steel material etc. by absorbing moisture in the air, the storage tank shall be sealed with a ventilation pipe; desiccant is to be placed in the pipe; and its effect shall periodically be confirmed.

Besides, as for its storage, it is cautioned that concentrated sulfuric acid separates when the liquid temperature is low than 3 degrees C. in the case of 98 percent solution; and -15 degrees C in the case of 95 percent solution.

⑦ The liquid barrier wall shall periodically be inspected and kept up, and at the same time, the existence of leakage shall be examined filling inside of the wall with water.

⑧ As to coagulation chemicals, the control valve, the distribution notches etc. may be clogged due to solid matters deposited during storage impairing their function, the tank shall periodically be inspected and cleaned.

2. Inventory control of powdered chemicals

① Powder is piled in bags in the store in a case; and it is received in a silo in another case. Storage shall be made moisture-proof as much as possible because moisture is prohibitive depending on the type of chemicals.

Especially, as sodium carbonate becomes very hard insoluble lumps if absorbing moisture and unsuitable for use, adequate attention is needed.

② When receiving powder, a dust-collecting device shall be engaged so that it will not scatter to outside, and the function of the safety valve, the existence of "flush" Note 1) (gush), the occurrence of bridging Note 2) etc. shall be confirmed.

③ In case calcium carbonate is stored in a silo, as the powder may gush out from the gland gasket on the rotating shaft of peripheral equipment of the silo, the gasket shall, as needed, additionally be tightened or replaced. Deposit of residual matters in the tank or the feeder, status of clogging due to bridging and flush etc. shall be confirmed.

Note 1) Flush (gush) means a phenomenon that powder is suddenly fluidized, and spill over from the outlet or aperture of the feeding equipment (delivery gate, feeder etc.). Its main cause is the collapse of bridge, which brings about rapid fluidization of the powder. In addition, while the rotating table of the feeder is taking out the powder always shearing the layers of the powder, flushing may be triggered by the slip plane which is turned from the shearing plane. To prevent flush, such ideas are needed as the prevention of bridge, and making the aperture for serving narrow.

Note 2) Bridge denotes a phenomenon that, when taking powder from the silo, the powder does not fall uniformly, and a large volume of powder remains in the silo supported by an arch-like bridge formed at upper part of the silo. The main causes of its occurrence are the small particle size and high moisture contents of the powder and the slope of the wall of the silo as the smaller the slope, the more tendency of bridge. As its preventive measures, there are installation of stirring bars at the lower part of the hopper, blowing dry air into the silo, and employment of a vibrator.

3. Daily inspection

① As for the storage tank, the condition of its outside and ancillary piping shall be inspected; and efforts shall be made to confirm the existence of a leak of the liquid so as to prevent such an accident as insufficient dosing. Additionally, the status of the drain valve for waste liquid inside the liquid barrier wall to be closed shall be confirmed.

② The storage tank shall be emptied for the inspection of its inside every several years, and sediments at the bottom of the tank shall be removed.

③ As the tank is lined or coated, exfoliation of the lining and the existence of a leak of liquid by corrosion shall periodically be confirmed.

④ In case a ventilation pipe is installed on the tank, it shall periodically be inspected and kept up so that an accident of rupture of the tank would not occur by vacuum to be caused by clogging of the pipe.

⑤ When inspecting the inside of the tank, measures for prevention of a fall, and caution shall be paid to the status of lack of oxygen in the tank.

4. Storage quantity

Inventory of chemicals shall properly be controlled in consideration of their characteristics, dosing quantity, response to high turbidity, and means and status of transportation.

Secondly, the delivery system of chemicals on holidays shall be confirmed as needed.

7.3.8. Dosing of chemicals

1. Method of dosing

There are a dry dosing method and a wet dosing method. In the dry dosing method, powder or granular chemicals are directly dosed as they are. As powder has not good fluidity, adequate attention shall be paid to prevent bridge and flush at the outlet section of the hopper of the tank and feeder.

As the wet dosing method, there are the gravity flow type, in which chemicals are fed in solution or slurry, the dosing pump type and the injector type.

2. Machinery and piping materials

Since the feeding equipment comes in contact with highly corrosive chemicals, corrosion resistant materials for the machinery and piping shall be used.

Measures for heating and anti-UV for piping materials shall be made and flexible joints shall be fit for their earthquake resistance.

What is more, to prevent mix-up of dosing pipelines at the time of maintenance work, the names of chemicals shall be inscribed in different colors on the pipe; and spare pieces of pipe and other piping materials shall always be stocked as preparation for an accident of breakage etc.

3. Points to remember at the time of dosing

① As aluminum sulfate and polyaluminum chloride are mixed, sediments are produced causing clogging in the liquid transmission pipeline, interchangeable use of the dosing facility for both chemicals shall be avoided.

② Leak of liquid from the gland of the pump shall be carefully watched; and water for treatment of chemicals and wastewater after cleaning of dosing equipment shall properly be neutralized.

③ Concentration of the slurry of calcium carbonate and sodium carbonate shall properly be controlled so that dosing is safely performed. Additionally, cleaning of equipment and transmission pipelines shall adequately be undertaken in case they are shut down for a long time.

④ In case calcium carbonate is dosed in 0.16 percent saturated solution, if it is poured more than the prescribed quantity, the burden on the stirrer will become large resulting in the cause of failure.

⑤ Although calcium carbonate is easy to use when it is prepared as lime milk in 10 to 20 percent solution, it is cautioned that deterioration in quality is fast if used in low concentration.

7.4. Coagulation basin

7.4.1. General

The coagulation basin is an important process in the rapid sand filtration method. The coagulation basin consists of the two processes, i.e., rapid mix, which doses a coagulant in raw water, disperses it into water, makes it to contact with turbidity matters, and forms micro flocs; and slow mixing, which makes the micro flocs to congregate into large flocs. The former is called mixing, and the latter, flocculation; the coagulation basin is composed of the mixing tank (rapid mixer) and the flocculation basin.

In case raw water turbidity is low and stable, the method of direct filtration, in which water is led to the filter right after rapid mix without flocculation and sedimentation, is also effective (See 7.6.6 Direct filtration method (Micro-floc method)).

Unless coagulation is appropriate, as the function as the rapid sand filtration method cannot be exerted, it is important to manage the system well understanding the coagulation mechanism. As main points for management of the coagulation basin, it is important to secure optimum condition for flocculation, and attend to operation and management while accumulating data in normal times, and investigating optimum coagulation condition. Moreover, it is needed to always watch condition of flocculation (See Table 7.4.1).

Table 7.4.1 Example of main points for inspection of the coagulation basin

Facility	Daily inspection		Periodical inspection		Detailed inspection (upkeep)	
	Cycle	Contents of inspection	Cycle	Contents of inspection	Cycle	Contents of inspection
Mixing tank (Rapid mixer)	As needed	1.To confirm raw water flow	1 year	1.Cracks, deterioration of concrete, existence of leak	2 to 3 yeas	1.Cleaning of mixing tank
	As needed	2.To confirm raw water quality (turbidity, pH, alkalinity)	1 year	2.Operation status of respective types of valves		
	As needed	3.To confirm chemical dosing rate (jar test)				
	1 day	4.To confirm condition of mixing	Inspection and upkeep of mixers			
Floccu-lation basin	As needed	1.Status of growth of flocs	1 year	1. Operation status of respective types of valves	1 year	1.Cleaning of flocculation basin
	As needed	2.To confirm water quality (turbidity, pH, alkalinity etc. at outlet of flocculation basin,	1 year	2. Cracks, deterioration of concrete, existence of leak	3 to 5 years	2.Repainting of machinery
	As needed	3.Trash, scum etc.				
	1 day	4.To confirm status of mixing	Inspection and upkeep of mixers			

7.4.2. Mixing tank

The mixing tank is a facility to rapidly mix a coagulant with water after its dosing and uniformly disperse the coagulant into raw water. The standard mixing time is 1 to 5 min. as to the design water treatment volume.

Methods of mixing in the mixing tank are illustrated in Figure 7.4.1.

- Methods of mixing
  - Utilization of energy of water flow itself
    - Zigzag flow type (Up-and-down, horizontal)
    - Weir type
  - Mechanical type
    - Mixing blade, shuttlecock (Mixer) plate
    - Water jet by a pump (Diffusion pump)

Figure 7.4.1 Mixing methods in the mixing tank

In case mixing is made by the energy of water flow itself, flow velocity of 1.5 m/s or so shall be secured by means of installing buffer plates in the channel to generate turbulent flow. However, it is cautioned that the head loss becomes large in this case.

Head loss can be disregarded in the case of the mixer and the diffusion pump. The intensity of mixing can voluntarily be regulated by setting the number of devices, and their number of rotation. In the case of the typical rapid mixer, the peripheral speed of its turning impellors is more than 1.5 m/s.

1. Operation

Although there are the zigzag flow, weir, and mechanical types in the mixing types, either one of them is required to quickly mix after dosing of the chemical and exert coagulation effect at the maximum.

① In the case of mixing by the zigzag flow and weir types, as the intensity of mixing is determined by the flow of water treatment, the magnitude of mixing at the times of the maximum flow and the minimum flow shall be studied in advance, and measures in case the mixing intensity is insufficient shall be provided.

② In the case of mechanical mixing, since mixing intensity can be changed according to raw water quality, water treatment flow, type of dosed chemical, and dosing rate, the number of mixers to be operated shall be changed to suit the proper mixing intensity suitable to the raw water quality.

③ In case a polymer coagulant is used, such condition for optimum application as location of its dosing, condition of ensuing mixing etc. shall be confirmed.

Likewise, in case a polymer coagulant is used as a coagulation aid, it is desirable to dose it at the moment when micro flocs are formed by aluminum sulfate. Additionally, unless strong mixing is applied at the dosing point, it has been reported that there is possibility of retarded coagulation and so forth.

④ If the mixer and diffusion pump are shut down, it is noted that the diffusion of coagulant becomes uneven resulting in insufficient coagulation.

2. Measures in an abnormal case

① As preparation for shutdown of the mixer and diffusion pump due to instantaneous voltage drop etc., such measures shall be provided as an automatic recovery device to make early restart possible when power supply is resumed.

② To prepare for shutdown of part of mixers because of their failure, inspection and maintenance etc., the effect of the condition of mixing to the entire water treatment function shall be studied in advance.

7.4.3. Flocculation basin

The flocculation basin is a facility to congregate coagulated micro flocs into large flocs, which are easy to settle. Formation of good flocs makes solid-liquid separation easy in the sedimentation basin and the filter. Unless the growth of flocs is sufficient, the turbidity of settled water becomes high, and, as a result, filter runtime may be reduced or turbidity matters, which are not coagulated, may come out to filtered water. As the method of mixing in the flocculation basin, there are the zigzag flow type, for which the energy of water flow is utilized, (up-and-down type, horizontal type and their combination) and the mechanical type applying mechanical energy.

Head loss shall be taken into account for the zigzag flow type as the source of mixing energy. As such, the range this type can cope with the change in the treatment flow is limited. The standard average flow velocity in the channel is 15 to 30 cm/s.

Head loss of the mechanical type is small, and the intensity of mixing can be changed by controlling the engaged number of units and the speed of revolutions so that it can deal with the change in raw water quality. The standard peripheral speed of the mixer is 15 to 80 cm/s.

GT values are used as an indicator of mixing. The value GT, obtained by multiplying G value as the mixing energy input into a unit volume of water by T for the retention time in the flocculation basin, is the indicator, by which the magnitude of mixing is evaluated.

Although to form good flocs, the GT value needs to be maintained in a certain range, even if large enough energy (a large G value) is given, but the retention time is too short (small T), flocs will be broken as the shearing force caused by water flow becomes excessively large.

Given this, it is desirable to employ a tapered flocculation method, in which strong mixing is given while the flocs are small, and mixing intensity is gradually lowered as the flocs grow.

In other words, as moving towards the rear section of the basin, the width of the channel is widened to reduce the flow velocity in the case of zigzag flow; the speed of revolution is lowered to make the peripheral speed small in the case of the mechanical type.

The standard retention time needed for flocculation is 20 to 40 min.

1. Operation

As for the operation of the flocculation, careful attention shall be paid to mixing and stirring condition, average velocity, the status of growth of flocs, the condition of settling of flocs in the sedimentation basin etc.

① When the treatment flow and the dosing rate of chemicals are changed, the condition in the flocculation basin shall be confirmed. The size and density of flocs are to be judged by visual observation at site, or by a submersible video camera in the basin to be always monitored at the control room.

② As for the zigzag flow type flocculation basin, the intensity of mixing is unmistakably determined by the treatment flow, the change in the treatment flow shall be dealt with by changing the size of buffer walls and their number. In general, it is desirable for the basin to be operated within the prescribed range of the treatment flow.

In case more than two flocculation basins are installed, the change in the treatment flow can also be dealt with by changing the number of basins in commission.

③ A large amount of sludge piles in the basin at the time of high turbidity, and the effective retention time may markedly be reduced. Therefore, cleaning and desludging of the basin shall properly be undertaken at appropriate time so that flocs do not deposit for a long time.

④ The openings cut through the flow arrangement walls for the cleaning purpose shall be closed lest short-circuiting occurs.

⑤ When inspecting and keeping up the mixer, more than two persons shall be engaged as there is a risk of fall, being caught in the machine etc.

2. Measures in an abnormal case

In such an abnormal case as high turbidity and failure of equipment, careful attention shall be paid to confirm the status of equipment, the condition of floc formation etc., and a measure shall immediately be implemented when an anomaly is found.

① As turbidity rapidly rises and the water quality changes in short period of time at the time of a flood etc., the status of floc formation shall adequately be monitored.

② If the flocculators are restarted after a prolonged time due to breakdown etc. with sludge deposited in the basin, as paddles of the flocculators may be damaged, the condition of sludge deposition shall be confirmed and it shall be cleaned depending on the situation.

③ In preparation for shutdown of flocculators due to power failure, breakdown etc., it is desirable to confirm, in advance, the status of floc formation when they stop. Especially, as for breakdown due to instantaneous voltage drop, such a measure as the installation of an automatic recovery device etc. shall be prepared so that the facility can quickly be resumed when power is recovered.

7.5. Sedimentation basin

7.5.1. General

The sedimentation basin is a facility to separate and remove major part of flocs which have grown through dosing of a coagulant, mixing and flocculation by gravity settling.

There are various types of sedimentation basin and classified as shown in Figure 7.5.1.

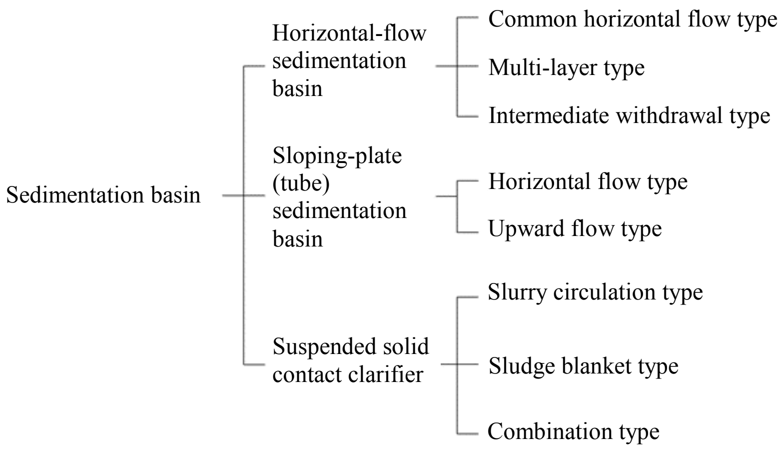


Figure 7.5.1 Sedimentation basin

When managing the sedimentation basin, attention shall be paid to changes in raw water quality, chemical dosage rate, operating status of equipment etc.; water quality after settling shall especially be watched; and setting a goal for the sedimentation process, when abnormal values are detected, their causes shall be investigated to carry out proper measure.

For its operation and management, a daily report shall be made to record raw water quality, treatment flow, findings in jar tests, condition of chemical dosing, settled water quality etc. Main points for inspection of sedimentation basin are presented in Table 7.5.1.

Table 7.5.1 Examples of points of inspection of the sedimentation basin

Facility		Daily inspection		Periodical inspection		Detailed inspection (Upkeep)	
		Cycle	Contents	Cycle	Contents	Cycle	Contents
Sloping-plate (tube) sedimentation basin	Horizontal flow sedimentation basin	As needed	1.Average flow velocity	1 to 3 months	1.Status of sludge deposition	1 mon. to 1 year	1.Cleaning of sedimentation basin
		As needed	2.To monitor regime of flow, settling of flocs	1 year	2.Status of accretion on wall		
		As needed	3.To confirm settled water quality (turbidity, pH, alkalinity etc.)	1 year	3.Cracks, deterioration of concrete, leak of water		
		As needed	4.Resurfacing of settled sludge	1 year	4.Level gauge, water quality testing equipment		
		As needed	5.Existence of trash etc.				
		1 day	6.Conditiion of adhesion of algae on settling device	6 months. to 1 year	5.Breakage, curving, fall of settling device	1 mon. to 1 year	2.Cleaning of settling device
		1 day	7.Understanding of quantity of sediment	1 year	6.Condition of paint on collecting troughs (steel)	2 months.	3.Cleaning of collecting troughs
				1 year	7.Operating condition of valves	3 to 5 years	4.Repaint of collecting troughs (steel)
			Inspection and upkeep of sludge scrapers Inspection and upkeep of motorized valves				

7.5.2. Horizontal-flow sedimentation basin

1. Operation

In the horizontal-flow sedimentation basin, the flow shall be uniform to make it to exert the effect of gravity settling.

Although, since the horizontal-flow sedimentation basin in general possesses long retention time; its buffer capacity is high against change in load; its structure and mechanism are relatively simple; except for sludge scrapers, there are few mechanical components, its operation and management are easy, attention shall be paid to the following points:

① When operating the sedimentation basin, status of settling of flocs, existence of resurfacing of settled sludge etc. shall be confirmed; its result shall be reflected for flocculation and dosing of chemicals; efforts shall be made to obtain good settled water.

② It is noted that while the flow velocity in the basin shall not exceed the design maximum velocity, efforts shall be made to make the basin to exert high sedimentation effect.

③ Although the settling condition of flocs can be visually observed in the horizontal-flow sedimentation basin, it can only be observed in the upper layer of a multi-layer sedimentation basin. Therefore, the turbidity of settled water needs to adequately be monitored.

④ In case algae grow in the basin, and there is a possibility for it to adversely affect the following processes, the algae shall be removed. Although there is a method to remove them by a chemical (chlorine agent etc.), the basin shall be emptied and cleaned in case the amount of algae is large.

⑤ In case the sedimentation basin is shut down for a long time, the basin is, as a general rule, to be cleaned before use.

⑥ Since there is a possibility of a density flow to occur in case raw water is received from more than two sources, or depending on the difference in water temperature and turbidity, caution is needed.

⑦ In case the sludge scrapers are operated, the speed of its blades shall be less than 12 m/hr (36 m/hr in case the settling velocity of flocs is large at the time of high turbidity) so that they do not fling up flocs or hinder their settling.

⑧ In the case of a sedimentation basin in which no sludge scrapers are installed, sludge shall be removed by a jet of water depending on the condition of sludge pile.

2. Daily inspection

The respective facilities for inlet, outlet, overflow etc. of the sedimentation basin shall always be inspected and maintained so that operation is soundly undertaken.

① It is desirable for the sedimentation basin to be emptied every year or so in order that cleaning of the inside, repair and upkeep of ancillary facilities which cannot be implemented at normal times. Especially, since all the sludge scraping section of the link-belt type is submerged, such their daily upkeep and management as monitoring and inspection are not easy, so their failure may be overlooked. As such they shall be inspected and maintained with considerable care.

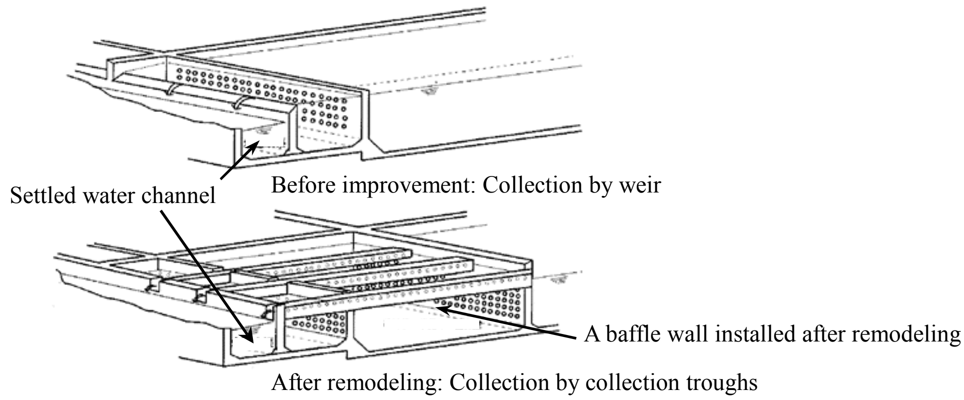
② When a leak from the sedimentation basin is found, it shall quickly be repaired investigating its cause. Besides, at the time when the sludge scrapers are inspected and so forth, a study of a leak from the inlet and outlet valves is to be conducted, and, if a leak is found, it shall immediately be repaired.

③ Inspection and upkeep of desludging valves and sludge scrapers shall periodically be undertaken so that their function can be exerted all the time. In case they happen to fail at the worst, its cause shall immediately be investigated, and it shall be repaired.

④ In the case of a simple rectangular basin, efficient condition cannot be obtained at times due to short-circuiting and a density flow. In such a case, such an idea as installation of guiding walls and improvement of the collection device is needed to raise the settling effect.

[Reference 7.4] Examples of improvement in the structure of the outlet section

As fling-up of flocs was seen, the weir loading rate was improved by improving the collecting device (See Reference Figure 7.4.1.).



Reference Figure 7.4.1 Example of improvement in the collection device

3. Measures in an abnormal case

At the times of high turbidity and abnormal quality of raw water, as the change in dosing of chemicals becomes frequent, condition of flocculation, settling status of flocs, quality of settled water etc. shall be inspected patrolling from the mixing tank through the sedimentation basin, so that treatment suitable to the raw water quality is to be carried out.

Unless the treatment goal has been fulfilled, an appropriate measure shall be undertaken studying the treatment flow, chemical dosing equipment, and the method of the operation of the flocculation basin.

7.5.3. Sloping-plate (tube) sedimentation basin

In the sloping-plate (tube) sedimentation basin, settling efficiency is raised utilizing the function of sloping-plates (tubes), which increase settling surface, flow rectifying effect etc. Although there are some differences between shapes, main components of all of the settling devices are made of hard PVC etc., and as the sloping-plates (tubes) have small strength as a single body, attention needs to be paid to these points for their maintenance.

Although the sloping-plates (tubes) are used for both horizontal flow type and upward flow type, they are used in several stories for the horizontal flow type, and only one layer for the upward flow type.

Since the sloping-plate (tube) sedimentation basin in general has short retention time, the quality of settled water is largely affected if short-circuiting or density flow occurs.

1. Operation

When operating the sloping-plate (tube) sedimentation basin, the following points shall be taken into consideration:

① If the average flow velocity becomes too large, settling effect diminishes since sludge, which slides down inside the sloping-plates (tubes), is flung up, so efforts shall be made to operate it at less the design maximum treatment flow.

② In the upward flow type sloping-plate (tube) sedimentation basin, when the raw water temperature rapidly increases, short-circuiting flow occurs due to the difference in density between staying water in the basin and incoming water resulting in carry-over and a rise in turbidity of settled water. There is an example of a measure in that buffer plates are set in parallel to the troughs from the sloping plates (tubes) up to the upper rim of the troughs to prevent density flow and a return current in the basin so that carry-over is inhibited.

③ Since, if algae stick on the sloping plates (tubes), settling effect is restrained, growth of algae shall be controlled by intermittent application of chlorine. In some cases, as adhesion of algae on the sloping plates (tubes) and the troughs is seen even by dosing of chlorine, in some utilities, the basin is cleaned twice a month in summer (July to October), and every month in other seasons.

④ In sloping-plate (tube) sedimentation basin, in some cases, sloping-plates (tubes) cannot be set in all the cross section or without opening from the basin wall because of restriction with the mounting brackets. For that reason, part of upward flow water rises bypassing the plates (tubes) resulting in lowered settling effect. Therefore, such opening shall be covered as required. The upward flow speed shall be set at less than 80 mm/min. when the treatment flow is changed.

⑤ If sludge excessively piles up and covers the lower part of sloping-plates (tubes), it not only hinders settling effect but will damage the sloping-plates (tubes). Therefore, adequate attention shall be paid to sludge piling and desludging, especially, at the time of high turbidity.

⑥ As to the upward flow type sloping-plate (tube) sedimentation basin, since the reciprocal travel distance of the sludge scraper is shorter than that for the horizontal sedimentation basin, the number of turning increases in case the travel speed is the same. Therefore, as the number of bending of the wire on the pulley, the life of the wire becomes short. To remedy this problem, there is an example of the effect of improvement in that its intermittent operation is implemented, and the construction of the rope shall be of a special specification, which prevents the extrusion of the core wire, and that the material of the pulley is changed to plastics.

2. Management of sloping-plats (tubes)

As the material of the sloping-plates (tubes) is not necessarily strong, their management needs to be conducted carefully.

① If such floating matters as sediments or PVC film stick to the sloping-plats (tubes), settling of flocs is hindered. However, since it is difficult to inspect the inside of the sloping-plats (tubes), monitoring and removal of floating matters shall be implemented in the receiving well, and accretions on the sloping-plats (tubes) shall also be removed by cleaning etc.

② In case the sedimentation basin is dewatered for cleaning, inspection and upkeep, if the water level is rapidly lowered, the sloping-plats (tubes) may fall because of weight of sludge deposited on the plates (tubes). Therefore. Water level shall gradually be lowered while washing the sludge down, or watching the condition of the plates (tubes). In case washing is performed with a spray-nozzle, a shower nozzle shall be used so as not to break the plates (tubes).

③ In case there is a risk of freezing in winter, such measure as setting a cover to retain warmth is needed; against deterioration by sunlight, it is effective to submerge the sloping-plats (tubes) 100 to 150 mm underneath water surface. This method is also effective as measure against debris and fallen leaves.

3. Daily inspection

Daily inspection of respective facilities for inlet, outlet, overflow etc., drain valves, sludge scrapers and so forth shall be carried out in accordance with 7.5.2 Horizontal Flow Sedimentation Basin.

The condition of adhesion of algae, piling situation of sediments, sticking of trash, fallen leaves etc. to the sloping-plats (tubes) shall be inspected as needed.

4. Measures in an abnormal case

In case treated water turbidity rises in spite of stable raw water quality, study shall be conducted whether or not a short-circuiting flow has occurred due to disengagement or damage of supporting frames of the sloping-plats (tubes).

In case the supporting materials of the sloping-plats (tubes) are damaged due to corrosion etc., they shall quickly be repaired for preparation for an unexpected event

7.5.4. Suspended solid contact clarifier

The suspended solid contact clarifier has functions of making efficient the processes of rapid mix, flocculation, separation and settling in one body in those micro flocs are made contacted with the existing flocs to largely shorten time required for the growth of flocs. From its principle or structure, it can be classified into the slurry circulation type, the sludge blanket type and their combination type,

1. Operation

Since the suspended solid contact clarifier has a large amount of flocs in its body, there are a number of points of attention for its operation and management as carry-over of flocs due to a sudden change in the treatment flow; deterioration in settled water quality due to decline in the function of trapping micro flocs and so forth. Given this, its operation and maintenance shall be carried out with adequate understanding of its structure and functions.

The standard overflow rate shall be 40 to 60 mm/min. Besides, in case there is diurnal variation in raw water quality, there is possibility of carry-over. Thus, monitoring of settled water quality shall be enforced.

7.5.5. Others (Floatation) (Annotation omitted)

7.6. Rapid sand filtration

7.6.1. General

In the rapid sand filtration method, turbidity matters in raw water are first coagulated by a chemical; then water is put through the filter layer in relatively fast seed; and turbidity matters are removed by the functions of adhesion on filter media and sieving by the filter layer.

When the incoming water on to a filter passes through interstices between filter media grains, micro flocs stick on the surface of the media. While the surface of the media is covered by flocs, the following micro flocs further stick on the foregoing flocks to be coagulated resulting in increase in deposit of flocs in the filter layer. As the thickness of the flocs on the surface of the filter media increases, the interstices gradually become small; the flow velocity through the interstices becomes greater; and it reaches the critical deposit, beyond which no more sticking is possible. In the case of flocs which possess strong binding force, as the thickness of accretion can be increased up to a large interstice velocity, a large deposit can be obtained. However, in the case of such flocs with high coagulant quantity per unit mass of turbidity (AL/T ratio) as flocs of organic matters and colored water, although the size of flocs is large, their strength is small; hence, they tend to break up and leak even when deposit does not fully progress. Since the rapid sand filtration method takes place in this manner, almost no effect can be expected from filtration of uncoagulated (with no flocs) water.

It is needed for objective turbidity matters to be made flocs, which are easily to stick or to be sieved, by coagulation function in advance. Even if raw water turbidity is low, since sufficient removal of colloids and suspended matters including cryptosporidium cannot be expected only by passing through the rapid sand filter, coagulation treatment with a coagulant shall be carried out.

Furthermore, since removal of dissolved matters cannot basically be expected, manganese can be removed using manganese sand under the presence of residual chlorine, the method to apply pre-chlorination prior to the rapid sand filtration treatment is widely in practice (See 7.15 Iron and manganese removal facilities.).

As the rapid sand filter, there are gravity open type filter, multi-media filter, pressurized filter and self-balanced type filter.

The rapid sand filter in commission shall synthetically be reviewed from the following points of view, and improvement of the method of operation, preparation and revision of a forthcoming facility improvement plan shall be implemented as required.

(1) Functions

① If the design flow can be secured while meeting the objective water quality.

② If cleaning of filter sand is properly performed.

(2) Facilities

① The condition of the filter layer

② The condition of the filter body (a leak, uneven sinking etc.)

③ The condition of the ancillary equipment (electric, mechanical and instrumentation)

Traditionally, pre-chlorination has widely been in practice to treat organisms and manganese. From 1980s, intermediate chlorination is also used in consideration of reducing disinfection byproducts.

The operation of the rapid sand filter is often remotely controlled. It always needs to monitor whether or not the operation is practically carried out properly by the observation of filtered water turbidity and the progress in the head loss; and visual inspection of the site and study of filter sand shall periodically be implemented.

7.6.2. Gravity open type filter

The gravity open type filter means a filter, which possesses free water surface in the filter basin, and is in a style to perform filtration by gravity.

1. Operation

1) Control of filtration flow

As the control method of filtration flow, there are the constant velocity filtration and the constant pressure filtration; and the declining rate filtration is the typical constant pressure filtration.

In the declining rate filtration, as filtration is carried out in constant pressure, the filtration rate gradually diminishes as the resistance in the filter layer builds up. As such, the change in filtration flow shall be watched where the number of filters is small, and such efforts need to be made for securement of filtration flow as to equalization of the allocation of filter backwash etc.

In the constant velocity filtration with a filter layer of single sand medium, the standard filtration rate shall be 120 to 150 m/day. In case coagulation and sedimentation treatment is especially good, filtration rate exceeding the standard is possible. Nonetheless, monitoring of treated water quality and management of filter layer need to strictly be performed.

2) Head loss

In a filter, of which structure has water level of the outlet side situated lower than the surface of the filter layer, as filtration is continued, and deposit of turbidity matters in the filter layer advances, the pressure of a section of the layer near its surface, where clogging is intense, locally becomes lower than the atmospheric pressure at times. If filtration is continued in such localized negative pressure, dissolved air in water separates making bubbles in the filter layer, water flow and air flow coexist between filter medium grains (air entrainment); the passing area of water flow diminishes, and head loss may increases or turbidity may break through.

To prevent such filtration deficiency caused by negative pressure, prerequisite water depth at each filter shall always be maintained. This water depth above the surface of the filter layer is set at 1 to 1.5 m in many cases.

3) Filtration rate

As rapid change in the filtration rate may dislodge flocs trapped in the filter layer resulting in deterioration in filtered water quality, it shall be avoided.

Likewise, since turbidity may leak due to rapid rise in the filtration rate at start of filtration, filtered water drain, in which filtered water is wasted for certain period of time after restart of filtration, or a slow start method, in which the filtration rate is gradually increased, is effective.

The magnitude of influence to filtered water quality of rapid change in the filtration rate depends on the type of the filter, the composition of the filter layer. Thus, it is desirable to decide the standard for changing the filtration rate with sufficient safety factor based on study on respective water treatment plants.

4) Record of operation

For the operation of the filter, a daily report shall be made to record amount of filtered water, head loss, filtered water turbidity, filter runtime, condition of filter cleaning etc.

2. Operation (Cleaning)

1) Purpose of cleaning

Although the process of filter cleaning is as shown in Figure 7.6.1, cleaning of the filter bed is carried out when it reaches either following condition:

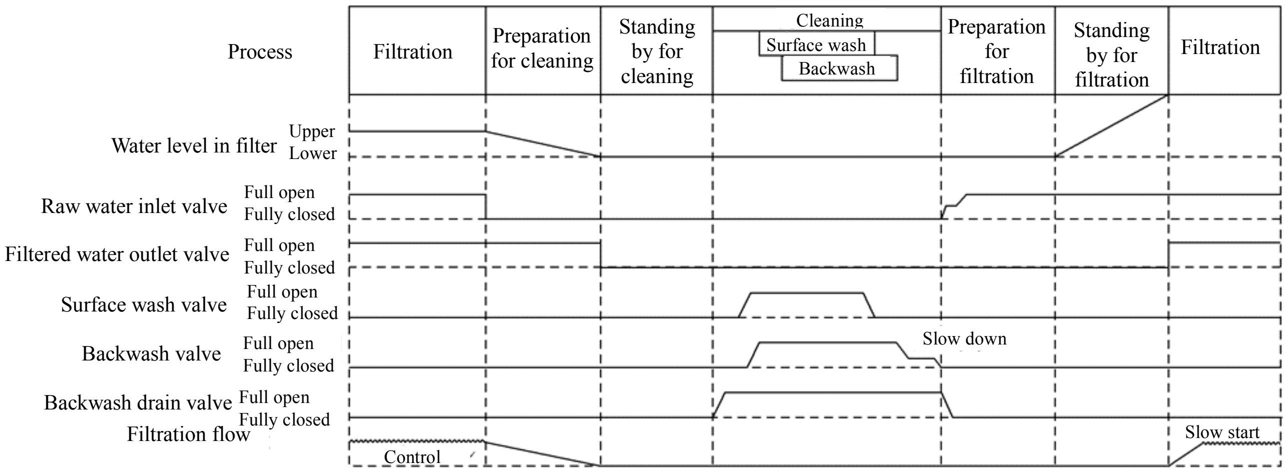


Figure 7.6.1 Example of process of filter cleaning

(1) In case turbidity matters exceeding the target value leaks.

(2) In case the head loss reaches the prescribed value.

If filtration is continued until head loss becomes excessive, air bubbles are generated, and shrinkage and cracking of the filter bed bring about a risk of deterioration in filtered water quality. Therefore, setting benchmark head loss, within which the filtered water quality can be maintained, cleaning shall be carried out when the head loss reaches the benchmark value.

(3) In case the filter runtime reaches the preset value.

Setting certain filter runtime (usually 24 hr to 1 week or so), within which the filtered water quality meets the target value, cleaning is carried out when the runtime reaches this value. If it is prescribed that the filter is cleaned when the runtime reaches the value, cleaning of filters can systematically be implemented, which is also useful for demand management of contracted power supply.

(4) In case operation is resumed after stop of the filter for a long time

In case operation of the filter is resumed after a long period of shutdown, algae and microorganisms grow in the filter layer, and they may cause their leak through the filter and trouble in filtration. Thus the filter shall be cleaned at the time of both its shutdown and resumption, and it shall periodically be cleaned even during shutdown.

2) Cleaning method

Cleaning is performed by the combination of backwash and surface wash or air wash. Only by backwash, cleaning will be insufficient, and mud balls will easily be formed.

The mud ball is a ball which is formed by agglomeration of balls of mud with a core of sand, and tends to develop in the corners of the filter or in the interface of two layers of a multi-media filter where the effect of surface wash becomes insufficient.

In case the density of mud balls is larger than that of filter media, while backwash, which expands the filter layer, is repeated, mud balls sink toward lower section of the layer, become large plate-like cakes, and they cause occurrence of undulation of the supporting gravel layer as short-circuiting currents are generated in backwash flow.

In air wash, it is important for air to uniformly be distributed all over the filter. In case surface wash or air wash and backwash are used together, since there is possibility for the filter media to spill out, caution shall be practiced at the time of cleaning.

3) Washing water

For cleaning, water with residual chlorine shall as a general rule be used so that growth of algae and microorganisms in the filter layer does not pollute it and does not cause troubles in filtration.

It is important for quantity, pressure and time of cleaning water to be so set as to exert sufficient cleaning effect.

If either one of them is too small, cleaning effect becomes insufficient, and, if too large, uneconomical. As the effect of cleaning depends on water temperature, the grain size and depth of filter media, and the time of cleaning, periodic studies on the effect of cleaning need to be conducted.

The appropriate expansion rate of the filter layer during backwash is 20 to 30 percent. However, since the expansion rate largely changes, especially, depending on water temperature, it is important for the water treatment plant, where water temperature widely varies, to change the backwash rate several times or so a year so as to obtain the same expansion rate.

4) Effect of cleaning

In day-to-day operation, the effect of cleaning shall be judged by the quality of wash waste water. Although the target terminal turbidity of wash waste water shall be less than 2 turbidity units, it is desirable to set it at less than 1 turbidity unit if possible from the view point of a measure against cryptosporidium. The final judgment of cleaning effect shall be conducted in that the quantity of turbidity matters in the filter layer collected right both before and after cleaning are measured, and the magnitude of stain is compared for judgment.

5) Abatement of rise in initial turbidity at resumption of filtration

When filtration is resumed after cleaning, the turbidity matters, which remain in water between filter media come out in filtered water. On the other hand, as a measure against cryptosporidium, it is prescribed to maintain the turbidity of water at the effluent of the filter at less than 0.1 turbidity units.

Given this, the slowdown method to lessen cleaning water step by step shall be carried out so that the turbidity after restart of filtration is maintained at less than 0.1 turbidity units.

6) Hindrance in filtration

If the method of cleaning is inappropriate, such troubles as the following will be brought about in the long run:

① Occurrence of mud balls

② Occurrence of cracks on the filter layer surface

③ Occurrence of opening between the filter layer and the filter basin wall (a sort of a crack)

④ Augmentation in the effective diameter of filter media

⑤ Reduction in the thickness of the filter layer

⑥ Occurrence of undulation in the interface between the gravel layer and the filter media (formation of wave-like surface)

Of the above, ① to ③ occur due to insufficient cleaning effect; ④ and ⑤ occur because fine filter materials spill out during cleaning. As to ⑥, when the filter layer is dirty, vertical revolving currents occur; and the gravel layer moves by horizontal flow at the surface of the gravel layer causing undulation in the gravel layer at times.

Secondly, when there is a big unbalance in the distribution of backwash rate, and also when air is mixed in backwash water, undulation of the gravel layer may occur.

Furthermore, even if the method of cleaning is appropriate, when such algae as Synedra largely flourish and are contained in a large amount in the incoming water to the filter, filter clogging may occur.

7) Measures against spill of filter media

① To maintain proper expansion rate during cleaning

② Appropriate adjustment of the angle of jet nozzles of surface wash, and the prevention of splash of filter media into the troughs by the water jet.

③ Prevention of splash of filter media into the troughs by means of placing the jet nozzles of surface wash so that they are submerged in the expanded filter media during backwash.

④ Prevention of splash of filter media into the troughs by avoiding mixing of air into backwash water.

⑤ Prevention of leak of filter media down to the collection chamber by means of inspection of the underdrain system.

3. Management of the filter layer

If the filter layer is left over in inappropriate condition, the filtered water quality is affected; the pollution of the filter layer will be accelerated; and a need will arise to complete replacement of the filter media. Therefore, it is needed to periodically investigate the filter layer; and immediately apply such proper remedy as the improvement in the cleaning method, replenishment of sand etc. in case anomalies are found.

What is more, it is essential to predict the long-term trend in the condition of the filter layer based on a study; establish a long-term plan for the improvement of the filter layer based on the above; and periodically implement its improvement.

1) Study on the filter layer (including the supporting gravel layer)

Although the study on the grain size distribution of filter layer, condition of contamination of filter media and supporting gravel, situation of undulation of the gravel layer etc. shall as a general rule be conducted for all the filters, in case the number of filters is large, the study shall be carried out on every representative ones, which are selected for their similarity in the history of their filter layer. There is also another method in that secular changes of the condition of filter layers are studied, and the relationship between other filters and the representative ones can be grasped by means of proper study items, frequency of study etc.

The frequency of the study is desirable to be set once in 1 to 3 years.

2) Record of filter layer management

As to the study on the filter layer, management record shall be made to grasp its secular changes and facilitate its improvement.

3) Improvement of the filer layer (including the supporting gravel layer and the underdrain system)

Improvement of the filer layer consists of the following:

① Replacement of the filter layer

② To take filter media out of the filter, wash it and return it to the filter.

③ As for replenishment of filter sand (The filter media are resupplied as much as the lost thickness of the layer.), its grain size distribution shall be made as the same condition as at the time of design.

④ The combination of ② and ③.

The gravel shall be taken out and washed when implementing ① or ②, and replenished as required. In this occasion, to prevent undulation of the gravel layer, a net for prevention of undulation made of stainless steel is set on the surface of the gravel layer in some cases.

The underdrain system shall also carefully be inspected when the gravel is taken out, and shall be repaired and improved depending on the condition.

An example of standards for the improvement of the filter layer is presented in Reference 7.7.

When using the filter, for which the filter layer has been improved, the filter layer shall repeatedly be cleaned until the wash waste water turbidity becomes less than 2 turbidity units in normal cases.

In such an occasion, since the head loss reaches the prescribed value in short period of time after restart of filtration due to fine filter grains collected on the filter layer in some cases, there is a method in that the filter media shall be filled in some surplus, and several cm of surface layer shall carefully be skimmed and removed after a study on the grain size distribution followed by a series of cleaning.

[Reference 7.7] An example of standards for the improvement of the filter layer and the gravel layer

The example of standards for the improvement of Osaka City

1. Standards for the improvement of the filter layer

Filter sand used for replacement of all the filter layer shall be of the effective diameter of 0.55 mm ±3% and the uniformity coefficient of smaller than 1.5. In addition, in case either one of the following conditions are met, improvement (replenishment and replacement of sand etc.) shall quickly be implemented:

① In case the effective grain diameter of sand become larger than 0.7 mm, replacement by new sand shall be carried out.

② During cleaning, if the filter layer is reduced to such extent as the surface wash nozzles are hardly submerged in the expanded filter layer, filter sand shall be replenished (For example, in case the depth of filter layer is 70 cm, expansion rate is 20 % and the position of the nozzles is 10 cm above, sand is to be replenished when the reduction in the depth reach 5 cm.)

2. Standards for the improvement of the gravel layer

In case either one of the following conditions is met, improvement shall be carried out:

① In case the accretion on the surface of gravels exceeds the target value.

② In case undulation exceeds 1/3 of the thickness of the gravel layer.

Other examples of improvement of filter layer are as follows:

・Sapporo City: Every 10 to 15 years
・Yokohama City: Every 10 years

A long-term filter layer improvement plan is prepared based on the study on the filter layer and the standards for the improvement of the filter layer.

4. Daily inspection

Examples of points for inspection of the filter are shown in Table 7.6.2.

If there is water leak, as there is a risk of contamination by groundwater etc. from outside, existence of water leak, condition of the body of the filter and water-proof coating on it shall especially carefully be inspected at the time of replacement of the filter layer.

5. Measures in an abnormal case

Abnormal events during operation of the filter, their causes and measures against them are presented in Table 7.6.3.

Table 7.6.2 Examples of points of inspection of the filter

Facility	Daily inspection		Periodic inspection		Detailed inspection (upkeep)	
	Cycle	Inspection contents	Cycle	Inspection contents	Cycle	Inspection contents
Gravity open type filter (Single sand layer and multi-media filter)	As needed	1.To confirm water level in the filter	2 to 6 months.	1.Inspection, cleaning of accretion on walls, troughs, wash waste water gutter	Situation as expanded filter layer does not reach surface wash nozzles	1.Replenishment of filter sand (in the case of the filter with only sand)
	Daily	2.To confirm filtration flow, filtration rate, head loss, filter run time)	2 to 3 years	2.If there are cracks, impairment and leak from water-proof layer	20 – 50% reduction in filter layer thickness	2.Refilling of anthracite (in the case of multi-media filter)
	Daily	3.To confirm filtered water quality (turbidity, pH, alkalinity, residual chlorine etc.)	1 to 3 years	3.Study on filter layer (contamination of filter media, occurrence of mud balls, effective diameter, uniformity coefficient, filter layer thickness etc.)	10 to 15 years or effective diameter > 0.7 mm	3.Replacement of filter media
		4.Inspection and upkeep of air source facility	1 to 3 years	4.If there is move of gravel layer	1 year	4.Upkeep of control devices, lagging on pipes
			1 year	5.Working condition of filtration rate controller, head loss indicator etc.		5. Inspection and upkeep of air source facility
			10 – 15 years	6.Condition of underdrain system		
				7.Inspection and upkeep of level gauges and flow meters		
				8. Inspection and upkeep of air source facility		
	As needed	5.To confirm wash water volume and cleaning time	2 to 6 months.	9.If there is damage of surface wash device (Especially, to confirm number of rotation of revolving type surface wash pipes)	3 to 5 years	6.Repainting of surface wash device
	3 to 4 days	6.Inspection of cleaning condition (expansion rate of filter layer, drainage of filter media, air trouble, cave-in on filter layer surface after cleaning)	2 to 3 years	10.Condition of painting on inside of elevated tank	5 to 8 years	7.Repainting of inside and outside of elevated tank
	As needed	7.To confirm turbidity of wash waste water		11. Inspection and upkeep of surface wash pump and vacuum pump		8. Inspection and upkeep of revolving type surface wash device
		8. Inspection and upkeep of vacuum pump				9. Inspection and upkeep of cleaning pump and vacuum pump
	When in operation	9.To confirm electric current values, oil level, vibration, water leak and oil leak of motorized valves		12. Inspection and upkeep of motorized valves		10. Inspection and upkeep of motorized valves
				13. Inspection and upkeep of air wash facility		11.Inspection and upkeep of air-wash device

Table 7.6.3 Measures in abnormal cases in rapid sand filters

Abnormal event			Cause	Measure
Anomaly in unfiltered water quality	Cloudy unfiltered water		Insufficient coagulation of unfiltered water (overdose of coagulant)	(1) Filtration rate is to be lowered; filtered water quality is monitored if it is anomaly; and filtration is stopped unless it can be remedied. (2) Proper dosing of coagulant and alkaline agent.
			Improper pH for coagulation (high pH, low pH)	
Abnormal filtered water quality	Leak of turbidity matters		Insufficient coagulant	Additional dose of coagulant
			Improper cleaning	Improvement of cleaning method
			Filtration under negative head loss	Shortening of interval of cleaning
			Abnormal filter (abnormal filter layer, abnormal underdrain system)	Upkeep of filter layer, repair of underdrain system
	Leak of color substances	Dark brown	With dissolved manganese in filtered water, it reacts with chlorine for disinfection, oxidized and colored.	(1) To remove by manganese sand under presence of free chlorine (2) To apply pre-chlorination and remove most of it
			In the case of intermediate chlorination etc., dissolved manganese is oxidized to manganese dioxide, not completely removed by filter, and leak.	Two-step coagulation
		Reddish	A lot of iron in filtered water	Aeration, pre-chlorination etc.
		Black	Leak of powdered activated carbon [PAC] (too large dosing rate of PAC, enlargement of filter media grain)	(1) Reduction in dosing rate of PAC (2) Improvement in filter layer
		Green	Leak of blue-green algae (esp. Microcystis spp.)	Two-step coagulation
	Leak of microorganisms (chironomids etc.)		Outbreak of chironomids etc. in sedimentation basin	Shortening of interval of cleaning, strengthening of chlorination (sedimentation basin)
	Excessive aluminum contents		Improper pH	To adjust pH to proper range
			Inadequate cleaning	To improve cleaning method
			Filtration under negative head loss	To shorten interval of cleaning
			Abnormal filter (abnormal filter layer, abnormal underdrain system)	Upkeep of filter layer, repair of underdrain system
			Excessive dosing of aluminum family coagulant	Proper dosing of coagulant. Direct filtration with less coagulant
			Insufficient coagulation due to too little dosing of aluminum family coagulant	Proper dosing of coagulant
	Excessive speed of head loss build-up		Filter layer clogging due to existence of excessive specific species of plankton in unfiltered water	(1) Spray of chemicals at water source (2) Shortening of interval of filter cleaning (3) Cleaning of sedimentation basin, strengthening of chlorination
			Air bubbles occur in filter layer due to negative head loss	
			As skimming of filter layer surface is not executed after its replacement, fine filter media collect on the surface, and clogging occurs.	Following a study on size distribution of filter media, several cm of its surface is to be skimmed. In the case of anthracite, skimming is made after several times of backwash.

		Grain size of filter media is too small as a whole.	(1) Observation of status (Fine components spill after repeated cleaning) (2) Proper adjustment of filter layer structure by replacing specific quantity of filter media
		A large amount of air is contained in unfiltered water and it turns into bubbles.	(1) Adjustment of gland of raw water intake and transmission pumps (2) Check of piping system (air valves)
Water flow	Too large initial head loss	As skimming of filter layer surface is not executed, fine filter media collect on the surface, and clogging occurs.	In the case of sand layer, surface layer is skimmed; in the case of anthracite, backwash is repeated for removal.
		Turbidity matters remain in filter layer due to insufficient effect of cleaning	Improvement of cleaning method
		Such foreign matters as pieces of plastic films accumulate in the interface between gravel layer and filter layer.	(1) To install dust scraper in intake facilities (2) Skimming of trashes floating in sedimentation basin and filter
	Too small initial head loss	Grain size of filter media is too large as a whole.	(1)Following a study on grain size distribution of filter media, sand is refilled so that grain size become proper as a whole.
	Sudden temporary drop in head loss	Part of flocs retained in filter layer dissolved by rapid change in pH of unfiltered water, and leak	Steadily dosing alkaline agent to avoid sudden change in unfiltered water.
	Abnormal filtration flow	Failure of flow control mechanism	Inspection of flow meter, controller and automatic flow controller
		Failure of driving pump (in the case of pressurized filtration)	Inspection of pump capacity and aperture of valves
Bubbles	Air bubbles occur when filtration rate is changed (reduced).	When (rapidly) reducing filtration rate under presence of negative head loss, bubbles separate.	(1) Reevaluation of cleaning condition so as not to cause negative head loss. (2) To avoid sudden change in filtration rate.
During cleaning	Occurrence of bubbles during cleaning	Release of air accumulated in backwash water pipe into filter layer	(1) Prevention of mixing of air into cleaning water piping system. (2) Prevention of entrainment of air into water due to eddy occurring in cleaning water tank.
	Abnormal local gushing of filter sand during backwash	Gravel layer largely undulates and heaves up to near filter layer surface, and backwash water concentrates there.	To study on undulation of filter layer, and replace it.
Filter layer	Spill of filter sand and anthracite	Too large cleaning water flow, improper angle of surface wash nozzles (reduced filter layer thickness)	(1) Implementation of improvement of filter layer (2) Investigation of cause of spill of filter media
		Mixing of air into cleaning water (in the case without air wash)	(1) Adjustment of gland on cleaning pump (2) Check of piping system (air valve)
		Too large air wash flow (with air wash)	Check of air wash control valve
	Cave-in of filter layer surface	Drain of filter media into collection chamber due to anomaly in underdrain system	Following study on collection chamber, to repair underdrain system if anomaly is found.
	Occurrence of mud balls in filter layer, crack on filter layer surface, and opening between filter layer and filter walls	Insufficient cleaning effect resulting in residual turbidity matters in filter layer	(1) Reexamination of cleaning condition (surface wash, air wash, optimization of expansion rate, shortening of cleaning interval) (2) Improvement of filter layer

	Undulation in interface between gravel layer and filter layer (waving)		(1) Improvement of filter layer (2) Reexamination of cleaning condition (3) Prevention of entrainment of air into backwash water
Others	Complete power failure Disability of central remote control		(1) According to response manual at an emergency, such event is to be dealt with. (2) Training against emergency is periodically to be carried out.
	Uneven water flow on to troughs	Uneven sinking of filter body and distortion in troughs	Reinstallation of troughs horizontally
	Water leak from filter body	Impairment of water-proofing layer, improper workmanship, cracks due to uneven sinking of the body	(1) As there is risk of contamination of filtered water, study is to be made after emptying the filter. (2) Taking out filter media, study is to be conducted on it.
	Growth of plant on troughs and filter walls	Filtration of water with almost no chlorine at outdoor	Implementation of cleaning Execution of shielding

7.6.3. Multi-media filter

For the multi-media filter, more than two filter media with different density and grain size are used, which form filter layers with media grain sizes reversely graded from coarse to fine in the direction of flow. In general, a dual media filter is used with anthracite (specific gravity 1.4 to 1.6) for the upper layer, and silica sand (specific gravity 2.57 to 2.67) for the lower layer.

Besides, there are some examples in which the tri-media filter is in use with garnet (specific gravity 3.15 to 4.3) in addition to the above filter media.

Placing filter medium of coarse grain in the upper section, roughing filtration is carried out; and with filter medium of fine grain in the lower section, turbidity matters penetrate down to the deep section to augment retained quantity, and the effect of filtration is enhanced as drain of turbidity matters is blocked.

In the meantime, in order that the filter layer arrangement from coarse to fine is not disturbed by backwash, the coarse grain medium in the upper layer needs to possess a smaller settling velocity than the fine grain medium in the lower layer. Hence, for the coarse filter medium in the upper layer, a medium of small specific gravity compared with the fine grain medium in the lower layer is used.

Since anthracite easily spills over, backwash rate, overlap time of surface wash with backwash, grain diameters of media, uniformity coefficient, distance from the surface of filter layer to the rim of wash trough etc. are recommended to be determined based on a study.

1. Operation (filtration)

Although the basic items related to operation and maintenance of the multi-media filter shall be in conformity with 7.6.2 Gravity type open filter, attention shall be paid to leak of turbidity matters since filtration is performed in relatively high speed through a filter layer structure with a large porosity.

2. Operation (cleaning)

① As anthracite has small specific gravity, so a large amount of it tends to spill at the time of cleaning compared with the case of sand, it is cautioned for the backwash rate not to become excessively large. Especially, caution shall be practiced since if the backwash rate for summer is used in winter when water temperature is low, spill of anthracite tends to augment.

② It is noted that, if air wash is employed, spill of anthracite to the wash trough easily occur as air bubbles sick to anthracite. Besides, as air tends to stay behind in the filter layer, backwash shall be carried out at the end to discharge it.

③ In the case of the air wash method, it is important for air to uniformly rise all over the filter layer surface, so the condition of bubbling on water surface shall be watched as needed.

3. Daily inspection

① Since, even though properly managing the volume of cleaning water, spill of anthracite is unavoidable to a certain extent, the thickness of the filter layer shall be measured every year, and anthracite shall be replenished if it is insufficient.

② In case there is undulation on the filter layer surface, it shall immediately be repaired, and, at the same time, its cause shall be studied and such a measure as the review of the method of cleaning, inspection of the underdrain system and so forth shall be implemented.

③ When resuming operation after shutdown of the filter lowering the water level below the filter layer surface, and carrying out some work, it is needed prior cleaning to sufficiently immerse anthracite in water, and completely extract air in the surface wash pipe so as to prevent spill of anthracite. Such operation shall carefully be undertaken while confirming the site situation.

④ After anthracite is replenished or replaced, it shall well get to fit water and its fine grains shall adequately be removed by several times of cleaning before start of filtration. It is cautioned that new anthracite may consume chlorine at times.

⑤ As for the revolving type surface wash device, efforts shall be made so that confirmation of the condition of its rotation and inspection of nozzles shall periodically be conducted to maintain its functions. As confirmation of condition of cleaning is important, it shall be undertaken at site as needed.

4. Measures in an abnormal case

As to measures in an abnormal case, Table 7.6.3 shall be referred to.

7.6.4. Pressurized filter

The pressurized filter generally possesses a sealed tank-like steel plate structure, and, because of its easy handling, relatively small scale pressurized filter is used under a pressure of 0.1 to 0.6 MPa or so. Its types are largely divided into the vertical type and the horizontal type. The former is used for treatment of small quantity whereas the latter is applied for treating relatively a large amount of water.

① Filtration can be made until relatively high head loss builds up without occurrence of negative pressure.

② As the filter is shielded, growth of algae is little.

③ If it is installed in a pressurized pipeline from water intake and raw water transmission through the service reservoir, it is economical as only one time of pumping will suffice.

④ The inspection of its inside is not easy. In case a flow controller is not mounted, the operation becomes constant pressure filtration resulting in a large change in the filtration rate.

1. Operation

The pressurized filter is in many cases introduced as a set of pressurized filtration device, and its capacity and characteristics differ depending on brand. Thus, it is needed to adequately refer to the respective user's instruction. Common points of attention are as follows:

① When staring filtration, water is slowly introduced in the filter so as not to disturb the filter layer surface while exhausting air in the tank, and fully fill it. Then filtered water drain is made and filtration is initiated after filtered water has become clear.

② In case removal of iron and manganese is aimed, a chlorine agent shall be dosed without fail to maintain the manganese sand so that free chlorine is secured in filtered water.

③ If filter runtime is long, there is a risk to bring about cracks on the filter layer and uneven filtration due to the consolidation of the filter layer. As such, it is desirable to implement cleaning periodically even in case head loss is relatively low.

④ Visual observation of cleaning waste water and water quality testing shall be conducted as needed.

2. Daily inspection

① Since, for a horizontal filter of a large capacity, cleaning of the section along the side walls is not easy, mud balls tend to develop there. Therefore, periodically inspecting the filter layer, if the development of mud balls is confirmed, they shall be removed and enhancement of cleaning needs to be implemented.

② In case the removal of iron and manganese is aimed, to confirm the function of the filter media, water quality tests on iron and manganese contained in the raw water, filtered water and cleaning waste water shall be conducted every month.

③ To grasp the deterioration of filtration function, a water quality test of raw water and filtered water shall be carried out every year under the same condition (water flow, pressure and quality). If deterioration in the function of the filter media is confirmed as a result of water quality tests, measurement of the thickness of the filter layer and a study on pollution of the filter media shall be made, and the filter media shall be replenished or replaced.

④ In case operation of the filter is shut down for a long time, water in the filter layer and piping shall be drained after sufficient cleaning so as to prevent growth of bacteria and microorganisms. Besides, for points of inspection of the pressurized filter, refer to Table 7.6.2.

3. Measures in an abnormal case

As to measures in an abnormal case, referred to Table 7.6.3.

7.6.5. Automatic balancing type filter

In the automatic balancing type filter, the incoming flow, outgoing flow and water level literally automatically balance. Automatic balancing type filters are roughly classified into the self-backwash type and the type with a backwash water tank. As characteristics common to the respective types, since such a flow control mechanism as valves on the inlet side is not installed, and water entering on to the filter exits as it is, the piping on the outlet side is simple. As a siphon or valve is installed on the inlet side, closing and opening of inlet flow can soundly be controlled.

7.6.6. Direct filtration method (Micro-floc method)

In the direct filtration method, raw water of low temperature and low turbidity is dosed with a small amount of coagulant, rapidly mixed, and directly filtered without passing through the flocculation basin and the sedimentation basin.

Dosing coagulant at 1/2 to 1/4 or so of the normal dosage, solid micro flocs of high density are formed and introduced on to the filter. Since the solid micro flocs is efficiently filtered, reliable treatment is possible. At the same time, as the coagulant is saved and so generated sludge become small in quantity. However, monitoring of filtered water turbidity needs to adequately be conducted.

Although this method can be employed in case raw water is low throughout the year, even for the usual filtration method, this method can be employed in a specific period of time when raw water turbidity is low. If a dual-media filter or multi-media filter is employed, more effect can be obtained.

7.7. Slow sand filter

7.7.1. General

The slow sand filtration method is a method to filter water through a sand layer at a slow velocity of 4 to 5 m/day, and, using no chemicals, natural purifying ability is utilized.

Filtration is performed by a sticky membrane (biofilm) composed of organisms growing on the surface and inside of the sand layer, and such suspended matters as turbidity matters and bacteria, and such dissolved matters as ammoniac nitrogen, iron, manganese, and odor causing substances are removed.

In the slow sand filter, since suspended matters are trapped by a biofilm formed on the very surface of the sand layer, it does not fit raw water with high turbidity or an excessively large amount of algae since such water raises the head loss at the surface of the layer in a short period of time, and reduces the filter runtime in days. In addition, turbidity of water incoming to the filter needs to be maintained at less than about 10 turbidity units.

For the slow sand filtration method, applicable raw water quality is restricted; and, due to the slow filtration rate, a large lot and management of the sand layer (skimming of sand, replenishment of sand, sand washing etc.) are needed.

Example of points of inspection of the slow sand filter is presented in Table 7.7.1.

Table 7.7.1 Example of points of inspection of the slow sand filter

Daily inspection		Periodical inspection		Detailed inspection (Upkeep)	
Cycle	Contents of inspection	Cycle	Contents of inspection	Cycle	Contents of inspection
As needed	1.To confirm water level of filter	Once /1 -2 months.	1.Working condition of filtration rate controller	When skimming sand	1.Cleaning of sedimentation basin
As needed	2.Filtration flow, filtration rate, filter head loss, filter runtime	1 year	2.Filter flow meter, filter head loss gauge	Once /0.5 – 2 months.	2.Skimming of sand surface
As needed	3.To confirm filtered water quality (turbidity, pH, alkalinity)	1 year	3.Condition of filter layer (contamination of filter sand, effective diameter, uniformity coefficient, layer thickness etc.)	In case layer thickness is less than prescribed value	3.Refilling of filter sand
As needed	4.Situation of occurrence of aquatic lives and algae	When skimming sand	4.Existence of cave-in on sand surface, growth of algae, insects etc.	10 years	4.Improvement of gravel layer and underdrain system
1 day	5.Condition of freezing of water surface in the filter	1 year	5.If there are cracks, impairment of concrete and water leak	6 months.	5.Cleaning and oiling of valve stand & other equipment
		1 year	6.Working condition of valves	Once /3 – 5 years	Repainting of steel parts
		1 year	7.Condition of paint on steel part		
		Inspection and upkeep of level gauge, flow meter and water quality testing equipment			

7.7.2. Plain sedimentation basin

As a pre-treatment facility for the slow sand filtration method, the plain sedimentation basin removes suspended matters in raw water, which is not coagulated as usual, by the natural settling action so that the load on the slow sand filter is reduced.

The standard overflow rate of the plain sedimentation basin is 5 to 10 mm/min., and the average flow velocity in it is 30 cm/min.

Example of points of inspection of the plain sedimentation basin is presented in Table 7.7.2.

Table 7.7.2 Points of inspection of the plain sedimentation basin

Daily inspection		Periodical inspection		Detailed inspection (Upkeep)	
Cycle	Contents of inspection	Cycle	Contents of inspection	Cycle	Contents of inspection
As needed	1.Average flow velocity	1 year.	1.Condition of sludge piling	2 years	1.Cleaning of sedimentation basin
As needed	2.To confirm water level in basin	1 year	2.Existence of cracks, impairment, and water leak of concrete	6 months.	2.Gate operation stand, other equipment
As needed	3.If there are floating matters, and resurfacing of sludge	1 year	3.Working condition of valves	3 to 5 years	3.Repainting of steel parts
As needed	4.To confirm settled water quality (turbidity, pH, alkalinity)	1 year	4.Conditioin of painted steel parts		
As needed	5.Condition of growth of algae				
As needed	6.To monitor settling condition of flocs (when coagulated)				
1 day	7.Condition of freezing of water surface in the filter				
1 day	8.Condition of algae on basin walls, and sticking of insects etc.				
		Inspection and upkeep of level gauge, flow meter and water quality testing equipment			

1. Operation

① Turbidity of raw water and settled water shall always be monitored so that turbidity of settled water is less than 10 turbidity units. Since the quality of settled water is affected by raw water quality, such appropriate measure as control of the inlet flow, and dosing of a coagulant shall be implemented.

② When raw water turbidity is more than 30 turbidity units, a coagulant is to be dosed as pre-treatment before inlet to the sedimentation basin so that efforts are made to obtain good settled water. In this occasion, consideration shall be paid in that supernatant is abstracted so that clogging of the filter is not quickened by flocs.

③ In a location where there is a risk that the function of the sedimentation basin is hindered by strong wind etc., a device to prevent waves shall be installed and monitoring shall adequately be practiced so that settled sludge does not resurface.

④ Settled sludge shall as needed be discharged depending on piling situation.

⑤ In case algae grow in the sedimentation basin, pH rises in general, and water in the basin become colored in green to dark red in some times. Fresh water sponges, bryozoans etc. in addition to algae may stick to basin walls forming a biofilm.

In such a case, although such organisms can be exterminated by chlorination etc., chlorination shall carefully be implemented so that all free residual chlorine is consumed before water goes on to the filter so as not to adversely affect the organic filter membrane of the slow sand filter.

2. Daily inspection

The respective facilities for inlet, outlet, overflow etc. of the sedimentation basin shall always be inspected and maintained so that operation is soundly undertaken.

7.7.3. Filter

1. Operation

① The water depth above sand surface shall be maintained at 90 to 120 cm.

② The standard filtration rate shall be 4 to 5 m/day. Even in case raw water quality is good, it shall be less than 8 m/day at the maximum.

③ The water level at the outlet of the filter shall not be lower than the level of sand surface to prevent negative head loss in the filler layer, which causes a trouble in filtration function.

④ When the water level at the filter outlet reaches the level of sand surface, skimming of sand shall be carried out

7.8. Clearwell

7.8.1. General

The clearwell not only controls and buffers the imbalance between the filtered water flow and the treated water transmission flow but plays the role of storing treated water for preparation for an accident. As it is a facility situated at the terminal stage of water treatment, it also serves as a service reservoir in case it is constructed with a large volume of storage. Therefore, adequate attention shall be paid to its hygienic management so that the treated water is not contaminated from outside periodically implementing inspection of its inside and so forth.

7.8.2. Clearwell

1. Operation and management

① It shall be confirmed that quality of treated water in the clearwell is properly maintained. Especially, it shall always be monitored whether or not the concentration of residual chlorine meets the target value.

② The water level in the clearwell shall at all times be grasped so that it can fully play its role.

2. Daily inspection

① The manhole, entrance to the inspection gallery, sampling hole etc. of the clearwell shall be locked without fail. To prevent water pollution, ventilation equipment, louvers and insect nets shall always be inspected and maintained so that rainwater, dust, insects, small animals etc. do not intrude from outside.

② As scale sticks or sediment deposits inside of the clearwell at times, inspection and cleaning of its inside shall systematically be implemented. After cleaning, drain with pouring water Note) shall be carried out. In case water is discharged to a public water body, dechlorination shall be undertaken as required. Secondly, a water quality test shall be carried out prior to the use of the clearwell.

③ At the time of cleaning of the clearwell, as water containing chlorine is used for cleaning in almost shielded space, the eyes and nose are excited by evaporating chlorine gas, and light symptoms of poisoning may be caused. Given this, when engaged in such a work, such protective measures as installation of an oxygen meter and a ventilator, wearing a protector need to be provided. Additionally, the same caution shall be practiced when entering the clearwell for daily inspection.

④ At the time of cleaning, the structure, condition of deterioration in the expansion joints and the inside waterproofing layer, existence of water leak from the ceiling and wall etc. shall also be inspected.

⑤ Since corrosion by chlorine is intense in the clearwell, the ancillary facilities (gates, valves, stepping irons etc.), instrumentation equipment (level gauges, flow meters etc.) shall adequately be inspected.

7.8.3. Disinfection

1. Disinfection work

In case a clearwell is newly constructed or repaired, its inside shall first be cleaned by high pressure water jet etc., and, after cleaning with treated water, it shall be filled with treated water containing 10 mg/L of free residual chlorine up to the design high water level. Leaving it still for 24 hours, it shall be confirmed that more than 5 mg/L of free residual chlorine is detected. If it is less than 5 mg/L, above cleaning and chlorination shall be repeated.

Besides, as alkali substances elute from its body, the clearwell is to be left still further for several days, and then a test for taste and odor shall be implemented. If the taste and odor are remarkable, the well is to be filled with water up to the design high water level, and left still for several days; and this operation shall be repeated until the taste and odor disappear. Thereafter, water left still is to completely be discharged. Then, water in the clearwell shall be drained with pouring water, and the clearwell is to be commissioned.

Note) "Drain with pouring water" means that Filling the clearwell with ordinary treated water up to 1 m or deeper, while making the inlet and outlet flows equal and keeping the water depth constant, water is drained until the retention time of the treated water become more than the design retention time of the clearwell (usually 1 hour or so). Such drain operation shall be continued until the water in the clearwell is replaced more than twice for the purpose of calculation.

7.9. Disinfection facilities

7.9.1. General

Disinfection of tap water is carried out for the purposes to prevent contamination by pathogenic organisms in water, and maintain hygienic safety in the water distribution system. Tap water must always be disinfected without fail. In case the disinfection facility is damaged by an earthquake etc., and disinfection cannot be undertaken, water treatment shall immediately be shut down; and water treatment shall be resumed after the function of the disinfection facility has properly been recovered.

As the action required for hygienic reason, in accordance with Article 17 of the Enforcement Regulation, under Waterworks Law, which stipulates the contents of residual chlorine to be retained, disinfection by other means than a chlorine agent is not permitted. Disinfection of tap water is to be made by a chlorine agent of sodium hypochlorite, liquid chlorine, calcium hypochlorite (high test hypochlorite) etc.

Disinfection by a chlorine agent has an infallible effect, can easily disinfect a large amount of water, and its effect stays behind as a merit. On the other hand, such disinfection byproducts as trihalomethanes are generated; it reacts with specific substances intensifying odor; and sometimes it reacts with ammoniac nitrogen weakening disinfection effect. If water contains turbidity matters, the disinfection effect is weakened because the turbidity matters become protector of pathogenic organisms, so turbidity removal shall properly be carried out at the stages of sedimentation and filtration.

As to inventory control of chlorine agents, proper amount of their storage shall always be secured; they shall be managed under the environment in accordance with their type avoiding deterioration and an accident; and measures for anti-earthquake, fireproofing etc. shall sufficiently be considered.

The dosing rate of the chlorine agent shall be determined so that the residual chlorine at the tap is always maintained in consideration of water quality, materials of facilities, retention time etc. However, caution shall be practiced so that it does not to become too large as prescribed in the Water Quality Management Target Setting Items (free residual chlorine: less than 1.0 mg/L), which supplement the Water Quality Standards.

7.9.2. Chlorine agent

1. Sodium hypochlorite

1) Characteristics etc.

Sodium hypochlorite is a light yellowish liquid containing 5 to 12 percent of effective chlorine, strong alkali, and corrosive. Moreover, it is unstable, and decomposes in a normal temperature as it discharges oxygen while stored. The composition is accelerated by sunlight, UV ray, a rise in temperature etc.

2) Points of consideration for use

(1) Handling etc.

It is cautioned that sodium hypochlorite is unstable as much as its effective chlorine concentration is high, and has high tendency to lessen effective chlorine contents. When dosing, attention shall be practiced to avoid occurrence of bubbles, and an accident of improper dosing due to scaling.

What is more, as sodium hypochlorite is rapidly decomposed by acid, discharges chlorine gas, which is dangerous, attention shall be paid not to mix it with such acid solution as an acid agent, aluminum sulfate etc. Secondly, as it is strongly alkaline, it needs to be handled so as not to make it to contact with skin and mucous membranes.

(2) Daily inspection

As daily inspection of sodium hypochlorite disinfection facilities, their operating condition etc. shall be checked during patrol.

2. Liquid chlorine

1) Characteristics etc.

Chlorine gas has extremely strong action and is a yellow-greenish gas at natural temperature having aggressive suffocating irritant odor weighing about 2.5 times the air.

Applying cooling and pressure on the chlorine gas, it liquefies at 6.6 atm at atmospheric temperature of 20 degrees C. forming orange liquid with a specific gravity of 1.56. For its delivery, the container is normally filled with about 90 percent of liquid chlorine and 10 percent of high-pressure chlorine gas at normal temperature. If vaporized, liquid chlorine becomes a gas with about 460 times of volume (at 0 degrees C., and 1 atm of atmospheric pressure). Chlorine gas is barely soluble to water forming light yellowish chlorine water.

In the case of a large scale water treatment plant, examining the risk of transporting a large amount of sodium hypochlorite, consideration for environment etc., some water utilities have introduced in-house manufacture of sodium hypochlorite.

2) Points of consideration for use

(1) Handling etc.

Since the liquid chlorine, which is cooled and pressurized chlorine gas, has strong toxicity, it shall be handled paying close attention with good knowledge about its nature.

(2) Daily inspection

As daily inspection of liquid chlorine disinfection facilities, their operating condition etc. shall be checked during patrol.

(3) Education on safety etc.

Businesses, which use liquid chlorine from a storage tank, are usually regarded as a high pressure gas manufacturer, so are obliged to establish a rule for prevention of human casualties, and a plan for safety education, and undertake safety education and training for their staff.

Safety education shall be implemented based on an execution plan aiming at raising safety mind, the basic nature of chlorine, safety technologies on facilities and their management, handling of high-pressure containers, emergency measures at the time of an accident, related laws and regulations etc. Such safety education shall be undertaken, as needed, when staff are newly recruited, or transferred; when there is a change in facilities or the method of their operation; and in the case of a disaster or an accident.

Training for an assumed accident shall be executed more than once a year on finding and reporting of an accident, a muster and evacuation of staff, emergency measures etc.

3. Sodium hypochlorite (high test hypochlorite)

1) Characteristics etc.

High test hypochlorite is colorless or white powder, granules or tablets, usually contains 60 to 70 percent of effective chlorine, has slight chlorine odor, and is relatively easily soluble in water.

2) Points of consideration for use

As high test hypochlorite possesses high stability and endures in long-time storage, it is suitable for use as disinfectant for emergency at the time of a disaster etc. When used, preparing its solution in advance, it is dosed by the same equipment as the one for sodium hypochlorite. In case dosing high concentration solution, caution shall be paid to scaling in dosing pipe and the drop in effective chlorine concentration. It shall be stored at a dry and dark sealed place where it does not come in contact with water, combustibles, and explosives. In case its packaging is broken and it spills, treatment by washing by more than 10 times volume of water and so forth.

Besides, it is cautioned that high test hypochlorite emits oxygen and chlorine by decomposition by heat at the time of a fire. Especially, there is a risk that, in a temperature of higher than 150 degrees C., it decomposes all at once, emits oxygen and explode. It is also noted that it discharges chlorine if it reacts with acid.

7.9.3. Chlorination of tap water

1. Basic items

The basic items to reliably undertake chlorination all the time are as follows:

① As for disinfection equipment, it shall always be prepared together with a spare unit so that disinfection is not to be interrupted.

② As for dosing of chlorine, it shall be inspected and confirmed as needed if chlorine and water are uniformly mixed including the terminal dosing device. Secondly, its quality control at storage shall adequately be considered.

2. Dosing rate of chlorine

In case disinfection is undertaken by free residual chlorine, the concentration of free residual chlorine to be maintained at the tap shall be set in adequate consideration of the chlorine demand of water and the quantity of chlorine consumed by water supply facilities, which come in contact with water.

In case it is done with combined residual chlorine, there are the method to use ammoniac nitrogen in raw water, and the one to add ammoniac nitrogen treatment with free residual chlorine.

1) Residual chlorine concentration to be maintained at the tap

As disinfection by chlorination is obligated, free residual chlorine in tap water is to be maintained at 0.1 mg/L or more (in the case of combined residual chlorine: 0.4 mg/L) under Article 17 (hygienically required measure) of the Enforcement Regulations of the Law.

In addition, free residual chlorine is to be maintained at 0.2 mg/L or more (in the case of combined residual chlorine: 1.5 mg/L) in the cases as follows:

① When a digestive system infective disease is prevailing

② In case water service is resumed after suspension of water service in the entire service area.

③ When water quality is markedly deteriorated due to a flood etc.

④ In case there is an anomaly in the water treatment processes

⑤ In case there is a possibility of severe contamination of water supply facilities due to a large construction work for water distribution mains etc.

⑥ In other case it is recognized to be especially needed.

2) Chlorine demand and chlorine consumption of water

Chlorine in disinfected water is consumed as the water comes in contact with the service reservoir, pumps, treated water transmission mains, distribution mains, water service fittings, water meters etc. while it flows through them.

3. Confirmation of residual chlorine

At the clearwell and the service reservoir, residual chlorine shall be measured at a fixed interval and as needed to confirm if the chlorine dosing rate is appropriate.

In case decline in residual chlorine is remarkable because of the retention time in the service reservoir, the facility size of treated water transmission mains, distribution mains etc., such a required measure shall be provided as additional chlorination equipment for intermediate chlorination to be made in between them.

Additionally, at the time of water quality tests of tap water to be conducted regularly and temporarily, if residual chlorine is not detected or its value abnormally changes, the cause thereof shall immediately be studied including the possibility of pollution by cross-connection etc. and a proper measure needs to be made.

Measurement of residual chlorine is to be conducted by the diethyl-p-phenylenediamine method (DPD method), polarography method etc.

7.9.4. Storage facilities

1. Method of storage etc..

Sodium hypochlorite is stored in a 20 kg container in a case, and delivered in a tank truck and stored in a storage tank in another case.

Liquid chlorine is stored in a container (a 50kg container or 1 t container) filled in a factory, or a storage tank at the water treatment plant etc.

These chlorine agents shall always be secured for use for more than 10 days.

2. Storage facilities and its management

1) Storage of sodium hypochlorite

(1) Inventory control

① The store room shall be in well-ventilated good condition with proper operation of a ventilator etc. to prevent a rise in room temperature; and, likewise, direct sunlight from windows, doors etc. shall be shielded.

② The container shall be placed on a stand in a cool, well-ventilated dark location so as not to flip.

③ The water service facilities for cleaning installed near the storage tank, the container store, and the liquid barrier wall shall be inspected and confirmed for their function.

④ As effective chlorine concentration declines during storage, the change in effective chlorine concentration at the present storage facility shall be grasped so as to control the period of storage and temperature during storage.

⑤ As effective chlorine concentration declines, the dosing rate of sodium hypochlorite increases as much as the magnitude of decline, attention shall be paid that bromic acid ion in water also increases.

⑥ It is noted that, if stored for a long time, chloric acid ion concentration may rise as a result of oxidation of hypochlorous acid ion.

⑦ Adequate attention shall be paid as there is contamination with foreign materials, especially, heavy metals, decomposition is accelerated resulting in decline in effective chlorine concentration.

⑧ Assuming a case of a leak, proper inspection of facilities and equipment shall be executed for prevention of spread of leak, mixing with other chemicals, or leak of the liquid to outside of the water treatment plant. For treatment of leaked liquid etc., reliable measurements shall be implemented including assignment to a specialized contractor.

(2) Receiving

① Twenty kg containers shall be carried in with their lids on top, and stored not by piling up.

② As the 20 kg container is fragile to impacts, it shall be handled so that it does not collide with a projection.

③ When receiving it from a tank truck, the remaining amount in the receiving tank shall be confirmed, and, at the same time, there is no anomaly in the level gauge, valves, strainer, pipelines etc.

④ Receiving shall be started after confirming that there is no mistake of the receiving tank or the receiving mouth; and that the tank truck and the receiving tank are firmly connected.

(3) Acceptance inspection

① At the time of receiving, quality test as well as measurement of the merchandise shall be executed.

② Where weighing facilities are unavailable, the supplier shall be requested to produce the certificate of weight to be issued by the measurement accreditation agent, and the quantity shall be confirmed by means of the level gauge on the tank. Acceptance inspection of delivery by a tank truck shall be made by the truck scale. Secondly, the quantity of delivery by container shall be made by a platform scale.

③ For quality control, considering that the effective chlorine concentration is not necessarily constant depending on the season of year and the condition of transportation, based on the price of purchase and purchase specification, measurement of effective chlorine concentration, specific gravity and liquid temperature shall be carried out, and its appearance shall be examined. Likewise, the concentration of bromic acid contained shall also be confirmed.

(4) Storage tank

The inside of the tank shall periodically be inspected on the condition of corrosion, and cleaned. The appearance and existence of liquid leak of attached level gauge, inspection manhole, outlet for connecting pipe (waste liquid, overflow liquid, cleaning etc.), ladder etc. shall periodically be inspected and confirmed.

(5) Service tank

① About the condition of the inside of the service tank, inspection and upkeep shall be executed in accordance with the storage tank.

② The liquid level of the service tank shall be maintained as high as possible in consideration of the time of power failure.

③ As for the service tank, in the same manner as the storage tank, appearance and existence of liquid of its respective sections need to be inspected including the outlet for connecting pipeline and accessories (such a liquid level controller as ball tap).

④ As to occurrence of air bubbles, refer to 7.9.5 Dosing equipment.

2) Storage of liquid chlorine

(1) Inventory control

① Chlorine in the chlorine gas container is highly pressurized and poisonous, absolutely avoiding its temporary placing, it shall carefully be handled in such a manner as placing it in a specified site orderly and so forth.

② If the humidity in the store room is high, ventilation is to be made to remove it.

③ Adequate attention shall be paid as there is a danger in that leak of chlorine gas erodes equipment and materials, poison operators etc. even if its quantity is small.

④ Anti-gas and neutralization measures shall be prepared. Even in case there is no provision of neutralization measures, calcium hydroxide as absorbent of leaked chlorine gas shall always be stocked and its quantity shall be more than the prescribed standard quantity. When actually operating neutralization measures, a dispenser (manual, pressurized, or motorized) shall be positioned at a location, where the operation is easy, so that a specified quantity of calcium hydroxide can uniformly be sprayed in as short time as possible.

⑤ At the storage room or during transportation of a container, such necessary measures as shielding direct sunray from windows, entrance etc. so that it does not irradiate the container, and attention shall be paid to always keep its temperature at lower than 40 degrees C.

⑥ At the place of storage of the container, no other fire or a heat source than the specified heating equipment shall be used.

⑦ A proper hole shall be dug on the ground in advance as preparation for such abnormal situation as leak of chlorine gas from a 50 kg container.

(2) Receiving by a container and its handling

① Filled containers and spent containers shall clearly be indicated by labels etc. to discriminate them.

② At the time of delivery by the container, existence of an inspection seal, and leak of chlorine gas from the main valve, container etc. to be tested by ammonia water shall be confirmed.

③ When using the container, tightening of the push nut (gland nut) for gasket on spindle of the main valve and existence of leak shall be confirmed. The gland nut may have to be tightened additionally as needed.

④ In case the container is transported, its valve shall be protected fitting it with a cap or cover; and it shall carefully be handled so as never to give an impact at the time of loading and unloading.

⑤ The main valve shall be opened and closed using an exclusive handle and not giving too much force.

⑥ At the time of installing an auxiliary valve, replacing the pipeline and so forth, it shall be confirmed that there is no accretion of foreign material on the gasket, and attention shall be paid so that the gasket is not left behind disengaged.

⑦ The valve of the spent container shall immediately be closed, and the container shall be capped so that moisture and dust do not enter in it.

⑧ When thawing the head of a frozen chlorine container, the use of boiling water shall be avoided so that the fuse (silver plate) does not melt.

⑨ In case the container is erected upright, it shall firmly be fixed on a rack; in case horizontally placed, it shall be fixed on a rack with corrugation. Objects, which may give an impact to the container, shall not be placed in the store room.

(3) Receiving by storage tank and monitoring.

① When receiving chlorine, working condition of the level gauge, pressure gauge, power of instrumentation apparatus, pneumatic air source, air source for receiving chlorine etc. shall be confirmed; and at the same time, the situation of the neutralization facilities, the condition of valves on the piping (including the route of pneumatic air), and the condition of connection with the tank truck shall be confirmed. As air for receiving, dry air, which has sufficiently been dehumidified by a dehumidifier (dew point: lower than -45 degrees C.), shall be used.

② Handling of receiving shall be executed according to the prescribed steps; and manual valves shall be opened and closed slowly. During receiving, the liquid level and pressure in the tank shall always be monitored; existence of chlorine leak from respective sections shall be tested by ammonia water.

③ The quantity to be received shall not exceed the maximum quantity prescribed for the tank. After receiving, a flange lid shall be fit on the connection section with the tank truck.

④ During storage, the liquid level, pressure, the temperature of the storage room shall be monitored; and it shall periodically be tested whether or not there is chlorine leak.

⑤ Function test of such monitoring devices as the level gauge, pressure gauge, thermometer, chlorine leak detector, and warning device shall periodically be conducted, and they shall be prepared so that they accurately work at all time. What is more, the working environment shall be tested every 6 months.

⑥ The operating condition of the storage tank shall clearly be indicated by signs etc.; at the same time, valves and operating switches shall be indicated by signs and firmly locked so that erroneous operation or wrong actions shall not occur.

7.9.5. Dosing equipment

1. Feeder of sodium hypochlorite

1) Dosing method etc.

① As, in the feeder, troubles in feeding may arise due to occurrence of air bubbles, and scaling in valves and piping, attention shall be paid. It shall be inspected as needed to prevent troubles in advance.

② To maintain proper residual chlorine concentration, it shall as needed be confirmed if sufficient mixing and contact time are assured at the dosing point.

2) Dosing type

As types of dosing, there are the injector type, pump type and gravity flow type. An example of dosing types is illustrated in Figure 7.9.4.

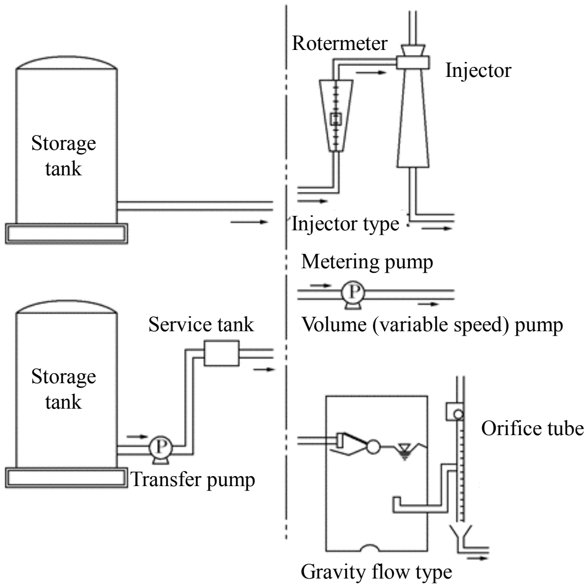


Figure 7.9.4 Example of dosing types

① The injector type is a method to feed pressurized water to the injector, make it mixed with sodium hypochlorite, and convey to the dosing point.

② The pump type is a type to transfer the liquid to the dosing point by various types of pumps etc.

③ The gravity flow type is a type to dose by potential head of a storage tank etc.

3) Dosing quantity

Dosing quantity is to be computed by the following formula multiplying the treatment flow with the dosing rate:

$$V=Q\times R\times 100/C\times 1/d\times 10^{-3}$$

V : Dosage (L/h)

Q : Treatment flow (m^3/h)

R : Dosing rate of chlorine (mg/L)

C : Effective chlorine concentration (%)

d : Specific gravity of sodium hypochlorite

4) Handling of the feeder

The feeder including a standby unit shall always be well prepared so that chlorine dosing is not interrupted.

(1) Confirmation of dosage

As to dosing of sodium hypochlorite, the condition of dosing shall be monitored and confirmed by residual chlorine concentration in treated water and working condition of the feeder; and, at the same time, the dosage shall precisely be corroborated from the actually measured value of dosage, and the difference between the liquid levels of the service tank and the storage tank.

(2) Points of attention for operation

① It is cautioned that oxygen gas generated by decomposition of sodium hypochlorite forms fine bubbles in the pipe easily causing hindrance in the suction side pipe of the pump and in the passage of inside of the feeder, so it will become the main cause of unstable dosing.

② As the phenomenon of the rise in oxygen gas is affected by the velocity and temperature of the liquid, occurrence of bubbles shall be monitored, and gas venting operation by a vacuum degassing device shall be carried out as needed.

③ In case the bubbles rise in a large quantity and degassing is insufficient, the cause of gas rising shall be investigated, and such necessary measure as improvement of the vacuum degassing device shall be implemented.

④ Since, if the hardness of injector water is high, it reacts with free alkali contained in sodium hypochlorite, and calcium carbonate etc. easily separates resulting in scaling around the dosing point, so inspection is needed.

⑤ In case sodium hypochlorite is dosed in its original solution, inspection is needed as scaling sticks around the dosing point.

⑥ In the case of the injector dosing type, as scale often develops at the exit of the injector, upstream section of dosing pipe, the bottom and bend of pipe, valves etc., inspection and upkeep shall be conducted.

⑦ As for the operation of the feeder, vacuum pressure and dosing pressure shall be monitored, the situation of scaling shall be checked at the time of unusual pressure.

⑧ The routine unit of feeder and piping and those of the standby unit shall periodically be put in operation by turns from the scaling removal point of view. Water shall be introduced to the derailed feeder and piping for a certain period of time to wash. In case there is no effect of washing, it is also successful to replace the piping etc.

⑨ In case the electromagnetic flow meter for measurement of the dosage is put out of service for a long time, water is always to be introduced and washed.

2. Dosing equipment of liquid chlorine

1) Method of dosing etc.

① As liquid chlorine evaporates with supply of heat through the outside surface of its container, the quantity of evaporation is 1 kg/hr or so for the 50 kg container, and 6 to 8 kg/hr or so for the 1 t container. Efforts shall be made that the temperature in the room of the chlorinator is to be maintained at higher than 15 to 20 degrees C. even in a cold season from the view point of evaporation of chlorine gas.

② The chlorine evaporator is in general used in case the use of chlorine is more than 20 kg/hr. An example of the chlorine evaporator is presented in Figure 7.9.6. An example of operation and handling of the chlorine evaporator is given in Table 7.9.7.

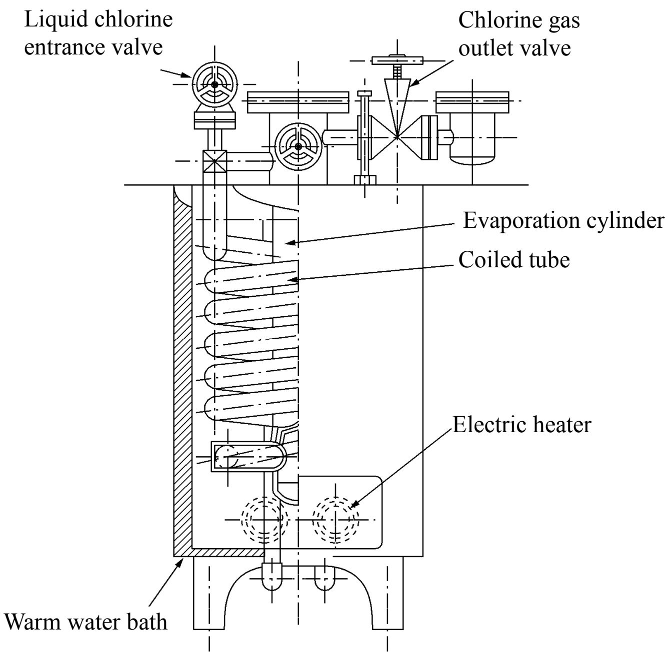


Figure 7.9.6 Example of a chlorine evaporator

Table 7.9.7 Example of operation and handling of the chlorine evaporator

	Operation	Function of evaporator	Point of attention
Start	1.To pour water in the bath	1.Water level is maintained at the low water level. 2.Indicator of water level gauge rises above red mark.	1.Attention for shortage in water 2.As scale deposit as aged, water is to be replaced every 3 months or so.
	2.Turning power on, water is heated.	1.Power is turned off by thermostat at temperature of 42 degrees C.	1.Setting of thermostat: 40 degrees C 2. Setting of thermometer: lower limit: 33 degrees C; upper limit: 50 degrees C.
	3.Openig liquid chlorine entrance valve, to introduce liquid chlorine	1. Liquid chlorine enters in evaporation cylinder through coiled tube. 2.Pressre gauge indicates gas pressure.	1.Attention to gas leak
	4.When heated up to 40 degrees C, to open gas outlet valve and supply gas.	1.Temperature is automatically controlled.	1. .Attention to chlorine gas leak 2.To slowly open outlet valve
Stop	1.As gas outlet valve is closed, gas is shut down.		1.When shutdown for short period of time 2.Not to close liquid chlorine entrance valve
	1.Power source is shut down.		1.In the case shutdown for a long time, inlet valve is closed and gas inside is removed, or if pressure of remaining gas becomes 0.05MPa, main valve of safety valve is closed. 2.If pressure of remaining gas becomes 0, outlet valve and main valve on pressure gauge is fully closed.

2) Dosing method

① The most commonly used chlorinator for water supply is the wet-vacuum type chlorinator which mixes chlorine gas with pressurized water by an injector.

② As, for measuring gaseous body, the temperature and pressure of the gas to be measured need to be maintained almost constant, it shall be considered that change in the room temperature is to be made as small as possible. Likewise, the pressure at the measurement section shall be controlled constant by the reduction valve and the vacuum control valve.

3) Dosage

Dosing quantity is to be computed by the following formula multiplying the treatment flow with the dosing rate:

$V = Q \times R \times 10^{-3}$

V : Dosage (kg/h)

Q : Treatment flow (m3/h)

R : Dosing rate of chlorine (mg/L)

4) Points of attention for operation of chlorinator

① Operation of the chlorinator is shown in Table 7.9.9. The chlorinator including a standby unit shall always be well prepared so that chlorine dosing is not interrupted.

Table 7.9.9 Operation of the chlorinator

	Operation	Movement of chlorinator	Points of attention
Start	1.To open water feed control valve	As pressurized water is fed to injector, vacuum develops.	To control water pressure as it indicates prescribed pressure.
	2.To open outlet valve	Vacuum pressure of vacuum control valve is activated.	
	3.To turn on power switch	Reduction valve heater is on	
	4.To open chlorine control valve	Vacuum, pressure in reduction valve activates.	
	5.To open main valve and auxiliary valve on container	Chlorine pressure gauge indicates chlorine gas pressure.	Chlorine leak is tested by ammonia.
	6.To adjust aperture of chlorine control valve	Dosage is indicated on flow rater	To confirm that heater is warming reduction valve
	7.To check chlorine gas pressure		
Stop	1.To close auxiliary valve (container's main valve when shutting down for a long time)	(to confirm) Chlorine gas pressure becomes zero.	
	2.To close chlorine control valve	Indicator of flow rater becomes zero.	Can be left closed preparing or operation for next time.
	3.Turn power switch off	Heater for reducer valve stops	
	4.To close outlet valve		
	5.To close water supply control valve		

② The chief person in charge (chief worker) shall be the one who has good knowledge of the functions of the chlorinator and the characteristics of chlorine gas; and shall be selected from those who have been engaged in handling of chlorine; or those who have finished a legal technical training course; and shall be assigned for security and inspection of facilities and equipment.

③ It is cautioned that, in case the dosage is smaller than the proper range of dosage, control of dosage becomes inaccurate.

④ It is noted that, if chlorine gas is at onetime used in a large amount, the surface of the container is frozen and the flow of chlorine gas reduces resulting in that dosing of prescribed quantity of chlorine becomes impossible.

⑤ Pressure and quantity of water required for mixing of chlorine depend on the type and capacity of the chlorinator. In case injection is made into a pressurized water main, water with double the pressure of the pressure of the main shall be fed.

⑥ For the chlorinator, direct heating shall be avoided, but indirect heating shall be applied.

⑦ As failures tend to happen at the times of start and stop due to the nature of the machine, short time intermittent operation shall be voided as much as possible.

7.9.6. Piping and other things

Piping for chlorine and sodium hypochlorite shall adequately be maintained lest leak occurs. Especially, the use of transparent pipe for visual observation of the condition of scaling and gas accumulation is effective. Besides, the piping shall be colored in different colors to avoid cross connection with other piping; and marking to clearly indicate the direction of flow shall be made and so forth.

7.9.7. Dosage control

As types of dosage control, there are manual control and automatic control. In manual control, the control valve etc. is operated manually while watching a dosage meter. In automatic control, control is automatically made in combination of such instrumentation apparatuses as the flow meter, controller, residual chlorine meter etc. In general, in automatic control, as the basic case, operation is made to directly control the dosage for the target value; and, as another case, the dosage is controlled for chlorine dosage and residual chlorine of water at the outlet of the clearwell as the target values and so forth. Unless such control is precisely made, the required dosage cannot be secured, so the characteristics of the respective types shall be understood so that accurate dosing can always be undertaken.

7.9.8. Safety equipment

1. Safety equipment for sodium hypochlorite

As sodium hypochlorite is highly alkaline and possesses an oxidative effect, the following matters shall be kept in mind at the time of its handling:

① At the time of its handling, sufficient ventilation shall be made, and respective proper protectors shall be worn to protect skin and mucous membranes.

② Workers shall well be informed about how to use the protector, the location of the water tap etc.

2. Safety equipment for chlorine

The facility, which handles liquid chlorine, shall possess all such safety equipment as safety tools, vibration detector, emergency isolation valves, chlorine leak detector etc. abiding by related laws, rules, standards and so on.

The location for storage of the safety tools shall be as close to the place as possible, where there is a risk of chlorine gas leak, where management is easy, and where they can be taken out without contact with chlorine gas at an emergency. Moreover, emergency lighting shall be provided so that emergency measures can be carried out even in the case of power failure.

The safety tools shall be kept in clean and good condition; such consumables as adsorption cans shall be inspected periodically or after use, and replaced or replenished; and at the same time training of the staff for wearing them shall be conducted for them to get accustomed to their use.

In addition, the experience of inspecting the protectors, replacing and refilling them following inspection, and training for wearing them shall be recorded and stored.

7.9.9. Response at the time of leak of chlorine

1. Measures at the time of leak of sodium hypochlorite

Waste liquid of sodium hypochlorite has high pH (higher than 12) and chlorine concentration, and will impose a large impact on environment. In case it sinks into the ground by a mistake, such measure as spraying sodium sulfite etc. and its treatment shall be entrusted to a specialized contractor.

In fear that the waste liquid is erroneously discharged outside, it is effective to make such a facility as a barrier wall everywhere.

Neutralization work as an emergency measure shall be undertaken with adequate attention to the following:

① At the time of liquid leak, after it is neutralized (dechlorination) by sodium sulfite etc., it shall be diluted by a lot of water. Its treatment shall be entrusted to a specialized contractor to make its pH higher than 5.8 and lower than 8.8, and residual chlorine less than the detection limit.

② Workers shall wear an appropriate protector and work paying careful attention. In case skin or clothes are contaminated, it shall quickly be cleaned with water and removed. If it gets in the eye, the eye shall be washed with a lot of water, and treated by a medical doctor.

③ In case the liquid is swallowed, cleaning shall immediately be made with water. Besides, although a doctor’s instruction shall be given, as an emergency measure, cleaning by a 30 to 50 g/L solution of sodium bicarbonate is to be performed, and then drinking a solution of 30 g magnesium sulfate and 10 g sodium bicarbonate in 250 mL water is said to be good.

④ Neutralization by a chemical shall be carried out in the following steps, and its effect shall be confirmed by residual chlorine and pH.

- After reducing the liquid in the tank as much as possible, and testing concentration of effective quantity of chlorine, sodium sulfite in 1.8 times that of effective chlorine is to be prepared.
- Making 5 percent solution of sodium sulfite as much as possible, it is to be slowly mixed with sodium hypochlorite; reaction takes place (reaction temperature: 30 to 40 degrees C.); the solution is to be diluted with water and neutralized by hydrochloric acid.
- Confirming neutralizing reaction by these methods of treatment, and testing residual chlorine and pH, the solution shall be diluted with water.

2. Measures at the time of leak of chlorine

At the time of leak of chlorine, necessary protectors shall be worn, and investigation and treatment shall be undertaken with very careful attention.

① At the time of leak of chlorine, although solutions of sodium hydroxide, soda ash, milk of lime, calcium hydroxide etc. are used for neutralization, sodium hydroxide solution is in general suitable.

② The neutralization device is a device to adequately neutralize leaking chlorine gas and exhaust gas of the storage tank, and discharge them to the atmosphere as harmless matter. As the neutralization capacity of the sodium hydroxide solution gradually diminishes as it reacts with chlorine, the concentration of the solution shall always be confirmed. When it becomes low, it shall quickly be replaced.

③ The volume of the sodium hydroxide solution to be stored is to be determined by the quantity of chlorine to be neutralized and the concentration of the solution.

④ Although, in general, sodium hydroxide solution is purchased in more than 45 percent concentration in many cases, if used in the original solution, as troubles arise in the separation of salt, crystal deposition at low temperature etc., it is needed to use it in dilution at 20 to 25 percent.

⑤ For small consumption with stock of less than 1,000 kg of liquid chlorine, although calcium hydroxide as the neutralizing agent is used in many cases, caution shall be made that, as calcium hydroxide tends to spatter around, dust goggles, a gas mask etc. shall be used lest it adversely affects the human body. In case calcium hydroxide is stored by bags, storage shall be made at a dry place as much as possible. When executing neutralization operation by calcium hydroxide, to uniformly spray a specified quantity of calcium hydroxide in as short time as possible, it is effective to employ a manual, pressurized, or motorized dispenser

⑥ When it is judged dangerous as gas leak is intense, the police station, fire department etc. shall quickly be informed, and nearby residents shall be publicized of the incidence so that they can evacuate to a safe place.

⑦ In case chlorine is leaking in liquid, the container shall be turned so that the leak point is set upward, and gas leaks instead of liquid. As chlorine gas becomes about 460 times (at 0 degrees C. and 1 atm) the volume of its liquid, the quantity of leak is much smaller. If the leaking hole is small, a specialty contractor shall quickly be requested to draw the liquid and empty the container.

⑧ When leak of chlorine gas from a 50 kg container cannot be stopped, the container shall be put in the hole dug in advance; covered by a sheet; further, filled with a lot of lime and earth; and dampen it lest the gas spills around. The work for solution thereafter shall be requested for a specialized contractor to treat it.

⑨ In the case of leak from the 1 t container, the storage tank, the dosing equipment etc., treatment work shall be undertaken after confirming if the neutralization device is working normally. Although the neutralization device usually starts automatically at the preset value of the leak sensor, in case it does not start automatically, it shall immediately be started in site operation so that efforts shall be made to neutralize gas, investigate on the leaking point, and emergency treatment shall be implemented.

7.9.10. Measures in abnormal cases

1. Response at the time of fire

When a fire breaks out at the store of liquid chlorine and sodium hypochlorite, in the chlorinator room or in their vicinity (the area which is affected by a fire), the fire department shall right away be informed; dosing shall be stopped; efforts shall be made to distinguish the fire; and the following measures shall be taken:

① In the case of liquid chlorine, the 50 kg container shall be moved to safe location where there is no effect of a fire. In the case of the 1 t container, the storage tank or the chlorinator, to prevent abnormal rise in pressure in these devices, chlorine in these devices shall be treated by the neutralization equipment; and at the same time efforts shall be made to cool down the site by pouring a lot of water from outside.

② In the case of sodium hypochlorite, the generation of such poisonous gas as chlorine gas, carbon monoxide, halogenated gas etc. is dangerous, it is needed to extinguish fire wearing a proper protector.

③ In case it is judged dangerous that the force of the fire is strong; chlorine gas is leaking; measures shall be taken in accordance with 7.9.9 2. Response at the time of leak of chlorine

2. Response at the time of earthquake

① At the time of an earthquake at the prerequisite magnitude (usually, higher than 4 of the Meteorological Agency’s seismic intensity), investigation of anomaly, damaged sections etc. inspection of facilities shall quickly be carried out so as to confirm and understand the situation.

② When an earthquake is detected, and it is judged from anomaly of monitoring apparatus and the status of the site that there is possibility of a disaster, the main valve of the container or the storage tank shall be closed.

③ In the case of liquid chlorine, after the tremor stops, immediately operating the neutralization equipment, while wearing or carrying a protector etc. to secure safety, inspection of equipment about whether or not it is leaking shall be implemented.

④ In the case of sodium hypochlorite, the liquid levels of the storage tank and the service tank, damage in the inside of the tanks and the piping and existence of leak shall be investigated. In case there are damaged positions in equipment etc., emergency repair shall be carried out.

⑤ When safety of the equipment is confirmed, dosing is to be resumed opening the valve which was closed.

3. Response at the time of power failure

In case there is no such standby unit of power source as an emergency power generator, if power failure occurs during the dosing equipment is in operation, power supply for the power system, instrumentation system and the control system is cut resulting in suspension of chlorine dosing. Therefore, in the case of dosing liquid chlorine, such measures for prevention of chlorine gas leak as the following shall be implemented:

① In the case of the wet vacuum type chlorinator, the pressure inside the equipment becomes positive; and the safety valve works resulting in discharge of chlorine gas to the inside of the room. Since the chlorine gas leak detector and the neutralization device cannot be used, the operator shall shut down the dosing equipment wearing a protector.

② In case power outage lasts for a long time, as there is a possibility of leak of liquid chlorine due to suspension of the function of the evaporator, the inlet valve on the evaporator and the outlet valve of the container shall be closed.

③ If the water feeding to the injector is done by a pumping system, as pressurized water becomes unavailable, steps shall be taken so that leak of chlorine does not occur in the chlorinator.

④ After recovery of power, in case manual operation is implemented, adequate attention shall be paid so as not to make a mistake in the operating procedure.

7.9.11. Sodium hypochlorite production equipment (Annotation omitted)

7.10. Chlorination equipment

7.10.1. General

The chlorine agent, in addition to its use as a disinfectant to be dosed in filtered water, it is used for treatment of bacteria, organisms, iron and manganese, ammoniac nitrogen, organic matters, taste and odor etc.

In the rapid sand filtration method, there are cases for chlorine to be dosed in the process prior to flocculation and sedimentation, and to be dosed in between the sedimentation basin and the filter. The former is called pre-chlorination, and the latter, intermediate chlorination.

To aim at the reduction in trihalomethanes and musty odor, intermediate chlorination, in which after trihalomethane precursors, musty odor producing blue-green algae etc. are removed as much as possible, chlorination is made, is superior to pre-chlorination.

Although pre-chlorination and intermediate chlorination are undertaken for the above purposes, as there are some case, in which sufficient effect cannot be obtained depending on the condition of water quality, their effect and characteristics shall adequately be confirmed when they are adopted.

In the slow sand filtration method, as the biological filter membrane, which possesses purifying function, bacteria in the sand layer etc. are damaged, pre-chlorination and intermediate chlorination are in general not implemented.

As to the dosing method, refer to 7.9.5 Dosing equipment.

7.10.2. Pre-chlorination

Pre-chlorination is a method to dose chlorine to the receiving well, rapid mixer etc. before the sedimentation basin, and secure time for contacting with chlorine.

1. Dosing rate of chlorine

Although the dosing rate of chlorine depends on raw water quality, the purpose of treatment etc., it shall be determined referring to the following:

① In case bacteria are the object of treatment, the dosing rate shall be set so that free residual chlorine to be retained in filtered water becomes 0.1 to 0.2 mg/L; and in case eradication and prevention of growth of organisms, and removal of manganese are the objects, so that it becomes 0.5 mg/L.

② Since the object of pre-chlorination is usually raw water containing ammoniac nitrogen in many cases, treatment shall be undertaken by break point chlorination. Chlorine is to be dosed at 10 times the contents of ammoniac nitrogen in raw water so as to maintain free residual chlorine in filtered water at 0.5 mg/L or so as a preliminary yardstick. In case the change in raw water quality, especially ammoniac nitrogen, is large, there is a control method to measure the residual chlorine after pre-chlorination by the automatic residual chlorine meter, and make the residual chlorine constant.

③ Consideration shall be given to the quantity of chlorine to be consumed in the flocculation basin and the sedimentation basin. As decomposition of chlorine is accelerated by direct sunlight, its consumption depends on the season, weather, and day or night.

④ In case powdered activated carbon (PAC) treatment is undertaken at the same time, 0.2 to 0.25 mg/L or so of chlorine is consumed per 1 mg/L of PAC.

⑤ In case filter cleaning waste water and waste water from wastewater treatment facilities are reused returning it to the receiving well, as the chlorine consumption may temporarily increase, its dosage rate shall be adjusted accordingly.

2. Points of attention for management of facilities and equipment

Although management of storage of chlorine agent, its dosing equipment and its neutralization device shall be carried out in accordance with 7.9 Disinfection Equipment, attention shall particularly be paid to the following:

① Since equipment etc. situated in and around the dosing point is corroded by chlorine gas, it shall be treated for corrosion-proofing and periodically inspected. Secondly, such concrete structures as the receiving well, and the flocculation basin and piping shall be applied with adequate corrosion-proofing, and periodically inspected.

② In case a house is built above the dosing point, sufficient ventilation shall be implemented.

7.10.3. Intermediate chlorination

Intermediate chlorination is a method to dose a chlorine agent between the sedimentation basin and the filter where good mixing is obtained. In this method, since a chlorine agent is dosed after trihalomethane precursors, musty odor causing blue-green algae etc. are removed in the sedimentation basin as much as possible, it is effective for containment of generation of trihalomethanes and as a measure against musty odor.

1. Dosing rate of chlorine agent

As for the dosing rate of a chlorine agent, refer to 7.10.2 Pre-chlorination.

2. Points of attention for management of facilities and equipment

As for points of attention for management of facilities and equipment, refer to 7.10.2 Pre-chlorination.

3. Effect of water quality improvement by intermediate chlorination

1) Reduction in formation of trihalomethanes

Changing pre-chlorination over to intermediate chlorination, the rate of reduction in the formation of trihalomethanes is reportedly 20 to 40 percent.

2) Reduction in odor causing substances

As odor causing substances, there are 2-Methylisoborneol (2-MIB) produced by such blue-green algae as Phormidium and Oscillatoria, and geosmin produced by such blue-green algae as Anabaena. Odor causing substances are contained in the body of algae, or in water which elutes from the body of algae.

There is an example that after removing algae, which contain odor causing substances in their body, by coagulation and sedimentation, and changing chlorination over to intermediate chlorination, the odor causing substances are removed by 25 to 90 percent.

4. Points of attention at the time of intermediate chlorination treatment

Changing pre-chlorination over to intermediate chlorination, as the algaecidal effect of pre-chlorination cannot be expected, algae may, at times, grow on walls of the sedimentation basin, sloping plates (tubes), collection troughs etc., or coagulation ability would be lowered.

7.10.4. Dechlorination

In case, after disinfection of a clearwell etc. with chlorine when it is built, water containing residual chlorine is discharged to a river etc., dechlorination shall be undertaken in consideration of influence to fish.

The concentration of residual chlorine shall be less than 0.1 mg/L when above water is discharged.

1. Method to use sodium thiosulfate

This is a dechlorination method by means of chemical reaction between sodium thiosulfate (commonly called "Hypo") and chlorine. The quantity of hypo required is 3.5 mg/L for 1 mg/L of chlorine. However, when pH of cleaning waste water is high, 0.9 mg/L of hypo will suffice for 1 mg/L of chlorine.

Hypo is usually used in 5 to 10 percent solution. It is cautioned that effect of this solution decline if stored for a long time.

2. Method to use sodium sulfite

This is a dechlorination method utilizing chemical reaction between sodium sulfite and chlorine. The quantity of sodium sulfite required is 1.8 mg/L for 1 mg/L of chlorine.

3. Method to use sulfurous acid gas

This is a dechlorination method applying chemical reaction between sulfurous acid gas and chlorine. The quantity of sulfurous acid gas required is 0.9 mg/L for 1 mg/L of chlorine.

In either method, consideration needs to be given to avoid overdose.

7.11. Aeration equipment

7.11.1. General

Aeration is employed to remove trichloroethylene, iron, odor, free carbonate etc. contained in groundwater. Making water to contact with air, volatile substances are removed by volatilization; and oxidizes soluble matters by oxygen in the air to make them easy to be removed. This method is often used for water supply facilities of which water source is groundwater or infiltrated water etc. containing a large amount of volatile chlorinated organic compounds and free carbonate.

1. Effect

① To remove free carbonate in water and raise pH.

② To remove volatile chlorinated organic compounds (trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane).

③ To feed oxygen from air to water so as to accelerate oxidation of iron.

7.11.2. Types of aeration

As the types of aeration, there are the fountain type, the packed tower type etc.

1. Operation

1) Fountain type

① In case a filter is not provided after the aeration equipment, a shed shall be built so as to prevent intrusion of dust, birds, insects etc.; ventilation holes with an opening area of 5 percent or more of the floor area shall be made at upper and lower positions of the walls; and mosquito nets with mesh of smaller than 1mm shall be set there.

② It is desirable to provide a shield to prevent growth of algae.

③ During operation of the fountain type, it is important for water to be uniformly sprayed so that the spray of water contact with air as much as possible; that the dynamic head at the spraying nozzle is 3 to 10 m or so.

④ During operation, spraying condition in the aeration room shall be monitored, and the delivery head of the pump for spraying shall be confirmed by a gauge.

2) Packed tower type

① Although the principle of aeration is to sufficiently make water to contact with air, as for operation of the packed tower type, since, if the air flow is excessively large, water does not flow down, but may overflow from the tower head as flooding phenomenon occurs, attention needs to be paid.

② It is said that the appropriate loading rate of water is larger than 4 $m^3/m^2/h$. For the operation of the packed tower type, the appropriate air flow velocity shall be about the loading rate or 50 to 75 percent of the flooding velocity.

③ The air-to-liquid ratio shall in general rule be determined based on the experimental data. It is extremely important to optimally control the supplied air flow for the given condition of the raw water quantity, raw water quality, target quality of treated water etc. Therefore, adequately referring to the experimental date obtained at the time of new construction, and the data based on the past experience, the rate of supplied air flow shall be determined; and a related manual is to be prepared.

④ In case air blowers are composed of a common use unit and a standby unit, they shall systematically be operated by turns to equalize their running time.

⑤ It is desirable to shield the inspection hole of packed materials to prevent the growth of algae.

⑥ Sufficient measures shall be provided against noise and vibration of blowers, sound of falling water etc.

⑦ In case the position of the treated water effluent pipe is too low, part of air for aeration may at times be entrained in treated water. As, in such a case, the air for aeration cannot only be fully utilized, but the withdrawal of treated water is obstructed, the position of the pipe shall properly be changed, or the method of withdrawal shall be modified.

⑧ Since it is presumed that the overflow pipe is clogged due to freeze of waterdrops, caution shall be paid in the region where freeze is apprehended.

2. Daily inspection

1) Fountain type

① The running condition (including electric current, delivery pressure) of the pump for fountain, existence of abnormal noise and vibration, and condition of spraying water shall be confirmed.

② Since the perforated pipe and nozzles are clogged by rust, iron bacteria, sulfur-reducing bacteria etc. and the efficiency drops at times due to uneven fountain, they shall be inspected, cleaned and repaired as needed.

2) Packed tower type

① Operating condition, existence of abnormal noise and vibration of the blower, and condition of falling water in the tower shall be confirmed.

② If a large amount of iron and manganese are contained in water, materials oxidized by aeration may stick to the packed materials. In case the degree of stain is heavy, the packed materials shall be taken out and cleaned. Moreover, the filter of the blower shall be inspected and kept up lest air flow diminishes due to its clogging.

3. Water quality test

① Since, in aeration, the removal function is stable insofar as the equipment is normally working and air-to-water contact is secured, water quality test can, in some cases, suffice to be conducted every month or so for each item of substances to be removed on raw water and treated water.

② In case removal of free carbonate is the purpose, as control is done by pH, a pH meter is to be installed on the aeration equipment to measure it continuously.

③ In case removal of such volatile organic matter as trichloroethylene is the purpose, such gas removal facility as activated carbon adsorption shall be installed as needed.

7.12. Activated carbon adsorption equipment

7.12.1. General

Activated carbon treatment is applied for removal of musty odor causing substances (2-MIB, geosmin etc.), anionic surfactants, phenols, trihalomethanes and their precursors, agricultural chemicals, such organic matters as trichloroethylene etc. which cannot be removed by the usual water treatment of coagulation, flocculation, sedimentation and sand filtration.

Activated carbon treatment is classified into PAC treatment, granular activated carbon (GAC) treatment, and biological activated carbon (BAC) treatment.

For PAC treatment, PAC, of which more than 90 percent passes 75 μm sieve, is used, and can be dosed in the existing facilities, so is suitable for emergency or temporary application.

For GAC treatment, GAC of controlled grain size of 0.3 to 2.4 mm is used; treatment is carried out with an exclusive adsorption tank; and it is used throughout the year or a relatively long time. There are a fixed bed type and a fluidized bed type in GAC treatment

For BAC treatment, in addition to the absorbing function of GAC, utilizing decomposing function of organic matters by microorganisms in the activated carbon layer, the adsorbing function of the activated carbon is further extended.

1. Materials of activated carbon

Materials of powdered activated carbon are mainly such woody materials as sawdust etc.; those of granular activated carbon are the coal family, the petroleum family and vegetable family. These materials are carbonized, and further activated.

2. Selection of activated carbon

As activated carbon possesses different specific absorbing characteristics depending on its type, absorbance tests etc. shall be conducted, and activated carbon suitable for objective substances to be treated shall be selected considering the nature of respective raw water.

Secondly, from hygienic point of view, activated carbon containing dissolved matters, which influence treated water, shall not be used.

The absorbing capacity is to be judged measuring the phenol number, the ABS number, methylene blue adsorbing potential, iodine adsorbing potential etc.

In the case of GAC, as it is used for a long time, consideration shall be paid to such a physical property as hardness etc.

[Reference 7.14] About phenol number, methylene blue adsorbing potential, and iodine adsorbing potential.

① Phenol number

The phenol number according to the standards of activated carbon stands for the quantity of activated carbon expressed in mg/L required to absorb phenol from a 100μg phenol solution and make the remaining quantity of phenol at 10μg/L. The smaller the number, the larger the absorbing potential.

② ABS number

The activated carbon standard ABS number denotes the quantity of activated carbon expressed in mg/L required to absorb ABS from a 5 mg/L ABS (anionic surfactant) solution and make the remaining quantity of ABS at 0.5 mg/L. The smaller the number, the larger the absorbing potential.

③ Methylene blue adsorbing potential

The activated carbon standard methylene blue adsorbing potential means the quantity of methylene blue expressed in mg/L which can be absorbed by 1 g of activated carbon. The larger the number, the larger the absorbing potential.

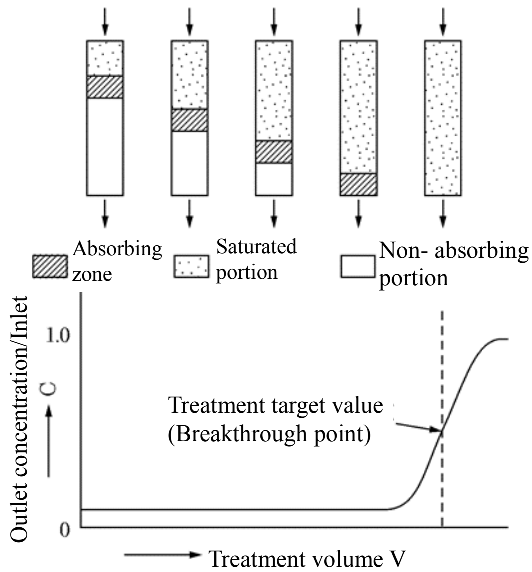
④ Iodine adsorbing potential

Iodine adsorbing potential, an activated carbon standard, stands for the quantity of iodine expressed in mg/g in the quantity of activated carbon (g) required to absorb iodine from a 0.05 mol/L iodine solution and make the remaining concentration of iodine at 2.5 g/L. The larger the number, the larger the absorbing potential.

As to the testing methods for the phenol number, the ABS number, methylene blue adsorbing potential, and iodine adsorbing potential, refer to JWWA K 113-2005 Powdered activated carbon for water supply etc.

[Reference 7.15] On breakthrough point

In the case of granular activated carbon, in the treatment process with a fixed bed and fluidized bed filled with activated carbon, good water can be obtained at the early stage of filtration. However, the treated water quality gradually becomes bad as the absorbing potential of activated carbon approaches its saturation as passing water continues. As treatment is continued under a certain condition, the point, at which remaining quantity of such objective substances as odor causing matters in treated water reaches the allowable value, is called the breakthrough point (See Reference Figure 7.1.1). The curve expressing the relationship between the concentration (C) in treated water and the treatment volume (V) is called the breakthrough curve.



Reference Figure 7.1.1 Development of absorbing zone and breakthrough curve

7.12.2. Powdered activated carbon adsorption equipment

Powdered activated carbon (PAC) adsorption treatment is usually applied to raw water prior to coagulation treatment, the activated carbon is removed by coagulation, sedimentation and filtration.

Although the characteristics and absorbing mechanism of PAC are as same as those of granular activated carbon, it is in general adopted for emergency or temporary use.

As the absorbing effect of PAC depends on the dosage rate, contact time, method of contact, type and quality of PAC, and objective substances in raw water, these items shall adequately be considered.

1. Dosing method

As the dosing point of PAC, although it is ideal if there is an exclusive contact tank, in case a contact tank is unavailable, the dosing point shall be such a location, where good mixing can be made, and prolonged contact time can be given as much as possible, as the intake pump well, grit chamber etc. of water intake facilities, raw water transmission main, raw water transmission tunnel etc. of raw water transmission facilities, or the receiving well, the rapid mixer etc. In the case of the suspended solid contact clarifier, it is an effective method to make PAC to contact and mix with slurry.

In case pre-chlorination and PAC treatment is simultaneously undertaken, effects of both pre-chlorination and PAC may at times be reduced; or the objective substances may not easily be absorbed by PAC as they react with chlorine.

Since the optimum pH for adsorption by activated carbon is generally in the acidic side, it is desirable for an alkaline agent to be dosed after dosing of activated carbon.

2. Method of dosing and dosing rate

As the method of dosing, there are the wet method to use carbon wetted by 50 percent of water, and the dry method to use dry carbon. In the wet method, mixing the wet carbon with water to make a slurry at specific concentration (2.5 to 5 percent: dry weight equivalent), it is dosed by an injector, pump etc. via a measurement device.

In the dry method, measuring dry carbon as it is by a powder measurement scale, and making a slurry in a mixing tank by mixing the carbon with water, it is dosed by an injector, pump etc.

Since the dosing rate differs depending on the type, concentration etc. of objective substances for treatment, the dosing rate shall be determined after studying the removal effect of the carbon by means of a jar test with the water to be treated. If a chart of correlation between the concentration of the objective substances to be removed and the optimum dosing rate is provided, quick response can be made.

The dosing rates usually used are the following:

① 10 to 30 mg/L in the case of removal of taste and odor (dry weight equivalent)

② 30 to 100 mg/L (do) in the case of removal of trihalomethanes precursors

③ 10 to 100 mg/L (do) in the case of removal of phenols

④ About 20 times the concentration of anionic surfactants for their removal

What is more, as activated carbon also absorbs other organic matters than the objective substances, it shall be taken into account when determining the dosing rate.

3. Points of attention on water treatment

1) Influence to coagulation, flocculation and filtration

Although dosed powdered activated carbon (PAC) is usually removed by coagulation, flocculation and filtration, as it is minute powder, it tends to break through the filter into filtered water at the times of its high dosage, and prolonged runtime of the rapid sand filter. Especially, as in winter with low water temperature, coagulation effect diminishes, leak of PAC shall be prevented by monitoring the existence of leak of PAC, control of the filtration rate, changing the coagulant dosage rate, and raising the effect of coagulation with application of coagulant aid.

The existence of leak of PAC in filtered water shall be confirmed under a 10-pwer microscope, and efforts shall be made for prevention of leak of PAC.

2) Consumption of chlorine

In case PAC and chlorine are simultaneously dosed, as 0.2 to 0.25 mg/L of chlorine is consumed for 1 mg/L of PAC, the dosage rate shall be adjusted so that the aimed residual chlorine is assured accordingly.

3) Influence to wastewater treatment and produced sludge cake

It is noted that although, if PAC is used, the dewaterbility of sludge produced in the water treatment processes generally become better, and useful for preventing odor, the sludge cake is colored black containing activated carbon, and its volume increases. Furthermore, the cake is utilized as soil for horticulture, consultation with the user shall be made in advance.

4. Storage etc. of powdered activated carbon

1) Storage quantity

The standard storage quantity of powdered activated carbon (PAC) shall be for the use of more than 20 days in the case of continuous dosing; and more than 10 days in case it is dosed as needed, so the storage quantity shall be determined by the used quantity, the period to be used and so forth.

Besides, in case the PAC, which has been stored for a long time (one year or so) is used, it shall be retested to confirm its condition and capacity, and the terms for its use shall be determined.

2) Inventory control

Although wet carbon is delivered and stored in bags (10 to 20 kg/bag or so) or container packs (100 to 500 kg/pack or so), they are needed to neatly be arranged in the store so that acceptance, transfer, unloading etc. can be smoothly handled, and used first from older ones.

In case dry carbon is stored in a tank, attention shall be paid to prevent absorbance of moisture and compaction.

3) Points of attention at the time of inspection of the storage tank

As PAC gradually absorbs oxygen in the air at the normal temperature, and there is a risk that deficiency of oxygen occurs in the tank, adequate attention shall be paid for ventilation of the tank at the time of inspection.

4) Measures against fire and dust

In the building (store room, store house and feeding room) or the storage tank, adequate attention shall be paid to handling of fire; and efforts shall be made to prevent a short-circuiting accident or burning by sparks of power equipment due to scatter of fine particles. Especially, control by complete sealing is needed for the dry carbon. When handling it, consideration shall be taken to environmental and hygienic aspects with provision of a dust collector and a dust protector. In addition, if PAC comes in contact with strong oxidant (chlorine, hydrogen peroxide, liquefied oxygen, ozone etc.), there is a risk of explosion to be caused by rapid oxidation, so attention shall be paid lest these chemicals contact with PAC.

5) Measures against corrosion and attrition

For sections in the storage tank, the slurry tank, the mixing tank (mixer and strainer), the dosing pump, piping, valves etc., which come in contact with PAC, materials with corrosion resistance and wear-proof property shall be used; and periodical inspection shall be conducted.

6) Actions to be taken after suspension of dosing

After suspension of dosing (during suspension) , the dosing pump, piping etc. shall be cleaned by clean water, and at the same time general inspection, and such maintenance as repair and improvement shall be carried out so as to prepare for the time of next restart.

5. Points of attention for facilities and equipment in regard to the work of dosing

1) Dosing equipment for wet type PAC

① As the container packs are in general piled up in two layers or so to be stored inside a building, they shall neatly be arranged and stored so that the work of moving or unpacking can smoothly be undertaken. Even in case they are temporarily placed outdoor unavoidably, attention shall be paid since the wet PAC solidifies if rainwater intrudes.

② Even the wet PAC scatters in fine particles during unpacking work, a dust collector shall be operated and workers shall wear a dust-proof work clothes.

③ PAC is often dosed intermittently or as an emergency measure. As such, after start of dosing, it shall be confirmed that dosing is normally carried out at the dosing point.

④ In case dosing of PAC is suspended leaving its slurry in the solution tank, the mixer of the tank shall as needed be operated during the suspension period so as to prevent solidification of PAC due to settling.

2) Dosing equipment of dry-type PAC

① In case dry PAC is stored in a silo, dry air needs to periodically be blown in to prevent moisture absorption and consolidation.

② Movements of the bridging breaker of the storage tank and the scale hopper shall be confirmed as needed so that the operation is not interrupted.

③ The inside of the scale hopper and the scale shall always be kept dry lest errors are brought about in the dosage due to adhesion of solidified powder.

④ In case dry PAC is dissolved to make slurry, the condition of falling PAC into the dissolving tank, mixing etc. shall as needed be confirmed so that resurfacing of PAC does not occur..

⑤ General points of attention at the time of start and stop of operation of the dry PAC dosing equipment shall be in conformity with those of wet PAC.

7.12.3. Granular activated carbon adsorption equipment

1. Fixed bed type adsorption equipment

The fixed bed type adsorption equipment has a similar structure as the normal rapid sand filter, and classified into the gravity type and pressurized type. Either crashed or molded type granular activated carbon (GAC) is applicable, and, many cases, used in the grain size of 0.4 to 2.4 mm in 1.5 to 3 m thick layer.

Since the filtration rate depends on the characteristics of the GAC, the type of objective substances to be removed, their concentration, it is to be determined by experiments. In the case of removal of taste and odor, it is run at the space velocity (SV) of 5 to 10h-1 or so in many cases. The SV is the quotient of the water volume passing filter layer per hour divided by the volume of the layer.

Since the head loss of the fixed type bed increase as turbid matters are trapped, the bed is cleaned. Caution shall be paid to the method of cleaning measures to prevent carryover of the GAC and so forth.

1) Operation and management

For operation of the adsorption tank, a table of operation and management plan shall be prepared. Designating the tanks for pause (replacing GAC), stand-by, and operation, the condition, under which the treatment flow can be dealt with, shall be maintained. The number of tanks to be operated shall be determined after confirming the SV

The effective time of the adsorption capacity depends on the concentration of objective substances for removal, it is important for treatment flow of respective adsorptions tank in the same block are uniformly distributed for averaging of adsorption by GAC. Therefore, understanding the hydraulic characteristics of the respective tanks at normal times, equalization of the load of treatment flow on the tanks shall be intended by adjusting the height of the inlet weirs depending on the case.

Secondly, confirmation of treated water quality needs to periodically be confirmed on the water quality items including objective substances to be removed. Especially, for daily Operation and management, attention shall be paid to turbidity, color, the quantity of leaking fine GAC particles (the number of leaking fine particles), existence of organisms etc.

2) Cleaning

The GAC bed is to periodically be cleaned when the head loss exceeds the preset value, or to prevent the growth of microorganisms in the GAC bed. Although the frequency of periodical cleaning is to be determined based on the condition of the drain of microorganisms and so on, it is carried out every 3 to 5 days. Suspended units of adsorption tanks (standby units) shall also be at a specific interval cleaned to prevent the growth of microorganisms at the lower section of the GAC bed, or restart of operation at an emergency.

Although, in case backwash is performed by water, the backwash rate needs to be adjusted since the viscosity of water depends on water temperature, backwash is, for an example, conducted at 30 to 40 percent of an expansion ratio, and for 10 to 20 min. of duration.

Moreover, in case air wash is used as a supplement to backwash with water, it is cautioned that air wash becomes a cause of the attrition of grains of GAC, their spill, and a biased flow due to remaining air.

To prevent drain of fine particles of GAC in filtered water after restart of filtration, filtered water shall be drained for a specific period of time.

Right after the GAC is laid in the basin, initial cleaning shall be conducted to remove fine particles of GAC and impurities.

3) Management of GAC

GAC shall be managed in that a record book is to be prepared to record the initial grain size (effective size and uniformity coefficient), bed depth, physical properties, values of adsorption capacity, the name of manufacturer, the number of times of regeneration etc.

The study on adsorption capacity shall periodically be carried out, and its result shall be reflected to the plan for regeneration and replacement of GAC.

4) Replacement of GAC

GAC shall be replaced with new or regenerated GAC when it has reached the breakthrough point. As for replacement of GAC, although there are choices between regeneration of spent GAC or purchase of new GAC, in the case of regeneration, it shall be decided in consideration of the condition of recovery of adsorption capacity, such physical properties as hardness, economic advantage etc. As replacement work is conducted while the adsorption tank is suspended, it shall systematically be undertaken in consideration of the plan for annual water treatment.

In case loading and unloading of GAC are carried out making GAC slurry, if the velocity is large, GAC will be warn away; if the velocity drops, it may clog the pipe. As such, the concentration of slurry shall be less than 20 percent; and the velocity in the pipe shall be in the range of 1 to 2 m/s.

In case a new GAC adsorption tank is started, or a tank with replaced with regenerated GAC, sufficient cleaning shall be conducted to prevent drain of fine particles of GAC in treated water. Attention shall be paid that pH is often high due to ash components to be left in the process of carbonization.

At the time of initial cleaning, attention shall be paid so as not to make the expanded surface of the GAC bed to excessively rise and GAC overflow onto the troughs. After initial cleaning, the water quality (turbidity, color etc.) of filter drain water shall be confirmed and the operation shall be switched to normal treatment.

5) Daily inspection

As to Operation and management of adsorption tanks, in addition to confirmation if the treatment flows on respective tanks are uniformly distributed, the condition of the water level, water quality etc. of respective tanks shall periodically be confirmed. In case the interface of GAC can be observed, management shall be made recording the undulation of the interface of the GAC bed and the condition of trapping (See Table 7.12.2). Other aspects on management shall be in conformity with 7.6 Rapid sand filter.

Table 7.12.2 Example of points of inspection of fixed type bed adsorption equipment

Facility	Daily inspection		Periodic inspection		Detailed inspection (upkeep)	
Adsorption tank	Cycle	Inspection contents	Cycle	Inspection contents	Cycle	Inspection contents
	Daily	1.To confirm water level	1 mon. to 1 year	1.To test deterioration of adsorption capacity etc.	3 mon. to 5 years	1.Regeneration of GAC and its replenishment
	Daily	2.To confirm space velocity (SV) and head loss	1 year	2.To check physical property of GAC	1 years	2.Cleaning of inside of the tank
	Daily	3.To confirm quality of treated water (pH, existence of microorganisms)	1 year	3.To check thickness of GAC bed	5 years	3.Repaint of inside wall of steel tank
			1 year	4.To check position (open/closed) of inlet valves and gates		
			1 year	5.To check air-tightness of lid		
			6 months.	6.Condition of accretions on walls, troughs etc.		
			1 year	7.Cracks on structures, deterioration in inside water-proofing and concrete, and existence of water leak		
			1 to 5 years	8.Study on condition of underdrain system		
			Inspection and upkeep of air source; maintenance of flow meter, pressure gauge etc.; Inspection and upkeep of pumps for cleaning			

6) Periodic inspection etc.

For the GAC adsorption tank, deterioration of inside concrete etc. and condition of water leak of the tank shall periodically be inspected every year; foreign matters in the tank shall be removed and so on.

Furthermore, in such occasion for the adsorption tank is emptied as the time of replacement of GAC, inspection shall be conducted on the condition of the GAC bed, the underdrain system, attrition and deterioration of concrete surface of the collection conduit etc., corrosion of piping, balance of air blow equipment and so forth; and such measures as repair shall be implemented as needed.

At the occasion of entering the adsorption tank, paying attention to residual ozone and deficiency in oxygen, and applying adequate ventilation, safety check shall be made by means of measurement of oxygen concentration and residual ozone concentration.

If the operation of an adsorption tank is suspended for a long time at the time of high water temperature, the GAC bed will become anaerobic, and ammoniac nitrogen may be produced by reduction. Therefore, the concentration of ammoniac nitrogen shall also be monitored when cleaning the GAC bed at the time of restart.

2. Fluidized bed type adsorption equipment

Fluidized bed type adsorption is a method to fluidize the GAC bed by conducting objective water for treatment upward through the layer of GAC placed on a flow-uniforming floor, and can reduce the number of cleaning compared with the fixed bed type.

GAC with the grain size of 0.3 to 0.9 mm and the uniformity coefficient of 1.5 to 2.1 or so and as high hardness as possible shall be used. The employed SV is 4 to 15hr-1.

Although the head loss in the fluidized bed type is small compared with

the fixed bed type, as finer grain size of GAC is used, attention shall be paid to the range of the change in treatment flow, the grain size distribution of GAC etc. from the view point of preventing runoff of GAC.

1) Operation and management

During normal operation, it shall be confirmed that the treatment flow is uniformly distributed to respective tanks, and at the same time attention shall be paid to maintain the interface of the fluidized bed at the preset level.

In case the interface abnormally rises, since there is a risk for GAC to carry over, its cause shall quickly be investigated so that an appropriate measure is taken.

Besides, even if the level of the interface is within the preset value, in case such abnormal movements of the interface as large waving are observed, as there is possibility of biased flow due to a defect in the flow-uniforming floor and so on, caution shall also be paid to the movements of the interface.

As to replacement and regeneration of GAC, the point of time, when the removal status of objective substances to be removed reaches the control target value, is defined as the breaking point; and then replacement and regeneration shall be undertaken at that point.

What is more, there are examples of water utilities which apply a method of periodically replacing GAC by 20 percent of the bed volume every year.

2) Method of operation

Operation of the adsorption tank consists of the seven processes of GAC loading process, loading adjustment process, initial cleaning, normal running process, unloading, cleaning of the flow-uniforming floor (sand), and shutdown.

(1) Processes of loading and loading adjustment

In the loading process, after cleaning of the flow-uniforming floor, new GAC or regenerated GAC is loaded from the scale in slurry, and transfer of GAC is conducted by pumping or pressurized conveyance by a pressure tank.

Secondly, in the loading adjustment process, after cleaning of the flow-uniforming floor, to level the surface of the GAC, the bed is fluidized by a linier velocity (LV) of 15 m/hr or so. This LV is the value of the treatment flow divided by the area of the adsorption tank floor, which is equivalent to the filtration rate.

(2) Initial cleaning process

Since the loaded new GAC or regenerated GAC are mixed with fine particles of GAC during the activation process and transportation, the portion of the grain size of smaller than 210μm or so shall be removed by cleaning.

For cleaning, caution shall be given not to make loaded GAC to run off, and at the same time, as the rate of expansion largely depends on water temperature, the LV needs to properly be adjusted. In the case of water temperature of 5 degrees C. or so, the maximum LV is 21 to 22 m/hr; and at water temperature of 20 degrees C., it is 28 to 29 m/hr (See Figure 7.12.1).

Device 80 ϕ Fluidized column
Tested GAC GAC regenerated at Kashiwai water treatment plant
Loading Approximately 1 m

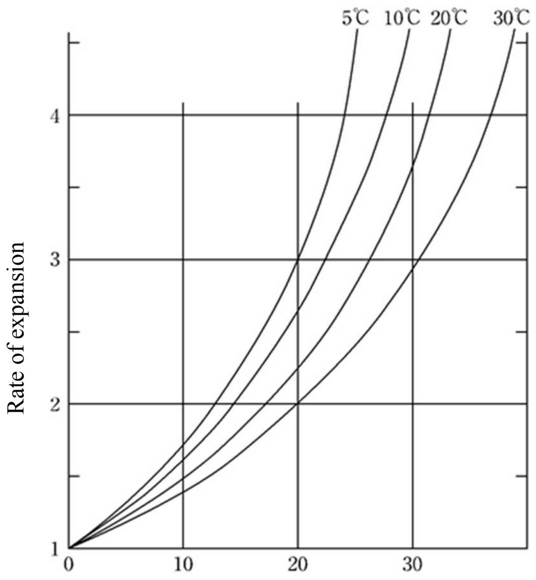


Figure 7.12.1 Water temperature, linier velocity and rate of expansion of regenerated GAC

(3) Normal running process

The LV is to be set at 10 to 15 m/hr or so.

(4) Unloading process

This is a process to fluidize the spent GAC by backwash into slurry (slurry concentration: 20 percent), unload it by an injector, and transfer it to a regeneration facility, so the fluidization LV (15 m/hr) needs to be maintained.

(5) Flow-uniforming floor cleaning process

Although after finishing unloading of GAC, the flow-uniforming floor is cleaned, the cleaning, which takes about two hours, will not be effective unless the linier velocity (LV) is as high as 40 m/hr or so.

3) Daily inspection

It is inspected whether or not crashed fine component of GAC is surfacing and carrying over. For other aspects, refer to 7.12.3 1. Fixed bed type adsorption equipment.

4) Periodic inspection

As for periodic inspection, refer to 7.12.3 1. Fixed bed type adsorption equipment.

3. Regeneration of GAC etc.

In case the absorbing capacity of GAC drops as its use continues and reaches the breakthrough point, the absorbing capacity needs to be recovered by some method. As the method to recover it, there are regeneration of the spent GAC, replacement with new GAC and so on.

1) Regeneration of GAC

After scaling, cleaning and drying (dehydration), GAC is processed by desorption of absorbed matters, carbonization and activation. There are cases of in-house regeneration to be implemented by a water utility; and entrusted regeneration by a specialized contractor.

In general, the attrition rate by regeneration is said to be 5 to 10 percent. The reduced amount is to be supplemented by new GAC.

In addition, as to regenerated GAC, the recovery of its absorbing capacity, such physical property as hardness shall be managed and, if the decline in the capacity is remarkable, it shall be replaced with new one.

2) Replacement of GAC with a new one

In case the absorbing capacity of regenerated GAC is not sufficiently recovered by repeated regeneration, or such physical property as hardness drops, or replacement is judged more economical than regeneration, GAC shall be replaced with new one.

Besides, there is an example for spent GAC to be utilized by processing it as a horticulture use.

7.12.4. Biological activated carbon adsorption equipment

1. Biological activated carbon treatment

Biological activated carbon (BAC) treatment is a treatment method to apply decomposition of organic matters produced in a biological membrane on the surface of GAC, and adsorption, which is taking place in micro pores inside the GAC. The long-lasting adsorption is regarded as a result of biological regeneration of GAC.

In the meantime, supply of nutrients required for growth of microorganisms is the condition for biological decomposition.

In this method, the optimum water temperature for microorganisms concerned with aerobic treatment to efficiently work is 20 to 30 degrees C., so, if temperature drops, treatment efficiency becomes low.

By applying ozonation before BAC treatment, organic matters, which are hardly biologically decomposable, can be converted to be decomposable, and at the same time the concentration of dissolved oxygen required for the activity of microorganisms can be increased.

Respective flow diagrams of BAC treatment are presented in Figure 7.12.2, and flow diagrams of actual advanced water treatment facilities are given in Figure 7.12.3.

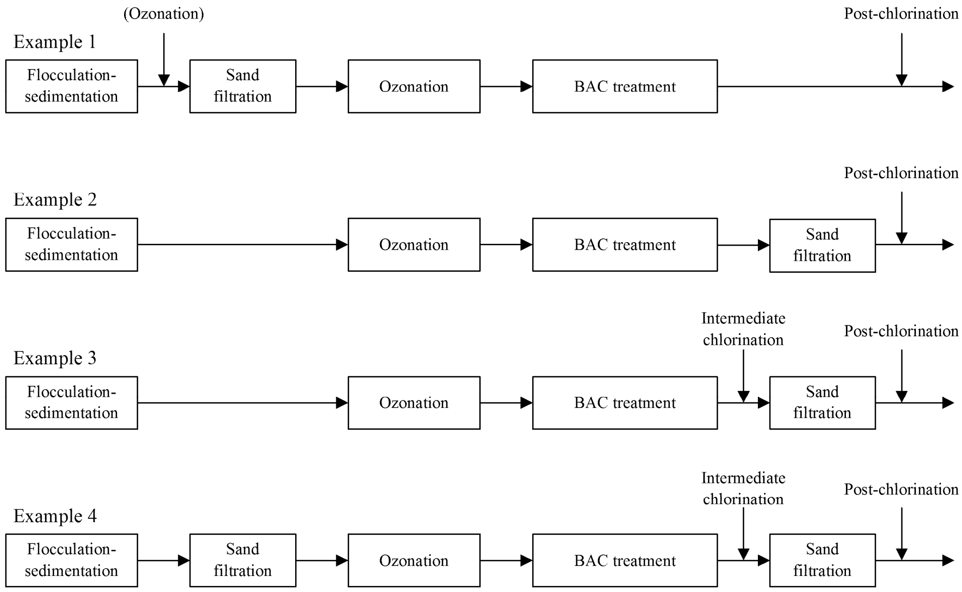


Figure 7.12.2 Flow diagrams of BAC treatment

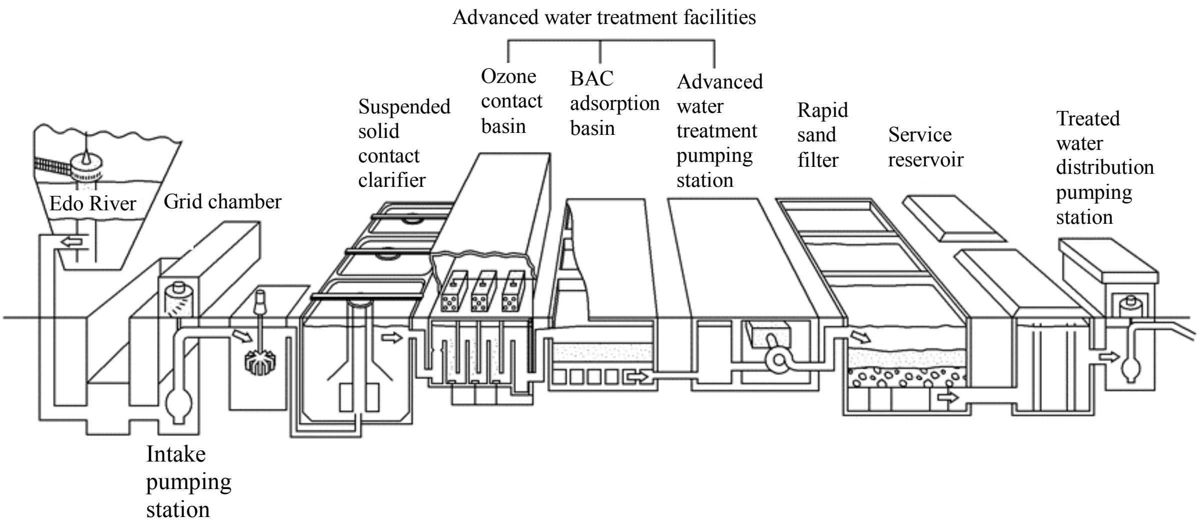


Figure 7.12.3 Flow diagrams of actual advanced water treatment facilities (Kanamachi water treatment plant, Tokyo Metropolitan Waterworks Bureau)

2. Quality and selection of GAC

Since the characteristics of GAC depend on the raw materials, the method of manufacture and shape, in case it is used as BAC, GAC, which is suitable for objective substances to be removed in consideration of its absorbing property and the growth of organisms, needs to be selected. Therefore, it is desirable to decide after conducting experiments of removal of substances to be removed.

Although the finer the grain size of GAC, the larger the absorption capacity per unit volume, the size needs to be determined in adequate consideration of resistance of passing water when it forms the GAC bed.

In the case of the fluidized bed, the uniformity of grain of GAC, its density etc. shall especially be noted.

3. Method of contact

As the method of making GAC to contact with water, there are the fixed bed type and the fluidized bed type, their structure, thickness of GAC bed etc. shall be in conformity with the granular activated carbon adsorption equipment (See 7.12.3 Granular activated carbon adsorption equipment.).

1) Fixed bed type

As the fixed bed type biological activated carbon (BAC) adsorption tank is in use, resistance of passing water increases, and such small animals as nematodes and rotifers grow, periodic cleaning with treated water is needed. Normally cleaning is conducted every 3 to 4 days or so.

GAC with the effective diameter of 0.4 to 2.4 mm and the uniformity coefficient of 1.3 to 2.1 or so is often used.

2) Fluidized bed type

Although the biological layer is always renewed by movement of GAC, so stable treatment effect can be expected, attention needs to be paid to strength, abrasiveness and fluidity of GAC.

The upward flow velocity is to be normally 10 to 15 m/hr. When restarting a fluidized bed, which has been suspended, or increasing the upward flow velocity, the velocity needs to gradually be increased since, if it is done abruptly, the interface of the fluidized bed is disturbed and GAC surfaces resulting in its drain.

GAC shall be cleaned with water and air, and stable fluidized bed needs to be maintained.

As GAC must uniformly be fluidized, GAC with an effective diameter of 0.3 to 0.9 mm and uniformity coefficient of 1.4 to 2.1 or so shaped almost sphere and as hard as possible shall be used.

Besides, a type of GAC, of which density does not largely change when it becomes BAC, shall be selected.

4. Points of attention for operation

1) Initial status

Although time required for BAC becomes stable after start of operation depends on water temperature, the type and concentration of nutrients to be used by microorganisms, the number and type of bacteria in incoming water, the method and frequency of cleaning etc., it is 20 to 30 days in general. It shall be controlled by predicting the status of biological activation in terms of nitrification of ammoniac nitrogen and so forth.

In case activated carbon treatment is the final step of water treatment, the system shall be managed paying attention to contamination of treated water from outside (dust etc.)

2) Contact time

Although according to experiences in Japan, contact time is 6 to 12 min. for the fixed bad, and 4 to 15 min. for the fluidized bed, it is desirable to confirm it by experiments etc. in advance.

3) Cleaning of the biological activated carbon adsorption tank

Although, for the activated carbon bed, the interval of its cleaning is set based on the indicators of head loss and the quality of treated water, at times microorganisms grow and animalcules propagate, which may break through the bed at times.

Given this, cleaning shall be carried out in consideration of the life cycle of these animalcules as well.

Although air wash to supplement backwash has the problems of spill over and attrition of activated carbon grains, and biased flow due to retained air bubbles, its effect of cleaning is large as the shearing force given between activated carbon grains is strong, so it is effective in case only backwash is insufficient.

A proper interval of cleaning, water flow and air flow need to be set in consideration that cleaning effect depends on water temperature and atmospheric temperature.

In the fluidized bed type, cleaning to timely be executed during adsorption operation is effective for removing accretions on the flow-uniforming floor and GAC.

If cracks develop in the underdrain system etc., air for cleaning will intensively leak from there causing spill-over of GAC, so periodical inspection is needed.

4) Life and regeneration of GAC

The absorbing capacity of GAC not only depends on the type of GAC and substances to be removed but also temperature, pH or coexisting matters of raw water. What is more, the activity of microorganisms in the GAC bed has not fully been elucidated. Accordingly, the timing for regeneration and replacement of GAC needs to be determined based on grasp and examination of changes on standing of the removal ratio of such objective substances for removal as trihalomethane precursors, ozonation byproducts etc. or UV260 absorbance in place of them and so on.

5. Water quality management

1) Grasp of goals for water quality

The goals for water quality shall be set in the course of day-to-day water quality analyses on influent and effluent water of the GAC bed and, in addition, such water quality testing apparatus as an ammonia meter, UV meter etc. shall be utilized as regular monitoring.

2) Effect of backwash

For grasp of the effect of backwash of the GAC bed of the fixed bed type, recovery of head loss after cleaning is an indicator. Secondly, the effect of backwash can also comprehended by breakthrough of turbidity matters and animalcules, the situation of turbidity matters in the GAC bed etc. so that efforts are to be made to carry out appropriate cleaning.

3) Others

As to breakthrough of animalcules, biological tests of treated water shall periodically be implemented; and, especially, the condition of such animalcules as nematodes and rotifers etc. shall be understood.

6. Management of ancillary equipment

As ancillary equipment, there are various monitoring apparatuses (water quality testing apparatus, level gauge, flow meter, warning devices etc.). For some facilities, management of a backwash pump, air blower for air wash, chlorination tank, flocculation basin, sedimentation basin etc. is needed. Standards for the respective equipment shall be provided, and periodic inspection, adjustment, repair etc. shall be executed. At the time of inspection of respective equipment, their respective standby units shall be used.

Furthermore, inspection of such deterioration phenomenon as impairment of concrete of respective facilities is needed.

7.13. Ozonation equipment

7.13.1. General

Ozone is an isotope of oxygen composed of three oxygen atoms forming a compound O3, and its oxidizability is stronger than chlorine.

The purpose of ozonation is to remove musty odor causing substances (2-MIB, geosmin etc.), color derived from humic substances etc., or odor of phenols, of which odor is increased by chlorine.

In addition, ozonation increases the biodegradability of non-biodegradable organic matters, and is also effective to make the treatability of ensuing biological activated carbon (BAC) treatment.

Since ozone reacts with organic matters and produces byproducts, installation of GAC treatment equipment after the ozonation equipment is obligated under the Technical Standards of the Ministry Ordinance.

Besides, in case there are bromide ions in raw water, bromic acid is produced. Production of bromic acid is affected by concentration of bromide ions in raw water, ozone dosage, water temperature, concentration of coexisting substances (ammoniac nitrogen and organic matters), pH etc. Hence, such control of ozone dosage as to avoid excessive dosage is needed to suppress production of bromic acid.

Dissolved ozone has tendency to start oxidizing reaction over time, and its concentration is going to decline while it is behaving autolysis. Time of autolysis is quicker as much as water temperature is high and pH is high.

Ozone, if released in the atmosphere, exerts very strong stimulant action on mucous membranes, and, since its effect become apparent on the bronchiole, alveoli etc. and causes pulmonary emphysema and so forth depending on its concentration, so as it causes adverse effect to health, it shall properly be treated.

7.13.2. Dosing of ozone (Annotation omitted)

7.13.3. Ozonation equipment

The ozonation equipment commonly used in water treatment plants utilizing air as its raw material is composed of the source gas equipment, the ozone generator, contact tank and the spent ozone treatment equipment. As ozone generation is in general made by the silent discharge method, to continuously generate ozone in stable concentration, power input to the generator, cooling water temperature, volume and pressure of source air, condition (oxygen concentration, humidity, impurities etc.) of the source air etc. shall properly be controlled.

1. Spent ozone treatment equipment

Although it is difficult to completely consume all ozone at the contact tank, it is needed to avoid to release residual ozone to the atmosphere.

As treatment method of spent ozone, there are the activated carbon decomposition method, the catalyst decomposition method, and their combination method. In general, the contact decomposition method is used for treatment of spent ozone from the contact tank as its concentration is high; and the activated carbon decomposition method is employed for it from the upper section of the BAC tank etc. as its concentration is low.

The acceptable concentration of photochemical oxidant including ozone in labor environment is set at less than 0.1 ppm in 8-hour average.

① During treatment of spent ozone, temperature inside the spent ozone adsorption tower and the concentration of exhaust gas are to be measured.

② In the activated carbon decomposition method, as carbon monoxide is produced by reaction with ozone, attention shall be paid to ventilation.

③ In case ozone in high concentration is treated by the activated carbon decomposition method, as there is a possibility that activated carbon may burn or explode, attention shall be paid.

④ In the catalyst decomposition method, such control is desirable as that, to secure the vitality of the catalyst, its moisture is to be removed by a mist separator, and the equipment is to quickly be heated in combination with a heater for starting the operation.

2. Safety and security equipment

As ozone possesses strong oxidizability, and high tension electricity is used for its generation, such safety measures as safety tools and emergency tools are needed against human casualties, fire, an electric accident etc.

In the ozone generator room, concentration of ozone shall continuously be measured, and efforts shall be made to early find the leak of ozone.

At the time of inspection of the inside of the contact tank, the concentration of ozone shall be measured, ventilation shall be made, and adequate attention shall be paid to such safety of work as that a portable gas detector etc. is to be provided

3. Daily inspection

In daily inspection of the ozonation equipment, it is important to pay attention in that aspects related to operation and management of respective treatment processes are properly maintained.

What is more, as ozone has strong oxidizability, water-proof coating and metal components of the ozonation equipment are easily oxidized and impaired.

In its daily inspection, attention shall be paid to such anomaly as deterioration of equipment etc. as well as leak of ozone.

7.14. Biological treatment equipment

7.14.1. General

Biological treatment means a treatment method to purify raw water by oxidation and decomposing function of microorganisms; and there are biological contact filter, the immerging filter bed (honeycomb type), the rotating disk type etc.

1. Treatment effect

Biological treatment is effective for removal of ammoniac nitrogen, musty odor causing substances, iron, manganese, anionic surfactant etc.

2. Characteristics

1) Operability

Although, as to its treatability, its artificial control is difficult as treatment largely depend on the vitality of the microorganisms, there is little need to frequently change the operating conditions once proper operating condition can be established.

2) Formation of biological membrane (biofilm)

To newly form biofilm and obtain definite treatment effect, it takes 2 to 3 weeks in a season of high water temperature, and 1 to 2 months or so in a low season.

7.14.2. Biological contact filter (Annotation omitted)

7.14.3. Immerging filter bed (honeycomb type) (Annotation omitted)

7.14.4. Rotating disk type (Annotation omitted)

7.15. Iron and manganese removal equipment

7.15.1. General

If a lot of iron is contained in tap water, its appearance becomes as unusual as colored in red etc. and it not only gives such obnoxious taste and odor as a metallic taste, but becomes a cause to stain clothes in brown. Besides, water containing iron nurtures growth of iron bacteria, and causes troubles in the water service system. Therefore, iron removal treatment is needed in these cases.

On the other hand, manganese becomes color of 300 to 400 times of its quantity by free residual chlorine, which at times brings about a so-to-speak black water trouble. Secondly, minute black oxide of manganese accumulates in water service fittings, and becomes a cause of turbid water. As such, it is desirable for contents of manganese to meet the target value (0.01 mg/L or less) prescribed as the water quality control target setting items.

What becomes a problem in water treatment is soluble bivalent manganese, which, if oxidized in water, becomes black, and, if coexisting with iron, extremely strongly develops color. Although this color does not appear in case it naturally exists in water, it develops color as, when chlorine is added for disinfection, it is oxidized in water distribution mains etc.

In ordinary water treatment, manganese passes water treatment processes as manganese ion without conversion to an insoluble form. Thus, in case the trouble of manganese affects up to water service systems, manganese removal is needed.

Besides, although the status of iron in surface water and groundwater is different from that of manganese, so the treatment method suitable to the status is to be applied, as both of them coexist in many cases, their treatment shall be carried out in consideration of such a condition.

7.15.2. Iron removal equipment

Aeration is useful for removal of iron dissolved in the form of ferrous bicarbonate $Fe(HCO_3)_2$ which is often seen in groundwater. Ferrous carbonate $FeCO_3$ in water is oxidized to insoluble ferric hydroxide $Fe(OH)_3$, precipitated and filtered. Furthermore, free carbonate, hydrogen sulfide etc. can also be removed at the same time.

Secondly, the favorable conditions for aeration are that pH is relatively high (8.5 or so), that iron exists in the form of ferrous bicarbonate (not an organic iron compound in a colloidal form), and that the concentration of dissolved silicic acid in water is less than 30 mg/L. In case this condition is not met, a treatment method by pre-chlorination etc. shall be used (See 7.11 Aeration equipment).

7.15.3. Manganese removal equipment

The manganese removal equipment is a removal method to make dissolved manganese existing in such natural environment as groundwater, river water, lake and impounding reservoir insoluble manganese.

1. Method by contact filtration

1) Removal by means of manganese sand

In this method, after raw water or settled water containing manganese ions is treated by pre-chlorination, it is filtered in a filter with filter medium of manganese sand, manganese is removed by contact oxidation. This method is suitable for such water with a little turbidity containing manganese as groundwater.

2) Removal by two-step filtration

As this method is suitable in case a lot of iron coexists with manganese, dosing a chlorine agent to raw water, large part of iron is removed through the primary stage filter by the catalysis function of iron hydroxide separated in the sand layer. Thereafter, manganese and residual iron oxidized and removed in the secondary filter (manganese sand).

2. Removal method with oxidation by chemicals

1) Removal by chlorination

Oxidation of manganese by a chlorine agent hardly takes place under pH value at lower than 9 in theory. Accordingly, pH needs to be raised higher than 9 by an alkaline agent to efficiently oxidize manganese in water.

2) Removal by ozonation

3) Removal by potassium permanganate

7.15.4. Utilization of iron bacteria

In this method, iron and manganese in water are removed using a slow sand filter utilizing iron bacteria. This method is used by a small-scale water treatment plant of which raw water is groundwater, spring water or infiltrated water with little change in its quality and suitable for growth of iron bacteria; and its operation and maintenance are easy. Likewise, even if the quantities of iron and manganese in raw water change certain extent, the treated water is stable, and ammoniac nitrogen in low concentration can also be removed. However, it is desirable that raw water does not contain such substances as heavy metals, organic chlorinated compounds etc. Hence periodic confirmation of raw water quality is needed.

In case the filter is clogged due to excessive growth of iron bacteria, the function of the filter can be recovered by scraping iron bacteria on the surface of the filter. Once iron bacteria grow, the filter layer with the bacteria will soon regain its function even if almost all of the bacteria layer is scraped. It is good practice to waste filtered water for 30 minutes to 1 hour after scraping.

7.16. Removal of organisms

7.16.1. General

As troubles which are caused by organisms and affect water treatment, there are troubled coagulation, clogged filters, breakthrough of organisms in filtered water, taste and odor, red water etc.

The causes of these troubles include phytoplankton, which extensively grow in an impounding reservoir and lakes, and exfoliation of algae and aquatic animals sticking on stones in river bed, walls of raw water transmission conduits, sedimentation basins, filters etc.

Likewise, in the case of groundwater, red water and bacterial cells caused by growth of iron bacteria may drain.

It is desirable that prevention of these biological troubles is carried out in the objective watershed of the water source where the organisms in question grow. However, in cases the organisms cannot be removed in the watershed, or even if preventive measures are undertaken, troubles are brought about in water treatment, countermeasures need to be implemented at the water treatment facilities.

In general, phytoplankton can be removed 80 to 90 percent by coagulation and sedimentation. Nonetheless, in case such plankton, which are difficult to be coagulated and settled, as Synedra, Melosira, Aulacoseira, Microcystis etc. grow in a large number, or even if 80 to 90 percent of them are removed, as the growth of phytoplankton is too intensive, a lot of algae still stay behind, there will be such an obstacles as their leak to filtered water.

As the method to remove organisms, there are a method to use chemicals and the one to install a removal equipment.

7.16.2. Removal by chemicals

1. Chemicals used

Although chemicals used for the removal of organisms is rightfully good if they are cheap and effective in small quantity, they need to be what do not adversely affect men and cattle and fish.

The chemicals used at present are chlorine agents (chlorine, sodium hypochlorite, calcium hypochlorite), copper sulfate etc.

7.16.3. Organism removal equipment

1. Microstrainer

Although the effect of removal of suspended matters by the microstrainer depends on such conditions as the material of strainer net, the type of weave, the mesh size, treatment flow, head loss, peripheral speed of the dram, quantity and pressure of wash water, what governs these conditions and the rate of removal are the size and shape of objective organisms in water to be removed.

Given this, proper operation is needed fully understanding quantity, characteristics etc. of objective organisms to be removed.

2. Two-step coagulation equipment

Two-step coagulation treatment is a treatment method to again dose a coagulant in the settled water which has been treated by ordinary coagulation and sedimentation. For this purpose, a mixing tank shall be installed between the sedimentation basin and the filter, or baffle plates are to be set in the pipe or conduit so that uniform mixing is made.

Although the dosing rate at the time of two-step coagulation treatment is implemented depends on the species of objective plankton and water quality, polyaluminum chloride is dosed at the range of 1to 5 mg/L in many cases.

3. Primary filtration

Primary filtration equipment denotes roughing filtration equipment to be built before slow sand filters to remove such suspended matters as phytoplankton, turbidity matters and abate the burden on the slow sand filters.

4. Multi-media filter

For the multi-media filter, more than two filter media of different density and grain size are applied to form filter bed of a rapid filter aiming at exerting filtration function more rationally and efficiently. In general, dual media layers with an anthracite layer with small specific gravity and large grain size on top of a sand layer are used in many cases (See 7.6.3 Multi-media filter).

Viewing the multi-media filter from standpoint of biological treatment, easing of filter clogging can be made by internal filtration in the upper layer of anthracite etc., which retains phytoplankton and turbidity matters.

The species of phytoplankton, of which removal effect by the multi-media filter is large, is a large diatom, especially, it is effective in the case of Synedra etc., of which removal by coagulation and sedimentation is difficult.

Clogging of the filter depends on the number of organisms, even if multi-media filtration is employed, coagulation and sedimentation treatment shall sufficiently be carried out; and monitoring of turbidity of filtered water needs to be enforced.

7.17. Other methods of treatment (Annotation omitted)

7.17.1. General (Annotation omitted)

7.17.2. Removal of erosive free carbon dioxide (Annotation omitted)

7.17.3. Removal of fluorides (Annotation omitted)

7.17.4. Removal of arsenic (Annotation omitted)

7.17.5. Removal of color (Annotation omitted)

7.17.6. Measures against trihalomethanes (Annotation omitted)

7.17.7. Measures against trichloroethylene etc. (Annotation omitted)

7.17.8. Removal of anionic surfactant (Annotation omitted)

7.17.9. Removal of taste and odor (Annotation omitted)

7.17.10. Removal of ammoniac nitrogen (Annotation omitted)

7.17.11. Removal of nitrate nitrogen (Annotation omitted)

7.17.12. Softening of hard water (Removal of hardness) (Annotation omitted)

7.17.13. Improvement in corrosiveness (Langelier's index) (Annotation omitted)

7.17.14. Removal of oils (Annotation omitted)

7.18. Wastewater treatment facilities

7.18.1. General

The wastewater treatment facilities are used to properly treat sludge of the sedimentation basin, cleaning waste water of the filter, sand cleaning waste water etc., which are discharged from the water treatment facilities, and separate solid and liquid in wastewater into release liquid and cake (solid). The separated release liquid is returned to the raw water and reused or discharged to the public water body. The cake is effectively utilized or disposed in landfill.

The common treatment train of wastewater treatment consists of conditioning → thickening → dehydration → drying and effective utilization or disposal. A conceptual schematic of wastewater treatment methods is illustrated in Figure 7.18.1.

When managing wastewater treatment facilities, it is important to precisely understand the relationship with the water treatment processes, and bear in mind so that water treatment is smoothly carried out. Therefore, it is needed to estimate quantity of sludge from treatment flow throughout the year and the situation of raw water, and prepare wastewater treatment plans for each season and month.

In case raw water turbidity is expected to become high due to a typhoon, heavy rain etc., it is needed to enhance the operation of wastewater treatment facilities so as to prepare the system for sludge treatment.

What is more, it is cautioned that if sludge is piled in the sedimentation basin etc. for a long time, sludge will decompose.

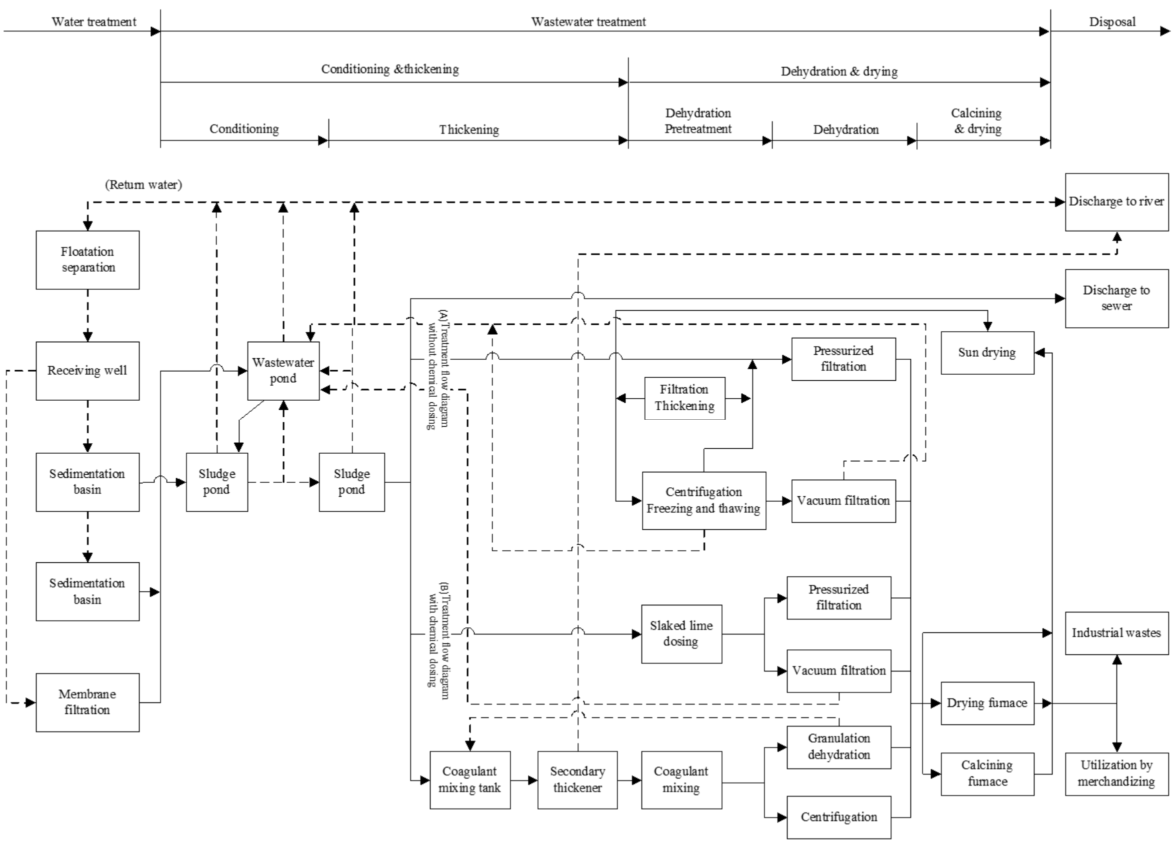


Figure 7.18.1 Conceptual schematic of wastewater treatment methods

In case treated water generated in the wastewater treatment process is returned to raw water, attention shall be paid to make its quantity and quality as uniform as possible. It needs to carefully be observed that, if not uniform, the returned water brings about significant trouble to management of chemical dosing to raw water.

In some examples, to remove turbidity and color matters, such microorganisms as algae, iron, manganese, treatment of returned water is carried out by the floatation method (bubble separation and pressurized floatation method).

Water to be discharged from a water treatment plant to the public water body etc. shall be monitored if it is in conformity with the wastewater quality standards, and, at the same time, water quality tests need to be conducted as required.

The cake generated in the wastewater treatment process is designated as sludge (inorganic sludge) under the Waste management and public cleansing law, and, as treated as industrial waste, the law shall be abided by for its disposal.

For disposal of the generated cake, it is important to establish a disposal plan aiming at the long-term prospect, and the location and the method of disposal shall be in conformity with the standards prescribed in the law. At the same time, adequate consultation with related local authorities, and related businesses shall be made lest troubles may arise for its implementation.

Moreover, due to difficulty for acquisition of the disposal site and from the environmental preservation point of view, the use of the cake as horticultural earth and materials for civil work is important.

Examples of principal points for inspection of wastewater treatment facilities are presented in Table 7.18.1.

Table 7.18.1 Examples of principal points for inspection of wastewater treatment facilities

Item / Equipment		Daily inspection		Periodic inspection		Detailed inspection (upkeep)	
		Cycle	Inspection contents	Cycle	Inspection contents	Cycle	Inspection contents
Conditioning and thickening	Conditioning pond	3 times/day	1.Delivery head (electric) current, abnormal noise, leak from gland, temperature of bearing of wastewater, sludge pump,	3 to 6 mon.	1.Piling of stained sand and sludge in wastewater pond	1 to 2 years	1.Cleaning of wastewater pond
		3 times/day	2.Abnormal noise, vibration, current, lubricating water of mixer, water currents around mixer	1 year	2.Piling condition of sludge in sludge pond	1 year	2. Cleaning of sludge pond
		3 times/day	3.Confirmation of working status of screen			1 to 2 weeks	3.Cleaning of piled dust and cleaning away
	Thickener (tank)	3 times/day	1.Confirmation of flow regime (inlet, overflow, settling of flocs etc.)	3 times/day	1.To measure sludge concentration and interface	1 mon.	1.Cleaning of inlet conduit, and around overflow weir
		As needed	2.Torque, current and abnormal noise of sludge scraper	3 times/day	2.To measure flow and output.	3 mon.	2. Cleaning of piping and valves
		3 times/day	3. Delivery head, current, abnormal noise, leak from gland of slurry pump	3 times/day	3.Quality test of supernatant (turbidity, pH, suspended matters)	3~6 mon.	3. Cleaning of piled dust and cleaning away
		3 times/day	4. To confirm working status of screen				
		3 times/day	5.Existencce of water leak from pipe and valves				
	Concentration control tank	Once/day	1.Abnormal noise, vibration, current of mixer and water current around mixer	Once/day	1.Situation of sludge piling	1 year	1.Cleaning of inside of tank, status of sludge piling
		Once/day	2.Working status of turbidimeter, pH meter, and flow meter	As needed	2.To confirm reagent for turbidimeter and pH meter, their cleaning	1 year	2.To confirm submersible bearing of mixer
		As needed	3. Delivery head, current of dilution pump, water leak from pipe and valve			1 year	3.To confirm driving unit of valves and flow meter.
Natural drying	Sun drying bed	2 times/day	1.Status of inlet of sludge	3 mon.	1.Condition of side walls	3 mon.	1.Cleaning of wastewater ditch
		2 times/day	2.Effluent stats of supernatant and filtered water	3 mon.	2.Woking condition of valves	3 mon.	2.Cleaning of respective pipelines
		Once /week	3.Condition of drying	3 mon.	3.Existence of clogging of respective pipelines	Every time of unloading	3.Repair of floor slab, side wall and flashboards
		Once /week	4.Existence of water leak				
		As needed	5.Condition of flashboards				
			Granular body transfer device				
Dehydration	Pressurized dehydrat	Always	1.Vibration, abnormal noise and current of dehydrator, status of cleaning of filter cloth	2~4 times/day	1.To measure concentration of condensed sludge, moisture and volume of cake	2 mon.	1.Cleaning of sludge conveyance pipe and valves (part)

		Always	2.Dehydration status of cake, conditions of exfoliation from filter cloth, and its fall on belt-conveyer	Always	2.Cleaning of filter cloth and filter plate		
		Always	3.Such operating condition as vibration, abnormal noise, current, pressure etc. of driving pump, hydraulic pump	At time of shutdown	3.Cleaning with water of main body of dehydrator and other parts with stuck sludge		
				At time of shutdown	2.Cleaning with water of main section of room		
			Inspection and upkeep of air compressor and various pumps				
	Vacuum dehydrator	3 times/day	1.Vibration, abnormal noise, current of dehydrator and status of cleaning with water of rotating part and other parts	2~4 times/day	1.To measure concentration of condensed sludge, moisture and volume of cake etc.	2 mon.	1. .Cleaning of sludge conveyance pipe and valves (part)
		As needed	2.Adjustment of tension and offset of filter cloth	At time of shutdown	2. Cleaning with water of main body of dehydrator and other parts with stuck sludge		
		3 times/day	3. Conditions of dehydration of cake, exfoliation from filter cloth, and its fall on belt-conveyer	At time of shutdown	3.Status of cleaning with water of filter cloth		
		3 times/day	4.Vacuum pressure, abnormal noise and current of vacuum pump	At time of shutdown	4.Desludging and cleaning of sludge pit for dehydrator		
		As needed	5.Water level and status of drain of filtrate tank	At time of shutdown	5.Cleaning with water of distribution tank for sludge feeding and sludge feeder pipe		
		As needed	6.Sludge level and status of sludge feeding of distribution tank for sludge feeding	At time of shutdown	6. Cleaning with water of main section of room		
			Inspection and upkeep of vacuum pump				
	Centrifugal dehydrator	Before operation	1.Setting value of air pressure of brake	One day	1.To inspect vibration		
		Before operation	2.Clogging of inner and outer cylinders with sludge	One day	2.Temperature of bearing		
		Before operation	3.To confirm breakage and preset position of safety pin	One day	3.Oil level of bearing box		
		Before operation	4.Slakness of casing cover	One day	4.Inspection and recording of instruments for lubrication device		

		Before operation	5.To confirm working condition of abnormal rotation detector	One day	5.Force of brake		
		Before operation	6.Recording of current	One day	6.To measure time for starting and braking work		
		Before operation	7.Sludge volume, sludge concentration, concentration of separated water	One day	7.Activation of detector of abnormal rotation		
		Before operation	8.Recovery ratio of condensed concentration	One day	8.Oil level in gearbox		
		Before operation	9.Sludge leak from casing	One day	9.Oil level in differential transmission		

7.18.2. Related laws and regulations (Annotation omitted)

7.18.3. Conditioning and thickening facilities (Annotation omitted)

7.18.4. Dehydration facilities

Dehydration facilities further reduces the moisture of condensed sludge so as to make handling and other operation of its cake easy, and also change its property to fit the condition required for effective utilization and final disposal.

As the method of dehydration, there are cases to utilize natural energy (natural drying) and to use mechanical force.

1. Natural drying facilities

Natural drying facilities, including the sun drying bed and the lagoon, utilize natural energy (radiant heat, wind, and freezing phenomenon), and reduce moisture of condensed sludge.

① In the sun drying bed, dehydration is undertaken by gravity through a sand bed and collection pipes, supernatant water is decanted via flashboards etc. and the sludge is left to dry. Usually, condensed sludge from the sludge pond or the thickener is put into the drying bed. Dehydration up to the moisture of 65 to 75 percent can be expected.

② In the lagoon, dehydration takes place by consolidation, decantation of supernatant water and evaporation of water, and sludge from the sedimentation basin etc., which is discharged from water treatment facilities, is directly received. As this method also performs the function of conditioning and thickening function, a large lot is needed.

In case they are situated in favorable geographical, social and meteorological conditions, and acquisition of their lot is easy, these natural drying methods are economically advantageous since little electric and mechanical energy is used; and they can bear the function of retention at the time of high turbidity.

1) Operation

① Since time required for one cycle of operation of the natural drying method is long, unless estimated volume of sludge generated, deposited volume of sludge in the sludge pond, status of the use of the drying bed, amount of dry cake to be carried out etc. are precisely be grasped, serious troubles in the operation of the entire water treatment plant will be brought about. Given this, it is important that the relationship among the volume of treated water at the water treatment plant in each season, loading of sludge and time in days required for drying shall be analyzed to prepare the base for a plan for drying bed application.

② As the higher the concentration of sludge to be introduced onto the drying bed, the better the efficiency, the concentration of sludge shall be raised as much as possible between the sedimentation basin and the thickening tank.

③ The treatment capacity of the natural drying bed is the product of the sludge loading per cycle and the number of uses per year. Whether to make the sludge loading small while to make the number of uses of the drying bed per year large, or vice versa shall be determined after examining such various conditions as the nature of sludge, the relationship between the sludge loading and drying time in days, whether receiving of sludge is done by a butch type or by continuous type and so forth.

④ The effect of drying depends on atmospheric temperature, quantity of solar radiation, evaporation, precipitation, air flow etc.; and it is also largely governed by receiving sludge loading. Removal of moisture is undertaken by filtration, evaporation, supernatant decanting; and the ratio of moisture removal by the respective processes is 20 to 40 percent or so.

2) Daily inspection etc.

① The drying bed shall fittingly be patrolled and inspected and efforts shall be paid to decant supernatant water. In case flashboards are provided, as, unless their water-tightness is good, sludge drains causing unexpected troubles, they shall carefully be inspected when patrolling, and need to be replaced if their damage is remarkable.

② Preparing for receiving the next cycle of sludge after carrying out dried cake, floor slabs, side walls and flashboards of the drying bed shall be inspected for their damage, and be fittingly repaired. Additionally, sand shall be replenished as needed.

③ To avoid clogging of sludge conveyance pipe and valves by sludge, they shall periodically be cleaned. Inspection of valves by opening and closing them in normal times also needed. Secondly, to smoothly discharge water from the drying bed, attention shall be paid to clogging of drainage channel, and it shall properly be cleaned (See Table 7.l8.1).

3) Measures in abnormal cases

As measures in abnormal cases, refer to Table 7.l8.3.

Table 7.l8.3 Measures in abnormal cases in wastewater treatment facilities

Facilities/equipment	Abnormal event	Cause	Measures (example of cause etc.)
Natural drying	Unacceptable dried cake	1.Excessive amount of incoming sludge	1.Control incoming amount suitable to capacity and condition of facility
		2.Insufficient concentration of sludge	2.Raise concentration of withdrawn sludge
		3.Insufficient drying time	3.Extend number of drying days, or plow by a hoe etc. to widen surface area to dry
		4.Inflow of rainwater	4.Improve drain channel, or cover the bed with a sheet.
	Emission of odor	1.Decomposition of sludge	1.Prevent decomposition by stirring with air, and spray deodorant; quickly carry away and dispose sludge.
		2.Contamination with odor causing matters	2.Remove material in question from original sludge.

7.18.5. Granulation dehydration equipment (Annotation omitted)

7.18.6. Dust collector and deodorizer (Annotation omitted)

7.18.7. Effective utilization and disposal of cake (Annotation omitted)

7.19. Interconnecting pipelines and conduits in the plant premises (Annotation omitted)

7.19.1. General (Annotation omitted)

7.19.2. Points of attention for management (Annotation omitted)

7.20. Management buildings (Annotation omitted)

7.20.1. General (Annotation omitted)

7.20.2. Points of attention for management (Annotation omitted)

7.21. Management of plant premises (Annotation omitted)

7.21.1. General (Annotation omitted)

7.21.2. Arrangement of plant premises (Annotation omitted)

7.21.3. Opening of facilities to the public (Annotation omitted)

13. Water quality management

13.1. General

13.1.1. Basic items

Water quality management in water supply means that water at the tap is basically made hygienically safe and is kept clean to be comfortably used. To this end, the water supply system shall be managed in that the water source is to be preserved as clean as possible; that water is to be properly treated at the water treatment plant; and moreover that water is not to be polluted in the water distribution mains and water service fittings.

As the means of water quality management, water quality is grasped by such water quality tests as physicochemical and biological tests and apparatuses installed in the facilities. Based on the results obtained from them, various operation and measures become possible.

For example, although a peculiar problem related to water quality, which becomes an obstacle for water treatment, may arise in a stagnant portion of an impounding reservoir, it is desirable to periodically carry out water quality testing, quickly understand the situation of water quality and take necessary steps. Since an unexpected accident of water pollution possibly arises in a river water source due to progress in urbanization in the river basin, it is advisable to establish a system of water quality monitoring and a communication and information system.

In water treatment at a water treatment plant, to confirm effect of treatment through testing water quality at respective processes of raw water, settled water, filtered water, treated water, and at the same time it is important to reflect the results of such testing to adjustment of chemicals for water treatment and improvement of the water treatment method.

As to tap water, since water quality may become deteriorated in water distribution mains and water service fittings, it is needed to always confirm that quality of the tap water is hygienically safe and clean.

For that purpose, it is desirable to make efforts to lessen causes of deterioration in water quality learning from various examples.

1. Purpose of water quality management

Water supply is obliged to supply safe and good quality water conforming to the water quality standards for water supply. Therefore, the water utility needs to implement water quality management covering all the steps, which affect quality of tap water, from the water source to the tap.

It is required to synthetically manage the entire water supply system from the water source and water treatment processes through to the tap so that water served through the tap is always in conformity with the water quality standards, and kept hygienically safe and in normal condition. In synthetic water quality management, water quality in all the steps is periodically tested and its result is to be confirmed. Additionally, it is important that undertakings and their implementation plan for preservation of water sources, facilities furnished with reliable water treatment function and their management, water distribution facilities, which can supply water without risk of pollution, and their operation and maintenance are functioning in coordination. A concept of synthetic water quality management in water supply is presented in Figure 13.1.1.

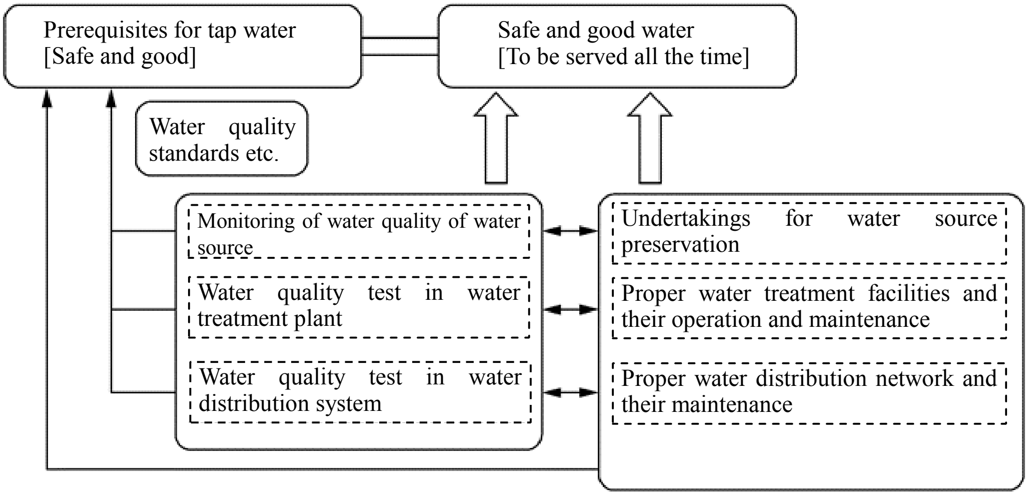


Figure 13.1.1 Concept of synthetic water quality management in water supply

To manage water quality denotes "confirmation of safety and good quality of tap water" and "to construct a system capable of always supplying such water". The fact that quality of tap water is safe and good shall be confirmed by conducting periodic water quality testing. On the other hand, for confirmation that safe and good tap water is always served, as water quality testing cannot all the time be conducted, it is required to construct a system, which can be reliable for production and supply of safe and good quality water from properly managed water supply facilities. For establishment of such a system, measures for water quality preservation to be implemented in the water source area as shown in Figure 13.1.1, the method of water treatment, such technical items required for water supply as water treatment plant, water distribution network etc. and their operation and maintenance become essential, and their method and contents shall be cooperated with the result of water quality measurement to be conducted at a regular frequency.

2. Establishment of a system for water quality management

As various factors are related to water quality management, sections in the water utility in charge of such factors are different from each other. Although all of the examples shown in Figure 13.1.1 are important factors for water quality management, the sections of the water utility in charge of such a duty are, in many cases, more than two sections such as the water quality management section, the water treatment plant, the water distribution section, the planning and programming section, the general affairs section etc.

Table 13.1.1 Factors related to water quality management

- Measurement of water quality, water quality survey and collection of related information
- Water quality management of water distribution (Setting of concentration of residual chlorine)
- Reception of complaints and inquiries from customers and response to them
- Collection of information on water quality preservation
- Participation in preparation of a plan for water quality preservation by related organizations

An example of coordination among sections of the water utility and other organizations in charge of respective factors is presented in Figure 13.1.2. In regard to involvement of the water utility in preparation of a water source preservation plan, to make the view of the water utility to be reflected to the water source preservation plan to be prepared by the other organization, the utility shall analyze the status quo by the result of water quality measurement etc., and, in an idea, request measures, which have been examined within the utility, to the said organization in coordination with other water utilities situated in the same water source system. Besides, in regard to customer's complaints etc., quick response is needed by the reception section and the section in charge of surveying the cause in coordination. As to management of distributed water quality, it is important to conduct measurement of residual chlorine concentration at the tap, analysis of its result, and setting of residual chlorine concentration at the outlet of the water treatment plant in coordination between respective incumbent sections. The section in charge of water quality management is desirable to possess a system to be able to share the result of water quality measurement, related information etc. by the utility as a whole

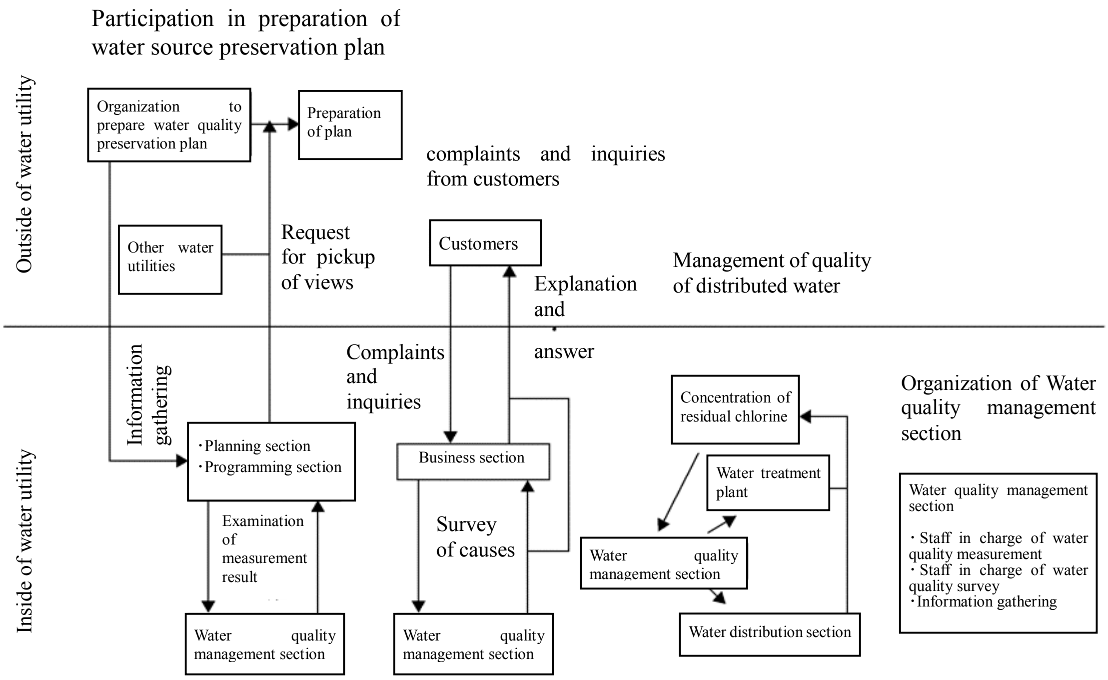


Figure 13.1.2 Coordination in inside of the water utility

To synthetically execute water quality management all over the entire water supply system, a management body, under which the water utility can centrally deal with all the factors associated with water quality measurement, shall be established in cooperation with respective incumbent sections.

3. Preparation of a plan on water quality measurement

To properly undertake water quality measurement, it is desirable to prepare a plan on water quality measurement, and make it a document. The plan on water quality measurement is not only a plan on water quality testing and examination, but it is needed to make it a plan on the entire water supply system. Besides, to properly implement water quality measurement, it is essential to evaluate the result of water quality testing and examination, and undertake necessary measures based on it.

Table 13.1.2 Preparation of a plan on water quality management

(1) Evaluation of characteristics, treatment capacity etc. of water supply system as a whole.
↓
(2) Identification of factors, which possibly affect water quality.
↓
(3) Identification of monitoring tool of factors, of which influence is predicted.
↓
(4) Setting of measures in case the influence is recognized.
↓
(5) Confirmation of effect of measures in case they are implemented.

The plan shall be examined including the items shown in Table 13.1.2, and prepared. As to preparation of the plan, characteristics of the water supply system as a whole and water treatment capacity etc. shall be evaluated and analyzed so that the whole system can be understood. As the object of evaluation and analysis, there are water quality in the normal condition, magnitude of influence of rain, and existence and type of sources of pollution etc. In addition, as to the water treatment plant, the method of water treatment, water treatment function etc. shall be evaluated, and retention time in the service area, the possibility of pollution etc. shall be evaluated. What is more, factors, which have possibility to affect water quality, shall be identified for the entire water supply system.

As examples of these factors, industrial wastewater, wastewater from cattle sheds, agricultural chemicals etc. are supposed to be in the water source area, improper dosing of chemicals, improper management of facilities, impertinent means of pollution prevention at the service reservoir, cross-connection etc. are enumerated.

Thirdly, a means of monitoring to watch if the identified factors are influencing water quality shall be established. For instance, a monitoring system for turbidity at the time of rain is to be provided in water supply where raw water turbidity becomes very high by rain. As a result of monitoring, measures or a control method in case influence is recognized shall be provided in advance; and, at the same time, in case the measures or the control method have been applied, their effectiveness shall be confirmed.

As one of important means for water quality management, water quality testing and examination are carried out in the water source, the water treatment plant etc. It corresponds to [(3) Identification of monitoring tool of factors, of which influence is predicted] in Table 13.1.2; its result evaluated and in case an anomaly is identified, measures are to be executed based on [(4) Setting of measures in case the influence is recognized]. One of methods to judge if the measured result is abnormal, the past results of measurement in water treatment processes are analyzed, and there is a method to set a standard to judge if the result of analysis is the normal value or abnormal one.

If the result of measurement is the normal value, water treatment is judged to be properly carried out; in the case of an abnormal value, its cause shall be investigated if water treatment is proper, or if there has been a big change in raw water quality, and necessary measures shall be implemented.

13.1.2. System of water quality standards and water quality management

1. Water quality standards

Under the current drinking water quality standards, standard values are set for 51 items (Enacted on April 1, 2015). Additionally, as items to supplement the water quality standards, [Water quality management goal setting items], which shall be taken into consideration, are laid down for 26 items as goal values. Likewise, maintenance of residual chlorine is prescribed as a hygienically necessary measure under the Waterworks Law. The water quality standard items and their standard values are presented in Table 13.1.3.

Table 13.1.3 Water quality standard items and their standard values (Enacted on April 1, 2015)

Item	Standard	Item	Standard
Standard plate count bacteria	Colonies formed by 1 mL sample < 100	Total trihalomethanes	< 0.1 mg/L
Coliform bacteria	Not to be detected	trichloroacetic acid	< 0.03 mg/L
Cadmium and its compounds	< 0.03 mg/L as quantity of cadmium	Bromodichloromethane	< 0.03 mg/L
Mercury and its compound	< 0.0005 mg/L as quantity of mercury	Bromoform	< 0.09 mg/L
Selenium and its compounds	< 0.01 mg/L as quantity of selenium	Formaldehyde	< 0.08 mg/L
Lead and its compound	< 0.01 mg/L as quantity of lead	Zinc and its compound	< 1.0 mg/L as quantity of zinc
Arsenic and its compounds	< 0.01 mg/L as quantity of arsenic	Aluminum and its compound	< 0.2 mg/L as quantity of aluminum
Hexavalent chromium compounds	< 0.05 mg/L as quantity of hexavalent chromium	Iron and its compounds	< 0.3 mg/L as quantity of iron
Nitrite nitrogen	< 0.04 mg/L	Copper and its compounds	< 1.0 mg/L as quantity of copper
Cyanide ion and cyanogens chloride	< 0.01 mg/L as quantity of cyanide	Sodium and its compounds	< 200 mg/L as quantity of sodium
Nitrate nitrogen and nitrite nitrogen	< 10 mg/L	Manganese and its compounds	< 0.05 mg/L as quantity of manganese
Fluoride and its compounds	< 0.8 mg/L as quantity of fluoride	Chloride ion	< 200 mg/L
Boron and its compounds	< 1.0 mg/L as quantity of boron	Calsium, magnesium etc. (hardness)	< 300 mg/L
Carbon tetrachloride	< 0.002 mg/L	Total solids	< 500 mg/L
1,4-dioxane	< 0.05 mg/L	Anioinic surfactant	< 0.2 mg/L
Cis-1,2-dichloroethylene and trans-1,2-dichloroethylene	< 0.04 mg/L	Geosmin	< 0.00001 mg/L
Dichloromethane	< 0.02 mg/L	2-methylisoborneol	< 0.00001 mg/L
Tetrachloroethylene	< 0.01 mg/L	Non-ion surfactant	< 0.02 mg/L
Trichloroethylene	< 0.01 mg/L	Phenols	< 0.005 mg/L as quantity of phenols
Benzene	< 0.01 mg/L	Organic matters (total organic carbon [TOC])	< 3 mg/L
Chloric acid	< 0.6 mg/L	pH	5.8<pH<8.6
Chloroacetic acid	< 0.02 mg/L	Taste	Not to be abnormal
Chloroform	< 0.06 mg/L	Odor	Not to be abnormal
Dichloroacetic acid	< 0.03 mg/L	Color	< 5 units
Dibromochloromethane	< 0.1 mg/L	Turbidity	< 2 units
Bromic acid	< 0.01 mg/L		

13.1.3. Treatability of various substances (Annotation omitted)

13.1.4. Water quality testing

1. Securement of accuracy and reliability for water quality testing

To secure accuracy and reliability of the results of water quality testing, the water utility, which conducts water quality testing, needs to positively undertake accuracy management. Nowadays, introduction of an assurance system of accuracy and reliability based on the Good Laboratory Practice (GLP) is required. In the assurance system of accuracy and reliability based on the GLP, an organization system with persons respectively in charge of the reliability assurance section and the water quality testing section shall be established; and testing is carried out preparing a standard work book.

13.1.5. Research and study (Annotation omitted)

13.1.6. Water quality and risk of tap water (Annotation omitted)

13.2. Water quality management system

13.2.1. General

Tap water shall all the time maintain water quality in conformity with the water quality standards and the standard for chlorination at the tap.

Therefore, the water utility needs to provide water treatment facilities suitable to respective water sources, and establish a system to always secure good water quality, i.e., a water quality management system.

Taking in a broad sense, although inspection of facilities and equipment, such technical work for the entire water supply system as maintenance can be recognized as part of water quality management, in this chapter, water quality management is defined as "the deed of evaluating the result of water quality testing and examination from the water source to the tap, properly taking measures based on the evaluation, and always securing tap water of good quality". Secondly, water quality testing denotes to judge from the result of testing whether or not the quality of water of the service reservoir or the tap is in conformity with the law with reference to the water quality standards and the standard for chlorination; and other water quality measurement to be performed for water quality management is defined as water quality examination.

13.2.2. Water quality measurement system

To always secure good tap water, a consistent water quality measurement system covering from the water source to the tap shall be established. It is needed to select and preserve a good water source, precisely grasp the risk factors of raw water (water quality monitoring), undertake proper water treatment (water treatment process management) according to the risk factors of raw water, convey water up to the tap without impairing water quality (water transmission management), and confirm that water is firmly conveyed (water quality testing).

The water treatment capacity of the existing facilities needs to accurately be understood to properly carry out water quality management. Besides, in case the potential risk factors of the existing water source exceed the treating capacity of the existing facilities, the introduction of more advanced water treatment facilities is needed.

1. Water quality management of water source

To understand the changes in raw water quality is extremely important in water quality management of tap water.

Among factors, which affect raw water quality, as natural factors, wildlife, climate, geographical features, geology, vegetation etc. are considered to correspond to them; as artificial factors, there are the sewage treatment plant and industrial waste as a point source, and drainage from roads, city life sewage, wastewater containing pesticides and fertilizer etc. as non-point sources.

In case lake water or impounding reservoir water are the water source, since generation of taste and odor and such trouble as clogging of filters arise by abnormal growth of organisms, which cause trouble in water supply at times, year-by-year change in water quality due to ups and downs of impeding organisms, the progress of eutrophication in water source area and so forth need to be grasped.

In case river water is the water source, as factors to influence water source quality, there are sudden change due to rainfall, an accident etc., and secular change due to development in the upstream region, so monitoring of the water source shall be undertaken taking these features into account. The causes and status of change in water quality need to correctly be understood by drawing a parallel between the result of water quality testing and locations of respective businesses, which can be a pollution source in the river basin, the form of land use, population, the ratio of sewer-served population etc. Furthermore, it will become important to make mid- and long-term prediction of raw water quality.

Although, in case groundwater is the water source, raw water quality is relatively good and stable in many cases, there are examples of pollution by nitrate nitrogen derived from fertilizer, wastewater etc., and trichloroethylene etc. used as solvent. Since, as once polluted, a long time is required to recover, potential risk factors in the water source area shall be grasped in advance, and at the same time monitoring of these risk factors need to be strengthened in such an area.

In water quality management of water source, it is needed to understand risk factors in normal times, and predict and prevent unexpected risk factors as well. As unexpected risk factors, an accident of a wastewater disposal facility of a business in the river basin, pollution by fuel and a cargo due to a traffic accident, and illegal dumping etc. are assumed. Against potential risk factors, proper fixed monitoring points shall be chosen from the drainage outfall of the business and the points, which represent the river basin, periodic survey shall be conducted in normal times in a proper frequency, and at the same time a speedy survey system and a communication network at an emergency in the case of occurrence of an accident of water pollution need to be established.

The "Plan for water quality management" of the water source area to properly carry out water quality management of water source shall be prepared in consideration of survey items, its frequency and monitoring points etc. in regard to the situation of the water source area, the importance of treatment technology and measures of the existing water treatment, and examining the priority of measures against risk factors and the priority for selection of survey points judging from significance of influence to the damaged water utility. For example, in a lake where there is a risk of growth of organisms, which produce odor causing materials, water quality items to know the progress of eutrophication, odor tests, biological tests to recognize the status quo shall be selected, and in the river basin where businesses, which handle toxic matters, exist, the toxic items in question and the items, which can be their indicators, shall be chosen.

Likewise, as to agricultural chemicals of the Water quality management goal setting items, the priority of agricultural chemicals (a priority list of agricultural chemicals for monitoring) to be monitored shall be prepared and selected based on the actual condition of their use and the experience of their detection. Survey points shall be chosen in consideration of potential risk factors and the magnitude of their influence. Furthermore, the water quality items and the survey points need to at any time be reviewed based on evaluation of the change in situation and the result of testing. In addition, it is needed to predict time required from the respective survey points, and prepare an environmental map of the river basin, a map of water channels, and a response manual against water quality accidents in advance.

2. Water quality management of raw water

Water quality management of raw water needs to properly be carried out in accordance with the type of the water source. Especially, in case the surface water of the lower reaches of a river, it is needed to prepare a method for continuous monitoring of water quality, which changes hour to hour. The use of automatic water quality instruments is effective for continuous water quality monitoring.

In case the nature of raw water quality exceeds the capacity of water treatment, as shutdown of water intake is required, it is needed to adequately understand the water treatment capacity of the existing facilities. In case deterioration in raw water quality occurs in a short period of time, or in case such a large change in the method of treatment as dosing of a lot of powdered activated carbon (PAC) is made even if the deterioration is within the capacity of the existing facilities, stop or curtailment of raw water intake in the time zone, in which the volume of water service is not significantly affected, becomes effective at times.

3. Water quality management in water treatment processes

A proper water treatment method needs to be selected according to risk factors of raw water. In water quality management in water treatment processes, it shall quickly be judged if the risk factors of raw water can be removed by the existing facilities. For that purpose, the capacity of the existing facilities needs to precisely be grasped in advance. Additionally, a system to decide that the risk factors have been removed as expected needs to be established.

As for substances, which were experienced in the past, or of which method of treatment have been known by literature, it is desirable to prepare a manual. Meanwhile, as for risk factors, which have not been experienced, it needs to be judged through the examination whether or not they can be treated by the existing facilities, or to find the most suitable treatment condition by an experiment (jar test etc.).

In water quality management in water treatment processes, to always secure good tap water, it is effective to set water quality goal values (water quality management goal values) at each point of treatment process for water quality management. The items, for which (water quality management goal values) are set, and other items to be monitored shall be measured by manual testing or continuously measured by automatic water quality testing apparatuses so that a system, which can implement stable water quality management, shall be established.

4. Water quality management in treated water transmission, distribution, and water service processes

In water quality management in treated water transmission, water distribution and water service processes, the items, which change in distribution mains etc., need to properly be managed. As examples of changes in water quality in distribution mains etc., there are deterioration in water quality due to the pipe material and its impairment, and such phenomenon as residual chlorine and disinfectant byproducts, which change over time. As an example of the former, occurrence of red water due to corrosion of pipe material etc., and elution of such metal as lead etc. due to stagnant water are enumerated. Red water due to corrosion of pipe material can be reduced by cleaning of pipe, and elution of metals etc. from pipe material can be decreased by management of Langelier's index and proper pH. However, in case sufficient effect is not obtained, such a measure as replacement of pipe needs to be implemented. In management of water quality, which changes over time as the latter example, changing potential of water quality items during water transmission with the parameters of time and water temperature, and travel time to respective survey points need to be comprehended.

Water quality testing of tap water is undertaken for insuring the quality of served water, so the accuracy of the result of analysis is important. In case the water utility itself carries out water quality testing, the accuracy of the result and the system of reliability assurance (GLP) need to be provided.

Inquiries on quality of tap water and reception of a request for water quality testing need to be dealt with the business section as well from customer service point of view. Secondly, it is desirable to prepare a customer service manual with reference to expected questions and examples of inquiries in the past.

5. Water quality management in storage tank type water supply

As to storage tank type water supply (water supply in a building etc.), hygienic problems often occur due to inadequate management, about which many users feel anxious. The water utility can stipulate guidance, advice and recommendation to the person who build the facility in its water service ordinance.

13.2.3. Plan on water quality management

The following items shall be stated in the plan on water quality management:

① Of items to be considered in water quality management, those which are included in the plan

② As for items for which periodic water quality testing is conducted, relevant items, locations of sampling, times of testing and its reason

③ As for items for which periodic water quality testing is omitted, relevant items and its reason

④ Items related to temporary testing

⑤ In case water quality testing is entrusted, contents of the said assignment

⑥ Other items to be taken into consideration for the implementation of water quality testing

As to ①, they are items to be considered for water quality management such as the situation of water quality from raw water through to the tap, main causes of pollution, and the objective items, which must be prioritized for water quality management. They are related to the preparation of the plan on water quality management. Specifically speaking, they are stated in consideration of such respective situation as the locations of sampling, the type of water source, raw water quality, the method of water treatment, the characteristics of the existing water supply facilities etc. For instance, the items to be stated are: disinfection byproducts in case pre-chlorination is undertaken; the fact if a peculiar pollutant exists in the water source; and the fact in case there is a seasonal change,

About ④, the prerequisites to conduct temporary water quality testing, and testing items in such an occasion are stated.

As to ⑥, items related to the evaluation of water quality testing, items related to the review of the plan on water quality management, items related to insurance of accuracy and reliability, items related to coordination with related organizations and so on shall be stated; and the method of official announcement of the plan on water quality management and its report, and the method of communication control shall also be stated.

Besides, all such water quality testing and examination as the water quality management goal setting items and water quality testing shall desirably be placed in the plan on water quality management.

Moreover, as for its public announcement, it is needed to take into consideration so that the customers can understand even if they do not have professional knowledge.

The water utility must insure that it undertakes proper water quality management, and that served water is at all time clean and safe. By preparing a plan on water quality management, reliability of water quality management is elevated, and at the same time water quality testing and examination can be executed efficiently and rationally. Moreover, accountability of the water utility can be raised by reporting the plan together with its result.

13.2.4. Water quality goal values for water quality management (water quality management goal values) (Annotation omitted)

13.2.5. Wide area water quality management and cooperative water quality testing (Annotation omitted)

13.2.6. Assignment of water quality testing (Annotation omitted)

13.2.7. [Plan on tap water quality management] of raw water etc. to be prepared by prefectures (Annotation omitted)

13.3. Water quality standards

13.3.1. General (Annotation omitted)

13.3.2. Water quality standard items (Annotation omitted)

13.3.3. Water quality management goal setting items (Annotation omitted)

13.3.4. Items to be reviewed (Annotation omitted)

13.3.5. Other matters related to Ministry Ordinance (Annotation omitted)

13.3.6. Related water quality standards (Annotation omitted)

13.3.7. WHO Guidelines on Drinking Water Quality and USEPA Standards (Annotation omitted)

13.4. Water quality testing and examination (Annotation omitted)

13.4.1. General (Annotation omitted)

13.4.2. Accuracy management and assurance of reliability (Annotation omitted)

13.4.3. Sampling of drinking water (Annotation omitted)

13.4.4. Water quality testing required for license application (Annotation omitted)

13.4.5. Water quality testing prior to commencement of water service (Annotation omitted)

13.4.6. Periodic water quality testing and examination (Annotation omitted)

13.4.7. Temporary water quality testing and examination (Annotation omitted)

13.4.8. Water quality testing in a requested case (Annotation omitted)

13.4.9. Water quality testing in accordance with other Ministry Ordinances (Annotation omitted)

13.4.10. Water quality testing for management of small-scale water supply and storage tank type water supply (Annotation omitted)

13.4.11. Recording of result of water quality testing and examination (Annotation omitted)

13.4.12. Public announcement of result of water quality testing (Annotation omitted)

13.4.13. Apparatuses required for water quality testing and examination (Annotation omitted)

13.5. Management of results of water quality testing and examination

13.5.1. General

Although such matters as turbidity, color and taste, which are sensed by sight, smell and taste, can be known for their anomaly, abnormality of water quality cannot usually be found in many cases unless water quality testing is carried out. Therefore, abnormality of water quality is judged based on the result of periodic and temporary testing and automatic water quality apparatuses. In case the result does not meet the water quality standards, appropriate measures shall be taken in accordance with 13.5.2 Measures in case testing result exceeds water quality standard values.

Furthermore, when, even if the result meets the water quality standards, it largely differs from the past result, and its cause is unknown, as it is considered there is an anomaly somewhere, the cause shall be studied and a proper measure shall immediately be implemented.

13.5.2. Measures in case testing result exceeds water quality standard values

1. Judgment and measures at the time of abnormal water quality (See Figure 13.5.1).

① As the result of water quality testing, in case the resultant values exceed the water quality standard values, retesting shall be carried out for confirmation; at the same time, investigation of its cause shall immediately be conducted; and necessary measures shall be undertaken based on the following ② to ⑥ to meet the standards.

② As to the standard plate count bacteria and coliform bacteria, as their existence in tap water directly indicates the possibility of pollution by pathogenic microorganisms, their evaluation shall be made by collating the results of respective testing against the standard values. In case the results exceeding the standard values are expected to continue, emergency measures for water intake and water service shall be implemented, and additionally, the consumers need to be notified that abnormal incidence has occurred or that there is such possibility by means of radio, TV, a loudspeaker van etc.

③ As nitrate nitrogen, nitrite nitrogen, chloride ion, organic matters, pH, taste, odor, color, and turbidity possess the property of indicators, which suspect the existence of pathogenic microorganisms, in case their values largely change, measures need to be taken in accordance with ②.

④ As to cyanide ion, cyanogen chloride and mercury, although their standard values are set in adequate consideration to the safety based on the level, which does not adversely affect the human health even if they are continuously consumed throughout one's lifetime, the similar measure as ② shall suitably be implemented taking into account the traditional handling in the past.

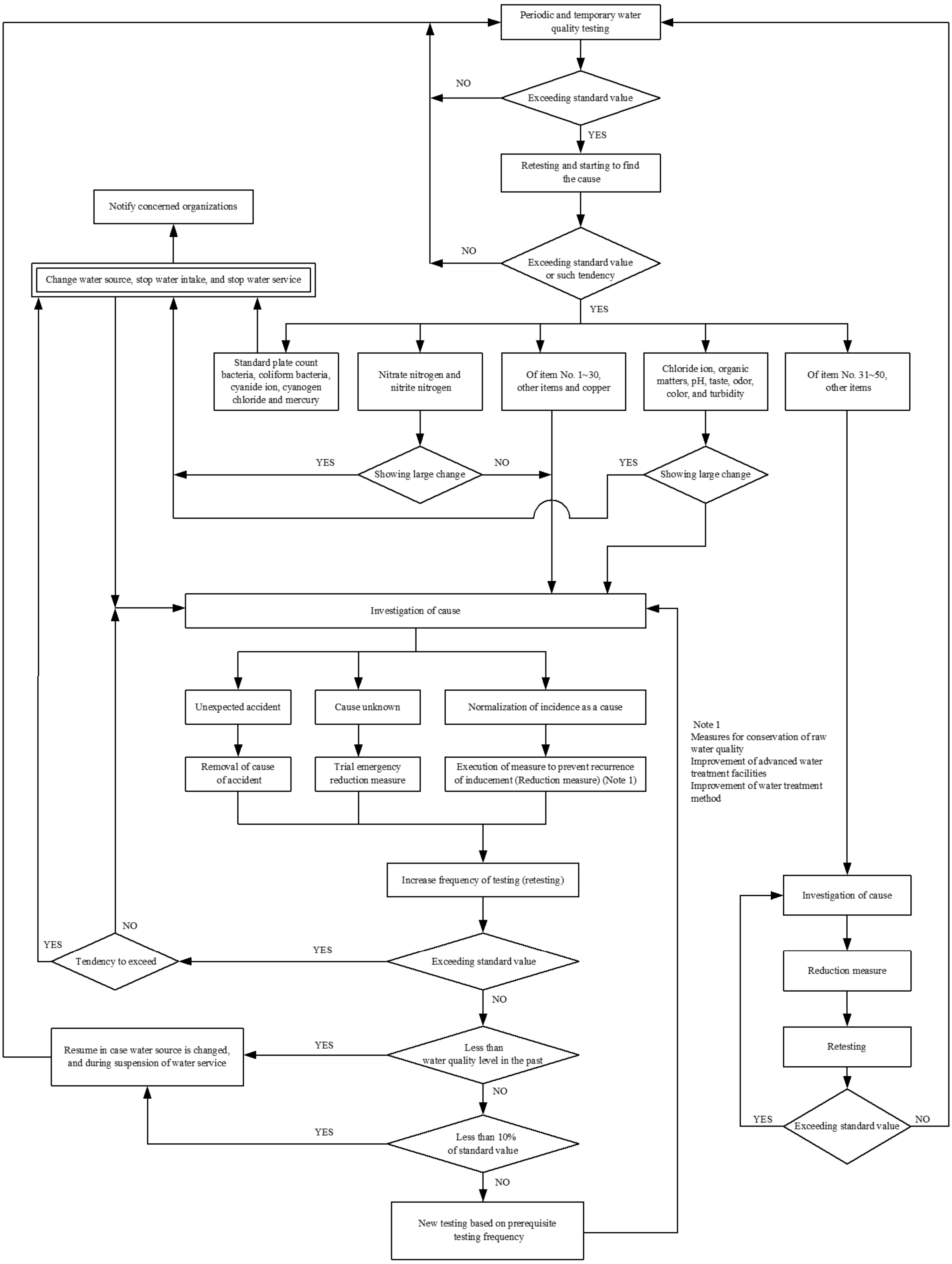


Figure 13.5.1 An example of measure when detecting abnormal values as result of water quality testing

In case water in the process of water source, water intake and raw water transmission shows such a change as follows, and the quality of tap water exceeds the water quality standards, water intake shall immediately be stopped, water quality testing shall be conducted, and water service shall be suspended as required:

① In case a remarkable change occurs in color and turbidity by an unknown cause.

② In case a significant change occurs in taste and odor.

③ In case a lot of fish died and surface.

④ In water supply serving water only with chlorination, such floating dirt as trashes and sludge is found in its water source.

13.5.3. Steps in case the water quality management goal setting item exceeds standard value (Annotation omitted)

13.5.4. Steps in case there is a risk of contamination with cryptosporidium and so forth (Annotation omitted)

13.6. Water quality management in water source

13.6.1. General

Although the most basic and important thing for water quality management in water supply facilities is to secure raw water of good quality, quality of raw water is largely influenced by the environment of the water source.

As water source for water supply, there are river water, lake water, groundwater etc., they have respective nature about water quality. For operation and management of water supply facilities, although proper water intake operation and water treatment must be undertaken in accordance with the quality of water source, to this end, characteristics of water quality of raw water shall be known, and at the same time the change and its trend need to all the time be monitored.

13.6.2. Information management in water source river basin (Annotation omitted)

13.6.3. Preservation of water source quality (Annotation omitted)

13.6.4. Water quality management in lakes and impounding reservoirs

1. Characteristics of water quality

Water in lakes and impounding reservoirs in general has such a nature that change in its water quality is slow, that its turbidity is low and that it contains few bacteria thanks to its self-cleaning action. On the other hand, trouble with taste and odor and impediment in filtration at times occur as plankton markedly grow as a result of stagnant water.

In addition, bottom water becomes anaerobic condition, iron and manganese in bottom sediment is reduced and eluting to cause the trouble of coloring at times.

2. Method of water quality survey

Unlike river water, as a large amount of water stagnates in the case of water source of a lake or impounding reservoir, a risk of unexpected contamination of a poison etc. is small. However, as various troubles in water treatment due to eutrophication phenomenon particular in the lake and the impounding reservoir occur at times, a water quality survey, water intake operation and water treatment according to such condition are needed. Likewise, when conducting a water quality survey of the lake and the impounding reservoir, together with monitoring for early finding of troubles for irrigation, a survey to know the trend of eutrophication needs to be carried out as well. Especially, it is important to conduct a synthetic survey on the environment of the river basin including its tributaries, weather, volumes of inflow and outflow, water quality etc.

Moreover, bottom sediment survey is undertaken at times for the purpose to obtain basic data on computation of inside load in the lake and the impounding reservoir, and dredging of bottom sediment.

1) River basin survey

Almost all nutritive salts of nitrogen and phosphorus, which are the main cause to bring about eutrophication in the lake and the impounding reservoir, in many cases, are fed from rivers flowing in. Given this, it is important that to precisely understand the present status of water quality of the lake and the impounding reservoir as the water source, not only water quality of the lake and the impounding reservoir but water quality of pouring rivers and the environment of their basin and flows, which constitute their quality, are surveyed, and that the total amount of turbidity matters to be fed from the pouring rivers to the lake and the impounding reservoir.

2) Water quality survey

In water quality survey of the lake and the impounding reservoir, in general, the center and the deepest points of the lake and effluent water (discharged water), which represent the entire water body, are commonly selected as points where water sampling is possible.

In addition to the basic items of water temperature, turbidity, pH, dissolved oxygen etc., the water quality testing items shall include such nutritive salts as nitrogen and phosphorus, which are the main cause of eutrophication, algae, odor substances, iron (soluble matter), manganese (soluble matter), chlorophyll which are the cause of water quality troubles.

3) Future prediction of water quality

To control water quality of the water source of the lake and the impounding reservoir, not only to understand the existing water quality, but to predict future water quality, foresee possible impediments, reflect it to water quality preservation measures for water source, related undertakings shall be made effective.

3. Trouble in water quality and its measure

Troubles in water quality in the lake and the impounding reservoir are often caused by the repression of intermix of the upper and lower layers as temperature strata are formed from spring through fall. As the strata are formed, algae, which are the cause of troubles, tend to grow in the surface stratum, whereas in the lower stratum anaerobic state occurs causing elution of iron, manganese etc. Methods to artificially improve or avoid such phenomenon are generally implemented.

1) Circulation of lake water

Circulation of lake water is performed for the purpose to break the stratification in that air is sent in the lake from an air compressor; when air becomes bubbles and rises, it entrains surrounding water, which accelerates circulation of lake water.

By circulation of lake water, as the anaerobic condition of the bottom stratum is resolved, and at the same time as algae in the surface stratum are sent down to the dark layer, where no light reaches, the growth of algae is depressed. Especially, effect to suppress the growth of blue-green algae including the algae, which cause musty odor, can be expected. Effect of circulation of lake water for suppressing algae is said to be large in case water depth is more than 2 m, and the capacity of the lake is large relative to its surface area.

When considering a measure by lake water circulation, sufficiently understanding the shape of the objective lake, necessary energy input (the volume of air to be dosed) needs to be examined so as to determine the elements of the circulation device.

2) Spraying of chemicals

It is a method to spray a chemical etc. in an impounding reservoir and so forth to depress the growth of organisms. As a treatment chemical, although the cheaper, the easier to store and handle, and the more effective in a small dosage, the better, on the other hand, it is needed not to be harmful to the human and the cattle, and adversely affect fish and agricultural crops. As chemicals to be used, although there are copper sulfate, chlorine agents (liquefied chlorine, sodium hypochlorite and calcium hypochlorite) etc., they have a merit and a demerit, copper sulfate is used in the most cases.

Copper sulfate is especially effective to algae, possesses durability, does not cause a danger in its handling unlike chlorine agents, and treatment work is thus easy. Nonetheless, it also has such shortcoming as that it takes 1 to 2 days for its effect to appear, that it induces growth of algae, which are immune to copper, and that algae acquire tolerance to copper.

Chlorine agents are highly effective to algae and such bacteria as iron bacteria and, in addition, has immediate effect, and easy to dose. Contrarily, it has such a demerit as that it has no durability, that taste and odor arise against animals and some species of algae, and that growth of algae, which have tolerance to chlorine, is induced.

Although spray of chemicals brings about little problem in the case of an impounding reservoir exclusively for water supply, influence to fish and agricultural crops become a problem in the case of a multi-purpose reservoir or a natural lake. Thus, spray of chemicals in such water body is difficult to execute. Besides, spray of chemicals needs to be implemented adequately understanding the situation of growth of trouble-making organisms, and proper monitoring of the water source is essential.

3) Selective water intake

It is a method to avoid such a trouble as turbid water after a flood and water containing taste and odor by selecting intake mouths for different water depth. In case selective water intake is implemented, water quality at respective water levels needs to be grasped in advance. Although selective water intake is effective when water temperature strata are formed, attention shall be paid to the concentration of iron, manganese, ammoniac nitrogen etc. in case water is abstracted from the level deeper than the thermocline.

What is more, when abstracting low temperature water, influence to agriculture and fishery needs to be considered.

13.6.5. Water quality management of river surface water

1. Nature of water quality

Water quality of river water largely changes seasonally and weekly due to weather and industrial activities at times, and often changes hourly even during a day. Difference in water temperature between summer and winter is significant, and diurnal change is especially large in summer. In addition, if there is a heavy rain in the river basin of the water source, turbidity remarkably rises in a short period of time in a case, and water quality differs depending on the change in flow, and such a location as the center line of the stream, the river bank, stagnant section etc. It is cautioned that change in water quality becomes remarkable in a dry season.

2. Method of water quality survey

Not only periodic water quality measurement in accordance with the law but selecting necessary items and survey points according to geophysical situation of the pollution source in the upstream basin area, diurnal, weekly, monthly changes of water source quality, synthetic water quality in the upstream river basin for each season, change in water quality at the time of rain shall be surveyed. It is important to grasp the present status and the trend over time based on analysis of the accumulation of these data.

Secondly, as unexpected pollution accidents tend to occur in river water, abnormal condition in water quality needs to all the time be monitored by means of aquarium to keep fish, automatic water quality testing apparatuses etc.

3. Water quality trouble and its measure

For specific measures, refer to 13.10 Water quality accidents.

13.6.6. Water quality management of groundwater

1. Nature of water quality

Groundwater is classified into unconfined groundwater (free surface groundwater) and confined groundwater from the formation condition of the aquifer.

Besides, from the depth point of view, it is divided into shallow groundwater and deep groundwater in a case. The well, which abstract unconfined groundwater, is called the shallow well, and its depth is less than 10 to 30 m. The deep well denotes a well which abstract confined groundwater, its depth is mostly deeper than 30 m, and it reaches down to 600 m or more in a case.

1) General characteristics

① As to groundwater, change in its temperature is small throughout the year; it does not contain turbidity; its dissolved matters are in relatively great quantity compared with surface water; but, as its nature, its water quality is good and stable.

② Groundwater often contains a large amount of iron and manganese, which become the cause of red water, black water and metallic smell. Such type of water contains small quantity of oxygen; is rich in contents of carbon dioxide and has some organic matters; and iron bacteria often grow in it. Iron bacteria epiphytically stick in aquifers, screen, inside of the riser pipe etc to form colonies, which cause pumping troubles due to clogging of the screen and the riser pipe; dirt, obnoxious taste and odor, red water etc. due to drain of floc-like colonies. Moreover, taste and odor may in a case arise due to sticking and decay of eumycetes, actinomycetes etc.

③ Groundwater, while staying in the ground for a long time, presents water quality specific to the geological features. It is cautioned that groundwater contains a large amount of arsenic and fluorides depending on region. Likewise, since groundwater contains high color and a lot of organic matters because of fumus in such a humus soil region as a peat area in many cases, trihalomethanes are formed in a large amount, or it is difficult to remove color by ordinary water treatment in a case.

④ In a coastal region and at a lower reaches of a river, there is a risk of salination of groundwater by the influence of seawater due to excessive groundwater pumping, river improvement, a large amount of gravel-digging etc. Attention shall be paid that it takes more than several years in many cases to recover once salination occurs.

⑤ Although groundwater is not easily contaminated, there is an example of detection of hexavalent chromium, cyan, agricultural chemicals as a result of permeation of industrial wastewater into the ground. Especially, pollution of groundwater has become a problem with such low boiling point organochlorine solvent as trichloroethylene and tetrachloroethylene used for manufacture of semiconductors, removal of grease of metal machine parts at small factories, such a solvent as 1,4-dioxan used for cellulose acetate, oil, wax, dyes etc. Caution needs to be practiced since once groundwater is contaminated, its recovery cannot usually be expected for a long time.

2) Characteristics of shallow well water

Shallow well water is groundwater (unconfined groundwater) with free water surface, which exists in the primary aquifer, and possesses the following characteristics:

① It is easily influenced by surface water, and, in case there are farms, orchards, livestock farms, golf courses etc., it may be affected by sprayed fertilizer, excreta of cattle, agricultural chemicals etc. Furthermore, it may also be influenced by seeping water and infiltrated water from nearby factories, an apartment complex, a terminal disposal site of wastes etc.

② Since it is under an aerobic condition as it contains a relatively large amount of oxygen, the nitrogen component has become nitrate nitrogen. Besides, as such a phenomenon as nitrate nitrogen abnormally increases in shallow well water has become more common, and examples with contents of nitrate nitrogen exceeding the water quality standard of 10 mg/L have been reported, which has become an issue. It is considered the influence of the use of a large amount of fertilizer in farm lands, and seepage of domestic sewage and industrial wastewater.

③ In general, despite of high alkalinity, it contains a lot of free carbonate; its pH is low (indicating at 6.0~6.8, but less than 6.0 sometimes); and in many cases shows corrosiveness to metals of iron, copper etc., and concrete.

④ In shallow well water, such small groundwater-based animals as gammaridea, Asellus hilgendorfi, Cyclops etc., which are visible in naked eyes, are sometimes seen. As these animals live in a dark place, lack pigments and their eyes usually atrophy. Although the presence of these small animals is not directly a hygienic problem, their removal by a strainer or a sand filter is needed for water service (See 13.7.2 Water quality management in the type with only chlorination).

3) Characteristics of deep well water

Deep well water is confined groundwater sandwiched by upper and lower impermeable strata, and possesses the following characteristics:

① Its hygienic safety is high as it is hardly influenced by surface water.

② Since it contains almost no oxygen, nitrate nitrogen and nitrite nitrogen are reduced and ammoniac nitrogen is contained at times. In this case, unless the result of bacteria tests show abnormality, it is recognized that there was no pollution.

③ In general, its alkalinity and hardness are high; little free carbonate is contained; it shows a pH of higher than 7.0 (normally 7.0~7.4).

④ It at times emits sewage-like smell or smell of rotten eggs. In many of such cases, it is because of the contents of hydrogen sulfide, and sulfur-reducing bacteria often grow in such water. As colonies of sulfur-reducing bacteria form sticky membrane like iron bacteria, they clog screens and pipe, give obnoxious odor in water, and they are related to corrosion of iron pipe in a case.

4) Characteristics of infiltrated water

Infiltrated water is water, which flows in gravel layers beneath the lake bed, river bed or sides, and has intermediate characteristics between shallow well water and surface water. Its main characteristics are as follows:

① As infiltrated water indicates the status that surface water is flowing through a stratum of good permeability, its turbidity is lower than that of surface water; its temperature is relatively stable, and indicates as almost the same nature as shallow well water.

② Since it is in such a status as vulnerable to the influence of surface water, direct mixing of surface water with the infiltrated water may occur at times depending on the location and depth of the infiltration gallery. Hence, if river water becomes turbid, infiltrated water also turns turbid; organisms on the riverbed intrude into it and drain at times.

2. Method of water quality survey

Since groundwater is vulnerable to pollution from the ground surface, and if once polluted, its recovery is extremely difficult, sufficient attention needs to be paid to seepage of wastewater and sewage into the ground. If possible, it is the most important to avoid the pollution source and conserve the replenishment area of the intake well. In case there is a risk of contamination, measures to prevent leakage, permeation etc. shall be implemented and water quality survey for monitoring needs to be continued.

1) Understanding of present status of the well

Obtaining the report on the survey and record of construction work at the time of sinking of the well, the shape, structure, soil samples, geological column etc. of the well shall be studied in advance. Secondly, as for water quality survey, it is needed to the surrounding environment of the objective well, the situation of the nearby wells need to be grasped.

2) Water quality survey

In accordance with the condition of the respective wells, analyses of acidity (free carbonate), alkalinity and cations and anions, which identify the nature of the wells shall be conducted. Measurement of water temperature and conductivity, even though simple, is a good indicator to understand the condition of the wells.

In case any sign of pollution, even if small, is observed in quality survey, the survey shall be continued to monitor the trend of pollution, and at the same time a survey of the surrounding environment is needed to investigate its cause. If appropriate steps of measures for prevention of damage can be undertaken, improvement in water quality may become visible by means of pumping of polluted groundwater. To this end, it is also needed to watch the values lower than the determinable limit.

Moreover, as water temperature, turbidity, color, pH, conductivity etc. can automatically be measured by apparatuses, measurement values obtained in such a way will become useful indicators to grasp the change in water quality in case abstracting shallow well water and infiltrated water, which are easily influenced by surface water, it is desirable to install automatic water quality testing apparatuses.

3. Troubles related to water quality and their measures

At the time of various troubles and anomalies related to water quality as stated in "Nature of water quality" occur, removal of causative matters can be made, or the damage can, in a case, be reduced if appropriate steps be taken.

In addition, as groundwater, either shallow well water or deep well water, possesses property to severely erode metals in many cases, it is desirable to give as much consideration as possible to corrosion-proofing on the part which comes in contact with water.

1) Change in water source

Although removal of nitrate nitrogen, fluorides, arsenic, and salt of seawater, which has intruded in groundwater, is technically possible, the measure by means of water treatment is extremely difficult the from view point of its cost. Therefore, as a practical measure, it is desirable to mix the water with water from another source, or, if possible, to change the water source.

2) Troubles caused by natural factors

① In case pH is low, a lot of free carbonate contained, carry out aeration.

② For groundwater containing a lot of iron and manganese, undertake iron and manganese removal treatment.

③ In case salination of groundwater due to intrusion of seawater is observed, salination shall be prevented by means of properly grasping the feasible amount of water to be abstracted and so forth.

④ In case a trouble by iron bacteria and sulfur-reducing bacteria occurs, improvement can be made in that the pump is taken out, and the inside of the well is investigated by a submersible TV camera; and that the screen, the pump, the riser pipe, the inside of casing are cleaned.

13.7. Water quality management in water treatment processes

13.7.1. General

As to the method of water treatment, an appropriate method in accordance with the quality of raw water shall be selected. Condition for water treatment needs to properly be set depending on the change in raw water quality as well.

Proper water quality management in water treatment is the most important for water service with safe and more quality tap water in conformity with the water quality standards. For the purpose to confirm that water treatment is properly functioning, and that safe and good quality water is produced, it is needed to prepare a monitoring plan related to water quality in accordance with the nature of raw water, method of water treatment and its condition and characteristics.

As for the plan, water quality items to be monitored are to be decided, and at the same time, treated water quality needs to adequately be monitored by setting management goal values. As items for measurement of treated water, in addition to ones required at the water treatment plant, items, which are considered necessary for monitoring in the steps of water distribution and water service in accordance with the characteristics of the water utility, shall also be measured.

To prepare for the occurrence of difference between the treated water quality and the management goal values, measures in relation to the difference need to be set in advance, and additionally a manual and a system of communication in accordance with such various situation as an accident related to water quality in water treatment need to be prepared.

13.7.2. Water quality management in the type only with chlorination

1. Characteristics of treatment in the type only with chlorination

In general the type only with chlorination is in many cases applied to groundwater with very good raw water quality (including spring water and infiltrated water). In this case, since the essential conditions are that the raw water quality is good and stable, so treated water with the quality, which meets the water quality standards, can be obtained only with chlorination, monitoring of raw water quality is to be conducted to confirm that raw water quality is stable and good. As to treated water quality, in addition to the testing stipulated in the Waterworks Law, water quality measurement to confirm the safety of tap water and needed for operation and maintenance of water supply shall be carried out according to the characteristics of the water supply.

2. Items for water quality monitoring

For water treatment only with chlorination, it is confirmed that raw water quality is stable and good, and, in addition, turbidity (muddiness), color, residual chlorine (disinfection effect) of treated water shall be conducted every day. It is important to confirm that chlorine in necessary and proper quantity for disinfection is surely dosed, and the residual chlorine management goal value etc. at the chlorine dosing point shall be set. In case raw water turbidity becomes higher than normal because of drought etc., suspension of water intake is needed as a general rule until when raw water turbidity declines. In the case of infiltrated water, monitoring of turbidity is necessary as turbidity occurs at the time of a flood.

What is more, to understand the change in water quality, it is desirable to periodically measure such items, of which measurement is relatively easy, and with which change in water quality can easily grasped, as pH, odor, taste, organic matters (TOC or potassium permanganate consumption) , and conductivity. Additionally, nitrate nitrogen and nitrite nitrogen, chlorides ions, ammoniac nitrogen, standard plate count bacteria, coliform bacteria, chlorine demand, iron, manganese etc. shall be measured at least every month to understand the trend of a long-term change in raw water quality.

Especially, in case groundwater is the water source, attention shall be paid to such organic solvent as trichloroethylene, and, in addition, for the shallow well, the trend of nitrate nitrogen and nitrite nitrogen shall be watched, and, in the case of the deep well, attention needs to be paid to the tendency of iron bacteria.

13.7.3. Water quality management in the slow sand filtration method

1. Characteristics of the slow sand filtration method

What is the most important in water quality management for the slow sand filter is filtered water turbidity. As daily management, turbidity and color of filtered water of each filter shall be tested every day, and an organic test shall be conducted as needed. The purification function of the slow sand filter depends on the activity of microorganisms, which are present 20 to 30 cm from the sand surface down to the lower sand layer, and can remove not only turbidity matters but odor causing substances, ammoniac nitrogen, and small quantity of manganese. For this reason, this treatment function is generally called biological filter membrane.

To maintain quality of filtered water, it is needed to make the biological filter membrane to fully exert purifying function, so incoming water to the filter needs to contain sufficient dissolved oxygen for nitrification of ammoniac nitrogen.

Besides, in the case of high turbidity of raw water, coagulation and sedimentation are to be undertaken beforehand, and, at the same time, it is important to keep such filtration rate as not to bring about shortage in oxygen in water, and not to make such filtration rate as to cause breakthrough of turbidity.

After skimming of the filter sand (Thickness of skimming is normally 1 to 2 cm), as for water quality testing prior to commencement of filtration, it is needed to confirm the exertion of treatment function by means of testing at least turbidity, color etc. when the filtration reaches the value preset by respective water utilities.

2. Items for water quality monitoring

In water treatment by the slow sand filtration method, raw water is to be monitored every day, it shall be confirmed that its quality does not affect the treatment function of slow sand filtration. The items to be monitored are the items, which cause clogging of the filter (turbidity, such large diatoms as Synedra etc.), the items, which are the causes of reducing the treatment function (ammoniac nitrogen, organic matters [TOC or potassium permanganate consumption, dissolved oxygen etc.]), the items, which have possibility to impair quality of filtered water or treated water (color, manganese etc.), and pollutants generated from a pollution source in case it is situated in the upstream section. Turbidity, color, ammoniac nitrogen, manganese, algae etc. increase in many cases at the time of rainfall and drought temporarily or seasonally, so the frequency of testing shall be determined in consideration of these factors. On the other hand, dissolved oxygen etc. may be tested at such a frequency as that it can be confirmed that the treatment function does not decline.

Likewise, it is desirable to every day measure such items as pH, organic matters (TOC or potassium permanganate consumption), conductivity, which are relatively easily measured, and with which the change in water quality can readily be known. Nitrate nitrogen and nitrite nitrogen, chlorides ions, standard plate count bacteria, coliform bacteria, chlorine demand, iron, manganese etc. shall be measured at least every month to understand the trend of a long-term change in raw water quality. As for raw water, it has been directed by the authority that water quality testing shall be conducted for items except disinfection byproducts and bromic acid at least once a year.

Water quality testing of filtered water shall be carried out in the necessary frequency for the items (turbidity, color, dissolved oxygen etc.) to confirm that treatment has properly been made, the items (ammoniac nitrogen etc.), which are the indicators for chlorine dosing control etc. In case there is a possibility of coloring by manganese, as a method to quickly know the magnitude of coloring by manganese, pH of filtered water is made at 10 or so; as much chlorine as actual treatment is added; the water is placed still while warmed; and then appearing color can be foreseen. As an example water quality management of filtered water, in a water utility, performance of the filter is judged by turbidity at 0.1 turbidity units, color at 1 to 3 units, standard plate count bacteria at less than 100/L as a temporary yardstick.

3. Removal of suspended matters in case raw water turbidity becomes high (more than 30 turbidity units)

In the slow sand filtration method, raw water is settled for 8 to 10 hours, and then filtered. In case turbidity exceeds 30 turbidity units, suspended matters accumulate on the sand surface, and cause filter clogging.

Caution is required as turbidity matters drains into filtered water sometimes.

1) Removal of suspended matters in case raw water turbidity temporarily becomes high

In case raw water turbidity temporarily becomes high, since effect of settling in a plain sedimentation basin is not sufficiently obtained, it is needed to dose a coagulant at the front section of the plain sedimentation basin to form flocs so that turbidity becomes less than 10 turbidity units.

2) Removal of suspended matters in case high raw water turbidity lasts for a long time

In case high raw water turbidity lasts for a long time, as treatment by the ordinary slow sand filtration method becomes difficult, such permanent facilities for coagulation as a chemical mixing tank, a flocculation basin etc. shall be built before the plain sedimentation basin to raise coagulation effect.

4. Troubles by growth of algae and propagation of small animals

In case filter clogging etc. occur by organisms and fine suspended matters, skimming of 1 cm or so thickness of the surface of the sand layer is needed.

Although there is a removal method to shield the slow sand filter, or apply chlorine, as the biological filter membrane may be damaged if residual chlorine exists, treatment by combined residual chlorine (0.3 mg/L or so) is desirable. However, even if treatment is made by combined chlorine, as the active organisms in the sand layer are killed and the filtration function may be impaired, treatment by chlorine shall be avoided as much as possible, and, even in an unavoidable case, the use of chlorine is to be limited for a short period of time.

In case small animals are removed, ordinary skimming is to be performed for a little thicker manner; the sand layer is immersed up to its surface with water containing about 30 mg/L of residual chlorine; and it is left for a day.

5. Troubles due to short oxygen in inside of sand layer

Since the biological filter membrane is mainly composed of aerobic bacteria, it cannot fully exert its function unless dissolved oxygen exists in water. If dissolved oxygen becomes short in the sand layer, its inside becomes anaerobic, and insoluble iron and manganese are reduced and eluting into water resulting in colored water at times. In case the concentration of dissolved oxygen is low, aeration of the raw water is needed to maintain the concentration of dissolved oxygen.

13.7.4. Water quality management in the rapid sand filtration method

1. Characteristics of the rapid sand filtration method

1) Coagulation and sedimentation treatment

In a water treatment plant by the rapid sand filtration method, implementation of coagulation, sedimentation, rapid sand filtration and chlorination is the basis, and it is the most important to soundly carry out coagulation and sedimentation treatment even in case raw water turbidity is as low as less than 2 turbidity units.

As colloids and suspended matters in water carry a negative charge, and disperse repulsing each other, if a coagulant having an opposite charge is added, their charge is neutralized. Colloids and suspended matters without charge, if they are stirred, form flocs, which can settle. Such a coagulant as aluminum sulfate and polyaluminum chloride consumes hydroxyl ion (OH^-), if alkalinity of water is low, pH is lowered resulting in insufficient coagulation. Therefore, in case alkalinity is low in relation to the quantity of the coagulant to be dosed, adjustment of pH is needed by adding such an alkaline agent as caustic soda, slaked lime, soda ash etc. so that pH becomes in the optimum range for coagulation. In general, in case alkalinity in raw water is low, or a lot of coagulant is used at the time of high turbidity, an alkaline gent shall additionally be dosed. Keeping alkalinity at 10 to 20 mg/L after coagulation, the optimum pH range for coagulation can easily be maintained.

In case dosage of coagulant etc. is excessive or insufficient, as fine flocs are suspended, the appearance of water is turbid like raw water. Especially, in the case of excessive dosage, flocs of poor settling property are suspended and water is colored opal. In case river flow temporarily increases due to a rainfall, as the grain size of turbidity matters is coarse at the beginning and its specific surface area is small, flocs of good settling property are formed with relatively small amount of coagulant. On the other hand, as the grain size becomes minute over time, difficulty in coagulation and sedimentation treatment is experienced at times even if a large amount of coagulant is applied. In case coagulation becomes poor, conducting jar tests as needed and grasping the proper dosage of coagulant, formation of flocs always needs to be confirmed.

2) Rapid sand filtration

In rapid sand filtration, settled water passes the sand layer at the filtration rate of 120 to 150 m/day; and the removal effect of turbidity matters is expected by means of attachment to filter media and sieving by them. Therefore, it is important to make flocs beforehand, which are in the status to be easily stuck to the filter media and sieved by them. In rapid sand filtration, in addition to the clay family turbidity matters, such suspended substances as bacteria, plankton, oxides of metals etc. can mostly be removed insofar as flocs are properly formed. If turbidity of settled water is high, flocks stuck to the filter layer move to the lower part of the layer, and tend to leak resulting in rise in filtered water turbidity. In this case, it is needed to properly implement coagulation and sedimentation, and alleviate the burden on the filter as much as possible.

3) Chlorination

Chlorination in the rapid sand filtration method is used not only as a disinfection agent but as an oxidizing agent for manganese and part of organic matters. In the case used as an oxidizing agent, it is applied as pre-chlorination or intermediate chlorination, and it is needed to maintain free residual chlorine after dosing for either case. In case the concentration of ammoniac nitrogen in raw water is high, and temperature and pH are low, it is important to firmly carry out break-point chlorination.

2. Items of water quality management

As raw water of water supply, for which rapid sand filtration method is applied, contains diverse types of objective substances to be removed, and as their concentration is high and the range of their change is wide in many cases, the number of items for water quality monitoring becomes large. Besides, as the number of types of chemicals to be controlled for their application is large, in addition to the water quality items required for control, the items of water quality to be measured in the water treatment plant is numerous including water quality items and so on needed to confirm if treatment is properly performed.

1) Raw water

As raw water of the water supply, which employs the rapid sand filtration method, shows frequent changes in water quality in many cases, it is needed to precisely understand the changes in water quality by day-to-day water quality monitoring, and, at the same time, to make proper water treatment possible. The items of water quality to be measured are turbidity, color, pH, odor, organic matters (TOC or potassium permanganate consumption), alkalinity, ammoniac nitrogen, conductivity, manganese etc. The result of measurement shall be reflected to the control of pre-chlorination or intermediate chlorination, dosage of alkaline or acid agents, and coagulant. Likewise, so as to be able to grasp the long-term trend of change in raw water quality, monitoring items shall be determined in accordance with the characteristics of the water source; and, in addition, in case there is a city etc. in the upstream area, and there is a possibility of pollution by wastewater etc., such water quality items as anionic surfactant, nonionic surfactant etc., by which pollution is possible, shall be measured at the necessary frequency.

In case the water source is a lake, an impounding reservoir etc., measurement shall be made in the season when plankton etc. outbreak. As for raw water, water quality testing shall be conducted for items except disinfection byproducts and bromic acid at least once a year.

2) Processes of rapid sand filtration treatment

In processes of rapid sand filtration treatment, for the purpose to confirm that respective processes are properly carried out, turbidity, color, pH, organic matters (TOC or potassium permanganate consumption), alkalinity, ammoniac nitrogen, conductivity, manganese, residual chlorine etc. shall be measured. As for respective water quality items, management goal values at each testing point shall be set, and confirmation shall be made if the results of measurement meet the goal values.

3) Treated water

As for treated water, turbidity, color, taste, odor, pH, residual chlorine etc. shall be tested every day.

3. Main points of management in the sedimentation basin

Monitoring of the magnitude of formation of flocs and situation of their settling is required in the sedimentation basin; formation of flocs are usually monitored by eyesight during patrol or the ITV; and situation of settling shall be judged by the result of daily water quality testing and settled water turbidity etc. by automatic continuous testing apparatuses.

Since turbidity matters in lakes usually contain little inorganic matters, and, on the contrary, a lot of organic matters, coagulation and sedimentation are not easy, and, especially, in a season when algae grow in a large quantity, coagulation is hindered. Settled flocs containing many algae may resurface in a case due to air bubbles generated by photosynthesis of algae during the day. For water containing a lot of plankton and organic matters, such treatment as dosing of a large amount of coagulant, change in coagulant, two-step coagulation (1 to 5 mg/L or so of polyaluminum chloride) or multi-media filtration and so forth is needed. In case a large amount of coagulant is dosed, attention shall be paid to runoff of flocs.

4. Main points of management in the rapid sand filter

Since oxidation reaction of manganese takes several hours to scores of hours, its reaction to become manganese dioxide slowly progresses in water distribution mains, and develops such a trouble as coloring of tap water in black etc. The oxidation method by manganese sand is the most effective for removal of manganese, and time required for removal is very short. As the manganese sand, which has removed manganese by contact oxidation, lacks vitality, and so free residual chlorine is indispensable for revitalization of manganese sand. Especially, in case intermediate chlorination is implemented, it is important to surely secure residual chlorine in influent water to the rapid sand filter.

Algae, which tend to leak to filtered water, include diatoms (Cyclotella etc.), blue-green algae (Microcystis etc.), and green algae (dictyosphaerium etc.). Especially, in case Synedra and Melosira of diatoms, which are difficult to be removed, are present in a great number, as filter clogging is caused, simultaneously applying augmented coagulant and pre-chlorination, multi-media filtration is effective. Moreover, as Microcystis of blue-green algae causes an obstacle in coagulation, passes the filter, makes filtered water turbidity to rise, increased dosing of coagulant and two-step coagulation are useful. In this case, if pre-chlorination is applied, there is a strong tendency for the colonies of Microcystis to be broken and leaks into filtered water, so caution shall be practiced.

Such small animals as larvae of chironomids and water fleas pass the filter at times. As larvae of chironomids and water fleas are in general resistant to chlorine, once they outbreak, pesticide effect by chlorine cannot be much expected. In such an occasion, efforts shall be made to prevent their outbreak by periodic cleaning of the inside of the sedimentation basin and washing of the inside wall of the filter. In case they outbreak inside the filter, making the number of filter cleaning larger, stabilize the filter sand after cleaning, filtration is carried out to prevent their leak.

In the rapid sand filtration method, even if raw water turbidity is low, the use of a coagulant is indispensable.

13.7.5. Water quality management in advanced water treatment

1. Characteristics of advanced water treatment

Advanced water treatment stands for treatment to be added to ordinary treatment for the purpose to treat odor causing materials (2-MIB, geosmin etc.), trihalomethane precursors, ammoniac nitrogen, anionic surfactant etc., which cannot sufficiently be removed by ordinary water treatment. As representative treatment methods, there are ozonation-activated carbon treatment, activated carbon treatment, biological treatment and so on.

These treatment methods are often combined with coagulation, sedimentation and rapid sand filtration; in water quality management, it is needed to synthetically examine water quality management of the entire system in addition to the treatability of each unit process.

In advanced water treatment with ozonation-activated carbon, attention needs to be paid to the dosing point of chlorine, and water quality management is needed in accordance with the respective characteristics from treatability and operation and maintenance points of view. In the method to carry out pre-chlorination, as trihalomethanes are formed, regeneration of granular activated carbon (GAC) needs to quickly be made to remove them. Furthermore, as free residual chlorine reduces the efficiency of oxidation by ozone, understanding of the concentration of free residual chlorine is also important.

Meanwhile, in case pre-chlorination is not applied, removal effect of organic matters is maintained for several years by biological activities in the GAC layer.

The main purposes of ozonation are decomposition of odor causing substances, oxidation of manganese etc., it is placed before GAC to remove aldehydes produced as a byproduct in the advanced treatment process. Additionally, as bromic acid ion is produced by ozonation, it is required to control the dosage of ozone as much as needed but as much as least needed. Although powdered activated carbon treatment and biological treatment are carried out prior to the rapid sand filtration method in many cases, and its objective substances for removal are odor causing matters (2-MIB, geosmin etc.), trihalomethane precursors, anionic surfactant, agricultural chemicals etc., removal of ammoniac nitrogen can also be expected by biological treatment.

2. Items of water quality monitoring

Raw water of water supply, which has introduced advanced water treatment, contains diverse types of objective substances in addition to objective matters to be removed for the purpose of introduction, their concentration is high, and the amplitude of their change is large in many cases, so the items of monitoring are numerous.

Furthermore, as the types of chemicals to be controlled for dosing are large in number, so, in addition to water quality items required to confirm that treatment is properly performed for water quality items necessary for their control, the items for water quality to be tested in the water treatment plant are considerably numerous because the number of points for water quality monitoring in the treatment processes becomes large.

1) Raw water

In case ozonation-GAC treatment is introduced, as they are used in combination with rapid sand filtration in many cases, the characteristics and items for water quality monitoring and testing are as same as those for the rapid sand filtration method, so the result of testing shall also be reflected to dosing control of chemicals. Since advanced water treatment is introduced for the purpose to remove trihalomethanes, odor causing materials, agricultural chemicals etc., those substances, trihalomethanes precursors and related items shall be measured in required frequency. Besides, so as to be able to grasp the long-term change in raw water quality, monitoring items according to the characteristics of the water source shall be decided, and, in addition, in case there are a city etc. in the upstream area and possibility of pollution by wastewater, water quality items, of which pollution is possible, shall be measured in required frequency. In case the water source is a lake or an impounding reservoir, odor causing matters (2-MIB, geosmin etc.) shall be measured in the season when plankton grow.

13.7.6. Water quality management in the membrane filtration method (Annotation omitted)

13.7.7. Management of treated water of wastewater treatment

Sedimentation sludge generated in water treatment processes, filter cleaning waste water etc. are treated in the wastewater treatment facility, and the treated water is discharged to outside of the water treatment plant or returned to raw water.

1. Management of water to be discharged

It is important that water quality testing of water discharged from the wastewater treatment facility shall periodically be conducted as well so that the quality of discharged water is to be understood. Especially, attention needs to be paid to the SS components of the water.

2. Influence of returned water to water treatment

In case the water discharged from the wastewater treatment facility is returned to raw water, efforts shall be made that the load of returned water on the water treatment process become to the minimum. Since the quality of returned water depends on raw water quality and the method of dehydration, fully understanding the quality (turbidity, iron, manganese, pH, organisms etc.) and volume of returned water shall sufficiently be grasped, and proper water treatment must be carried out.

In general, the following tendency is observed:

① The quality of returned water is different from when the wastewater treatment facility is in operation to when it is off. To avoid this problem, with the provision of a storage tank, the water quality can be equalized.

② When treating raw water with much organic matters, as the concentration of organic matters in sludge becomes high, and the inside of thickener become anaerobic, elution of iron and manganese and increase in BOD tend to occur. Secondly, iron and manganese can be settled if pH is raised before water is discharged.

③ In case an acid agent is used in pretreatment of dehydration, elution of metals increases.

④ As water fleas, aquatic sowbugs, nematodes, rotifers, algae etc. occur in the sludge pond of the wastewater treatment facility at times, it is needed to study species and quantity of organisms in returned water and examine their treatment.

⑤ In case such organisms as Synedra, which cause filter troubles, outbreak in a great number in raw water, as organisms concentrated in the wastewater treatment facility are returned to raw water in a large number, caution shall be practiced.

13.8. Water quality management in treated water transmission and distribution

13.8.1. General

The purpose of management in treated water transmission and distribution is to always maintain water quality of hygienically safe and clean water produced in good condition up to the terminal end of distribution mains. Under the Waterworks Law, free residual chlorine in tap water must be maintained at more than 0.1 mg/L (0.4 mg/L for combined chlorine) as a hygienic measure.

Besides, free residual chlorine is prescribed to be at less than 1.0 mg/L as a water quality management goal setting value from the palatable water point of view.

Given this, to control water quality in treated water transmission and distribution, considering structure of facilities, condition of piping, change in water quality in the system for each water source, water treatment plant and treated water transmission and distribution system, and selecting the most effective locations, it is desirable to periodically implement water quality testing. Furthermore, it is a very effective way to do continuous monitoring by installing automatic water quality testing apparatuses for residual chlorine, pH, conductivity etc. at treated water transmission mains, inlet and outlet of the service reservoir, and water distribution mains.

As water quality pollution in treated water transmission and distribution, there are pollution by intrusion of sewage, foreign matters etc. in the said facilities, quality deterioration of treated water during its contact with and retention in them, water quality trouble arising from treated water and so forth. As such, it is desirable to make efforts to eliminate causes of anomaly of water quality as much as possible in normal times.

Water quality survey requested by an inquiry shall be carried out to identify the area where abnormal water quality occurred; its cause shall quickly be investigated; and proper improvement measure need to be implemented.

13.8.2. Water quality management in treated water transmission and distribution

Water quality in the treated water transmission and distribution process changes in the service reservoir in case water become stagnant in a section in it, in case the capacity of the service reservoir is larger than the design water distribution flow and thus the retention time in it become long, and at locations in terminal sections of distribution mains where water tends to become stagnant.

Accordingly, for water quality management in the water distribution process, water quality survey shall in normal times be conducted in appropriate locations at inlet and outlet of the service reservoir, and at halfway and terminal end in distribution mains, and it is desirable to understand the condition of water quality in the service area.

The cause of change in water quality in the treated water transmission and distribution facilities is derived from chemical and physical property of pH of treated water, residual chlorine, free carbonate, water temperature etc., stagnant sections in the structures and water mains, change in flow velocity and direction, characteristics of material of facilities etc.

Of water quality standard items etc., items, of which concentration can change in the treated water transmission and distribution, are as follows:

① Items of which change in the water distribution is possible
Total trihalomethanes, chloroform, bromodichloromethane, dibromochloromethane, bromoform, organic matters (TOC or potassium permanganate consumption), iron, manganese, pH, odor, taste, color, turbidity, residual chlorine, dichloroacetic acid, trichloroacetic acid, chloral hydrate, chloroacetic acid, and dichloroacetonitrile

② Items of which origin is the water distribution system itself
Lead and iron

1. Change in water quality in water distribution mains and measures against it

1) Disinfection byproducts

As such disinfection byproducts as trihalomethanes produced by reaction of chlorine with organic matters in water are affected by the concentration of residual chlorine, pH, water temperature and contact time, it is desirable to reduce the retention time in water distribution facilities, and, at the same time, to control residual chlorine low.

In the period of high water temperature in May through October, disinfection byproducts increase. Especially, when abstracting raw water from a water source where treated wastewater etc. is discharged, and pre-chlorination is undertaken in water treatment, attention shall be paid to the formation of trihalomethanes.

In case there is a possibility that total trihalomethanes at the end of water distribution mains exceed the management goal value, there are following measures to be applied from water intake to water service:

① In case there are more than two water sources, the water source, of which trihalomethane precursors are lower, is to be taken. Likewise, to shorten time to be consumed from the water treatment plant to the tap, the water distribution system is to be changed.

② Instead of pre-chlorination, intermediary chlorination is to be employed so as to decrease formation of trihalomethanes.

③ Trihalomethane precursors etc. are to be absorbed by powdered activated carbon and the formation is suppressed.

④ Advanced water treatment is to be introduced to improve treated water quality.

2) Color and turbidity

Even if turbidity of treated water is low, turbidity matters gradually accumulate inside of distribution mains for a long time, at the time of control of water distribution or discharge from a hydrant, and change in flow velocity or direction, the deposited turbidity matters at once gush out causing a trouble of turbid water at times.

Although turbidity is to be less than 2 turbidity units under the Waterworks Law, as the goal to aim at higher level of water supply, less than 1 turbidity unit at the tap, and less than 0.1 turbidity units at the inlet to the treated water transmission and distribution facilities are considered appropriate.

Red water as the cause of color and turbidity occurs as incrustation of iron, which is formed by corrosion of the inner wall of the pipe, breaks and drains. Causes of red water are largely divided into the chemical cause and the physical cause.

As the chemical cause, influence of dissolved oxygen, free carbonate, sulfate ion, chloride ion, nitrate nitrogen etc. are considered.

As the physical cause, there are water temperature, contact time with water, flow direction and velocity in the pipe etc.

As red water occurs by intertwined various causes, it is observed that red water often occurs in case pH and Langelier's index are low, and corrosiveness of water is high; in case the distribution main is formed as cul de sac and retention time is long; and in case the distribution main is aged, and due to change in flow direction and velocity, deposited iron incrustation drains at once. Given this, for its prevention, control of pH of treated water, such piping as no retention of water occurs, periodic drainage of stagnant water, rehabilitation and replacement of superannuated water mains and so forth are needed.

As troubles related to water treatment, although there are a trouble induced by improper dosing of such chemicals for water treatment as coagulant, chlorine, alkaline agent etc., and a trouble brought about by raw water containing substances, which cannot be removed by ordinary water treatment, main examples are suspended matters and manganese.

To avoid improper dosing of chemicals for water treatment, water quality management and operation and management of dosing equipment in the water treatment plant are important.

What is more, in case coagulant leaks due to its overdose, turbidity in water distribution facilities is caused, and in case slaked lime is dosed as post-alkaline agent, trouble of turbid water occurs, in a case, due to its residue (insoluble portion of lime) deposited in the service reservoir and its runoff.

When turbidity trouble occurs, its cause shall be investigated and such a measure as drain of turbid water needs to be implemented.

3) Taste and odor

At the time of commencement of a new service reservoir, or such repair work as water-proofing of a service reservoir is carried out, if curing and cleaning are insufficient, taste and odor of concrete material or solvent of epoxy resin paint may brought in treated water, so adequate attention shall be paid. It needs to beware that in case distribution water mains are newly laid, or water mains are replaced for repair, but their cleaning is insufficient, taste and odor of inside coating, or plastic pipe may be brought in water.

4) Foreign materials

As exfoliation of the inside coating materials etc. occurs by various intertwined causes, the problem is that exfoliated materials are deposited in the pipe, drain from distribution mains when flow direction or velocity changes, trapped by the strainer causing insufficient discharge or runoff from the tap as foreign materials.

Foreign materials are derived from exfoliation of such materials as inside coating materials of the pipe (acryl resin, PVC resin, epoxy resin etc.), caulking agent, rubber gasket, cement mortar etc., which are used in the treated water transmission and distribution facilities.

5) Such metals as manganese etc.

Manganese is often contained in raw water, and cannot basically be removed by water treatment with rapid sand filtration and post-chlorination. Also in water treatment with the slow sand filtration method, manganese may at times leak in filtered water in case contents of manganese become large.

Even if the concentration of manganese in treated water is less than 0.05 mg/L, manganese oxides, which are generated by oxidation of manganese by chlorine, gradually deposit on the inside wall of distribution mains, drain at once in case the flow velocity or direction changes in the occasion to control the regime of water distribution or change distribution flow, and cause black water. Therefore, a survey on distribution mains shall periodically be conducted, and they shall be cleaned if needed.

In the case of manganese oxides only, water is colored black, and colored blackish brown or dark brown if iron is also contained. As to the water quality standard item, although contents of manganese is prescribed at less than 0.05 mg/L, as to water quality management goal setting item, it is set at less than 0.01 mg/L to be able to be met in case the manganese removal facilities are properly managed.

Although an aluminum family coagulant is used in the water treatment plant, at times it leaks into water distribution mains, and aluminum contents become high due to poor coagulation in case the coagulant dosage rate is inappropriate, or in case the condition for coagulation is unsuitable.

2. Management of residual chlorine

In tap water, disinfection effect shall be maintained under the Waterworks Law. Chlorination must be implemented so that free residual chlorine is to be maintained at more than 0.1 mg/L (more than 0.4 mg/L in the case of combined residual chlorine) at the tap. However, if the concentration of residual chlorine is too high, chlorine odor becomes strong, and so complains may arise sometimes.

Diminishing rate of residual chlorine in distribution mains depends on water temperature, water quality, retention time etc. It is small in winter when water temperature is low whereas it is large in summer. As such, as the diminishing rate depends on the season, it is needed to always monitor the concentration of residual chlorine at the terminal end of distribution mains and properly manage chlorine dosing.

To maintain residual chlorine at the terminal end of distribution mains, the following measures are recommended:

① Additional chlorination is to be implemented at a suitable location.

② At a place where a pipeline is formed as cul de sac, or water becomes stagnant, periodic drainage is to efficiently be undertaken.

③ To prevent prolonged retention in water mains, retention time is to be reduced by means to secure a circulation route by setting valves.

④ Treated water quality is to be improved introducing advanced water treatment etc.

In case, even if residual chlorine is maintained almost constant in the service reservoir, residual chlorine largely diminishes or disappears in a particular area of the service area, it is considered that there are cross-connections or stagnation of water in the area.

Besides, if water containing free residual chlorine is mixed with water combined residual chlorine, residual chlorine reduces or disappears, so their mixing must be avoided.

Residual chlorine evaporates from the water surface of the service reservoir etc. The quantity of reduction of chlorine is proportional to the water surface. In addition, the higher the water temperature, the larger the effect according to a report.

3. Prevention of pollution from outside

Pollution in treated water transmission and distribution occurs by influent of groundwater and sewage into the facilities; intrusion of such animals as insects etc.; cross-connection of water mains and such pipes for other uses as pipes of industrial water supply; and improper cleaning and disinfection to be undertaken at the time of repair work of a service reservoir, or at the end of pipe laying work.

In case pollution is confirmed, its cause shall quickly be investigated, and speedy and proper measure needs to be implemented. Also at the time of ordinary maintenance work, it is important to make efforts to eliminate what the cause of pollution would be as much as possible.

Respective measures for prevention of pollution are elucidated as follows:

① To install a mosquito net in the ventilation device of the service reservoir to prevent the intrusion of insects etc., and periodically inspect it.

② To prevent cracks in concrete structures of the service reservoir etc., and inflow of dirty water from leakage points on water distribution mains, patrol and inspection of respective facilities are to strictly be implemented and discovery of pollution and proper measures against it shall be undertaken.

③ In case workers enter in the service reservoir for repair work etc., adequate consideration for prevention of pollution shall be taken such as disinfection of shoes by sodium hypochlorite beforehand.

④ To clean and disinfect water mains at the time of completion of laying of distribution mains.

⑤ To prevent cross-connection of water mains with other pipelines for different uses, confirmation shall be made after completion of pipe laying by means of water quality testing in that the pipe in question is a water main for water supply.

⑥ To implement thorough health education for workers related to construction for prevention of pollution.

13.9. Water quality management in water service

13.9.1. General

As to water quality of tap water, it is prescribed for tap water to maintain required quantity of residual chlorine to meet the Water Quality Standards as a hygienic measure. In this case, consideration shall be taken to maintain good water quality even at such a location as the terminal points of water mains where water tends to become stagnant. Selecting places including the above locations where it can be judged if tap water meets the Water Quality Standards, periodic water quality testing needs to be conducted.

Even though there is no problem in water quality when treated water leaves the water treatment plant, various problems in water quality occur in tap water in some cases.

In such a case, quickly investigating the cause, measures for improvement shall be taken. In addition, in case a trouble in water quality is found by reporting from a user as well, the same measure shall be implemented. Although water service fittings are assets of the private person, when a trouble in water quality occurs because of the water service fittings, and the user requests the water utility for an examination saying that tap water is bad, the water utility takes a measure for it in many cases.

13.9.2. Water quality testing of tap water

Water quality testing of tap water can be said to be one of the most important steps for implementing appropriate water quality management to secure the safety and comfort of tap water.

Although, as a general rule, the object of water quality testing of tap water is tap water, treated water at the water treatment plant, treated water transmission facilities, or water distribution facilities are the objects depending on water quality items in a case. Besides, for selection of taps, on which water quality testing is to be performed, at least one point in each water distribution system shall essentially be selected. Therefore, it is effective to plan water quality testing in coordination with water quality management in the water treatment processes, treated water transmission and distribution, and water service.

The number of sampling points is set so that it rationally represent each type of water source, water treatment facilities and water distribution facilities; and in addition, it is also a rule to select the points at the terminal ends of distribution mains etc. where water tends to become stagnant.

The results of water quality testing are the certificate of quality assurance of tap water, and so shall be stored for a fixed period (five years). Moreover, it is needed to quickly open them to the public through the internet etc. and acquire reliability to tap water. It is desirable to also disclose such condition of the water source as quality of raw water, and that water treatment is properly carried out. The records of water treatment and water distribution are needed to be stored for a fixed period.

13.9.3. Securement of safety of water service fittings and direct pressure water service

Since water service fittings are directly connected with the water distribution mains of the water utility forming one body, in case their structure, materials and workmanship are inappropriate, and their proper maintenance is not carried out, the consumers cannot only receive safe and good quality water, but, in case backflow occurs, serious influence to the management of water supply facilities and public health will be brought about.

To prevent accidents of water quality pollution and water leakage due to the water service fittings, it is important to install proper fittings in conformity with the structure and materials standards, and properly carry out their everyday maintenance so as to assure the safety of drinking water and public health.

Furthermore, under direct connection water service and direct pressure water service, the water service fittings cover up to the tap, and, since no cistern is needed, it can solve the hygienic problem caused by inappropriate management of the receiving cistern.

13.9.4. Management of downstream facilities of the storage tank type water supply

Even if water supplied by the water utility is good, water gets deteriorated in some cases when maintenance of facilities downstream of the storage tank is inadequate.

13.9.5. Troubles in water quality and their measure

As water is always conveyed to water distribution mains and water service pipe under pressure, there is no fear of water pollution in the course of water distribution and service. However, troubles in water quality in tap water may occur due to the following:

① Elution from materials and paint of water service fittings

② Exfoliation and drain of accretion on the inside of pipe due to a change in flow direction, velocity etc. on the occasion of construction work and so on.

③ Inflow of dirty water and foreign materials into water mains, of which pressure becomes negative due to a suspension of water service.

④ In flow of water of other than water supply due to cross-connection of water mains with the water pipe for other use.

13.9.6. Judgment of water springing from leakage

As effective use of water resources are purveyed, loss of water due to leakage is a big issue at present. The origin of water, which is springing up from roads, manholes, the garden of a house etc., is considered to be either tap water, water of industrial water supply, rainwater, groundwater, river water, sewage etc. If the springing water can be judged as tap water or not, the measure against it, ensuing work etc. can easily be implemented.

Although, as the method to judge whether the springing water is tap water or spring water, there are a method by physicochemical testing and another method by biological testing, it is needed to synthetically judge by means of studying by more than two methods, and from the condition of the site and its surroundings to precisely decide. It is cautioned for the sampling container for judgment of leakage and the method of sampling not to influence the result of testing. What is more, if water from a neighboring tap with direct connection to the water main, river water, sewage etc. are tested in the same manner as the reference, judgment can be easier.

1. Physicochemical testing

1) Method by residual chlorine

If residual chlorine is present, it is tap water.

2) Method by trihalomethanes

If trihalomethanes, which are chlorination byproducts, are detected, possibility is high that the water is tap water. However, as there is also a possibility for it to be treated sewage, if such other items as chloride ion, conductivity etc. are similar to those of tap water, it is judged as tap water. Likewise, a synthetic judgment shall be made studying the situation of piping at the site and the surroundings.

2. Biological test

Observing organisms in water under the microscope, judgment is made whether the observed organisms belong to tap water, groundwater, sewage etc.

13.9.7. Causes of troubles in water quality and their remedies

Although troubles in treated water transmission and distribution are presented in Table l3.9.2, and the remedies for them are almost basically identical, respective causes are to be investigated and need to be remedied since the structures of facilities, the condition of piping, the characteristics of the area, water quality etc. are different.

Table l3.9.2 Main troubles in treated water transmission and distribution and their remedies

Phenomenon	Main cause	Situation	Remedy	
			Temporary remedy	Permanent remedy
Disappearance of residual chlorine	Aging and corrosion of distribution mains and service pipe	Consumption by reaction with iron etc.	Drainage from the drain valve etc.	Rehabilitation or replacement of water mains
	Stagnation of water in distribution mains and service pipe	Reaction with organic matters in water and pipe materials and self-decomposition	Drainage from the drain valve etc.	Improvement in water mains network, securement of circulation routes
	Cross-connection and inflow from leaking points	Inflow of groundwater, dirty water, industrial water etc..	Drainage from the drain valve etc. Discovery and repair of cross-connection and leaking points	Inspection and upkeep of water mains. Enhancement of water quality monitoring system.
Red water	Drain of iron rust	Drain of accretion of iron in treated water to pipe wall	Drainage from the drain valve etc.	Intensive removal of iron in water treatment
	Corrosion of distribution mains and service pipe	Elution of iron due to stagnation in distribution mains and service pipe of treated water with such high corrosiveness as low pH etc.	Drainage from the drain valve etc.	pH control, Rehabilitation or replacement of water mains
Black water	Drain of manganese	Physical runoff of manganese oxide sticking on pipe wall	Drainage from the drain valve etc.	Intensive removal of manganese in water treatment. pH control. Rehabilitation or replacement of water mains

Whitish water	Mixing of air	Mixing of air due to work for service suspension	To discharge water from the tap for certain time.	To exhaust air from water mains
	Elution of zinc	Elution of zinc from galvanized steel pipe	To discharge water from the pipe when used.	To change type of pipe
Blue water	Elution of copper	Elution of copper from copper pipe for hot water	To discharge water from the pipe when used.	To change type of pipe
Turbidity	Runoff of such inorganic matters as silt etc.	Physical runoff of accretion on pipe wall caused by troubled coagulation	Drainage from the drain valve etc.	To optimize water treatment.
	Excessive or too little dosage of coagulant	Turbidity arises in water distribution facilities	Drainage from the drain valve etc.	To optimize water treatment.
	Leak of organisms	Organisms growing in water source or raw water pass through filter and enter into water mains	Drainage from the drain valve etc.	To optimize water treatment.
Taste and odor	Contamination by musty odor causing substances	Growth of odor causing organism in water source	Application of powdered activated carbon	Installation of advanced water treatment Change in water source
	Inflow from cross-connection or leaking points	Inflow of groundwater, dirty water etc.	Drainage from the drain valve etc. Finding of cross-connection and leaking points and repair	Inspection and upkeep of water mains. Enhancement of water quality monitoring system.
	Insufficient wiping at the time of pipe laying	Odor caused by solvents and machining oil used for pipe laying	Cleaning discharge from tap	Careful workmanship
	Deterioration of PVC pipe and polyethylene pipe	Permeation of organic solvent, gasoline etc.	Replacement of service pipe. Removal or replacement of contaminated soil.	Use of pipe material, to which organic solvent etc. does not penetrate.
Foreign materials	Exfoliation of inside wall coating	Corrosion of water mains and cracking in lining cement mortar	Drainage from the drain valve etc.	Rehabilitation or replacement of water mains. Control of pH.
	Runoff of gasket etc.	Deterioration of such rubber products as gasket	Drainage from the drain valve etc.	Replacement and repair of deteriorated gasket, diaphragm etc.
	Runoff of sand	Intrusion of sand and soil in water mains at construction	Drainage from the drain valve etc. Cleaning of meter strainer and drainage	Careful workmanship
High pH	Elution of alkaline ingredient from cement mortar lining etc.	Elution of alkaline ingredient from lining due to stagnation	Drainage from the drain valve etc.	Improvement in water mains network Rehabilitation or replacement of water mains.
	Trouble when controlling pH.	Abnormal dosage of alkaline agent etc.	Drainage from the drain valve etc.	Intensive water treatment
Organisms	Inflow of organisms	Organisms grow in water source	Drainage from the drain valve etc. Enhancement of water treatment	Enhancement of water quality monitoring system. Change in water source
		Intrusion of organisms from leaking points etc.	Drainage from the drain valve etc. Finding of location of intrusion and repair.	Inspection and upkeep of water mains. Enhancement of water quality monitoring system.

13.10. Water quality accident and its measure

13.10.1. General

Water supply plays a role in supporting one of important lifelines for sustaining citizen's lives, so it is the duty of the water utility to reliably supply safe water. Unexpected accidents related to water quality can occur in not only a water source but water treatment facilities and water distribution facilities. In the worst case, it entails reduced discharge or suspension of water service causing great troubles to users, and giving them a sense of distrust about the safety of tap water.**

Although it is ideal that raw water of water supply is free from pollution and clean, an accident of inflow of chemical substances or oils occurs at times.

In addition, an unexpected accident may be brought about by leak of chemicals in the water treatment facilities, and improper water treatment as well. Even in water distribution facilities, there is an example that water without chlorination was served for a long time due to a cross-connection with an industrial water supply.

To prevent the occurrence of accidents related to water quality, although efforts to prevent them beforehand and measures against them are needed, against the accident, that has already occurred, it is necessary to restrict its influence to a minimum by means of early identification of the site, quick and precise communication of information, implementation of proper response and measures and so forth. To carry out proper and speedy response, understanding of sources of pollution, establishment of a water quality monitoring system, preparation and training of an emergency response system at the time of an accident must be implemented as everyday activities.

13.10.2. Establishment of a response system to water quality accidents

1) Manual for response to water quality accidents

As to response to water quality accidents, it is desirable for respective water utilities to prepare a response manual to water quality accidents suitable to them with reference to Figure 13.10.2 and samples of manuals of other water utilities.

In the response manual to water quality accidents, judgment standards of abnormal water quality, which occurred by the accident, shall clearly be stated. It is also important that training on communication and response to an accident at normal times to be able to cope with an emergency. When suspension of water service is decided due to a water quality accident, public relations (PR) is needed for the consumers in the service area, so the means of PR, the contents etc. to be announced (the reason for suspension of water service, the affected area, the alternative means of water service, and expected time for recovery) shall be described in the manual.

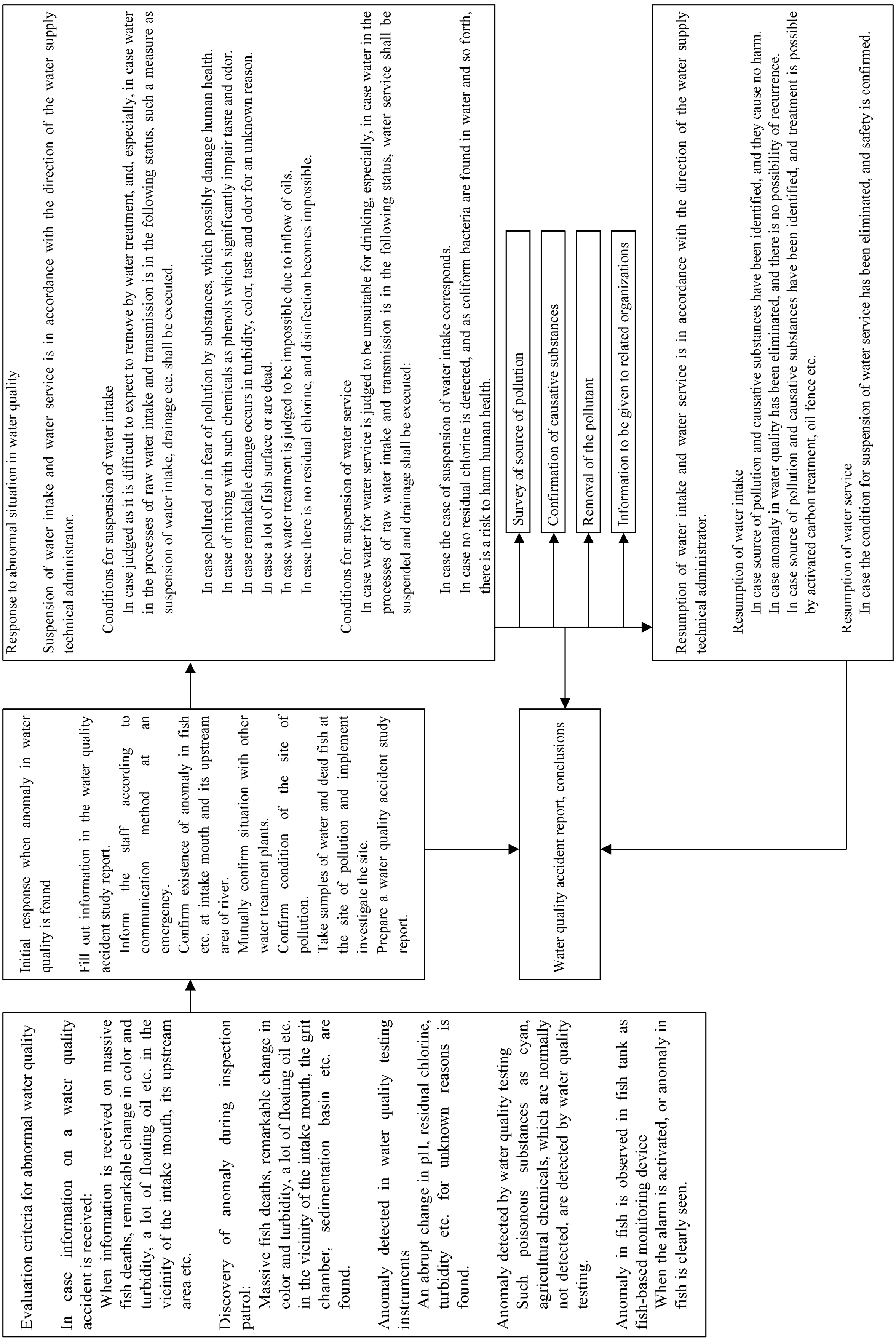


Figure 13.10.2 Flowchart of manual for response to abnormal condition in water quality (Okayama City Waterworks Bureau)

13.10.3. Water quality accidents in water source and water intake facilities

1. Situation in occurrence of pollution accidents

Accidents related to water quality in the water source of the water utility are mostly caused by spill of oils followed by surfacing of fish, dumping of waste, taste and odor, and coloring in order. Although their ratio to the total number is small, accidents caused by phenols and bubbling by synthetic detergent also occur.

Many of accidents related to water quality, which affect water intake and water treatment are caused by accidents of spill of oils and taste and odor, and, from the view point of the number of their occurrence and their influence, they are accidents, to which special attention shall be paid.

Meanwhile, since water utilities, which possess more than two water sources, can avoid intake of water from the contaminated source, the magnitude of influence to water intake and water treatment is small in comparison with the number of accidents.

2. Response to water quality accidents

As a means for a water utility to early find an accident, physicochemical monitoring of raw water by automatic water quality testing instruments, biological monitoring, visual monitoring by the industrial TV, and patrol of the premises of the water treatment plant are implemented. What is more, a periodic survey on water quality of water source is an effective opportunity to detect the source of water pollution.

In case possibility of pollution of raw water for water supply due to a water quality accident arises, although the best protective measure is to stop intake of water, its influence to the operation of facilities and measures for water distribution and water service shall be taken for granted. To limit the influence of a water quality accident to a minimum, speedy response at the water intake facilities and proper water treatment suitable to the pollutant are needed.

1) Inflow of oils

In case an accident of pollution by oil spill occurs in the water source and its basin, oil is usually warded off by oil fences and oil mats and it is recovered.

Minute particles of oil dispersed in water can hardly be warded off completely by oil fences and oil mats resulting in oily smell in water. In such a case, depending on the scale of oil spill, suspension of water intake until oil flows away, or treatment for removal of oil by application of powdered activated carbon (PAC) is necessary.

2) Inflow of chemical substances

Against inflow of such a poison as cyan, mercury etc., water intake shall immediately be suspended. Against other chemicals, measures shall be examined in consideration of removal effect of respective objective substances to be removed referring to 13.1.3 Treatability of respective substances. It is important to store such treatment materials as PAC for an emergency, or to be ready to quickly order for them.

In case poisonous substances flow in the water source, there are changes in pH, and conductivity, and also such a reaction as deaths of fish, or their surfacing is seen.

3) Obnoxious odor due to wastewater from factories and businesses

Obnoxious odor is roughly classified into such chemical odor as phenols, oily smell, chlorine odor, fragrant smell, perfume smell, hydrogen sulfide odor, solvent odor, resin-like odor, tar odor etc., and such putrid odor as septic odor, excreta odor, sewage odor etc.

4) Inflow of excreta and domestic wastewater

As remarkable increase in ammoniac nitrogen is observed by the inflow of excreta and domestic wastewater, and also as TOC, potassium permanganate consumption, color, threshold odor number (TON) increase, the existence of contamination and its magnitude shall synthetically be judged.

As measures, pre-chlorination, especially, breakpoint chlorination, and enhancement of coagulation and sedimentation are employed. Although items to be monitored are ammoniac nitrogen, chlorine demand, color, conductivity, TOC, potassium permanganate consumption, residual chlorine in treated water etc., especially, it is important to pay attention to changes in their values. Besides, even though testing of standard plate count bacteria and coliform bacteria cannot be used for judgment at the time of the accident as their results are given one day later, they are effective as evidence after the fact.

13.10.4. Water quality accidents in water treatment facilities

1. Coagulation and sedimentation facilities

1) Excessive or insufficient dosage of chemicals

Although chemicals are dosed by gravity in some cases, dosing is mostly made by pumping. In the pumping method, as power outage, clogging of pipe, breakdown of pumps etc. are expected, it is important to sufficiently implement inspection on the principle of safety also from equipment point of view. Especially, as many of chemicals used in water treatment facilities possess strong corrosiveness, inspection of the storage tank, dosing pumps, liquid feeding pipe etc. and measures for prevention of their corrosion are needed.

Just in case, when the dosage becomes too short, manual dosing shall be made with securement of coagulant, acid and alkaline agents, and disinfection agent which can manually be dosed. In the case of coagulant, it shall be dosed at least up to the end of the sedimentation basin so that micro flocs are formed and can be treated in the filter.

In the case of acid and alkaline agents as well, although the filter can play the role of the mixing basin, even if detection of the accident is late, duplicated or triplicated backup measures are required. At the worst, there is a possibility that water is served without disinfection, water service shall right away be suspended, water must be discharged from drain valves etc.

Overdose of coagulant can at times be found by opaque color in the sedimentation basin and low pH. In this case, such measure as dosing of an alkaline agent, slow-down of filtration rate etc. shall be undertaken.

In the case of excessive dosing of disinfectant, although depending on its concentration, if possible, it may be made low in concentration by dilution. In the worst case, water shall be drained from the water supply facilities and discharged outside after dechlorination.

2) Measure at the time of power failure

As the measure at the time of power failure, treatment after the fact is important, and, especially, it is needed to wholly inspect such points of attention as inspection of dosing equipment for chemicals for water treatment, inspection of automatic water quality testing instruments etc. After recovery of power, confirmation of the safety of treated water shall be made through water quality testing of respective water treatment processes such as pH, residual chlorine etc. in the mixing basin.

2. Filtration facilities

1) Slow sand filter

In case a river, in which pollution is in progress, is the water source, as raw water at times becomes anaerobic in summer, and microorganisms cannot live, the slow sand filter ceases to function. In such a case, it is needed to maintain dissolved oxygen in raw water by aeration.

2) Rapid sand filter

As examples of an accident related to the rapid sand filter, there are one related to the supporting gravel, another one related to failure of the automatic control system etc.

As an example related to the supporting gravel layer, a fault was formed due to a change in the grain size of gravel, gravel was heaved by 20 to 30 cm above the sand surface, which impeded normal filtration.

As an example of an accident caused by failure of the automatic control system, there is a report that the inside of a pipe laid through the wall of the filter at the position of the underdrain system was clogged by hard accretion of fine clayish slime, which obstructed normal indication of the differential pressure meter, resulting in a failure of automatic filter cleaning system.

Furthermore, when part of sedimentation basins and filters are derailed because of construction work in winter, there are examples that treated water turbidity rises because filter runtime is set as normal; and that, as raw water turbidity becomes high due to a continuing rain since the day before, and the processes of coagulation, sedimentation and filtration cannot deal with it, treated water turbidity exceeds 2 turbidity units. To prevent such incidences, it is needed to strive in jar tests in normal times, and carefully examine the number of basins and filters to be suspended during construction work, their influence to water treatment and so forth in case construction work is implemented.

13.10.5. Water quality accidents in water distribution facilities

Since accidents related to water quality in water distribution facilities directly affect the users, in case, studying the cause of the water quality accident, tap water is hazardous to human health, water service shall immediately be suspended. Besides, it is needed to take a measure to announce to the concerned people that the use of the water is dangerous and, at the same time, implement such an appropriate step as to drain water and so on (See 13.5.2 1. Judgment and measures at the time of abnormal water quality).

13.11. Water quality management by automatic water quality testing instruments

13.11.1. General

1. Purpose and effect of water quality management by automatic water quality testing instruments

Although it is impossible to automatically measure all the water quality items, various automatic testing apparatuses have been developed for the many items. If applying automatic testing apparatuses, continuous water quality monitoring can be made from the water source to the tap. As technologies for testing apparatuses have markedly been improved, they exert great ability for water quality management by means of proper maintenance. Automatic water quality testing instruments is indispensable for monitoring of raw water quality, chemical dosing control in the water treatment plant, water quality monitoring in water treatment processes, management of treated water quality, water quality monitoring in the water distribution process etc.

The purpose of installing automatic water quality testing instruments is primarily improvement in safety. Anomaly in raw water, failure of facilities etc. can early be detected by continuous monitoring, and an accident can be prevented. Secondly, it is for securement of good water quality. The results of continuous monitoring shall be reflected to chemical dosing control, and operation and maintenance of water treatment facilities etc. including water intake and water distribution so that tap water of good quality is reliably served. Automatic control of chemical dosing can lead to labor saving in operation and maintenance and efficient use of chemicals as well. What is more, analyses of accumulated data collected by automatic water quality testing instruments are useful for the improvement of facilities.

13.11.2. Types of automatic water quality testing instruments (Annotation omitted)

13.11.3. Utilization of measurement data (Annotation omitted)

13.11.4. Processing of data (Annotation omitted)

13.12. Management of the laboratory (Annotation omitted)

13.12.1. General (Annotation omitted)

13.12.2. Working environment of the laboratory (Annotation omitted)

13.12.3. Handling of reagents (Annotation omitted)

13.12.4. Handling of sealed radioactive source (Annotation omitted)

13.12.5. Management of power, city gas, water supply and wastewater (Annotation omitted)

13.12.6. Management of liquid waste, wastewater and exhaust gas from the laboratory (Annotation omitted)

13.12.7. Measures against an earthquake (Annotation omitted)

13.12.8. Measures against terrorism etc. (Annotation omitted)

13.13. Management of water quality testing and examination

13.13.1. General

In water quality testing for the purpose to confirm that the water quality standards are met, as the recent trend, it is required to maintain high measurement accuracy, and, at the same time, securement of reliability on measurement. Meanwhile, in water quality testing for the purpose of confirming that water treatment is properly performed, the rapidity of measurement becomes important, while testing items, frequency of testing etc. are largely different depending on the characteristics of respective water utilities. Such an analysis, which is different from ordinary water quality testing, as identification of foreign matters contained in tap water is requested in a case.

Although which factor is to be considered important in water quality testing and examination depends on the purpose of measurement, to precisely measure without fail is basically important factor in either measurement. To this end, it is needed that analytical tools and instruments are managed not to be contaminated, and, at the same time, they are periodically inspected so that they can always work in normal condition. Moreover, as to reagents as standards for concentration, their concentration and quality shall periodically be confirmed, while required knowledge and technology shall be obtained from the staff in charge of measurement so that maintenance can be made.

For water quality analysis diverse types of devices, instruments and tools are used. They are roughly classified into such sampling device as high-funnel sampler, such a preservation device as refrigerator, such a tool as pipette used for preparation of analytical reagents and samples, such a device for pre-treatment as evaporator and purge-trap thickener, the spectrophotometer, such measurement device as gas chromatograph-mass spectrometer, and data processing device to manage measurement data. Proper management of these devices is the basic condition for water quality analysis. Proper management means to manage these devices so that they are not polluted by the substances as the objects of water quality analysis, and manage the devices so that they fully exert required functions. Especially, for the devices, which analyze the infinitesimal concentration of substances at a ng/L level, more delicate management is required.

13.13.2. Water quality analytical devices and testing items

For testing of items of the water quality standards, although such a simple device as the pH meter is used, in case heavy metal, agricultural chemicals, in case musty odor causing matters etc. are analyzed at the infinitesimal concentration, such complex and advanced devices as inductively coupled plasma atomic emission spectroscope, gas chromatograph mass spectrometer, high-performance liquid chromatograph etc. are used.

In water quality testing in the water treatment processes, in addition to such manual analysis as titration etc., such analytical devices, of which handling and upkeep are relatively easy, absorptiometer, conductivity meter etc. as listed in Table 13.13.1 are used in a large number. As these devices are relatively simple as to their structure, it is desirable to periodically confirm their working condition and status of calibration.

Table 13.13.1 Water quality analytical tools and devices needed for process management.

Measurement objective	Analytical device (analytical method)	Measurement location	Purpose
Turbidity	Turbidimeter	Raw water, settled water. Treated water	To decide dosage rate of coagulant.
Color	Color meter	Raw water, settled water, treated water	To decide dosage rate of coagulant.
Alkalinity	Burette (titration method)	Raw water, flocculated water	To confirm situation of pollution. To decide dosing rates of coagulant, coagulant aid.
pH	pH meter (colorimetry, electrode method)	Raw water, flocculated water, treated water	To confirm situation of pollution. To decide dosing rates of coagulant, coagulant aid.
Chlorine demand	Chlorine demand meter	Raw water	To decide dosage rate of disinfectant.
Conductivity	Conductivity meter (electrode method)	Raw water, treated water	Indicator of situation of pollution
Water temperature	Thermistor thermometer, bar thermometer		To decide disinfectant dosage rate.
Ammoniac nitrogen	Spectrophotometer (1-naphthol method, indophenols method)	Raw water, settled water, ozonated water, GAC filtered water	To decide disinfectant dosage rate.
Odor	Organoleptic method	Raw water, treated water	Sensing of odor
Taste	Organoleptic method	Treated water, distributed water	Sensing of taste
Dissolved manganese	Spectrophotometer (formadoxime method) Atomic absorption analyzer	Raw water, filtered water	To decide disinfectant dosage rate. To confirm removal of manganese.
Fish	Bioassay	Raw water, treated water	Detection of poisons
Residual chlorine	Residual chlorine meter (DPD method)	Filtered water, treated water, distributed water	To confirm effect of disinfection. To confirm removal of manganese.
Acidity, free carbonate	Burette (titration method)	Raw water, treated water	To decide dosage rate of coagulant aid. Indicator of Langelier's index
Dissolved oxygen	DO meter	Filtered water	To monitor the function of slow sand filtration.
UV absorbance	Spectrophotometer (E260)	Filtered water, treated water, distributed water	To confirm effect of advanced water treatment.
Musty odor	GC/MS	Raw water, filtered water	To monitor odor casing substances.
TOC	TOC meter	GAC filtered water	To monitor pollution with organic matters. To confirm effect of advanced water treatment.

13.13.3. Management of water quality analytical devices (Annotation omitted)

13.13.4. Staff training (Annotation omitted)

13.13.5. Water quality testing and examination and Good Laboratory Practice (GLP) (Annotation omitted)