Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 06
Water quality, testing, treatment
Lecture - 30
Water Treatment Part III

In lecture 30, Water Treatment - Part III will be discussed.

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The different concepts that will be covered in this lecture are filtration, disinfection, other treatments and case studies.

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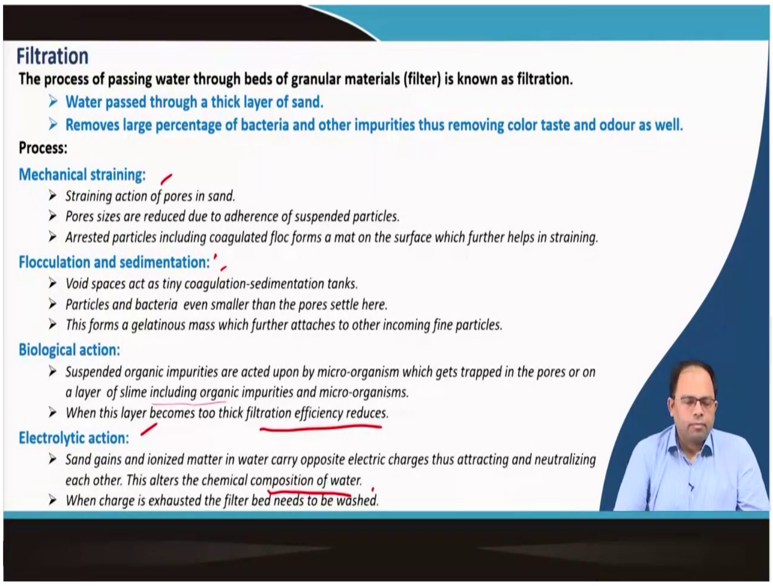

Filtration

The filtration in the process when water is passed through beds of granular materials called as filter. There could be different kinds of filter materials, but usually we use a thick layer of sand and this helps in removal of bacteria and other impurities and particularly color, taste and odour.

The process of filtration involves many steps or it involves many different ways of removal of impurities.

The first process is mechanical straining that is the straining action of the pores in the sand; that means, any kind of filter media either sand, pebbles, gravel or coarse sand that has pores can be used. The straining action of the pores helps in retaining the impurities. They are stuck in the media as the impurities bigger than pores cannot pass through. On continuous use, pore sizes are reduced due to adherence of the suspended particles. As more amount of filtration happens, the pore size gradually get clogged and arrested particles including the coagulated floc forms a mat on the surface which further helps in straining. Along with mechanical straining, there is natural flocculation and sedimentation. The voids act as tiny coagulation and sedimentation tanks.

The particles and bacteria which are even smaller than the pores can pass through the pores. However, they come in contact with the coagulation and sedimentation tanks (within the pores) mentioned earlier and they form a gelatinous mass and this further attaches the incoming fine particles. So, they are able to retain other particles which are even smaller in size and are able to pass through the pores.

Biological action happens when suspended organic impurities are acted upon by micro-organisms which get trapped in the pores or particularly on this slime. The micro-organisms act on the organic impurities and they break it down further. When this slime layer gradually becomes thicker, the filtration efficiency reduces.

In addition to these processes, electrolytic action happen in which sand grains and ionized matter in water carry opposite electric charges which helps in attracting and also neutralizing each other. This alters the chemical composition of water to some extent and when the charges are exhausted or the sand grains loose the charge, then one need to clean this sand bed and it can be reused because they will have their charge again and it can again help in separating the impurities by using this electrolytic action. That means, change in chemical composition helps in treatment of the water. Thus pH can also be modified using this kind of action.

So, filtration actually helps in different ways. It is not just the mechanical straining. It has lot of other properties such as it helps in flocculation, sedimentation and biological action. Also, electrolytic action helps in further reduction of impurities or further reduction of BOD.

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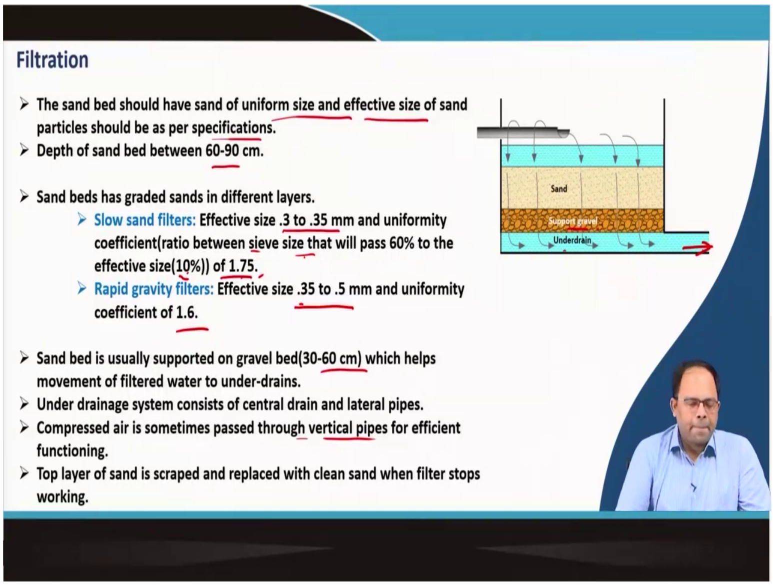

In sand filters, the sand beds should have sand of uniform size and effective size of sand particle should be as per specification. It has to be effective that means most of the sand has to be of particular size. Then depth of sand bed should be at least 60 to 90 centimeter.

Sand beds have graded sands in different layers. The sand particles can be of same size and type or different kinds of sand. Thus, the filters can be slow sand filter or rapid gravity filters. It depends on the size of sand in the filter media.

In slow sand filters, the effective size of sand is 0. 3 to 0.35 millimeter and uniformity coefficient is 1.75. The uniformity coefficient is the ratio between sieve size that will pass 60 percent of the effective size of sand which is 10 percent. That means most of the sand particles is of a particular size. In slow sand filters, the size of sand particles is small.

In rapid gravity filter, the effective size of sand particles is large, i.e., 0.35 to 0.5 mm and the uniformity coefficient is 1.6. Both the size and the uniformity coefficient play a role. As the pore sizes are larger, it allows water to pass faster. The sand bed is usually supported on a gravel bed of 30 to 60 centimeter which helps movement of filtered water to the under drain.

The gravel supports the sand. So, water passes through sand and then gravel into the under drainage system. Sometimes, compressed air is used through vertical pipes for efficient functioning or movement of water or for cleaning the sand or back washing. The top layer of sand is scraped and replaced with clean sand when filter stops working and media prevents the entry of water. So, one has to remove the top layer of sand, clean it and put it back.

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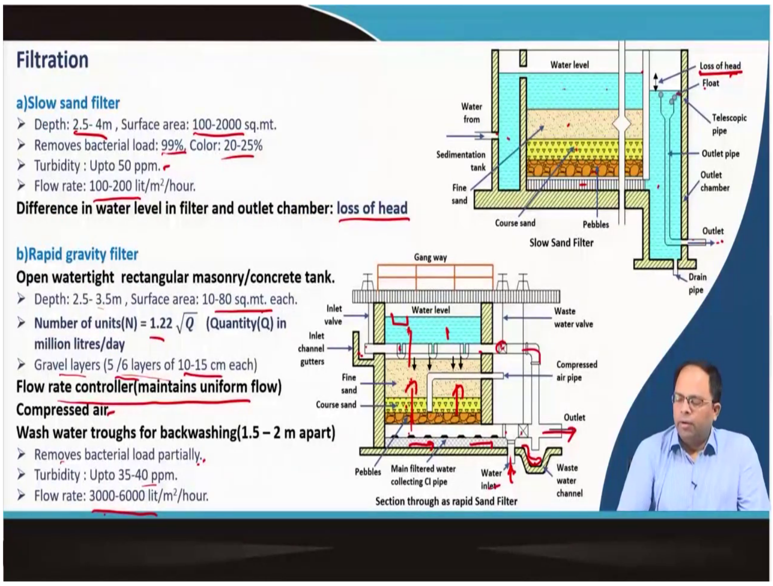

Regarding the design of slow sand filter, the water comes from sedimentation tank to the first chamber from where the water goes into the main filter. From here, the water goes down where fine sand is at the top, followed by coarse sand or pebbles or gravels. Below these layers, there is under drainage system from where water is collected into a sump which is taken out.

A float is used to determine the head of water and this measures the loss of head and to maintain that loss of head, one need to adjust the flow rates in this particular unit. As the water is passing through a slower speed, it may lead to loss of head.

This is one issue which has to be taken care of in design of water treatment plants, but it depends on how the flow rate is adjusted. In addition, the technology and area required also needs to be considered. The depth is around 2.5 to 4 meter and the surface area is 100 to 2000 square meter. It removes bacterial load of over around 99 percent and color to around 20 to 25 percent. It can take care of turbidity up to 50 ppm and if beyond 50 ppm, other kinds of plain sedimentation processes needs to be employed. The flow rate is 100 to 200 liter per square meter. That gives an idea about the surface area of tank required. Difference in water level in filter and outlet chamber is basically due to loss of head.

Rapid gravity filters are open watertight rectangular masonry or concrete tanks whose depth is 2.5 to 3.5 meter and surface area is 10 to 80 square meter each. Its size is much smaller as compared to slow sands filters. As filtration has to be done faster, instead of having one unit, multiple units can be installed where water water goes into all these units parallelly and then taken out. To determine the number of units required, a simple formula that is shown below:

$$Number\ of\ units\ (N) = 1.22\sqrt{Q}$$

where Q is quantity in million liters per day

In rapid gravity filters, 5 to 6 layers of 10 to 15 centimeter gravel layers are used. Sometimes, rapid gravity filters could also use coarse sand.

It has a flow rate controller which maintains uniform flow and compressed air is used to clean this filter when it is clogged that helps in loosening the pores of particles.

By back washing, water is sent in the opposite direction and that cleans up the pores and the water is collected in some troughs at the top. There is a gangway at top from where one can open and control the valves.

Filter has an inlet channel and the filter media which includes coarse sand, pebbles or different layers of gravel. It depends on what kind of treatment needs to be done.

The compressed air pipe helps to blow air and the clogs are actually loosened up and water comes down, taken out and goes into the outlet.

Backwashing also cleans the pores as water goes in the opposite direction along with loosening of the media using compressed air. When the water is sent, it cleans the pores and the water goes up and the water can be collected in wash water troughs.

Wash water troughs for back washing are 1.5 to 2.5 meter apart. Usually these kind of troughs are at the top so that when the dirty water comes up, it is collected in those troughs and it would be taken out. There is another arrangement where the water could be also taken out through a pipe.

Rapid gravity filter removes bacterial load partially compared to slow sand filter. The process is much faster and thus, the treatment level is lesser.

It removes turbidity up to 35 to 40 ppm and flow rate is 3000 to 6000 liter per meter square which is much higher than the slow sand filter.

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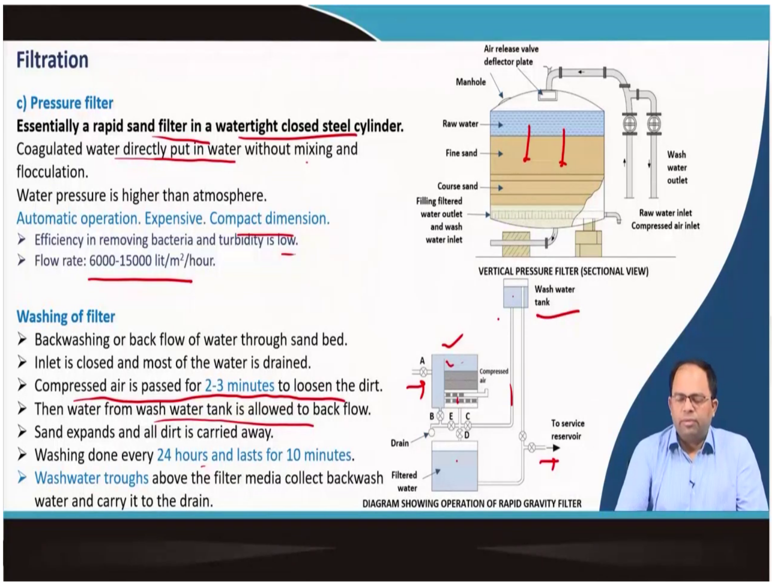

Pressure filter is another form of rapid gravity filter which is enclosed in a water tight closed steel cylinder. It is totally a compact process where coagulated water is directly put in without mixing and flocculation. The water pressure is higher than atmosphere as artificial pressure is created.

This is an automatic operation which is relatively expensive. Compact chambers are used for these filters. Its efficiency of removing bacteria and turbidity is lower as compared to the other filters, but flow rate is much higher in the range 6000 to 15000 liters per meter square per hour.

As seen in the Figure, depending on gravity, water come down and pressure is applied on the water in pressurized chambers. The treatment level is lower but the flow rate could be much higher.

For back washing of filter, the setup consists of overhead tank, wash water tank and sand filter. The compressed air is used for cleaning the pores.

The water comes out gradually cleaned via the filter media and then it is collected. Some amount of water is taken to the service reservoir, but some amount is pumped to the overhead wash water tank. When cleaning is required; the operation is stopped by using valves. Instead, the back wash water is released and gets collected in troughs.

During back washing inlet is closed and most of the water is drained, compressed air is passed for 2 to 3 minutes to loosen the dirt. Then, water from wash water tank is allowed to back flow. Sand expands and all dirt is carried away. The washing is done every 24 hours and last for 10 minutes. Thus, every day the washing needs to be done in case of sand filters otherwise it will not work. Wash water troughs above the filter media collect backwash water and carry it to the drain.

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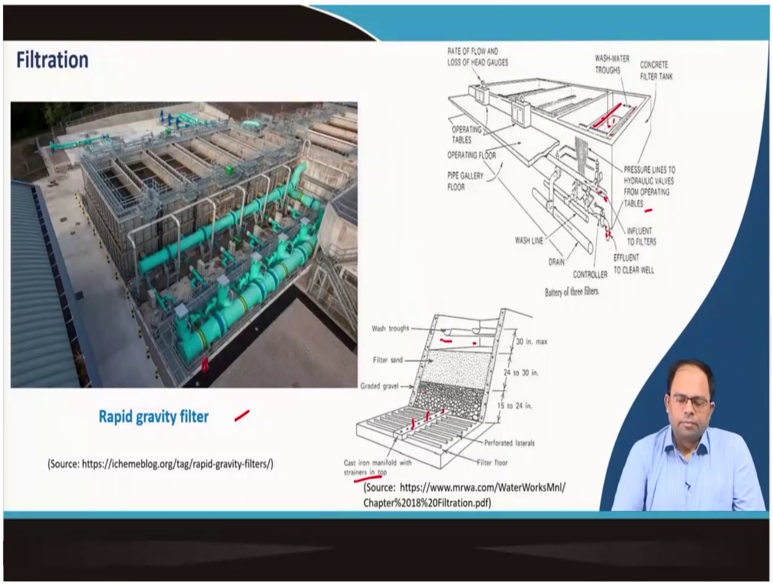

The Figure shows a rapid gravity filter. There are wash water troughs where water comes up and then it can be carried out through these troughs. It also shows the overall tank and pipelines, hydraulic valves etc. Drainage channels are also shown.

It shows the layers of the filter media. The graded gravel is at the lower part below which there are cast iron manifold with strainers in the top to allow entry of water. From the perforated laterals, water is taken out from below. It also comprises of the wash troughs at the top and filter sand.

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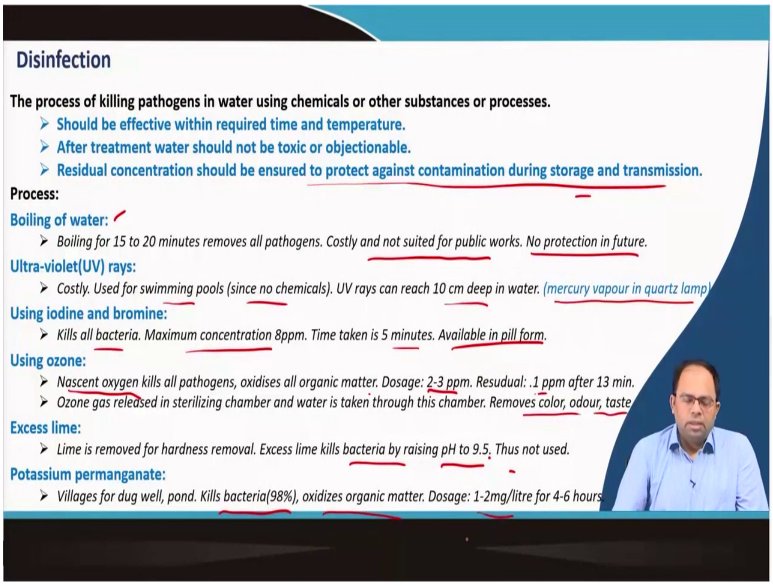

Disinfection

The next process is disinfection. In this process, pathogens in water are killed using chemicals, other substances or processes. It is not only just mixing chemicals, other processes can be used. It should be effective at that particular temperature and for a particular time period. Once it is done, the pathogen should not be there in water for a certain amount of time when the water stays in the distribution network till the time it is consumed.

After treatment, water should not be toxic or objectionable; that means, the use of the chemical should not make it objectionable. Residual concentration should be ensured to protect against contamination during storage and transmission. Even after the time period it is treated; till the time it is consumed, it still remains safe.

There are different processes of disinfection, the first process is boiling of water for 15 to 20 minutes. It removes all pathogens, but this is costly and this is not suitable for public work. In certain homes for certain purposes, it can be used. One has to spend a lot of energy in boiling water and it does not offer any protection for future during storage and transmission.

Ultraviolet rays can also be used but this also costly. Usually it is used in swimming pools because chemicals are not expected in the pool water. UV rays can reach up to 10 centimeter deep in water and it is usually provided through mercury vapour in quartz lamp. Thus, quartz lamp with mercury vapour is used to create UV rays.

Iodine and bromine can also be used. These kills all the bacteria and maximum concentration could be given is 8 ppm. Time taken is around 5 minutes and it is also available in pill form.

Ozone is also a good disinfectant. Ozone has nascent oxygen which kills all pathogen and oxidises all organic matter. A dosage of 2 to 3 ppm is required. Residual is 0.1 ppm after 30 minutes and ozone gas released in sterilizing chamber and water is taken through the chamber which removes color, odour and taste of water.

Though lime is used for removal of hardness, but excess lime result in killing a bacteria. However, it raises the pH of water to 9.5 due to which it is usually not used.

Potassium permanganate is a solution for rural areas in villages for dug well, and ponds. This kills bacteria up to 98 percent and oxidizes organic matter. Dosage is around 1 to 2 miligram per liter for 4 to 6 hours.

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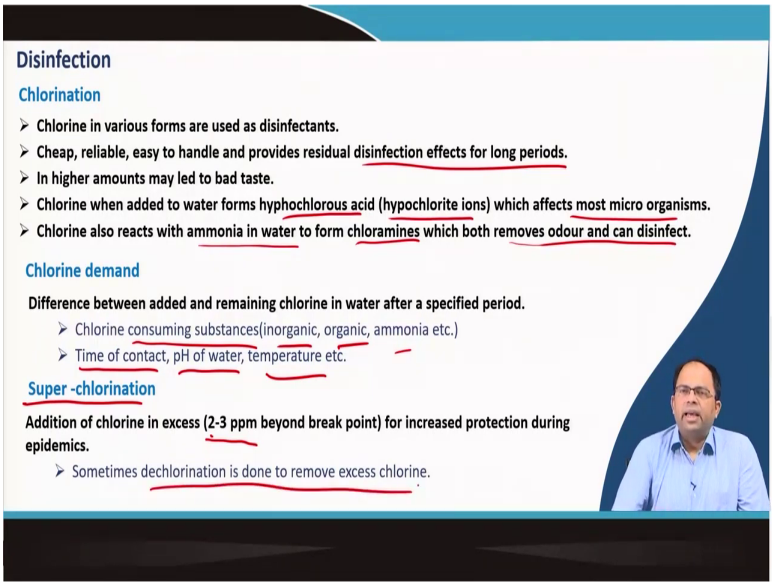

The most common process used for disinfection is chlorination which is both inexpensive, and reliable. This is easy to handle and provide residual disinfection effects for long period. So, this is one of the primary reasons why chlorine is used in various forms but if there is too much amount of chlorine, it actually results in bad taste. Sometimes it leads to loss of hair. Chlorine when added to water forms hyphochlorous acid which releases hypochlorite ions which affects most of the micro-organisms. So, this is the likely process in which micro-organisms get killed and chlorine also reacts with ammonia in water and to form chloramines which also removes odour. So, chlorine demand for water is the difference between added and remaining chlorine in water after a specified period. So, one needs to determine how much chlorine is required to be added in a water or what is the chlorine demand for water.

One need to add some amount of chlorine in water and after a specified period, it is observed that how much of it is there still in water. This amount is actually utilized for disinfection. Based on that, one can determine the total amount of chlorine that is used.

Chlorine consuming substances are inorganic, organic and ammonia and this also depends on time of contact, pH of water, and temperature.

Based on that, one can determine the chlorine rate or rate of chlorine application. Usually when we have certain kind of pandemics or certain other epidemics, there is chance of more contamination. In that case, we add a little bit more chlorine than usual. So, this process is known as super chlorination and we add 2 to 3 ppm beyond the break point of chlorine and sometimes dechlorination is also done to remove excess chlorine from water.

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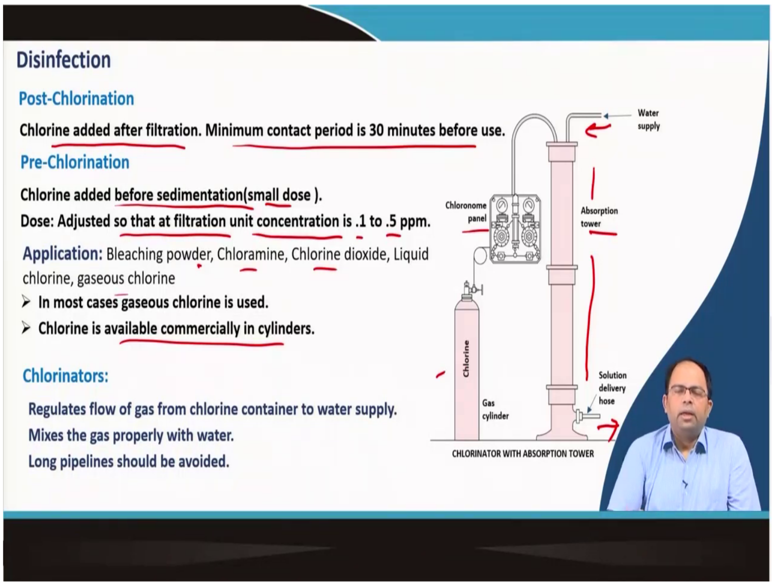

Usually there is pre-chlorination and post-chlorination. Post-chlorination is adding of chlorine after the process of filtration. Minimum contact period is 30 minutes before use.

In case of pre chlorination, chlorine is added before sedimentation, but a small dose is added compared to post chlorination and this is adjusted so that at filtration unit, concentration is around 0.1 to 0.5 ppm and this is applied through bleaching powder, chloramine, chlorine dioxide, liquid chlorine or gaseous chlorine.

In a treatment unit, we usually go for gaseous chlorine and it is available in commercial cylinders as seen in the Figure. Chlorinators are used and through a control panel, we can control the flow. So, we use chlorinators which regulates the flow of gas from chlorine container to water supply and this allows mixing of the gases properly with water and long pipelines are usually avoided for this kind of process.

Figure shows the absorption tower where the chlorine gets absorbed into the water which is supplied and the water is eventually taken out. The chlorine is being sent from this chlorine gas cylinder into the particular chamber. This is how we mix chlorine in the water.

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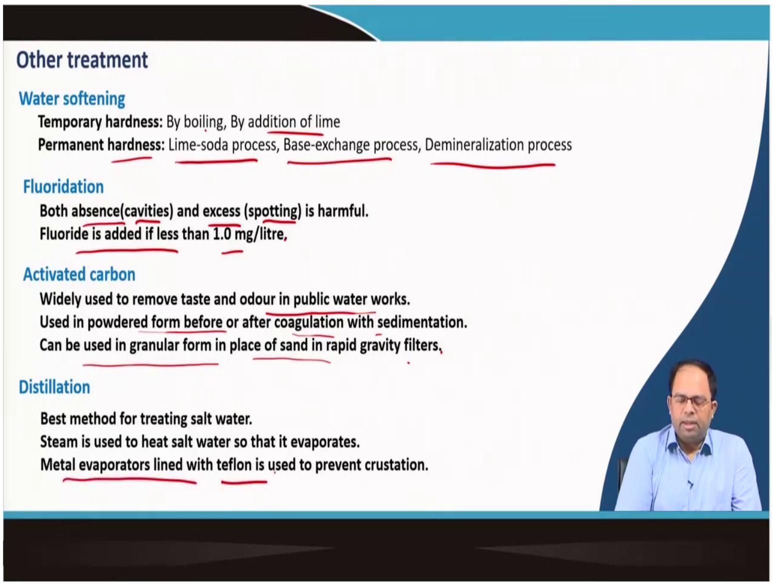

There are some other treatments in addition to disinfection as well in some water treatment plants depending on what type of water is treated. For example, one can do water softening to reduce hardness temporary hardness. It could be removed by addition of lime and by boiling. However, boiling is usually not done. Permanent hardness could be removed through lime soda process or base-exchange process or demineralization process. So, these are the different techniques that are utilized.

Regarding fluoride, both absence and excess is harmful. Absence of fluoride causes cavities, whereas, excess causes spotting which is harmful. So, fluoride is added in the water if it is less than 1 milligram per litre.

Activated carbon is used to remove taste and odour in public water works. These are used in powdered form before and after coagulation with sedimentation and can be used in granular form in place of sand in rapid gravity filters. Distillation process is the best method for treating salt water and steam is used to heat salt water so that it evaporates. In this process, metal evaporator lined with Teflon is used to prevent crustation. Once the water evaporates, after distillation, it becomes clean water..

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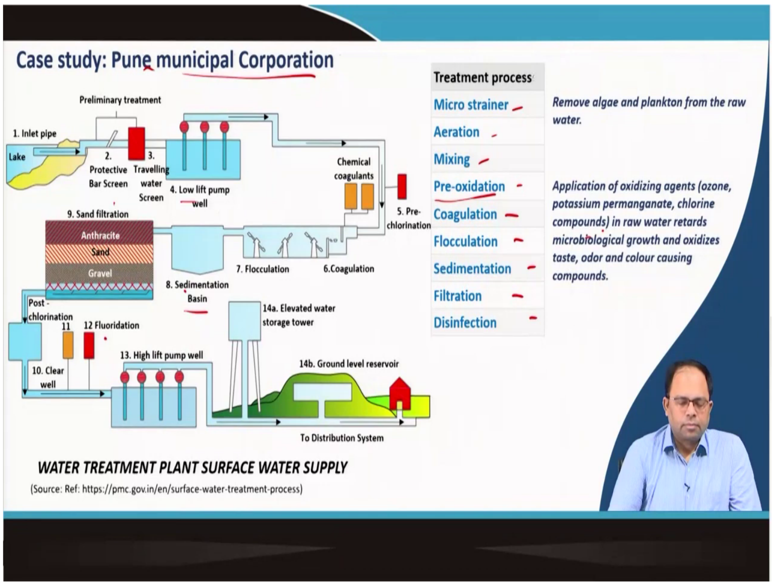

Case study: Pune Municipal Corporation

In the treatment plant installed by Pune Municipal Corporation in this treatment plant, first after the inlet of water, protective bar screens is installed followed by a travelling water screen.

There are two sets of screens. Then it is stored in a reservoir using low lift pump, then pre-chlorination/ pre-oxidation is done. Next, it is mixed with chemical coagulants and then flocculation, and coagulation happens. After this, sedimentation and sand filtration happens. The sand filter has various media layers. Next disinfection is done using post-chlorination and fluoridation.

From the clean water chamber, using high lift pumps, the water is sent to the elevated water storage tower from where it is sent to the different zones of the city where water is supplied.

The micro strainer is also being used in addition to the process of aeration, then process of mixing, then pre oxidation using oxidization agents like ozone, potassium permanganate, chlorine compound. Then coagulation, flocculation, sedimentation, filtration and disinfection happen. These are the different treatment process this Pune municipal corporation has adopted.

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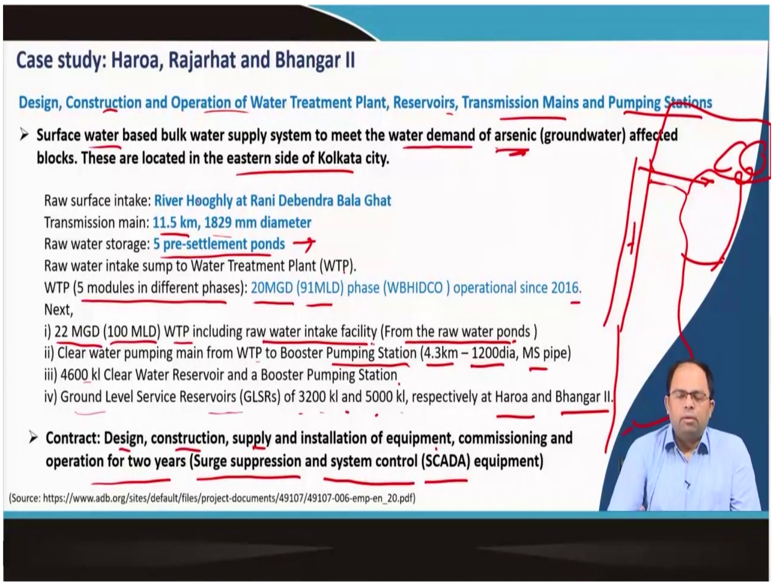

In the water treatment plant in Haroa, Rajarhat and Bhangar II in Kolkata area, design, construction and operation of water treatment plant, reservoirs, transmission mains and pumping stations were all taken up together.

This is a recent project and surface water-based bulk water supply system. The intake is at the surface water sources. This was done to reduce dependency on ground water because the ground water was arsenic contaminated and this was done in the eastern side of the Kolkata city because some of these blocks were contaminated because of arsenic.

It was planned to bring the surface water from far away and then treat it and then supply. The raw surface water intake was taken from river Hooghly at Rani Debendra Bala Ghat.

This project also involved developing the transmission main from river Hooghly directly to New Town where the distance was 11.5 kilometers and the pipe diameter was around 1829 millimeter and raw water storage was first in 5 pre settlement ponds.

This is where pre sedimentation happens. So, 5 pre settlement ponds were also there in the water treatment plant. From raw water intake sump, the water is taken to water treatment plant.

WTP was planned for 5 modules in 5 different phases. Already a 20 MGD or 91 million litres per day phase was done and it was in operation since 2016. The next plan was to design a plant with treatment capacity of 22 MGD or 100 million litres per day. So water treatment plant include raw water intake facility from the pre-settlement tank.

Clean water goes from pumping main to booster pumping station. As the pumping main is far away (4.3 kilo meters) from booster pumping stations, 1200 dia. MS pipes were used. 4600 kilo litre clear water reservoir and a booster pumping station was also constructed. Ground level service reservoirs of 3200 kilo litre and 5000 kilo litre were also constructed at Haroa and Bhangar II. So, there were three clear water reservoirs which have been constructed.

The entire contract including design, construction, supply and installation of equipment, commissioning and operation for two years was given to the agency. So, it is built, operated and then supposed to be transferred. Thus, it is a BOT contract. Care was taken to counter surges in the pump and also for controlling the water treatment units; that means, SCADA equipment was also installed in this particular system.

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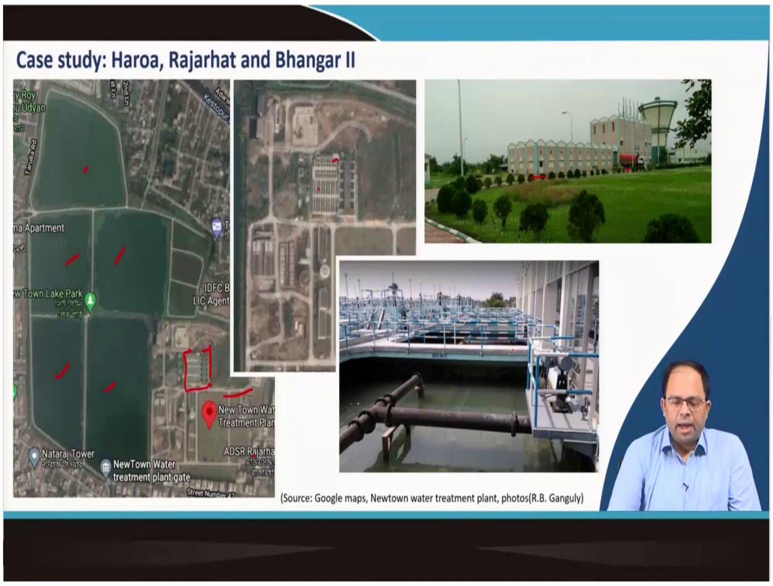

This is the map showing the location of water treatment plant in New Town. It also shows the pre-settlement ponds. One can understand the size required for pre-settlement ponds compared to the size of the plant.

The Figure shows the details of the water plant building with different units.

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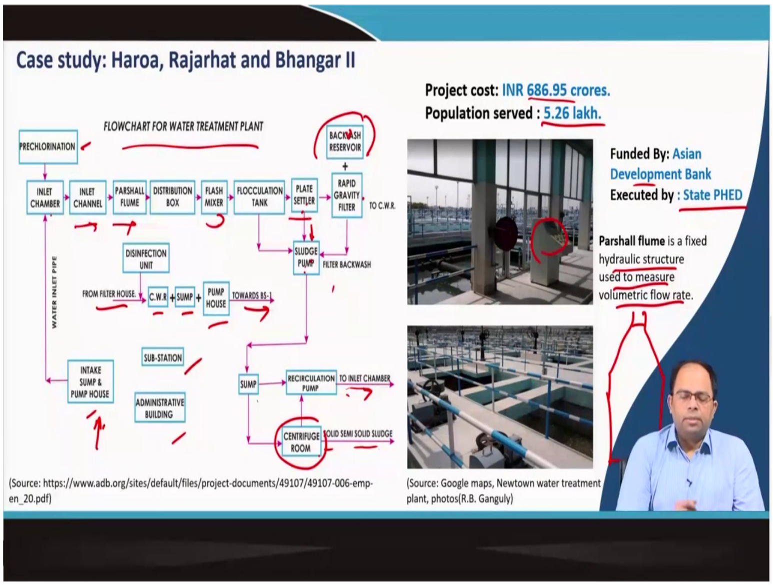

This is the sequence of treatment for the water treatment plant. The total project cost was around 686.95 crores. The total population served is around 5.26 lakhs. This provides an idea about the amount of money required for these kind of project.

Whenever a development plan is prepared, one need to make sure that this is the amount of finances that are available with the municipality. Based on this, one can determine what type of plants can be designed, the number of those plants, and what phasing needs to be done.

The funding is partly funded by the Asian Development Bank and was executed by the State PHED department. As given in the different images, these are the controls, valves and semi-automatic control systems.

Treatment sequence first includes pre chlorination, then the intake sump and pump house from where water is taken.

In the inlet chamber, pre-chlorination is done, then there are inlet channel, then there is a partial flume which is basically a fixed hydraulic structure used to measure volumetric flow rate. This is how the water flows and it is measured. Then there is a distribution box, a flash mixture for mixing the chemicals and then a flocculation tank and a plate settler.

Then there is a settlement tank and a sludge collection unit where there is a sludge pump, then there is a rapid gravity filter which has a backwash reservoir and then the sludge is taken to a sump where there is a recirculation pump to the inlet chamber.

The sludge is recirculated back into the system. Then, there is a solid semi sludge formed in the centrifuge room where the sludge is probably rotated.

That means some amount of de-watering is taking place and then there are substations for electricity, administrative building, a separate disinfection unit where the clean water from rapid gravity filter comes and then the sump and clean water reservoir pump house and then it is sent to the boosting station.

It is very difficult to determine the amount of area required for a pump house until and unless the actual design is done. Roughly one can form an idea and then the area reserved for this kind of units can be determined.

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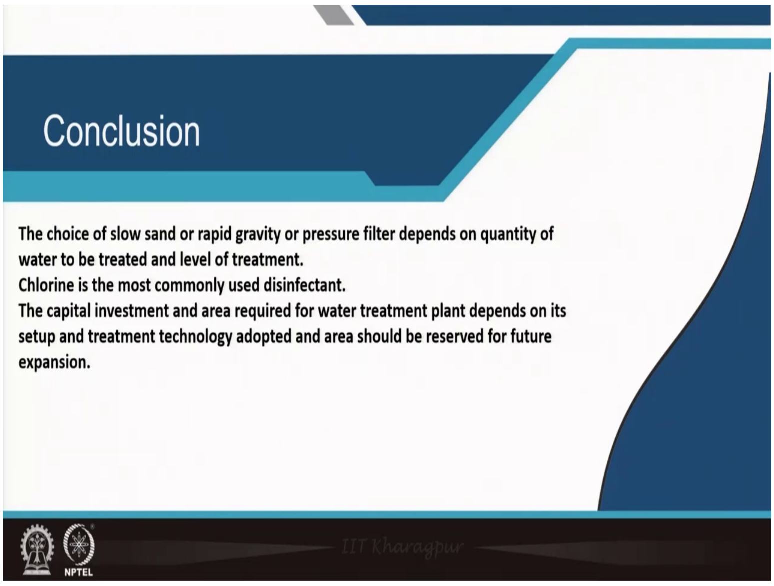

Conclusion

To conclude, the choice of slow sand or rapid gravity or pressure filter depends on quantity of water to be treated and level of treatment. Chlorine is most commonly used disinfectant and the capital investment and area required for water treatment plant depends on its setup and treatment technology adopted and area should be reserved for future expansion.

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References These are the references that can be used.