CHAPTER 5

# WATER TREATMENT PLANT

## 5.1 INTRODUCTION

Water to be supplied for public use must be potable i.e., satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Drinking water should, preferably, be obtained from a source free from pollution. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes. The objective of water treatment is to produce safe and potable drinking water.

Some of the common treatment processes used in the past include Plain sedimentation, Slow Sand filtration, Rapid Sand filtration with Coagulation-flocculation units as essential pretreatment units. Pressure filters and Diatomaceous filters have been used though very rarely. Roughing filters are used, under certain circumstances, as pretreatment units for the conventional filters.

The treatment processes may need pretreatment like pre-chlorination and aeration prior to conventional treatment. The pretreatment processes comprising of Coagulation and Flocculation have been discussed under the main title of Rapid Sand filters in para 5.4 of this chapter. Detailed discussion on all such aspects as well as recommended unit operations, is given in the Manual on Water Supply and Treatment (1999 Edition) Ministry of Urban Development.

Figure 5.1 shows typical flow patterns of a Conventional Treatment Plant.

## 5.2 FILTRATION PLANTS

### 5.2.1 SLOW SAND FILTER-PLANT

It may include Plain Sedimentation basins followed by the conventional Filter-Plant.

### 5.2.2 RAPID SAND FILTER PLANT

It can be briefly divided into two main components:

1. The Pretreatment Works

   These include the (1) Coagulation- Flocculation Units with adequate chemical dosing and rapid mixing facilities, and (2) Sedimentation Units to handle the effluent from the Coagulation-flocculation units.

2. Filter units.

### 5.2.3 OTHER CATEGORIES

There are a number of other categories of filtration plants but not of common use. Of these Pressure filters are used for small treatment plants or industries. Roughing filters may be used to reduce load on the treatment plants. Small streams of water in the catchment areas may carry large particles and floating matter. Introduction of the roughing filters will ensure entrapping of such undesirable material prior to the storage structures of the treatment units.

## 5.3 SLOW SAND FILTRATION

### 5.3.1 PROCESS

Slow Sand filtration was the first type of porous media filtration used in water treatment. This process is known for its simplicity and efficiency.

During the initial operational period of slow sand filters, the separation of organic matter and other solids generates a layer of biological matter on the surface of the filter media.

### 5.3.2 FILTER CONTROLS

The pipe work, valves and devices used to regulate the operation of a filter should be properly planned. Adequate means must be available to:

- Deliver raw water into the supernatant reservoir,
- Remove scum and floating matter,
- Drain off supernatant water prior to filter cleaning,
- Lower water level in the bed,
- Control the rate of filtration and adjust it as bed resistance increases,
- Ensure that negative pressures cannot occur within the bed (the weir is the device usually used for this purpose),
- Convey filtered water to the filter water tank,
- Run filtered water to waste or to the inlet side of other filters during the ripening process,
- Fill sand bed from below with filtered water (from other filters) after cleaning.

### 5.3.3 OPERATION

The operation of the filter is determined by the filtration rate, which is controlled at the effluent outlet. Inflow, which may be by gravity from a constant level reservoir, or by a pump, is adjusted so that the head of water in the supernatant reservoir remains constant at all times. Excessive raw water delivery will cause overflow through the scum outlets, while a reduction in the rate of inflow will cause the level in the supernatant water reservoir to drop; either condition should alert the operator to a defect in the mechanism controlling the supply of raw water.

The filtration rate is controlled by a single regulating valve on the effluent delivery. At the beginning of the filter run this will be partially closed, the additional resistance thereby provided being equal to that which will later build up within the filter bed. Day by day as the run continues this valve must be checked and opened fractionally to compensate for the choking of the filter and to maintain a constant filtration rate. In the early part of the filter run the daily build up of resistance will be almost imperceptible, calling for very little valve adjustment, but towards the end of the filter run the resistance will increase more rapidly, necessitating a more positive opening of the valve and signalling the impending need for filter cleaning.

To enable the operator to regulate the valve precisely it is necessary to have some form of measuring device on the effluent outlet.

### 5.3.4 CONTROL OF ALGAL GROWTH

Excessive algal growth may cause trouble in the operation of open filters. Pretreatment by microstrainers is one method of removing the algae contained in the raw water. For more details please refer to para 5.8 of this chapter.

### 5.3.5 DISSOLVED OXYGEN

If the dissolved oxygen content of the raw water drops below the potential oxygen demand, anaerobic conditions may develop within the bed. To some extent a reasonable growth of algae in the supernatant reservoir oxygenates the supernatant water. Where the composition of raw water or climate does not favour the growth of algae, or where chemical dosing or some other device has been used to remove or exclude them, it may be necessary to use other expedients to increase the dissolved oxygen content, such as aeration of the incoming raw water.

Ventilators are provided as an integral part of the filter bed. It should be ensured that these function properly.

### 5.3.6 WATER QUALITY

Samples of raw and treated water will be taken at regular intervals for analysis. In a large waterworks with its own laboratory, sampling will almost certainly be carried out daily, since the effluent analysis constitutes the only certain check that the filter is operating satisfactorily and the raw water analysis provides what is possibly the only indication of a change in quality that might adversely affect the efficiency of treatment. In case of small plants with no laboratory facilities, an attempt should be made to conduct sampling on regular basis. Field testing equipment may be used to measure water quality. For more details please refer to Chapter 9 of this manual.

### 5.3.7 FILTER CLEANING

While the filter is in operation, a stage comes when the bed resistance increases so much that the regulating valve has to be fully opened and it is the right time to plan the cleaning of the filter bed since any further resistance is bound to reduce the filtration rate. Resistance accelerates rapidly as the time for cleaning approaches. Indicators may be installed showing the inlet and outlet heads, from which the head loss can be regularly checked; this gives a clear picture of the progress of choking and the imminence of the end of the run. Without any measurement of the head loss the only true indicator of build up of resistance is the degree of opening of the regulating valve, though the experienced operator may be able to recognize preliminary visual warnings in the condition of the filter bed surface. A slight deterioration in the effluent quality may be a reason for the need for cleaning.

To clean a filter bed, the raw water inlet valve is first closed, allowing the filter to discharge to the clear water well as long as possible (usually overnight). As the head in the supernatant reservoir drops, the rate of filtration rapidly decreases, and although the water above the bed

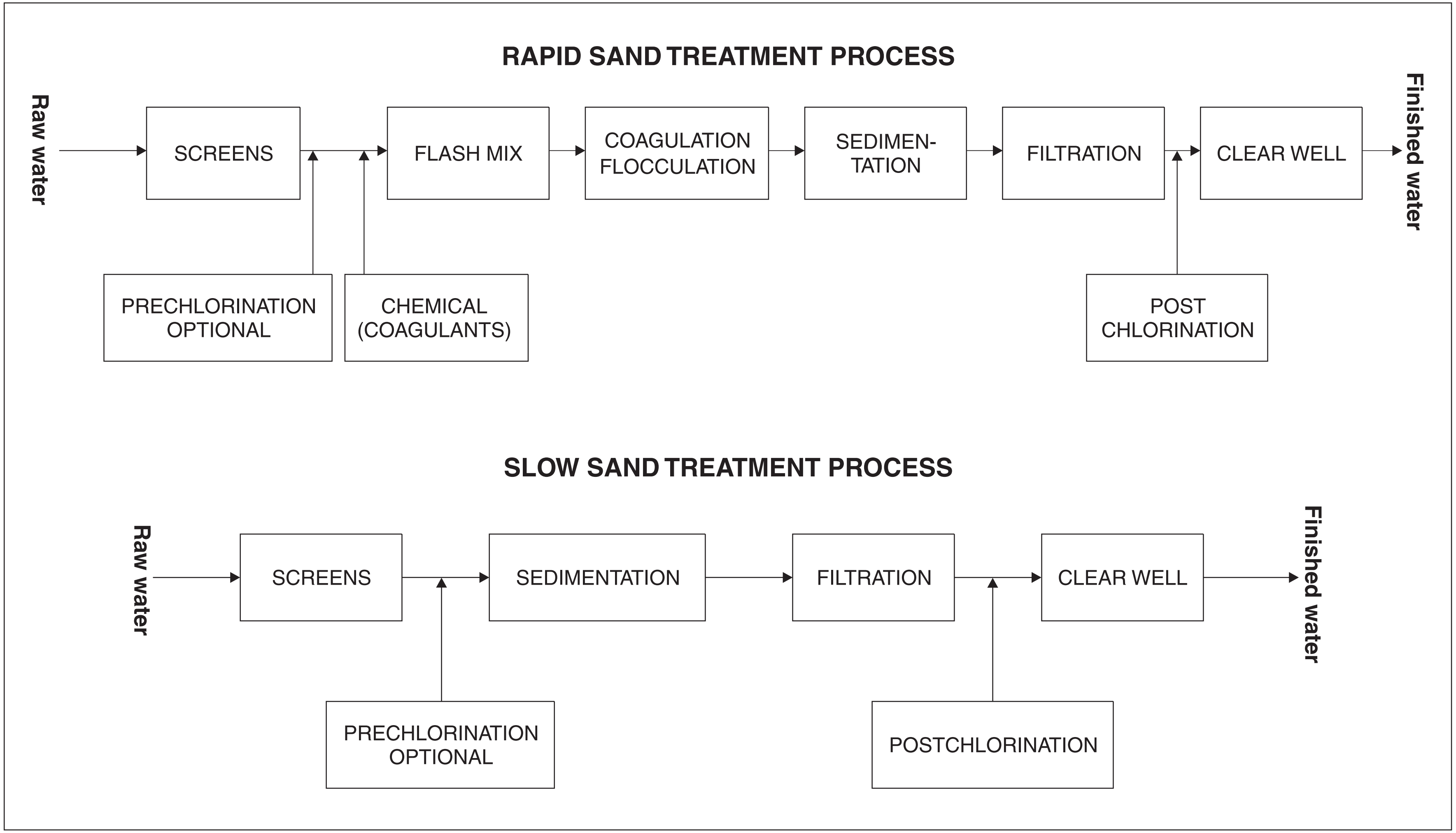


FIG. 5.1: CONVENTIONAL FILTRATION PROCESSES

would continue to fall until level with the weir outlet, it would take a very long time to do so. Consequently, after a few hours, the effluent delivery to the clear water well is closed, and the supernatant water outlet is run to waste through the drain valve provided.

When the supernatant water has been drained off (leaving the water level at the surface of the bed) it is necessary to lower the water within the bed still further, until it is some 100 mm or more below the surface .This is done by opening the waste valve on the effluent outlet pipe. As soon as the Schmutzdecke is dry enough to handle, cleaning should start. If the filter bed is left too long at this stage it is likely to attract scavenging birds that will not only pollute the filter surface but also disturb the sand to a greater depth than will be removed by scraping.

The cleaning of the bed may be carried out by hand or with mechanical equipment. Working as rapidly as possible, they should strip off the Schmutzdecke and the surface sand adhering to it, stack it into ridges or heaps, and then remove the waste material by barrow, hand cart, basket, conveyor belt or other device.

After removal of the scrapings the bed should be smoothed to level surface. The quicker the filter bed is cleaned the less will be the disturbance of the bacteria and shorter the period of re-ripening. Provided they have not been completely dried out, the microorganisms immediately below the surface will quickly recover from having been drained and will adjust themselves to their position relative to the new bed level. In this event a day or two will be sufficient for re-ripening.

Before the filter box is refilled, the exposed walls of the supernatant water reservoir should be well swabbed down to discourage the growth of adhering slimes and algae, and the height of the supernatant water drain and of the outlet weir must be adjusted to suit the new bed level. The water level in the bed is then raised by charging from below with treated water from the clear water well or from one of the other filters. As soon as the level has risen sufficiently above the bed surface to provide a cushion, the raw water inlet is gradually turned on. The effluent is run to waste until analysis shows that it satisfies the normal quality standards. The regulating valves on the effluent line will be substantially closed to compensate for the reduced resistance of the cleaned bed, and the filter will then be ready to start a new run.

During the cleaning operations precautions must be taken to minimize the chances of pollution of the filter bed surface by the labourers themselves. Such measures as the provision of boots that can be disinfected in a tray of bleaching solution should be taken. Hygienic personal behaviour must be rigidly imposed, and no labourers with symptoms that might be attributable to water borne or parasitic diseases should be permitted to come into direct or indirect contact with the filter medium.

### 5.3.8 RESANDING

After several years' operation and, say, twenty or thirty scrapings the depth of filtering material will have dropped to its minimum designed level (usually 0.5 to 0.8 m above the supporting gravel, according to the grain size of the medium). In the original construction, a marker, such as a concrete block or a step in the filter box wall, is sometimes set in the structure to serve as an indication that this level has been reached and that resanding has become due.

During the long period of the filter use/run some of the raw water impurities and some products of biochemical degradation will have been carried into the sand-bed to a depth of some 0.3 to 0.5 m according to the grain size of the sand. To prevent cumulative fouling and increased resistance this depth of sand should be removed before resanding takes place, but it is neither necessary nor desirable that it should be discarded. Instead it is moved to one side, the new sand is added, and the old sand replaced on the top of the new, thus retaining much of the active material to enable the resanded filter to become operational with the minimum re-ripening.

This process (of replacing old sand on the top of the new) known as "throwing over" is carried out in strips. Excavation is carried out on each strip in turn, making sure that it is not dug so deeply as to disturb the supporting gravel layers below. The removed material from the first strip is stacked to one side in a long ridge, the excavated trench is filled with new sand, and the adjacent strip is excavated, throwing the removed material from the second trench to cover the new sand in the first. The operation is illustrated in Fig. 5.2. When the whole of the bed has been resanded, the material in the ridge from the first trench is used to cover the new sand in the last strip.

In areas where sand is expensive or difficult to obtain, the surface scrapings may be washed, stored and used for resanding at some future date. These scrapings must be washed as soon as they are taken from the filter, otherwise, being full of organic matter, the material will continue to consume oxygen, quickly become anaerobic, and putrefy, yielding taste and odour producing substances that are virtually impossible to remove during any washing process.

Sand Washing Machines should be provided for the bigger plants. Wherever provided, these should be operated regularly to prevent accumulation of sand and also to keep the machine in working condition.

### 5.3.9 RECORD KEEPING

The following are the basic records that must be maintained:

1. The date of each cleaning (commencement)
2. The date and hour of return to full service (end of re-ripening period)
3. Raw and filtered water levels (measured each day at the same hour) and daily loss of head.
4. The filtration rate, the hourly variations, if any.
5. The quality of raw water in physical terms (turbidity, colour) and bacteriological terms (total bacterial count, E.Coli.) determined by samples taken each day at the same hour.
6. The same quality factors of the filtered water.
7. Any incidents occurring e.g. plankton development, rising Schmutzdecke, and unusual weather conditions.

### 5.3.10 AUGMENTATION OF THE CAPACITY OF AN EXISTING PLANT

Some of the existing slow sand filtration plants need augmentation. There is a tendency to abandon the old plants and substitute the same with Rapid sand Filtration plants. It is suggested that wherever possible the old Slow sand Filtration plants may be retained on account of the following reasons:

i) Slow sand filter is less likely to go wrong under inexperienced operation.

ii) It does not require skilled attendance.

iii) Head consumed is less.

iv) It provides greater reliability of the removal of bacteria.

v) Operating costs may be less.

It is, however, adapted to waters low in colour, turbidity and bacterial count. Under such circumstances, provision of a roughing filter as a pretreatment unit gives good results.

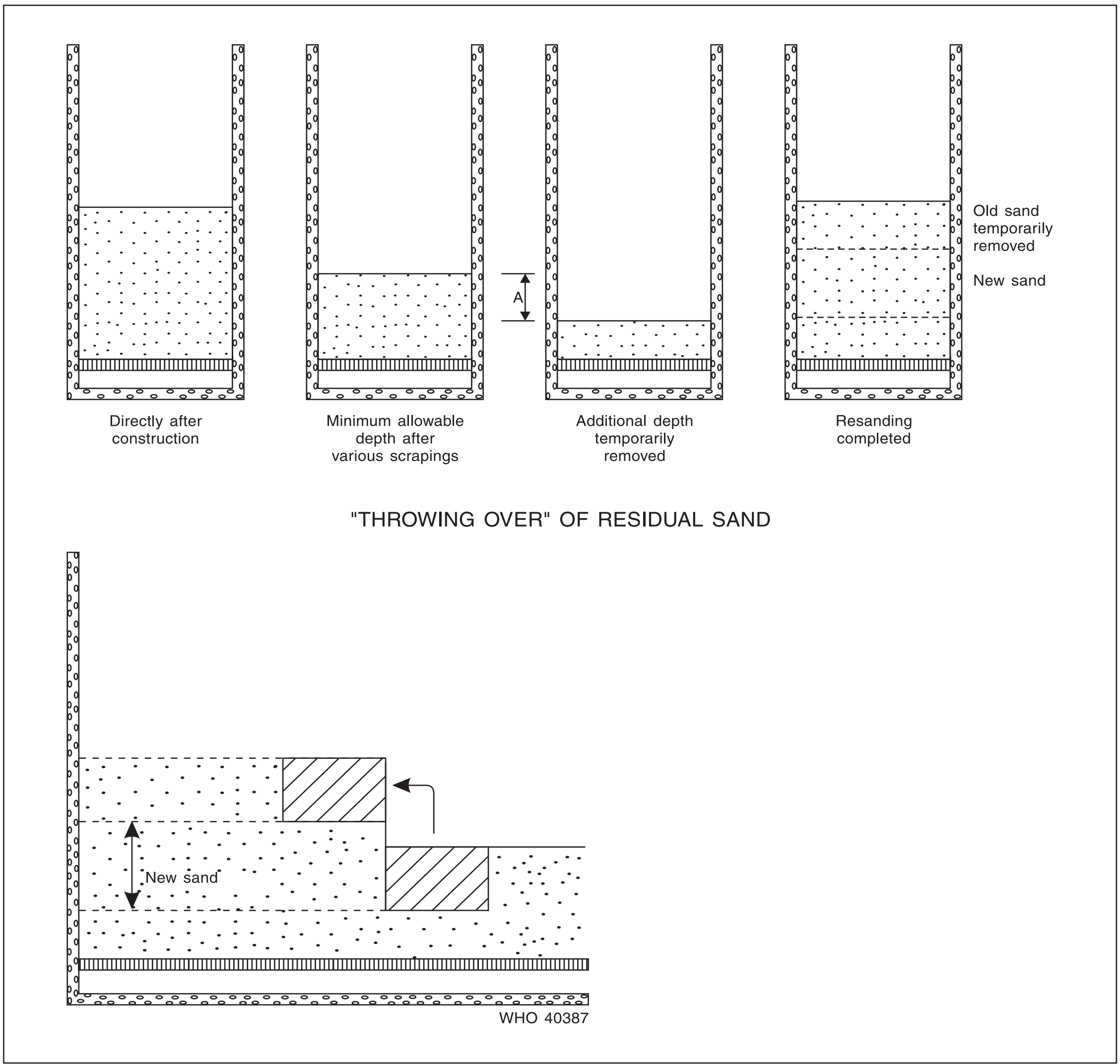


FIG. 5.2: RESANDING OF A SLOW SAND FILTER

## 5.4 RAPID SAND FILTRATION PLANTS

The pretreatment units which form essential parts of a Rapid sand filtration unit include (a) Coagulatlion and flocculation with rapid mixing facilities and (b) Sedimentation units.

### 5.4.1 COAGULATION AND FLOCCULATION

#### 5.4.1.1 Purpose

The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settleable solids (particularly colloids) and colour from the water being treated. Non-settleable particles in water are removed by the use of coagulating chemicals.

#### 5.4.1.2 Chemical Coagulants Commonly used in Treatment Process

**TABLE 5.1: CHEMICAL COAGULANTS**

| Name | Formula | Coagulant Primary/Aid |
|---|---|---|
| Ferric Alum | $Fe_2.(SO_4)_3.Al_2(SO_4)_3.24H_2O$ | Primary |
| Poly Aluminium Chloride | $\{Al_2(OH)_{2.7}\ Cl_{3.3}\}_{15}$ | Primary |
| Ferric Chloride | $FeCl_3.6H_2O$ | Primary |
| Calcium Hydroxide | $Ca(OH)_2$ | Primary/Aid |
| Calcium Oxide | $CaO$ | Primary/Aid |

The most commonly used coagulant is ferric alum. However, Poly Aluminium Chloride (PAC) is also used as a coagulant. The advantages of PAC are i) it gets properly dispersed, ii) it does not have any insoluble residue, iii) it does not affect the settling tanks, iv) it is more effective than alum v) it requires less space (may be about 50%). The disadvantage of PAC is that it is less effective in removal of colour.

#### 5.4.1.3 Selection of Coagulants

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocs.

The most important consideration is the selection of the proper type and amount of coagulant chemical to be added to the water to be treated.

Overdosing as well as underdosing of coagulants may lead to reduced solids removal efficiency. This condition may be corrected by carefully performing Jar tests and verifying process performance after making any change in the process of the coagulation process.

#### 5.4.1.4 Jar Test

The jar test has been and is still the most widely used method employed to evaluate the coagulation process and to aid the plant operator in optimizing the coagulation, flocculation and clarification processes.

From the turbidity values of the settled water, settling velocity distribution curves can be drawn. These curves have been found to correlate well with the plant operating data and yield useful information in evaluating pretreatment, such as optimizing of velocity gradient and agitation and flocculation, pH, coagulation dosage and coagulant solution strength. Such curves cannot be generalized and are relevant to the plant for which the data have been collected through the Jar tests.

Typical Jar test Data sheet is given in Table 5.2.

In addition, the turbidity, colour and alkalinity of the raw and treated water should be measured for evaluation of the treatment.

**TABLE 5.2: JAR TEST DATA SHEET**

| Date & Time | Flocculation period with RPM | Settling period | Jar no. | pH | Turbidity | Colour | Alkalinity $CaCO_3$ | Time for first floc. Form-ation | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | Control | | | | | | |
| | | | 1 | | | | | | |
| | | | 2 | | | | | | |
| | | | 3 | | | | | | |
| | | | 4 | | | | | | |
| | | | 5 | | | | | | |
| | | | 6 | | | | | | |

#### 5.4.1.5 Mixing

The main requirement of the mix is that all the coagulant be rapidly mixed with all the water instantly so as to achieve complete homogenization of a coagulant chemical in the stream to be treated. The reason is that the chemical reaction is extremely rapid, practically instantaneous, especially in waters with high alkalinity. Since this is not physically possible although desirable, it is important to approximate as nearly as possible to instant and complete dispersion.

To accomplish the mixing of the chemicals with the water to be treated, several methods can be used.

Hydraulic mixing

Mechanical mixing

Diffusers and grid system

Pumped blenders.

Mixing of the chemical coagulant can be satisfactorily accomplished in a special coagulant tank with mixing devices. Mixing may also occur in the influent channel or a pipeline to the flocculation basin if the flow velocity is high enough to produce the necessary turbulence. The shape of the basin is part of the flash mix design.

#### 5.4.1.6 Flocculation Basin – Operation

The objective of a flocculation basin is to produce a settled water of low turbidity which in turn will allow reasonably long filter runs. Following points should be considered during the operation of the flocculation basins.

*Short Circuiting*

An important factor that determines the functioning of a flocculator is the short circuiting. In such a basin, against a predetermined 30 minutes agitation, a large portion may get only 10 minutes while another sizeable amount may get 60 minutes. Under such circumstances very inferior settled water is produced.

Short circuiting in flocculation basins is characterized by currents which move rapidly through and continue into the settling tanks .The floc removal problem is compounded then with flocculation which is incomplete and currents introduced into the settling process which further inhibit removal. Properly operated entrance, curtain baffles and exit weirs and launders can significantly improve settling.

The flocculators may be circular, square or rectangular. The best flocculation is usually achieved in a compartmentalized basin. The compartments (most often three) are separated by baffles to prevent short circuiting of the water being treated. The turbulence can be reduced gradually by reducing the speed of the mixers in each succeeding tank or by reducing the surface area of the paddles. This is called tapered-energy mixing. The reason for reducing the speed of the stirrers is to prevent breaking apart the larger floc particles, which have already formed. If the floc is broken up nothing is accomplished and the filter gets overloaded.

*Dosing of the coagulant at a spot of maximum turbulence*

Rapid mix of coagulant at a spot of maximum turbulence, followed by tapered flocculation in three compartmentalized units allows a maximum of mixing, (reduced short circuiting) followed by a period of agglomeration intended to build larger fast settling floc particles. The velocity gradient is gradually reduced from the first to the third unit. The concepts of velocity gradient and tapered flocculation have been discussed in the Manual of Water supply and Treatment (1999 edition).

#### 5.4.1.7 Interaction with Sedimentation and Filtration

The processes of coagulation and flocculation are required to precondition or prepare non-settleable particles present in the raw water for removal by sedimentation and filtration. Small particles (particularly colloids), without proper coagulation and flocculation are too light to settle out and will not be large enough to be trapped during filtration process.

Since the purpose of coagulation – flocculation is to produce particle removal, the effectiveness of the sedimentation and filtration processes, as well as overall performance, depends upon successful coagulation - flocculation.

#### 5.4.1.8 Coagulation - Flocculation Process Actions

Typical jobs performed by an operator in the normal operation of the coagulation flocculation process include the following:

- Monitor process performance.
- Evaluate water quality conditions (raw and treated water).
- Check and adjust process controls and equipment, and
- Visually inspect facilities.

Fig. 5.3 shows the overall plan view of the coagulation-flocculation process of a typical plant.

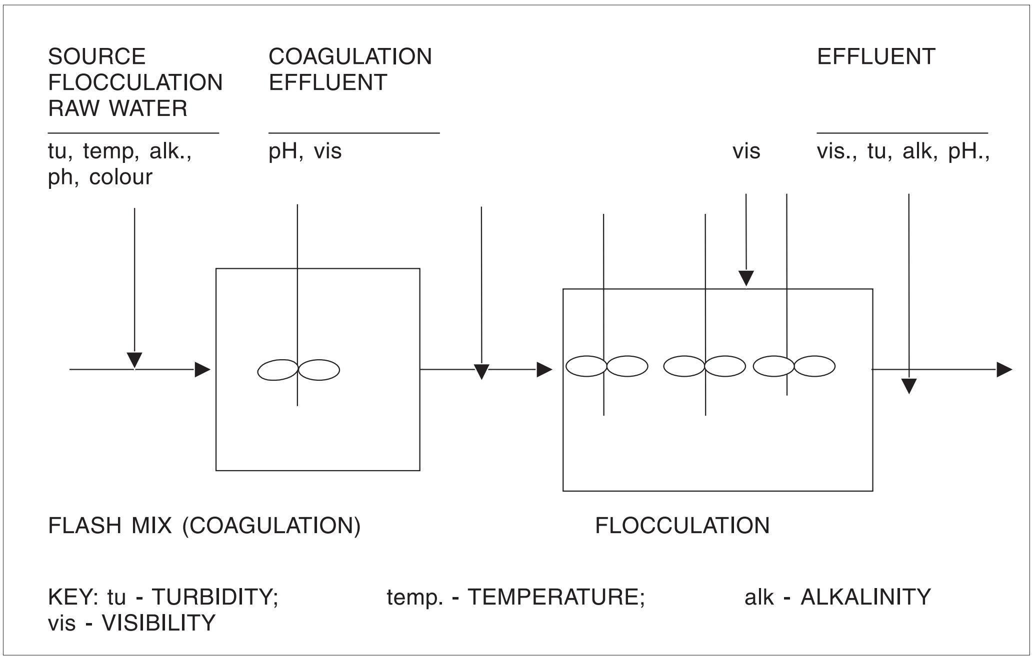


FIG. 5.3: COAGULATION-FLOCCULATION PROCESS MONITORING GUIDELINES

#### 5.4.1.9 Examination of the Floc

Examine the water samples at several points enroute the flow line of the water. Look at the clarity of the water between the flocs and study the shape and size of the floc.

- Observe the floc as it enters the flocculation basins. The floc should be small and well dispersed throughout the flow.
- Tiny alum floc may be an indication that the chemical dose is too low. A 'popcorn flake' is a desirable floc. If the water has a milky appearance or a bluish tint, the alum dose is probably too high.
- As the floc moves through the flocculation basins the size of the floc should be increasing. If the size of the floc increases and then later starts to break up, the mixing intensity of the downstream flocculator may be too high. Try reducing the speed of these flocculators or increasing the coagulant dosage.
- Examine the settlement of the floc in the sedimentation basin. If a lot of floc is observed flowing over the laundering weirs the floc is too light for the detention time. By increasing the chemical dose or adding a coagulant aid such as a polymer, a heavier, larger floc may be produced. The appearance of the fine floc particles washing over the effluent weir could be an indication of too much alum and the dose should be reduced. For precise evaluation you should make only one change at a time and evaluate the results.

Table 5.3 is a summary of coagulation-flocculation process problems; how to identify the causes of these problems and also how to go to correct the problems.

#### 5.4.1.10 Record keeping

Records of the following items should be maintained:

- Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and colour.
- Process water quality (pH, turbidity, and alkalinity).
- Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage).
- Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments).
- A plot of key process variables should be maintained. A plot of source water turbidity vs. coagulant dosage should be maintained. If other process variables such as alkalinity or pH vary significantly, these should also be plotted.

**TABLE 5.3: COAGULATION-FLOCCULATION PROCESS TROUBLESHOOTING**

| **Source Water Quality Changes** | **Operator Actions** | **Possible Process Changes** |
|---|---|---|
| Turbidity<br><br>Temperature | 1. Perform necessary analyses to determine extent of change.<br>2. Evaluate overall process performance.<br>3. Perform jar tests.<br>4. Make appropriate process changes (see right-hand column-Possible Process Changes).<br>5. Increase frequency of process monitoring. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing intensity.<br>3. Add coagulant aid or filter aid.<br>4. Adjust alkalinity or pH.<br>5. Change Coagulant(s) |
| **Coagulation Process Effluent Quality Changes** | **Operator Actions** | **Possible Process Changes** |
| Turbidity<br>Alkalinity<br>pH | 1. Evaluate source water quality.<br>2. Perform jar tests.<br>3. Verify process performance:<br>(a) Coagulant feed rate(s),<br>(b) Flash mixer operation.<br>4. Make appropriate process changes. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer intensity (if possible).<br>3. Adjust alkalinity or pH.<br>4. Change Coagulant(s). |
| **Flocculation Basin Floc Quality Changes** | **Operator Actions** | **Possible Process Changes** |
| Floc formation | 1. Observe floc condition in basin:<br>(a) Dispersion,<br>(b) Size, and<br>(c) Floc strength (breakup).<br>2. Evaluate overall process performance.<br>3. Perform jar tests<br>(a) Evaluate floc size, settling rate and strength.<br>(b) Evaluate quality of supernatant; clarity (turbidity), pH, and color.<br>4. Make appropriate process changes. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/ flocculator mixing intensity.<br>3. Add coagulant aid.<br>4. Adjust alkalinity or pH.<br>5. Change Coagulant(s). |

Note: All major problems should be reported to the authorities and response duly followed up.

#### 5.4.1.11 Safety Considerations

In the coagulation-flocculation processes, the operator will be exposed to a number of hazards such as:

Electrical equipment,

Rotating mechanical equipment,

Water treatment chemicals,

Laboratory reagents (chemicals),

Slippery surfaces caused by certain chemicals

Flooding.

Confined spaces and underground structures such as valve or pump vaults (toxic and explosives gases, insufficient oxygen).

Strict and constant attention must be given to safety procedures. The operator must be familiar with general first aid practices such as mouth-to-mouth resuscitation, treatment of common physical injuries, and first aid for chemical exposure (chlorine).

For more details, a reference may be made to "Safety Practices" in Chapter 19.

#### 5.4.1.12 Startup and Shutdown Procedures

***(a) Conditions requiring Implementation of Startup and Shutdown Procedures***

This is not a routine operating procedure in most of the plants. These procedures generally happen when the plant is shut down for maintenance. In some rare instances, shut down may be required due to a major equipment failure.

***(b) Startup Procedures***

1. Check the condition of all mechanical equipment for proper lubrication and operational status.
2. Make sure all chemical feeders are ready. There should be plenty of chemicals available in the tanks and ready to be fed to the raw water.
3. Collect a sample of raw water and immediately run a jar test using fresh chemicals from the supply of chemicals to the feeders.
4. Determine the settings for the chemical feeders and set the feed rates on the equipment.
5. Open the inlet gate or valve to start the raw water flowing.
6. Immediately start the selected chemical feed systems.

   Open valves to start feeding coagulant chemicals and dilution make-up water.

   Start chemical feeders.

   Adjust chemical feeders as necessary.
7. Turn on the flash mixer at the appropriate time. You may have to wait until the tank or channel is full before turning on the flash mixer. Follow the manufacturers instructions.
8. Start the sample pumps as soon as there is water at each sampling location. Allow sufficient flushing time before collecting any samples.

9. Start the flocculators as soon as the first basin is full of water.
10. Inspect mixing chamber and flocculation basin. Observe formation of floc and make necessary changes.
11. Remove any debris floating on the water surface.
12. Perform water quality analysis and make process adjustments as necessary.
13. Calibrate chemical feeders.

Note: Do not allow any untreated water to flow through the plant.

***(c) Shut down Procedures***

1. Close raw water gate to flash-mix chamber or channel.
2. Shut down the chemical feed systems.
   Turn off chemical feeders.
   Shut off appropriate valves.
   Flush or clean chemical feed lines if necessary.
3. Shut down flash mixer and flocculators as water leaves each process.
4. Shut down sample pumps before water leaves sampling location.
5. Waste any water that has not been properly treated.
6. Lock out and tag appropriate electrical switches.
7. Dewater basins if necessary. Waste any water that has not been properly treated.

Note : Do not dewater below-ground basins without checking groundwater levels.

Close basin isolation gates or install stop-logs.

Open basin drain valves

Be careful that the basin may float or collapse depending on ground water, soil or other conditions.

Good records of actions taken during start/shutdown operations will assist the operator in conducting future shutdowns.

#### 5.4.1.13 Laboratory Tests

Process control water quality indicators of importance in the operation of flocculation process include turbidity, alkalinity, chlorine demand, colour, pH, temperature, odour and appearance.

### 5.4.2 SEDIMENTATION

#### 5.4.2.1 Sedimentation Basins

The Basin can be divided into four zones.

Inlet zone

Settling zone

Sludge zone

Outlet zone

For more details a reference may be made to the Manual on "Water Supply and Treatment" published by Ministry of Urban Development. (1999 edition).

#### 5.4.2.2 Basin Types

The basins may be of the following types:

Rectangular basins.

Circular and square basins.

High Rate Settlers (Tube Settlers).

Solid Contact Units (Up-flow solid-contact clarification and up-flow sludge blanket clarification).

#### 5.4.2.3 Sludge Handling

***(a) Sludge characteristics***

Water treatment sludges are typically alum sludges, with solid concentrations varying from 0.25 to 10% when removed from a basin. In gravity flow sludge removal systems, the solid concentration should be limited to about 3%. If the sludges are to be pumped, solids concentrations as high as 10% can be readily transported.

In horizontal flow sedimentation basins preceded by coagulation and flocculation, over 50% of the floc will settle out in the first third of the basin length. Operationally, this must be considered when establishing the frequency of the operation of sludge removal equipment.

***(b) Sludge Removal Systems***

Sludge which accumulates on the bottom of the sedimentation basins must be removed periodically for the following reasons:

i) To prevent interference with the settling process (such as resuspension of solids due to scouring).

ii) To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that create taste and odour problems.

iii) To prevent excessive reduction in the cross sectional area of the basin (reduction of detention time).

In large-scale plants, sludge is normally removed on an intermittent basis with the aid of mechanical sludge removal equipment. However, in smaller plants with low solid loading, manual sludge removal may be more cost effective.

In manually cleaned basins, the sludge is allowed to accumulate until it reduces settled water quality. High levels of sludge reduce the detention time and floc carries over to the filters. The basin is then dewatered (drained), most of the sludge is removed by stationary or portable pumps, and the remaining sludge is removed with squeegees and hoses. Basin floors are usually sloped towards a drain to help sludge removal. The frequency of shutdown for cleaning will vary from several months to a year or more, depending on source water quality (amount of suspended matter in the water).

In larger plants, a variety of mechanical devices can be used to remove sludge including

Mechanical rakes.

Drag-chain and flights.

Travelling bridge.

Circular or square basins are usually equipped with rotating sludge rakes. Basin floors are sloped towards the centre and the sludge rakes progressively push the sludge toward a centre outlet. In rectangular basins, the simplest sludge removal mechanism is the chain and flight system.

#### 5.4.2.4 Interaction with other Treatment Processes

The purpose of sedimentation process is to remove suspended particles so as to reduce load on Filters. If adequate detention time and basin surface area are provided in the sedimentation basins, solids removal efficiencies greater than 95% can be achieved. However, high sedimentation basin removal efficiencies may not always be the most cost effective way to remove suspended solids.

In low turbidity source waters (less than about 10 NTU) effective coagulation, flocculation and filtration may produce satisfactory filtered water without the need for sedimentation. In this case, coagulation-flocculation process is operated to produce a highly filterable pinpoint, which does not readily settle due to its small size; instead the pinpoint is removed by the filters.

There is, however, a practical limitation in applying this concept to higher turbidity conditions. If the filters become overloaded with suspended solids, they will quickly clog and need frequent back washing. This can limit plant production and cause degradation in filtered water quality.

Thus the sedimentation process should be operated from the standpoint of overall plant efficiency. If the source water turbidity is only 3 mg/l, and the jar tests indicate that 0.5 mg/l of coagulant is the most effective dosage, then you cannot expect the sedimentation process to remove a significant fraction of the suspended solids. On the other hand, source water turbidities in excess of 50 mg/l will probably require a high coagulant dosage for efficient solids removal. In this case, the majority of the suspended particles and alum floc should be removed in the sedimentation basin.

#### 5.4.2.5 Operating Procedures

From a water quality standpoint, filter effluent turbidity is a good indication of overall process performance. However one must monitor the performance of each of the individual water treatment processes, including sedimentation, in order to anticipate quality or performance changes. Normal operating conditions are considered to be conditions within the operating ranges of your plant, while abnormal conditions are unusual or difficult to handle conditions. In normal operation of the sedimentation process one must monitor.

- Turbidity of the water entering and leaving the sedimentation basin and temperature of the entering water. Turbidity of the entering water indicates the floc or solids loading on the sedimentation process. Turbidity of the water leaving the basin reveals the effectiveness or efficiency of the sedimentation process. Low levels of turbidity are desirable to minimize the floc loading on the filter.
- Temperature of the water entering the sedimentation basin is important. As the water becomes colder, the particles will settle more slowly. To compensate for this change, you should perform jar tests and adjust the coagulant dosage to produce a heavier and thus a settling floc. Another possibility is to enforce longer detention times when water demand decreases.

- Visual checks of the sedimentation process should include observation of floc settling characteristics, distribution of floc at the basin inlet and clarity of settled water spilling over the launder weirs. An uneven distribution of floc, or poorly settling floc may indicate that a raw water quality change has occurred or that the operational problems may develop.

#### 5.4.2.6 Process Actions

In rectangular and circular sedimentation basins, it is generally possible to make a judgment about the performance of the sedimentation process by observing how far the flocs are visible beyond the basin inlet. When sedimentation is working well, the floc will only be visible for short distance. When the sedimentation is poor, the floc will be visible for a long distance beyond the inlet.

In up-flow or solid-contact clarifiers, the depth of the sludge blanket and the density of the blanket are useful monitoring tools. If the sludge blanket is of normal density (measured as milligrams of solids per litre of water) but is very close to the surface, more sludge should be wasted. If the blanket is of unusually light density, the coagulation-flocculation process (chemical dosage) must be adjusted to improve performance.

With any of the sedimentation processes, it is useful to observe the quality of the effluent as it passes over the launder weir. Flocs coming over at the ends of the basin are indicative of density currents, short circuiting, sludge blankets that are too deep or high flows. The clarity of the effluent is also a reliable indicator of coagulation-flocculation efficiency.

Process equipment should be checked regularly to assure adequate performance. Proper operation of sludge removal equipment should be verified each time the equipment is operated, since sludge removal discharge piping systems are subject to clogging. Free flowing sludge can be readily observed if sight glasses are incorporated in the sludge discharge piping . Otherwise, the outlet of the sludge line should be observed during sludge pumping. Frequent clogging of sludge pipe requires increasing frequency of sludge removal equipment and this can be diagnosed by performing sludge solids volume analysis in the laboratory.

A summary of routine sedimentation process actions is given in Table 5.4

Table 5.5 gives a summary of sedimentation process problems and remedial measures.

#### 5.4.2.7 Record Keeping

Maintain daily operations log of process performance and water quality characteristics and keep the following records:

1. Influent and effluent turbidity and influent temperature.
2. Process production inventory (amount of water processed and volume of sludge produced).
3. Process equipment performance (type of equipment in operation, maintenance procedures performed and equipment calibration).

### TABLE 5.4: SUMMARY OF ROUTINE SEDIMENTATION PROCESS ACTIONS

| 1. Monitor Process Performance and Evaluate Water Quality Conditions | Location | Frequency | Possible Operator Actions |
|---|---|---|---|
| Turbidity<br><br>Temperature | Influent/ Effluent<br><br>Influent | At least once every 8-hour shift<br><br>Occasionally | 1. Increase sampling frequency when process water quality is variable.<br>2. Perform jar tests.<br>3. Make necessary process changes:<br>a) Change coagulant dosage.<br>b) Adjust flash mixer/flocculator mixing intensity.<br>c) Change frequency of sludge removal.<br>d) Change coagulant |
| **2. Make Visual Observations** | | | **Possible Operator Actions** |
| Floc settling characteristics<br><br>Floc distribution<br><br>Turbidity (clarity) of settled water | First half of basin<br>Inlet<br><br>Launders of settled water conduit | At least once per 8-hour shift<br>At least once per 8-hour shift<br><br>At least once per 8-hour shift Note-Depends on size of plant | 1. Perform jar tests.<br>2. Make necessary process changes:<br>a) Change coagulant dosage.<br>b) Adjust flash mixer/flocculator mixing Intensity.<br>c) Change frequency of sludge removal.<br>d) Change coagulant |
| **3. Check Sludge Removal Equipment** | | | **Possible Operator Actions** |
| Noise, Vibration, Leakage, Overheating | Various | Once per 8-hour shift | 1. Correct minor problems.<br>2. Notify others of major problems. |
| **4. Operate Sludge Removal Equipment** | | | **Possible Operator Actions** |
| Perform normal operations sequence<br><br>Observe conditions of sludge being removed | Sed. Basin | Depends on process conditions (may vary from once per day to several days or more) | 1. Change frequency of operation:<br>a. If sludge is too watery, decrease frequency of operation and/or pumping rate.<br>b. If sludge is too dense, bulks, or clogs discharge lines, increase frequency of operation and/or pumping rate.<br>c. If sludge is septic, increase frequency of operation and/or pumping rate. |
| **5. Inspect Facilities** | | | **Possible Operator Actions** |
| Check sedimentation basins<br>Observe basin water over launder weirs.<br>Observe basin water surface<br>Check for algae buildup on basin walls and launders | Various<br>Various<br>Various<br>Various | Once every 8-hour shift<br>Once per 8-hour shift<br>Once per 8-hour shift<br>Occasionally | 1. Report abnormal conditions.<br>2. Make flow changes or adjust launder weirs.<br>3. Remove debris from basin water surface. |

Note: All major problems should be reported to the competent authorities and response duly followed.

## TABLE 5.5: SEDIMENTATION PROCESS TROUBLESHOOTING

| **1. Source Water Quality Changes** | **Operator Actions** | **Possible Process Changes** |
|---|---|---|
| Turbidity<br>Temperature<br>Alkalinity<br>pH<br>Color | 1. Perform necessary analysis to determine extent of change.<br>2. Evaluate overall process performance.<br>3. Perform jar tests.<br>4. Make appropriate process changes (next column).<br>5. Increase frequency of process monitoring. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing intensity.<br>3. Change frequency of sludge removal (increase or decrease).<br>4. Increase alkalinity by adding lime, caustic soda or soda ash.<br>5. Change coagulant. |
| **2. Flocculation Process Effluent Quality Changes** | **Operator Actions** | **Possible Process Changes** |
| Turbidity<br>Alkalinity<br>pH | 1. Evaluate overall process performance.<br>2. Perform jar tests.<br>3. Verify performance of coagulation flocculation process.<br>4. Make appropriate process changes (next column). | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing intensity.<br>3. Adjust improperly working chemical feeder.<br>4. Change coagulant. |
| **3. Sedimentation Basin Changes** | | |
| Floc Settling<br>Rising or Floating Sludge | 1. Observe floc settling characteristics:<br>a. Dispersion<br>b. Size<br>c. Settling rate<br>2. Evaluate overall process performance.<br>3. Perform jar tests.<br>a. Assess floc size and settling rate.<br>b. Assess quality of settled water (clarity and color).<br>4. Make appropriate process changes (next column). | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing intensity.<br>3. Change frequency of sludge removal (increase or decrease).<br>4. Remove sludge from basin.<br>5. Repair broken sludge rakes.<br>6. Change coagulant. |
| **4. Sedimentation Process Effluent Quality Changes** | | |
| Turbidity<br>Color | 1. Evaluate overall process performance.<br>2. Perform jar test.<br>3. Verify process performance: Coagulation-flocculation process<br>4. Make appropriate process changes (next column). | 1. Change coagulant.<br>2. Adjust coagulant dosage.<br>3. Adjust flash mixer/flocculator mixing intensity.<br>4. Change frequency of sludge removal (increase or decrease). |
| **5. Upflow Clarifier Process Effluent Quality Changes** | | |
| Turbidity<br>Turbidity Caused by Sludge Blanket Coming to Top Due to Rainfall on Watershed | 1. Sec 4. above.<br>2. Open main drain valve of clarifier. | 1. See 4. above (sedimentation process).<br>2. Drop entire water level of clarifier to bring the sludge blanket down. |

Note: All major problems should be reported to the competent authorities and response duly followed up.

#### 5.4.2.8 Start Up and Shut Down Procedures

In the event of requirement for shut down or start up of processes on account of maintenance or a major equipment failure, proper procedures must be followed as per recommendations of the manufacturer of the plant and equipment. The procedures, in general, are given below:

***(a) Start up Procedure***

1. Check operational status and mode of operation of equipment and physical facilities.

   Check that basin valves are closed.

   Check that basin isolation gates are closed.

   Check that launder weir plates are set at equal elevations.

   Check to ensure that all trash, debris and tools have been removed from basin.
2. Test sludge removal equipment.

   Check that mechanical equipment is properly lubricated and ready for operation.

   Observe operation of sludge removal equipment.
3. Fill sedimentation basin with water.

   Observe proper depth of water in basin.

   Remove floating debris from basin water surface.
4. Start sample pumps.
5. Perform water quality analyses.
6. Operate sludge removal equipment. Be sure that all valves are in the proper position.

***(b) Shut Down Procedures***

1. Stop flow to sedimentation basin. Install basin isolation gates.
2. Turn off sample pump.
3. Turn off sludge removal equipment.

   Shut off mechanical equipment and disconnect where appropriate.

   Check that valves are in proper position.
4. Lock out electrical switches and equipment.
5. Dewater basin if necessary.

   Be sure that the water table is not high enough to float the empty basin.

   Open basin drain valves.
6. Grease and lubricate all gears, sprockets and mechanical moving parts which have been submerged immediately following dewatering to avoid seize up.

#### 5.4.2.9 Equipment

***(a) Types of support equipment – Operation and Maintenance***

The operator will need to be thoroughly familiar with the operation and maintenance instructions for each specific equipment.

Flow meters and gauges.

Valves.

Control Systems.

Water Quality monitors such as turbiditimeters.

Sludge removal equipment.

Sludge pumps.

Sump pumps.

*(b) Equipment Operation*

Check the following:

1. Proper lubrication and operational status of each unit.
2. Excessive noise and vibration, overheating and leakage.
3. Pumps suction and discharge pressure.

### 5.4.2.10 Safety Considerations

*(a) Electrical Equipment*

Avoid electric shock.

Avoid grounding yourself in water or on pipes.

Ground all electric tools.

Use a lock out and tag system for electric equipment or electrically driven mechanical equipment.

*(b) Mechanical Equipment*

1. Keep protective guards on rotating equipment
2. Do not wear loose clothing around rotating equipment.
3. Keep hands out of valves, pumps and other equipment.
4. Clean up all lubricant and sludge spills.

*(c) Open Surface water – filled structures*

1. Use safety devices such as hand rails and ladders
2. Close all openings.
3. Know the location of all life preservers.

*Valve and Pump Vaults, Sumps*

1. Be sure all underground or confined structures are free of hazardous atmosphere (toxic or explosive gases, lack of oxygen).
2. Work only in well ventilated structures.
3. Take proper steps against flooding.

For more details please refer to Chapter 19 - Safety Practices.

#### 5.4.2.11 Corrosion Control

All metallic parts which are liable to corrosion must be protected. Please refer to Chapter 9 of Manual on "Water Supply and Treatment" (1999 edition) for detailed discussion on Corrosion Control.

#### 5.4.2.12 Preventive Maintenance

Such programmes are designed to assure the continued satisfactory operation of treatment plant by reducing the frequency of breakdown failures. Typical functions include.

1. Keeping electric motors free of dirt and moisture.
2. Assuring good ventilation.
3. Checking pumps and motors for leaks, unusual noise and vibrations, overheating or signs of wear.
4. Maintaining proper lubrication and oil levels.
5. Inspecting alignment of shafts and couplings.
6. Checking bearings for overheating and proper lubrication.
7. Checking for proper valve operation.
8. Checking for free flow of sludge in sludge removal collection and discharge systems.
9. Good House Keeping.

### 5.4.3 FILTRATION (RAPID SAND FILTERS)

#### 5.4.3.1 Interaction with Other Treatment Processes

The purpose of filtration is the removal of particulate impurities and floc from the water being treated. In this regard, the filtration process is the final step in the solids removal process which usually includes the pretreatment processes of coagulation, flocculation and sedimentation.

The degree of treatment applied prior to filtration depends on the quality of water.

Typical treatment processes are shown in Figs. 5.4, 5.5, 5.6.

#### 5.4.3.2 Operation

**Filter Operation:** A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed (generally 24 hours).

**Backwashing:** After a filter clogs or breakthrough occurs or a specified time has passed, the filtration process is stopped and the filter is taken out of service for cleaning or backwashing.

**Surface Wash:** In order to produce optimum cleaning of the filter media during backwashing and to prevent mud balls, surface wash (supplemental scouring) is usually required. Surface wash systems provide additional scrubbing action to remove attached floc and other suspended solids from the filter media.

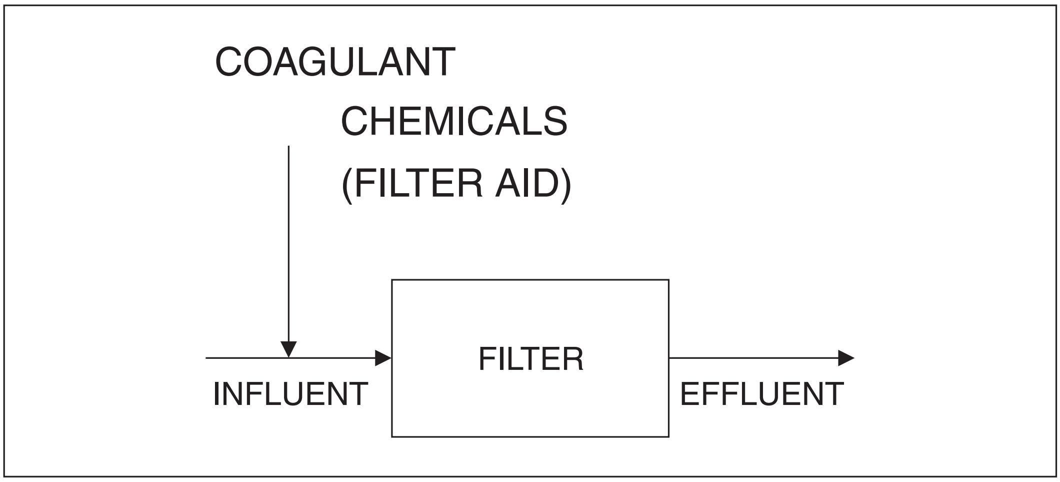


FIG. 5.4 IN LINE FILTRATION

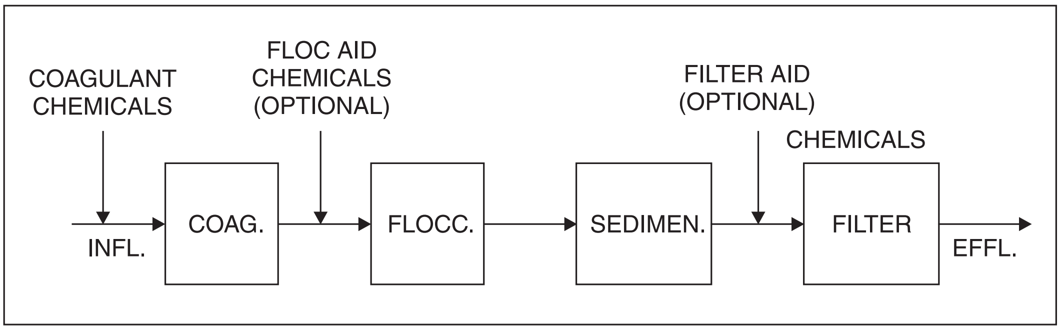


FIG. 5.5 CONVENTIONAL FILTRATION

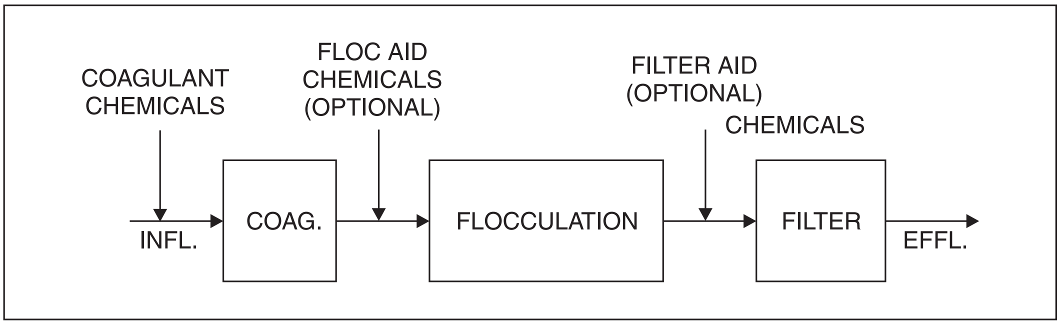


FIG. 5.6 DIRECT FILTRATION

#### 5.4.3.3 Operational Procedures

***(a) The indicators of Normal Operating Conditions***

The filter influent and effluent turbidities should be closely watched with a turbidimeter. Filter Influent turbidity levels (settled turbidity) can be checked on a periodic basis at the filter or from the laboratory sample tap. However, the filter effluent turbidity is best monitored and recorded on a continuous basis by an on-line turbiditimeter.

***(b) Process Actions***

Follow the steps as indicated below:
Monitor process performance.
Evaluate turbidity and make appropriate process changes.
Check and adjust process equipment (change chemical feed rates).
Backwash filters.
Evaluate filter media condition (media loss, mud balls, cracking).
Visually inspect facilities.

***(c) Important process activities and Precautions.***

1. Monitoring process performance is an ongoing activity. You should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure.
2. Measurement of head loss built up (Fig.5.7) in the filter media will give you a good indication of how well the solids removal process is performing. The total designed head loss from the filter influent to the effluent in a gravity filter is usually about 3 meters. At the beginning of the filtration cycle the actual measured head loss due to clean media and other hydraulic losses is about 0.9m. This would permit an additional head loss of about 2.1m due to solid accumulation in the filter.
3. The rate of head loss build up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth penetration). Early detection of this condition may permit you to make appropriate process changes such as adjustment of chemical filter aid feed rate or adjustment of filtration rate.
4. Monitoring of filter turbidity on a continuous basis with an on-line turbiditimeter is highly recommended. This will provide you with continuous feed back on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level. Preset the filter cutoff control at a point where you experience and tests show that breakthrough will soon occur. (Fig. 5.8).
5. In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the following guidelines:

   Head loss.

   Effluent turbidity level.

   Elapsed run time.

A predetermined value is established for each guideline as a cut off point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.

6. At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.

7. Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.

8. Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. You should routinely inspect physical facilities and equipment as part of good housekeeping and maintenance practice. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.

9. Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.

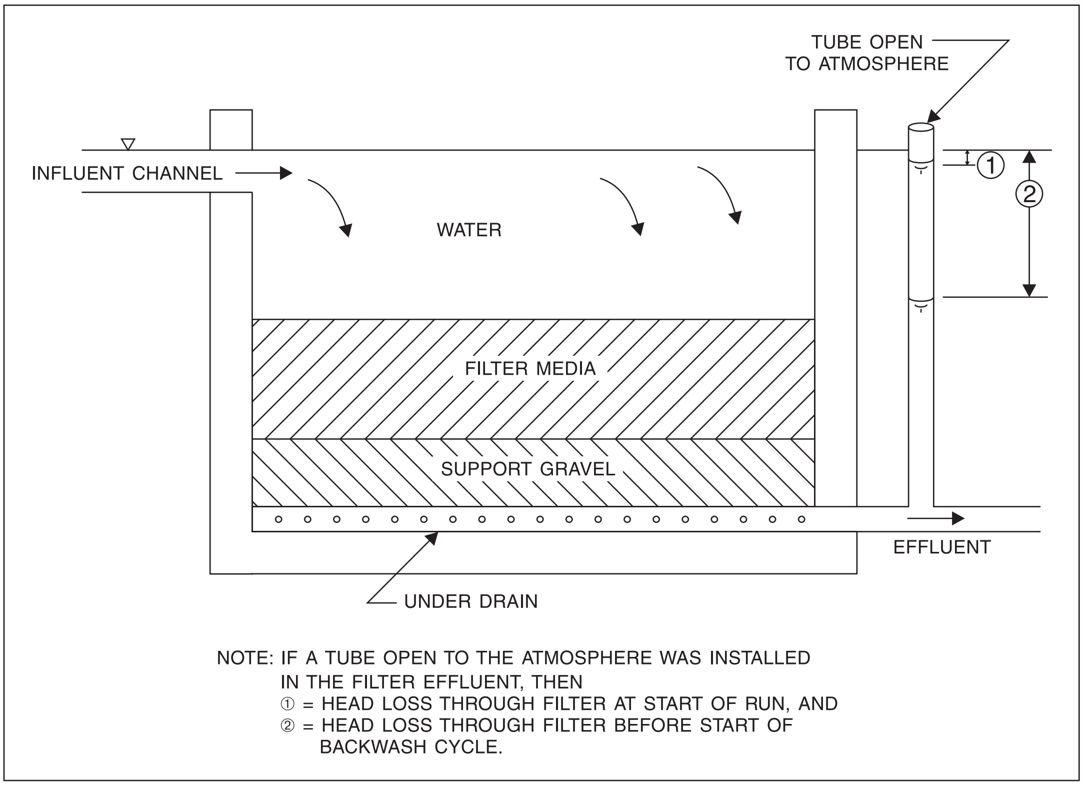


FIG. 5.7: MEASUREMENT OF HEAD LOSS

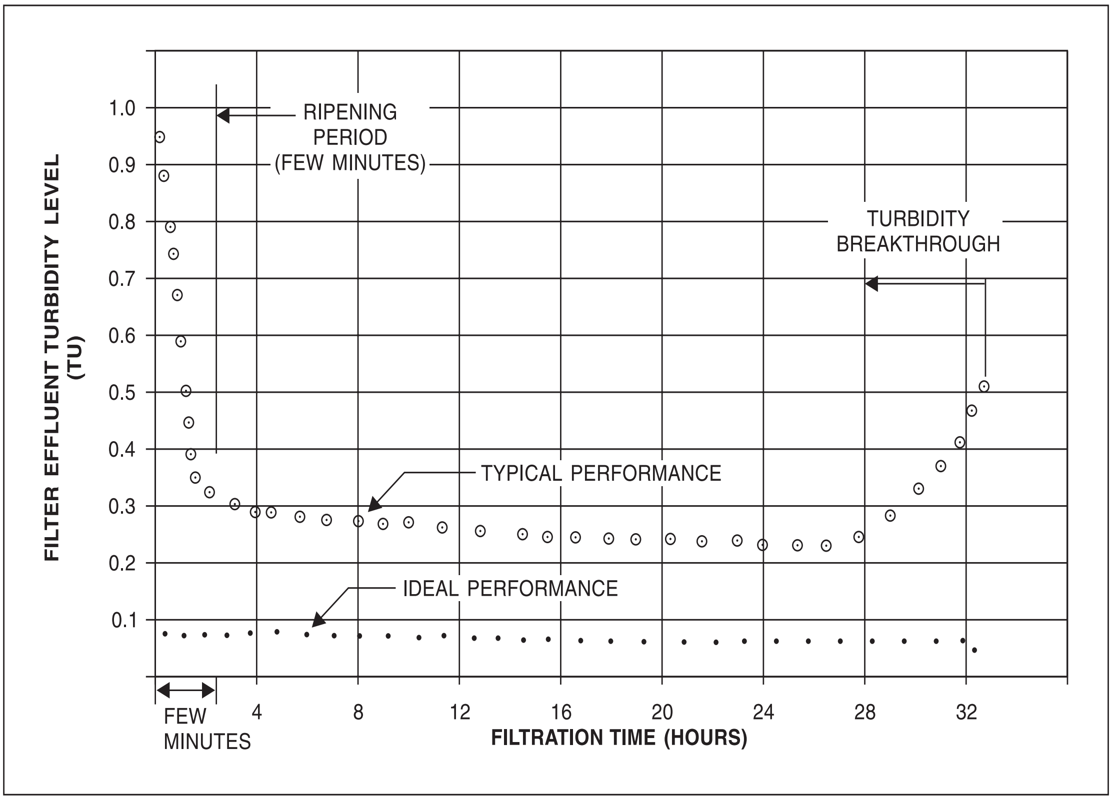


FIG. 5.8: TYPICAL FILTER EFFLUENT TURBIDITY DATA

10. Shortened filter runs can occur because of air bound filters. Air binding will occur more frequently when large head losses are allowed to develop in the filter. Precautions should be taken to minimize air binding to avoid damage to the filter media.

A summary of routine filtration process action is given in Table 5.6.
Table 5.7 gives Filtration process trouble shooting problems.

### 5.4.3.4 RECORD KEEPING

Maintain a daily operations log of process performance data and water quality characteristics. Accurate recording of the following items should be maintained.

1. Process water quality (turbidity and colour).
2. Process operation (filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash, backwash rates, and UFRV-unit filter run volume).
3. Process water production (water processed, amount of backwash water used, and chemicals used).
4. Percentage of water production used to backwash filters.
5. Process equipment performance (types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration).

   A typical daily operating record for a water treatment plant is shown in Table 5.8.

## TABLE 5.6: SUMMARY OF ROUTINE FILTRATION PROCESS ACTION

| Monitor Process Performance and evaluate Water Quality Conditions | Location | Frequency | Possible Operator Actions |
|---|---|---|---|
| Turbidity<br><br><br>Colour<br><br><br><br><br>Head loss | Influent/ Effluent<br><br><br>Influent/ Effluent | At least once per 8-hour shift.<br>At least once per 8-hour shift.<br><br>At least two times per 8-hour shift. | 1. Increase sampling frequency when process water quality is variable.<br>2. Perform Jar Tests.<br>3. Make necessary process changes:<br>Adjust coagulant dosage.<br>Adjust flash mixer/flocculator mixing intensity.<br>Change filtration rate.<br>Back wash filter.<br>Change chlorine dosage.<br>Change Coagulant. |
| **Operate Filters and Backwash** | | | |
| Put filter into service.<br>Change filtration rate.<br>Remove filter from service.<br>Backwash filter.<br>Change backwash rate. | Filter module | Depends on process conditions | See Operating Procedures (para 5.4.3.3) |
| **Check Filter Media Condition** | | | |
| Media depth evaluation.<br>Media cleanliness.<br>Cracks or shrinkage. | Filter module | At least monthly. | 1. Replace lost filter media.<br>2. Change backwash procedure.<br>3. Change chemical coagulants. |
| **Make visual Observations of Backwash Operation** | | | |
| Check for media boils and media expansion.<br>Check for media carryover into washwater trough.<br>Observe clarity of wastewater. | Filter module | At least once per day or whenever backwashing occurs. | Change backwash rate.<br>Change backwash cycle time.<br>Adjust surface wash rate or cycle time.<br>Inspect filter media and support gravel for disturbance. |
| **Check Filtration Process and Backwash Equipment Condition** | | | |
| Noise, Vibration,<br>Leakage, Overheating | Various | Once per 8-hour shift. | Correct minor problems. |
| **Inspect Facilities** | | | |
| Check physical facilities and algae on sidewalls and troughs. | Various | Once a day. | 1. Remove debris from filter media surfaces<br>2. Adjust chlorine dosage to control algae. |

Note: All major problem should be reported to the competent authorities and response duly followed up.

### TABLE 5.7: FILTRATION PROCESS TROUBLE SHOOTING

| **Source Water Quality Changes** | **Operator Actions** | **Possible Process Changes** |
|---|---|---|
| Turbidity<br>Temperature<br>Alkalinity<br>pH<br>Colour<br>Chlorine Demand | 1. Perform necessary analysis to determine extent of change.<br>2. Assess overall process performance<br>3. Perform Jar tests.<br>4. Make appropriate process changes.<br>5. Increase frequency of process monitoring.<br>6. Verify response to process changes (be sure to allow sufficient time for change to take effect)<br>7. Add lime or caustic soda if alkalinity is low. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer /flocculator mixing intensity.<br>3. Change frequency of sludge removal (increase or decrease).<br>4. Adjust backwash cycle (rate, duration).<br>5. Change filtration rate (add or delete filters).<br>6. Start filter aid feed.<br>7. Change coagulant. |
| **Sedimentation Process Effluent Quality Changes** | | |
| Turbidity or floc carryover | 1. Assess overall process performance.<br>2. Perform Jar tests.<br>3. Make appropriate process changes. | Same as source water quality changes. |
| **Filtration Process Changes/Problems** | | |
| Headloss increase<br>Short filter runs<br>media surface sealing Mudballs<br>Filter media cracks, shrinkage<br>Filter not clean<br>Media boils<br>Media loss<br>Excessive head loss | 1. Assess overall process performance.<br>2. Perform Jar tests.<br>3. Make appropriate process changes. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing Media intensity.<br>3. Change frequency of sludge removal.<br>4. Adjust backwash cycle (rate, duration).<br>5. Manually remove mudballs.<br>6. Decrease filtration rate (add more filters)<br>7. Decrease or terminate filter aid.<br>8. Replenish lost media.<br>9. Clear under drain openings of media, corrosion or chemical deposits; check head loss.<br>10. Change coagulant |
| **Filter Effluent Quality Changes** | | |
| Turbidity breakthrough<br>Colour<br>pH<br>Chlorine | 1. Assess overall process performance.<br>2. Perform Jar tests.<br>3. Verify process performance:<br>a) Coagulation and Flocculation<br>b) Sedimentation process<br>c) Filtration process.<br>4. Make appropriate process changes. | 1. Adjust coagulant dosage.<br>2. Adjust flash mixer/flocculator mixing intensity.<br>3. Change frequency of sludge removal.<br>4. Start filter aid feed.<br>5. Decrease filtration rate (add more filters).<br>6. Change chlorine dosage.<br>7. Change coagulant. |

Note: All major problems should be reported to the competent authorities and response duly followed up.

**TABLE 5.8: FILTER DAILY OPERATING RECORD**

FILTERS DAILY OPERATING RECORD

| No. | Time | | Hours operated | | | Head loss | | Wash | | Physical condition of filters |
|---|---|---|---|---|---|---|---|---|---|---|
| | Start | Stop | Today | Previous | Total | Start | Stop | Min. | M.Gals | |
| 1. | | | | | | | | | | |
| | | | | | | | | | | |
| 2. | | | | | | | | | | |
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| 3. | | | | | | | | | | |
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| 10. | | | | | | | | | | |
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| 11. | | | | | | | | | | |
| | | | | | | | | | | |
| No. of filters washed | | | | | | Average filter rate | | | | |
| Average run-hours | | | | | | Max. hourly rate | | | | |
| Total wash water | | | | | | Total water filtered | | | | |
| Percent of water filtered | | | | | | No. filters operating | | | | |
| Av. Time of wash-min | | | | | | Filters out per wash-min. | | | | |
| | | | | | | | | | | |
| | | | | | | Shift | | | | |
| | | | | | | Operator | | | | |

### 5.4.3.5 Startup and Shutdown Procedures

***(a) Routine Procedure***

Most plants keep all filters on line except for backwash and in service except for maintenance. Filters are routinely taken off line for backwashing when the media becomes clogged with particulates, turbidity breakthrough occurs or demands for water are reduced.

*(b) Implementation of Startup and Shutdown Procedures*

**1. Filter checkout procedures**

- Check operational status of filter.
- Be sure that the filter media and wash water troughs are clean of all debris such as leaves, twigs, and tools.
- Check and be sure that all access covers and walkway gratings are in place.
- Make sure that the process monitoring equipment such as head loss and turbidity systems are operational.
- Check the source of backwash to ensure that it is ready to go.

**2. Backwash Procedure**

i) Filters should be washed before placing them into service.

The surface wash system should be activated just before the backwash cycle starts to aid in removing and breaking up solids on the filter media and to prevent the development of mud balls. The surface wash system should be stopped before completion of the backwash cycle to permit proper settling of the filter media.

A filter wash should begin slowly for about one minute to permit purging (removing) of an entrapped air from the filter media, and also to provide uniform expansion of the filter bed. After this period the full backwash rate can be applied. Sufficient time should be allowed for cleaning of the filter media. Usually when the backwash water coming up through the filter becomes clear, the media is washed. This generally takes from 3 to 8 minutes. If flooding of wash water troughs or carryover of filter media is a problem, the backwash rate must be reduced.

ii) Procedure for backwashing a filter is as follows: (Fig. 5.9).

Log length of filter run since last backwash.

Close filter influent valve (V-1).

Open drain valve (V-4).

Close filter effluent valve (V-5).

Start surface wash system (Open V-2).

Slowly start backwash system (Open V3).

Observe filter during washing process.

When wash water from filter becomes clear (filter media is clean), close surface wash system Valve (V-2).

Slowly turn off backwash system (close V-3).

Close drain valve (V-4).

Log length of wash and the quantity of water used to clean filter.

*(c) Filter Startup Procedures*

Start filter

Slowly open influent valve.

When proper elevation of water is reached on top of filter, filter effluent valve should be gradually opened. This effluent control valve should be adjusted itself to maintain a constant level of water over the filter media.

Waste some of the initial filtered water if such a provision exists.

Perform turbidity analysis of filtered water and make process adjustments as necessary.

*(d) Filter Shutdown Procedures*

Remove filter from service by closing influent valve and closing effluent valve

Backwash filter.

If filter is to be out of service for a prolonged period, drain water from filter to avoid algal growth.

Note status of filter in operations log.

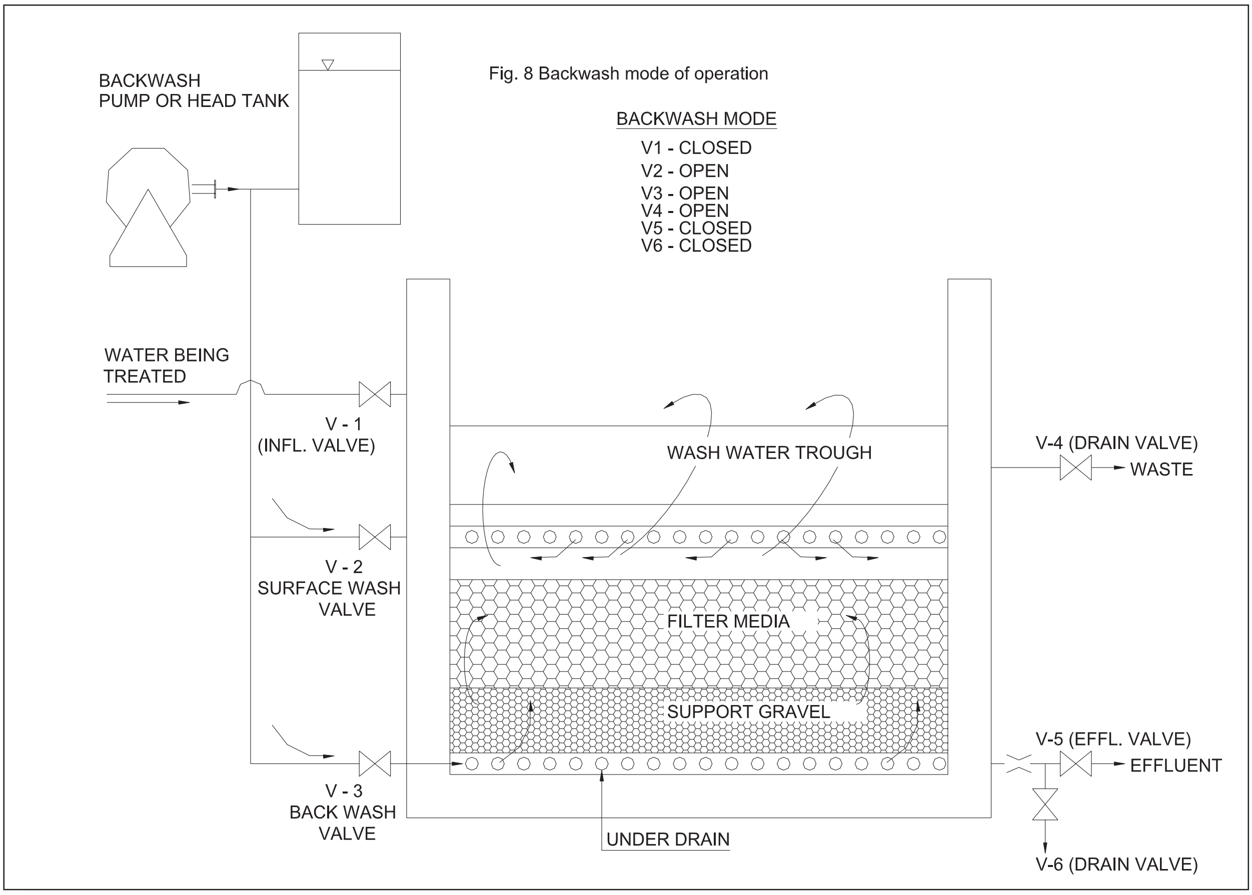


FIG. 5.9: BACKWASH OPERATION

#### 5.4.3.6 Support Equipment

The operator must be familiar with the operation and maintenance instructions for each specific equipment item or control system.

***(a) Types of Equipment***

1. Filter Control Valves.
2. Backwash and surface wash pumps.
3. Flow meter and level/pressure gauges.
4. Water quality monitors such as turbiditimeters .
5. Process monitors (headloss and water level).
6. Mechanical and electrical filter control systems.

***(b) Equipment Operation***

Before starting a piece of mechanical equipment, such as a backwash pump, be sure that the unit has been serviced on schedule and its operational status is known.

After startup, always check for excessive noise and vibrations, overheating, and leakage (water, lubricants). When in doubt about the performance of a piece of equipment, refer to manufacturer's instructions.

Periodic calibration and maintenance of the equipment is necessary.

#### 5.4.3.7 Preventive Maintenance Procedures

Preventive maintenance programmes are to assure the continued satisfactory operation of treatment plant facilities by reducing the frequency of breakdown failures.

Routine maintenance functions include:

- Keeping electric motors free of dirt, moisture and pests (rodents and birds).
- Assuming good ventilation (air circulation) in equipment work areas.
- Checking pumps and motors for leaks, unusual noise and vibrations or overheating.
- Maintaining proper lubrication and oil levels.
- Inspecting for alignment of shafts and couplings.
- Checking bearings for overheating and proper lubrication.
- Checking the proper valve operation (leakage or jamming).
- Checking automatic control systems for proper operation.
- Checking air/vacuum relief systems for proper functioning, dirt and moisture.
- Verifying correct operation of filters and backwashing cycles by observation.
- Inspecting filter media condition (look for algae and mudballs and examine gravel and media for proper gradation).
- Inspecting filter underdrain system (be sure that the underdrain openings are not becoming clogged due to media, corrosion or chemical deposits).

#### 5.4.3.8 Safety Considerations

***(a) Electrical Equipment***

1. Avoid electric shock (use preventive gloves).
2. Avoid grounding yourself in water or on pipes.
3. Ground all electric tools.
4. Lock out and tag electrical switches and panels when servicing equipment.

***(b) Mechanical Equipment***

1. Use protective guards on rotating equipment.
2. Don't wear loose clothing around rotating equipment.
3. Keep hands out of energized valves, pumps and other pieces of equipment.
4. Clean up all lubricant and chemical spills (slippery surfaces cause bad falls).

***(c) Open – Surface Filters***

1. Use safety devices such as handrails and ladders.
2. Close all openings and replace safety gratings when finished working.
3. Know the location of all life preservers and other safety devices.

***(d) Valve and Pump Vaults, Sumps, Filter galleries***

1. Be sure that all underground or confined structures are free of hazardous atmospheres (toxic or explosive gases, lack of oxygen) by checking with gas detectors.
2. Only work in well ventilated structures (use air circulation fans).

For more details please refer to Chapter 19 - 'Safety Practices'

### 5.4.4 AUGMENTATION OF RAPID SAND FILTRATION PLANTS

Augmentation of an existing Rapid Sand Filtration Plant can be carried out by converting the conventional filtration process to Variable Declining Rate Filtration with dual media filter units. The filter unit will, however, require additional depth. Special precautions are required to strictly adopt the specifications of the two filter media as regards effective size and specific gravity. During operation a special watch has to be kept to avoid intermixing of the two media.

## 5.5 PRESSURE FILTERS

### 5.5.1 INTRODUCTION

Pressure Filters are Rapid Sand Filters placed in a closed water-tank. The water passes through the sand and emerges from the filter under a pressure greater than atmosphere.

Pressure filters are used primarily in small plants and in industries where the raw water is received, and the filtered water is discharged, under pressure.

The use of pressure filters for public water supplies is unusual because of cost, inefficiency of filtration and the relative poor quality of results obtained.

### 5.5.2 OPERATION

The filter is operated similar to a gravity- type filter except that the coagulated water is applied directly to the filter without mixing, flocculation, or conditioning. Automatic filters are available in which the valves are manipulated automatically to backwash at a predetermined time or head loss. It is to be noted that the head loss through the filter is approximately the same as through a gravity filter. The term "pressure filter" does not imply that water is pumped through the filter under a high pressure loss.

The coagulant, normally, is applied under pressure in the influent line to the filter, the influent water dissolving the alum as it enters the filter.

Following drawbacks have been noticed in the working of the Pressure filters. Efforts should be made during their maintenance to avoid the same.

- There is no scope for proper formation of the flocs, the entrapment of the unsettleable and colloidal particles and independent settlement of the settleable solids.
- The filter media becomes mixed up due to the water pressure. Cracks develop within the filter sand media and serious piping develops within the entire media.
- Due to intermixing of the media the under-drainage system gets damaged.
- The behaviour of the filter operation cannot be examined properly.

## 5.6 ROUGHING FILTERS

These filters are used to remove solid matters which would, otherwise, impair the operation of the conventional filters.

These may be of Horizontal flow or Vertical flow. When used as pretreatment units in slow sand filter, the plant can handle raw water of higher turbidity, colour and bacterial count.

When installed in a catchment area it reduces the load on the conventional plant by arresting courser impurities and floating matter.

## 5.7 CHECK LIST

**Water Treatment Plant Information, Operation, Maintenance, Records etc.**

### 5.7.1 PLANT INFORMATION

#### 5.7.1.1 Source

Surface i. River ii. Reservoir iii. Dam iv. Lake v. Canal.
Ground i. Well ii. Tubewell iii. Infiltration well/gallery

#### 5.7.1.2 Intake

i. Location. ii. Pollution Source iii. Gates and Valves iv. Structural details.

#### 5.7.1.3 Treatment Processes

1. Screens.
2. Storage tanks/Pre-settling tanks.
3. Pre-disinfection/Pre-chlorination.

4. Aeration.
5. Coagulation and Flocculation.
   (a) Mixing tank or Mixing channel,
   (b) Chemicals: lime, alum, or others
       Conventional or tapered flocculation.
       Independent tank or in the form of a clarifier.
6. Sedimentation.
   Tanks (circular or rectangular)
   If circular, as independent tanks or as clariflocculators
   with or without Scrapers.
   Other important features.
7. Filters
   Slow, Rapid or Others.
   Filter box
   Filter media
   Desludging.
   Backwashing with water only or both with and air.
8. Clear Water Tanks.
   i) Capacity ii) Number iii) Size

### 5.7.2 OPERATION, MAINTENANCE, RECORDS ETC.

#### 5.7.2.1 Flow

Measurements: i. Raw ii. Settled iii. Filtered iv. Chlorinated.

**Flow Meters**

i) Calibration and accuracy of equipment.
ii) Charts and pen recorder.
iii) Servicing of equipment.
iv) Cleaning of sump, water channel etc.

#### 5.7.2.2 Chemical Feeding

i) Dosing at a point of maximum turbulence
ii) Jar test apparatus - ascertaining coagulant dosing.
iii) cleaning V-notches, weirs and floor.
iv) Mixer painting.
v) Painting alum tank.
vi) Spares for rapid mix

#### 5.7.2.3 Flocculator

i) Observing floc formation.
ii) Checking speeds of paddles.
iii) Checking short circuiting.
iv) Sludge collection, if any, and to take remedial measures to stop it.
v) Lubrication of mechanical devices.
vi) Dosing lines
vii) Valves and pipes.

#### 5.7.2.4 Settling Basins

i) Examination of floc:
   observing floc formation efficiency .
   floc distribution
   clarity of settled water.
ii) Checking short circuiting.
iii) Scrapers and squeezers.
iv) Outlet weir adjustment, biological growth.
v) Sludge lines and telescopic sludge devices if any.
   density of sludge.
   accumulation of sludge
   bleeding of sludge
   sludge disposal
vi) Measuring turbidity at the end.
vii) Watching efficiency of various components.
viii) Overhauling all equipment.
ix) Painting.
x) Rail tracks.
xi) Reduction gear box.

#### 5.7.2.5 Filters

i) Checking turbidity at start and end
ii) Adequate depth of water
iii) Rate of filtration
iv) Head loss at different important stages
v) Negative head
vi) Filter run
vii) Filter media surface cracks.
   mud balls
   slime growth

intermixing of media

uplifting of under drain nozzles.

filter media carry over.

viii) Backwashing

time and quantity of water used in backwashing.

uniform washing of filter media.

thickness of filter media before and after washing.

ix) Water quantity

received; wasted; consumed for backwashing; produced

x) Operation of Valves.

xi) Performance of blowers.

xii) Status of functioning of Instruments

xiii) Corrosion of Underwater equipment.

#### 5.7.2.6 Records

***(a) Coagulation and Flocculation***

1. Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and colour).
2. Process water quality (pH, turbidity, and alkalinity).
3. Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage).
4. Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments).

***(b) Sedimentation***

1. Influent and effluent turbidity and influent temperature.
2. Process production inventory (amount of water processed and volume of sludge produced.)
3. Process equipment performance (type of equipment in operation, maintenance procedures performed and equipment calibration).

***(c) Filtration***

1. Process water quality (turbidity and colour).
2. Process operation (filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash, backwash rates, and UFRV).
3. Process water production (water processed, amount of backwash water used, and chemicals used).
4. Percentage of water production used to backwash filters.
5. Process equipment performance (types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration).

## 5.8 ALGAL CONTROL

Note : Only a brief description of removal of algae is being given in order to help the operator to understand and take effective steps in operating and maintaining such plant processes. For more details a reference may be made to the Manual of Water Supply and Treatment (Chapter 9).

### 5.8.1 INTRODUCTION

Algae are unicellular or multicellular chlorophyll bearing plants without any true root, stem or leaves. They may be microscopic unicellular colonial or dense mat forming filamentous forms commonly inhabiting surface waters. Their growth is influenced by a number of factors, such as mineral nutrients, availability of sunlight, temperature and type of reservoir. During certain climatic conditions there is an algal bloom which creates acute problems for treatment and production of potable water.

The algae encountered in water purification plants are Diatoms, Green Algae, Blue Green Algae and Algal Flagellates. Algae may be seen floating (plankton) in the form of blooms.

### 5.8.2 PROBLEMS CAUSED BY ALGAE

1. Many species of algae produce objectionable taste and odour due to characteristic oil secretions (Table 5.9). These also impart colour ranging from yellow-green to green, blue-green, red or brown.
2. Profuse growth of algae interferes with chemical treatment of raw water by changing water pH and its hardness.
3. Some algae act as inhibitors in process of coagulation carried out for water purification.
4. Some algae clog filters and reduce filter run.
5. Some algae produce toxins and their growth in drinking water reservoirs is harmful for humans and livestock.
6. Some algae provide shelter to a large number of bacteria, some of which may be pathogenic.
7. Some algae corrode metal tanks, forming pits in their walls.
8. Algae may also cause complete disintegration of concrete in contact with them.
9. Prolific growth of algae increases organic content of water, which is an important factor for the development of other organisms.

### 5.8.3 REMEDIAL MEASURES

#### 5.8.3.1 Preventive Measures

Preventive measures can be taken to a limited extent by making environmental conditions unfavourable as explained in Chapter 9 on Manual for "Water Supply and Treatment" (1999 edition).

#### 5.8.3.2 Control Measures

Adequate records of number, kind and location of algae becomes handy for algal growth control. Details are given in the Manual for "Water Supply and Treatment" (Chapter 9).

*Algicide* dose used should be harmless to humans, have no effect on water quality, should be inexpensive and easy to apply. The most commonly used *algaecides* are copper sulphate and chlorine.

### 5.8.4 COPPER SULPHATE TREATMENT

#### 5.8.4.1 Toxicity and Dosage

Copper Sulphate is toxic to many algae at comparatively low concentration, which is normally non-lethal to fishes and is relatively inexpensive.

Dosage of copper sulphate lethal for algae is expressed in terms of concentration of $CuSO_4.5H_2O$ in mg./l. The quantity of copper sulphate required has to be calculated on the basis of the type of algae present, period of its multiplication and volume of reservoir. Temperature, alkalinity and carbon dioxide content of water also influence dosage. Low temperature, high alkalinity and low carbon dioxide decrease effectiveness of copper sulphate.

Table 5.9 shows the approximate amount of copper sulphate required as lethal dose for various algae. It may be noted from the table that the mean recommended dose is 0.3mg./l; thus this dose may be used even in absence of laboratory control.

#### 5.8.4.2 Points to be taken into Account while Formulating Copper Sulphate Dosage

The dose of copper sulphate, to be added to unknown water depth, has to be calculated by considering 4.5 metres depth of water as algae congregate in the upper zone only.

For alkaline water (alkalinity above 50mg./l as calcium carbonate) the dose should be based on surface area rather than volume of water as *algaecide* will be precipitated as copper bicarbonate before it can diffuse to lower depths. This difficulty can be overcome by scattering fine granular copper sulphate over the water surface. Water of intermediate alkalinity may be treated on volume basis.

Copper Sulphate is not effective at pH 8.5, hence before copper sulphate treatment pH should be adjusted to maximise result.

Laboratory tests should be performed ensuring that copper content is within permissible limit in water supplied (i.e. 0.05 mg/l).

Depletion of dissolved oxygen due to decomposition of dead algae and clogging of gills of fish by dead algae clusters can be avoided by starting application of copper sulphate at the dams or reservoirs, which gives ample time to fishes to get away from treatment sites.

#### 5.8.4.3 Method of Application

Several methods of applying copper sulphate are available:

1. *General practice:* a bag containing required amount of copper sulphate crystals is hung at the point of entry of raw water into treatment plant.
2. *Burlap bag Method:* Required quantity of crushed copper sulphate crystals is placed in a cloth bag, which is dragged under the water surface by using a boat.
3. *Box Method:* Perforated wooden box containing copper sulphate crystals is supported in such a way that the depth of submergence can be varied as required at the point of entry of raw water into the treatment plant. The box should be filled to a point above

water level. Copper sulphate crystals are dissolved by water flowing through the box. Dose of copper sulphate can be controlled by raising or lowering the box.

4. *Spray Method:* 0.5-1% copper sulphate solution may be sprayed over the surface of water by conventional spraying equipment.

5. *Blower Method:* Large quantities of copper sulphate may be distributed over large reservoirs or lakes by using blower fitted motor boats. Finely granulated copper sulphate is fed into air entering the blower from a hopper fitted with a control valve.

### 5.8.5 CHLORINE TREATMENT

#### 5.8.5.1 General

Chlorine treatment is relatively cheap, readily available and provides prolonged disinfecting action. Though chlorine is generally used for disinfecting potable water it can also be used as an algaecide. Prechlorination has specific toxic effect and causes death and disintegration of some of the algae. It also assists in removal of algae by coagulation and sedimentation. It prevents growth of algae on basin walls and destroys slime organisms on filter sand thus prolonging filter run and facilitating filter washing.

*Dosage :* Lethal dose of chlorine for common types of algae is given in Table no. 5.9. Effective chlorine dose should be such that sufficient chlorine is there to react with organic matter, ammonia, iron, manganese and other reducing substances in water and at the same time leave sufficient chlorine to act as algaecide. Dose required for this purpose may be over 5mg/l. With chlorine treatment essential oils present in algae are liberated which may lead to development of odour and color and taste. Occasionally these oils as well as organic matter of dead algae may combine with chlorine to form intensified odour and taste. In such cases break point - chlorination is required. Post chlorination dose can be adjusted to obtain minimum 0.2mg/l residual chlorine in potable water at consumer end.

#### 5.8.5.2 Method of Application

Chlorine is preferably applied as a strong solution of chlorine from chlorinator. A slurry of bleaching powder can also be used. For algal growth control, generally, chlorine is administered at the entry of raw water before coagulant feeder.

#### 5.8.5.3 Chlorine Treatment vs. Copper Sulphate Treatment

Chlorination is preferred over copper sulphate treatment in certain conditions, which are as follows:

1. Copper Sulphate cannot be used when the application is too close to pipeline, as copper will plate out on metal thus becoming inactive.

2. Copper sulphate cannot be used to prevent algal growth in coagulant basin, as it will be immediately thrown out of solution.

3. If adequate time (for proper precipitation of the added copper sulphate) is not available between copper sulphate treatment and supply of water, copper sulphate treatment should be avoided and chlorine treatment should be preferred.

4. Death and decay of algae imparts taste and odour to water. It also results in increase of organic matter, which supports proliferation of saprophytes (organisms growing on dead organic matter) resulting in lowering of oxygen content of water. Breakpoint pre-chlorination helps in removal of taste and odour, also assists in coagulation and controls growth of saprophytes.
5. Certain algae are resistant to copper sulphate treatment.

### 5.8.6 MICROSTRAINER

Algae can be removed from water by using microstrainer. The infested water can be passed through stainless steel drums with cloths of mesh size ranging from 15-45 µm. Microstraining is a useful process for the removal of filaments and colonial algae, but it does not remove smaller species or reproductive forms which can multiply later on, creating problems. Microstraining cannot constitute a complete treatment for effective disposal of algae, but it can be used as a part of treatment line. Moreover, this procedure requires frequent cleaning of strainer.

## 5.9 REMOVAL OF IRON AND MANGANESE

Note: Only a brief description of removal of iron and manganese is being given in order to help the operator to understand and take effective steps in operating and maintaining such plant processes. For more details a reference may be made to "Chapter of Manual of Water Supply and Treatment" (1999 edition).

### 5.9.1 INTRODUCTION

Minerals like iron and manganese generally make their way into ground water from shale, sand stone and other rocks. These minerals dissolve in water containing carbon dioxide in absence of oxygen; the insoluble oxides of these elements being reduced and transformed into their soluble bicarbonates. These soluble bicarbonates when exposed to air by pumping lead to the formation of brown coloured oxides of iron and manganese which creates unaesthetic condition giving characteristic metallic taste and colour from brownish to blackish. It also stains plumbing fixtures and laundered material.

### 5.9.2 IRON

#### 5.9.2.1 Occurrence

Iron exists as reduced ferrous and chelated forms dissolved in ground water or in deeper layers of some water reservoirs lacking oxygen. In surface water, iron is generally found in its precipitated ferric form. Reduced iron in water promotes the growth of autotrophic bacteria in distribution mains creating serious nuisance. The problem is further aggravated when water also contains sulphates, as reduction of iron and sulphate compounds leads to the formation of disagreeable odour and black deposits of iron sulphide.

#### 5.9.2.2 Removal of Iron

Chemical analysis of water for iron content as well as its various forms is a good start to provide clue to the removal method to be adopted. But it is always advisable to perform laboratory analysis and pilot plant studies before any particular method is adopted.

### TABLE 5.9: APPROXIMATE AMOUNT OF COPPER SULPHATE & CHLORINE REQUIRED AS A LETHAL DOSE FOR VARIOUS ALGAE*
### (Suggested- to be adjusted according to alkalinity and temperature)

| Organism | Odour, Taste & Colour | Cause of Other Trouble | Copper Sulphate Dosage (Mg/L) | Chlorine Dosage (Mg/L) |
|---|---|---|---|---|
| *Diatomaceae:* | | | | |
| Achnantes | – | – | – | 0.25 |
| Asterionella | Aromatic, Geranium, Fishy | – | 0.12-0.20 | 0.5-1.6 |
| Cyclotella | Faintly aromatic | Yes | – | 1.0 |
| Diatoma | Faintly aromatic | Yes | – | – |
| Fragilaria | Geranium, musty | Yes | 0.25 | – |
| Melosira | Geranium, musty | Yes | 0.20 | 2.0 |
| Meridion | Spicy | – | – | – |
| Navicula | – | Yes | 0.07 | – |
| Nitzschia | – | – | 0.50 | – |
| Stephanodiscus | Geranium, Fishy | – | 0.33 | – |
| Synedra | Earty | Yes | 0.36-0.50 | 1.0 |
| Tabellaria | Aromatic, Geranium, Fishy | – | 0.12-0.50 | 0.5-1.0 |
| *Chlorophyceae:* | | | | |
| Chara | Garlic | Yes | 0.1-0.5 | – |
| Cladophora | Septic | Yes | 0.5 | – |
| Closterium | Grassy | – | 0.17 | – |
| Coelastrum | – | Yes | 0.05-0.33 | 1.0 |
| Conferva | – | Yes | 0.25 | – |
| Desmidium | – | – | 2.0 | – |
| Dictyosphaerium | Grassy, Nasturtium, Fishy | – | – | 0.5-1.0 |
| Draparnaldia | – | – | 0.33 | – |
| Eudorina | Faintly fishy | – | 2.0-10.0 | – |
| Entrtomorpha | – | – | 0.5 | – |
| Gloeocystis | Septic | – | – | – |
| Hydrodictyon | Septic | Yes | 0.1 | – |
| Microspora | – | – | 0.4 | – |
| Nitella flexilis | Bitter taste | Yes | 0.1-0.18 | – |
| Palmella | – | – | 2.0 | – |
| Pandorina | Faintly fishy | – | 2.0-10.0 | – |
| Protococcus | – | – | – | 1.0 |
| Scenedesmus | Grassy | – | 1.0 | – |
| Spirogyra | Grassy | Yes | 0.12 | 0.7-1.5 |
| Staurastrum | Grassy | – | 1.5 | - |
| Tetrastrum | – | – | – | 1.0 |
| Ulothrix | Grassy | – | 0.2 | – |
| Volvox | Fishy | – | 0.25 | 0.3-1.0 |
| Zygnema | – | – | 0.5 | – |
| *Cynophyceae:* | | | | |
| Anabaena | Mouldy, Grassy, vile | – | 0.2-0.48 | 0.5-1.0 |
| Aphanizomenon | Mouldy, Grassy, sweet taste | – | 0.12-0.5 | 0.5-1.0 |
| Clathrocystis | Sweet grassy, vile | – | 0.12-0.25 | 0.5-1.0 |
| Coelosphaerium | Sweet grassy | – | 0.2-0.33 | 0.5-1.0 |
| Cylindrospermum | Grassy | – | 0.12 | – |
| Gloeocapsa | Red colour | – | 0.25 | – |
| Microcystis | Sweet taste | – | 0.2 | – |
| Oscillatoria | Musty, spicy | Yes | 0.2-0.5 | 51 |
| Rivularia | Mouldy, grassy | – | – | – |

The most common method for iron removal from water is oxidation followed by sedimentation and filtration. In certain types of water treatment like pH correction and chemical oxidation can be carried out in addition to above mentioned processes.

***(a) Oxidation by Aeration***

The first stage of iron removal involves the oxidation of bivalent iron with oxygen present in air. Aeration also removes carbon dioxide and taste and odour producing substances. The rate of aeration depends on pH, alkalinity and organic content of water. Iron is oxidised at wide pH range. Increased aeration time is necessary for water containing carbon dioxide and hydrogen sulphide. Oxidation of iron on the other hand is retarded by the presence of humic acid.

***(b) Oxidation by Chlorination***

Oxidation of iron can be inhibited possibly due to binding of ferrous iron with organic substances, ammonia and other reducing agents. Chlorination can bring about oxidation of organic matter and other reducing agents in such conditions, which facilitates ferrous iron oxidation. Chlorination will oxidize iron without lime treatment for pH adjustment.

***(c) Oxidation by Potassium permanganate***

Potassium permanganate is more effective oxidising agent than chlorine. The reaction is independent of pH above 7.0 and is rapid, except in presence of hydrogen sulphide and organic matter where reaction time increases to 5-20 minutes prior to filtration.

***(d) Catalytic Method***

The process involves only oxidation and filtration and does not involve base exchange. In this method water is percolated through suitable contact material which oxidizes the iron. The contact material is made up of siliceous base exchange material, successively treated by solution of manganese chloride and potassium permanganate. It is used as filter as such or a layer of this material may be sandwiched between sand bed of pressure filter. Iron is oxidized when water percolates through this bed and also filters out. At intervals, filters should be backwashed to remove the deposits. The bed can be regenerated by potassium permanganate solution treatment.

***(e) Zeolite Plants***

Many times ground water or bottom strata of deep reservoirs contain iron in reduced state (i.e. its soluble form). In such condition Zeolite beds are used which takes up iron by process of ion exchange.

#### 5.9.2.3 O&M problems and remedial measures of typical IRP (Iron Removal Plants)

Two types of such plants are described below:

**Compact type plant**

The process comprises of

i) Spray Aeration through a grid of pipes to flush out $CO_2$, $H_2S$ and to improve pH level.

ii) Trickling of aerated water through a contact catalytic media viz., limestone of 20 mm size or a combination of $MnO_2$ (Manganese dioxide) and lime; or hard coke, $MnO_2$ and limestone.

iii) Sedimentation.

iv) Filtration through Rapid Gravity Filter.

v) Disinfection.

The structure consists of ordinary masonry or concrete. The aerator with contact media may be placed at the top of the sedimentation tank. Sedimentation tank may be rectangular with a length to breadth ratio of 3:1. The detention time may be around 3-5 hours. The surface loading may be around 25 $m^3/d/m^2$. Filter media shall consist of sand with effective size 0.5-0.7 mm and a depth of 750-1000 mm over a 450-600 mm deep gravel 3 to 50 mm size.

**Operation and Maintenance**

1. The nozzles/orifices attached to the aeration pipe grid shall have their angles so adjusted as to ensure maximum aeration and to prevent loss of water. These nozzles/ orifices shall require regular manual cleaning to remove incrusted iron. The residual iron deposits from inside the pipe grid shall be flushed out by opening end plugs or flanges. These operations should be repeated at least once in 2 months.
2. The limestone and other contact media require manual cleaning and washing at least once in 45-60 days.
3. The contact media bed should not remain exposed to sun for a long time to prevent hardening of bed by iron incrustation.
4. The sedimentation tank inlet baffle wall opening shall be cleaned of iron slime at least once in 45-60 days.
5. Sedimentation tank bed should be regularly scoured for removal of sludge.
6. Floc forming aid (coagulant aid) may be used for better coalescing and agglomeration.
7. The rapid gravity filter should have a water depth of about 1.2-1.5 m.
8. Since iron deposits create incrustation of filtering media, at least 100-150 mm of top sand layer of sand shall be scrapped and replenished with fresh sand at least once on 60 days. The whole bed may require replacement once in 2 years or so.
9. The characteristics of iron flocs are different from those of surface (river) water flocs. Due to the aeration process and contact of water with air, there may be incrustation of filter bed by residual oxidized deposits. To avoid this, common salt may be mixed with standing water and after 1-2 hours, the filter may be backwashed for better results and longevity of sand bed.

**Package Type IRP (Iron removal plant)**

The process incorporates the following steps:

i) Dosing of sodium aluminate solution to the raw water pumping line, to raise pH up to the optimum level and to ensure subsequent coagulation, as it is an alkaline salt.

ii) Injection of compressed air for oxidation of dissolved iron.

iii) Thorough mixing of raw water, sodium aluminate and compressed air for proper dispersion in a mixing chamber of M.S. welded cylindrical shell equipped with one M.S perforated plate fitted inside through which the mixture flows upward.

iv) Passing the mixture through an oxidation chamber of M.S. shell, in which a catalytical media of $MnO_2$ (Manganese dioxide) is sandwiched between two M.S. perforated circular plates. (through which the mixture flows).

v) Passing the above mixture in to a M.S. welded cylindrical shell type of filter in which dual media comprising of Anthracite Coal or high graded bituminous coal, 3-6 mm size, is placed at the top and finer sand of 0.5-1.00 mm size with 98% silica content is placed at the bottom, over a gravel supported bed. At the bottom is the under drainage system. Backwashing is done by air agitation followed by backwash with water.

vi) Disinfection.

**Operation and Maintenance**

1. Sodium aluminate should be so mixed as to raise the pH up to 8.5-9.5.
2. The quantity of compressed air should be so regulated as to achieve the optimum oxygen level.
3. The $MnO_2$ (Manganese dioxide) may need replacement every 6-9 months.
4. The inside of both the mixing chamber and oxidizing chamber should be coated with epoxy resin to avoid corrosion and incursion.
5. The filtration rate should be controlled within a range of 100-125 lpm/$m^2$.
6. The inlet pipe at the top should be fitted with a cylindrical strainer to obviate the possibility of loss of anthracite coal during washing.
7. After backwashing, rinsing of filtering media for at least 5 minutes has to be done to resettle the filtering media before normal functioning.
8. Where the iron content is very high the whole media like $MnO_2$ (Manganese dioxide), anthracite coal, sand, gravel, strainers etc. require replacement and replenishment at least once a year for effective functioning and performance. The interior epoxy painting should also be done simultaneously.

## 5.10 MANGANESE

### 5.10.1 OCCURRENCE

In water manganese is usually present in soluble ionized form- manganese ion and manganese hydroxide. It can form complexes with bicarbonates, sulphates, silicates as well as with certain organic matter. It is often associated with iron and ammonium.

### 5.10.2 REMOVAL OF MANGANESE

Manganese can be removed following the same procedure as for iron removal i.e. by oxidation, followed by sedimentation and filtration. Removal of manganese is a little difficult and complicated as compared to the iron removal. Oxidation of manganese is carried out by using following methods.

***(a) By Aeration***

Oxidation by aeration needs high pH of at least 8.5-10 with lime treatment to enhance the oxidation of manganese on coke or sand beds coated with manganese oxide; however, high removal is not assured.

***(b) By Catalytic Action***

Oxidation by catalytic action of pyrolusite ore is used in absence of air to change complex manganese compound to manganese hydroxide which is further oxidized to insoluble manganese hydroxide by aeration in second contact bed followed by filtration.

***(c) By Chlorination***

Manganese is oxidized by free residual chlorine at pH 8.4-10. The dose of chlorine should be selected to provide about 1.25 ppm free chlorine for each ppm manganese to be oxidized. Oxidation is aided by the use of 0.2 ppm copper sulphate, the copper acting as catalytic agent.

***d) By Potassium Permanganate***

Potassium permanganate provides better oxidation than chlorine and the reaction is independent of the pH in range above 7.0; so manganese may be oxidized without lime treatment. The dose is about twice the content of manganese.

***(e) By Manganese Zeolite***

Manganese zeolite is an active contact material, which removes 1.63 kg. of manganese per cubic meter of zeolite per cycle by oxidation. Regeneration of zeolite bed can be accompanied by backwashing with solution of 3.26 kg. of potassium permanganate per cubic meter of zeolite. Incomplete regeneration will result in passage of manganese through contact beds.

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