Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 11
Sewage treatment
Lecture - 51
Sewage Disposal and Treatment in India: Introduction

In module 11, sewage treatment is discussed. In lecture 51, an introduction to sewage disposal and treatment in India will be discussed.

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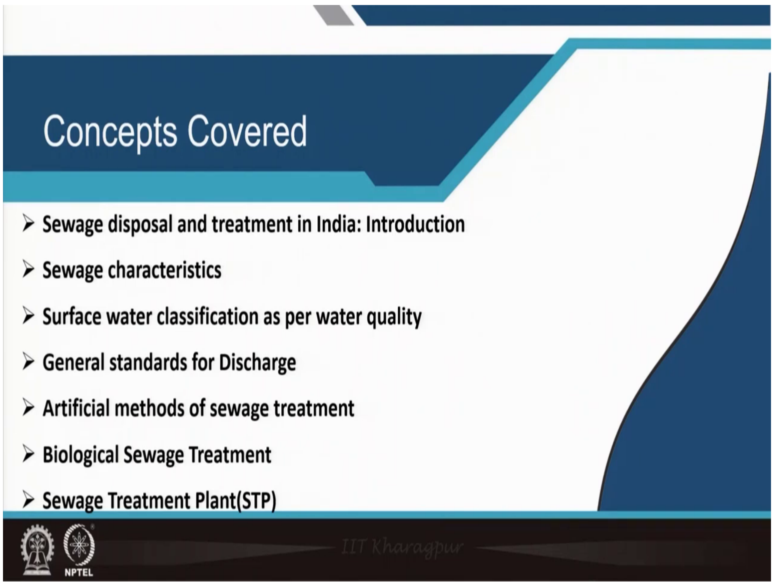

Concepts covered

The different concepts that will be covered are introduction to sewage disposal and treatment in the Indian context then, sewage characteristics, surface water classification as per water quality. Then, general standards for discharge, artificial methods of sewage treatment, biological sewage treatment and sewage treatment plants in general.

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Sewage disposal and treatment in India: Introduction

Regarding sewage disposal and treatment in the Indian context, it could be estimated that over 60 percent of urban India's sewage enters water bodies untreated.

Most Indians cities have combined sewers and most places in India receive a significant amount of rainfall. So, it is economically not viable to treat the entire volume of the sewage or the combined sewage that is generated.

The sanitary sewage is the dry weather flow; the normal flow during the non rainy season. In that case, the waste goes via pipe to the wastewater treatment facility.

But during the rainy season, the combined flow increases and is too high to be treated. Then the excess flow is diverted and disposed via the outfall to the river. After treatment, sewage could be reused or it could be again disposed to the river as well.

Roughly this is the design in most Indian cities. So, we are not able to treat the entire volume of sewage. In most cases, we dispose the sewage directly into the river and roughly we can see that 60 percent of total sewage is not treated at all. The disposal point is known as an outfall and it is a discharge point of both treated as well as untreated sewage.

Usually, sewage flows via gravity conduit. It can be via pressured conduit as well, because sometimes the outfall is at a higher level, due to presence of levees and other embankments of the river.

At the outfall, there is a need to keep the invert level of the conduit at least 0.5 meter above the flood level of the receiving water body to prevent backflow. Even though backflow prevention devices can be installed, the standard norm is to maintain this.

Usually the discharge is first let into a receiving well from where it spills over to the river or the water body; that means, always there is storage. In case of a backflow prevention device; sewage has to be stored for a certain point of time. So, some amount of storage is provided at the outfall.

In this particular lecture, two ways are discussed to treat sewage; one is the natural method under which there is dilution and land treatment, another is the artificial method which include primary and secondary treatment.

First of all, there is a need to understand when to adopt a natural method and when to adopt artificial method. What are the standards of discharge; that means, once the sewage is treated, how much amount of treatment has to be given to it. It again depends on the characteristics of the sewage. All these things play a role in determining what kind of sewage treatment is provided in a particular scenario or a particular context.

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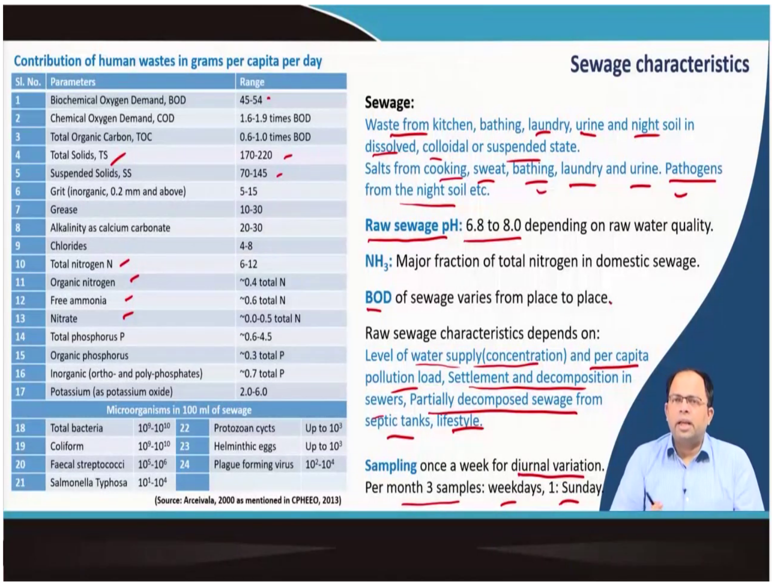

Sewage characteristics

The Table shows the contribution of human waste in terms of grams per capita per day. The Biological Oxygen Demand from human waste comes to around 45 to 54 grams per capita per day. Similarly, total solids comes to around 170 to 220 grams and suspended solids 70 to 145 grams. There are limits for ammonia, nitrogen, chlorides, and phosphorus as well.

For creation of biogas, mixing both human waste as well as cattle waste is done. Human waste has certain nutrients that could be used as manures and can be used for creation of energy from the gas as well.

Based on different components of the waste in sewage, one can determine the type of treatment.

Apart from human waste, sewage also includes waste from kitchen, bathing, laundry, etc. since, most Indian cities have combined sewage. The waste is either in dissolved, colloidal or suspended state in water. In addition, there are different kinds of salts which mainly comes from cooking, human sweat, bathing, laundry, urine, etc. Sewage also includes pathogen from night soil. Thus, there is a need for provision of treatment of pathogens in addition to removal of basic dissolved, colloidal and suspended waste. The pH value of raw sewage influences different chemical processes. Raw sewage has a pH of around 6.8 to 8.

Although ammonia is the major fraction in terms of nitrogen in domestic waste, there are other components as well such as total nitrogen, organic nitrogen, free nitrogen, and nitrate. During sewage treatment, there are two components that need to be removed, i.e., organic loading or BOD loading and total suspended solids or total dissolved solids in the sewage. Primary treatment reduces the total TSS or total solids whereas; the secondary treatment removes the BOD from the waste. Every plant is designed to reduce the certain amount of BOD and total solids. Regarding BOD, if more amount of sludge is added from this septic tank into the sewage treatment plant, it affects the BOD loading of the plant.

BOD of sewage varies from place to place depending on the raw sewage characteristics, level of water supply, per capita pollution load, settlement and decomposition in sewers, designs of the sewers, and age of the sewers. If already lot of settlement and decomposition is happening, it does affect the BOD content as well as the total solid content. Lifestyle of the people in a given area or the economic profile also plays a role in determining the sewage characteristics.

Regarding sampling strategy of sewage, we should be able to consider the diurnal variation throughout a day to study the variation in the flow of sewage. Usually, we can take three samples per month; two from weekdays and one from a Sunday to determine the sewage characteristics. Accordingly, the kind of treatment process can be designed. It can also be determined if the existing processes in the sewage treatment requires change in certain parameters based on the service.

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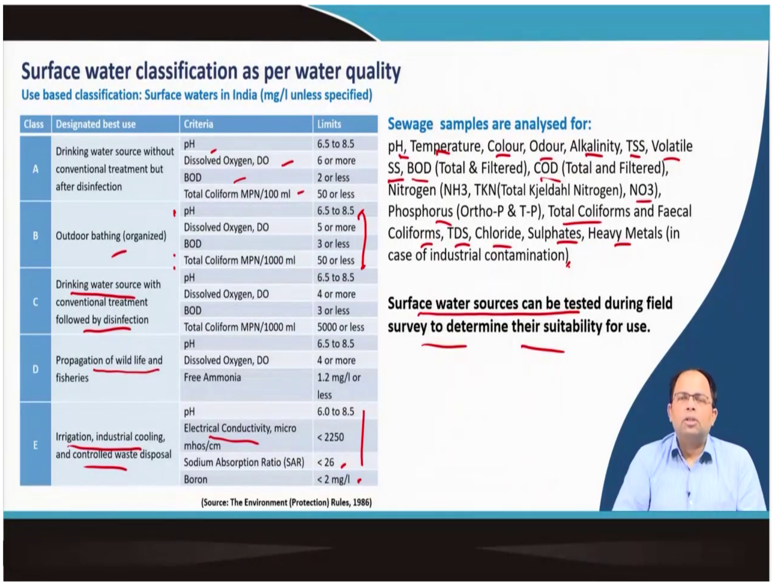

Surface water classification as per water quality

For testing water quality of a particular area, i.e, when we go for some planning exercises, we need to carry kits with us to test water and to see what is its quality.

Sewage samples should be analyzed for Ph, Temperature, Colour, Odour, Alkalinity, TSS, Volatile, suspended solids, BOD, COD, Nitrogen, (ammonia, TKN [Kjeldahl Nitrogen] NO_3), Phosphorus, Total Coliform and Faecal Coliform, TDS, Chlorides, Sulphates, and heavy metals. These are the different components that need to be tested to determine the quality of sewage. Similar test has been done for water quality as well. As sewage is 99.9 percent water, one can determine the quality of water to determine the quality of sewage.

During a field survey, surface water sources can be tested and determined if they are suitable for certain purposes. If not then, certain remedy measures need to be implemented.

In urban areas, different surveys are conducted on water bodies and accordingly proposals are given including need of prevention of sewage entry into water bodies or need for some form of treatment of water before it goes into the water body. Water can be tested based on the standards given in the Table.

The Table shows if the water is suitable for drinking without conventional treatment, but maybe after disinfection. Then probably, the pH value of the water has to be within 6.5 to 8.5, DO levels has to be 6 or more, BOD value has to be less than 2 and total coliform MPN should be 50 or less.

Similarly, the standards are given for outdoor bathing, drinking water source (with certain amount of conventional treatment followed by disinfection), water bodies suitable for wildlife and fisheries, water bodies for irrigation or industrial cooling, etc. In case, the water body is used for industrial cooling, electrical conductivity can be also checked and the value should be less than 2250 micro ohm per centimeter. In addition, sodium absorption rate and boron values should be also checked. In this way, sewage quality is tested and if the given water body is suitable for certain purpose or not is determined.

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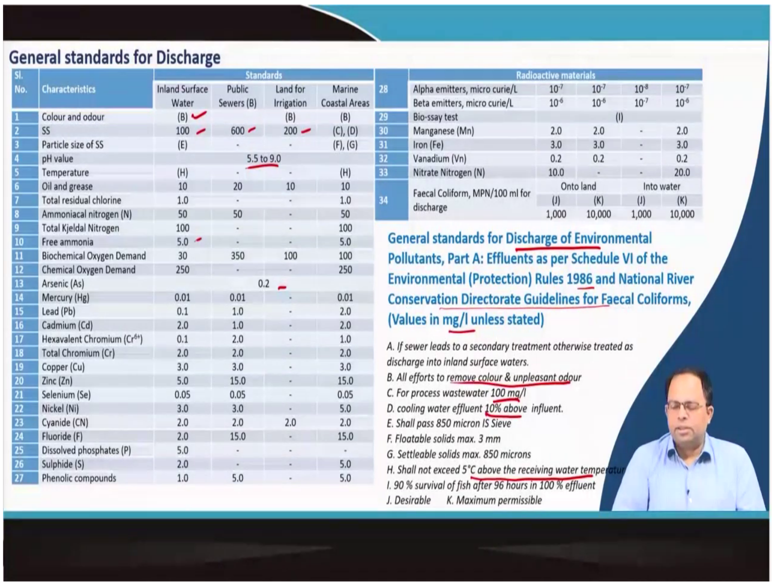

General standard for discharge

The Table shows the general standards for discharge of environmental pollutants, Part A: Effluents as per schedule IV of the Environmental (Protection) Rules 1986 and the National River Conservation Directorate Guidelines for Faecal Coliforms (values in milligrams per litre unless stated).

This Table gives an idea about standards for discharge of environmental pollutants so that one can make sure that after treatment, the sewage reaches this particular quality.

Regarding colour and odour, all efforts should be there to remove colour and unpleasant odour. Suspended solids value should be 100 mg/l for inland surface water, 600 mg/l for public sewers, 200 mg/l for land for irrigation, 100 mg/l for marine coastal area and if it is used in cooling water effluent, 10 percent above influent.

pH value should be around 5.5 to 9, temperature shall not exceed 5 degree centigrade above the receiving water temperature. Free ammonia value is 5. Arsenic values are given as 0.2. Similarly, the standards for mercury, lead and all components are given.

If the quality do not conform to the given standards, then one need to look for treatment measures to treat the sewage further. During testing, the concentrations of given elements can be matched with the standards to determine if discharge adheres to these standards or not.

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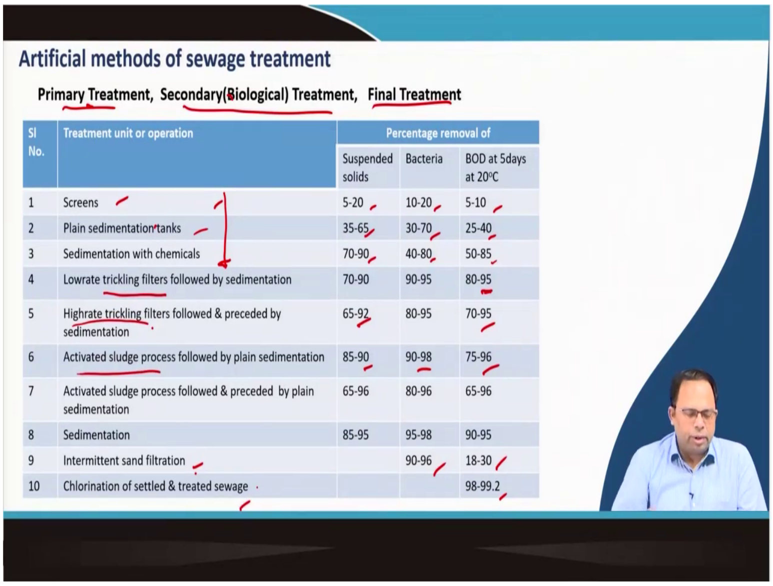

Sl No.	Treatment unit or operation	Percentage removal of		
		Suspended solids	Bacteria	BOD at 5days at 20°C
1	Screens	5-20	10-20	5-10
2	Plain sedimentation tanks	35-65	30-70	25-40
3	Sedimentation with chemicals	70-90	40-80	50-85
4	Lowrate trickling filters followed by sedimentation	70-90	90-95	80-95
5	Highrate trickling filters followed & preceded by sedimentation	65-92	80-95	70-95
6	Activated sludge process followed by plain sedimentation	85-90	90-98	75-96
7	Activated sludge process followed & preceded by plain sedimentation	65-96	80-96	65-96
8	Sedimentation	85-95	95-98	90-95
9	Intermittent sand filtration		90-96	18-30
10	Chlorination of settled & treated sewage			98-99.2

Artificial methods of sewage treatment

Artificial methods of sewage treatment includes primary treatment, secondary or biological treatment and final treatment.

First, primary treatment is done to reduce the suspended solid load of the sewage. It is achieved through sedimentation, coagulation, etc.

Next, secondary or biological treatment is done where aerobic and anaerobic microorganisms act upon the sewage using several techniques. This helps to remove the BOD of the sewage. During final treatment, filtration and disinfection is done to remove the pathogenic bacteria and metals. Sewage is passed through certain filters to remove given metals and minerals.

The Table shows the treatment units and percentage removal of different components. Screens reduce suspended solids by 5 to 20 percent, bacteria by 10 to 20 percent and BOD by 5 to 10 percent. Plain sedimentation tank which is a primary treatment reduces suspended solid by 35 to 65 percent , bacteria by 70 percent and BOD by 40 percent.

On the other hand, sedimentation with chemicals reduces the suspended solid up to 90 percent, bacteria by 80 percent and BOD by 50 to 85 percent.

Low-rate trickling filter followed by sedimentation can achieve around 95 percent BOD removal. High-rate trickling filter followed and preceded by sedimentation can achieve around 95 percent BOD removal and 92 percent suspended solids removal, because we are using both the sedimentation as well as the trickling filter together, i.e., , both primary and secondary treatment together. Similar to trickling filter, there are other set of process which are based on activated sludge process where we mix the sludge back into the incoming wastewater so that we introduce the bacteria in the sludge to start their growth earlier. It can remove around 98 percent of microorganisms, 90 percent of solids and 96 percent of BOD.

The intermittent sand filtration is another form of biological treatment where the bacteria and the BOD are removed and finally, chlorination is targeted towards removal of bacteria or pathogens. In this process, 99.2 percent of BOD is removed.

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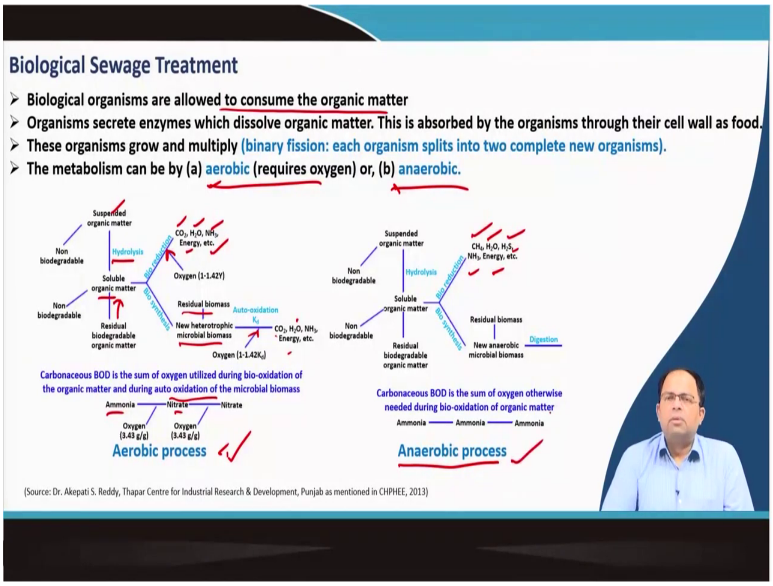

Biological sewage treatment

In biological sewage treatment, biological organisms are allowed to consume the organic matter. Biological organisms act upon the sewage and the organism secrete some enzymes which dissolve organic matter. Organic matter is the food for the biological organisms. Once they get food, they grow and multiply and consume more amount of waste.

Once the entire organic waste is consumed, due to the lack of oxygen, bacteria dies. Thus, the organic loading and BOD is reduced and the bacteria itself would be removed at the end of the treatment process.

Biological processes involve aerobic process which requires oxygen and anaerobic process which also requires oxygen, but the oxygen is not from environmental oxygen. The oxygen molecules are taken by breaking the complex organic matter. The reactions and outcome of both the processes are also different.

When suspended organic matter is mixed with water, hydrolysis happens and chemicals break down because of mixing with water. Soluble organic matter is acted upon by microorganisms. Also, there is a residual biodegradable organic matter in the particular sewage.

Entire sewage is acted upon by this microbial biomass and due to that, bio reduction happens which leads to the production of CO_2, H_2O, ammonia and heat energy in the presence of oxygen.

At the same time, along with with the residual biomass, and new heterotrophic microbial biomass, new microbes are created. These are again acted upon by the oxygen and we have auto oxidation which again breaks down into CO_2, H_2O, NH_3, and energy.

This is an aerobic process when ammonia gets converted into nitrates and carbonaceous BOD is the sum of the oxygen utilized during bio-oxidation of the organic matter and during auto oxidation of the microbial biomass.

The anaerobic process is similar to aerobic process with difference in the final products. In this process, instead of ammonia, methane and hydrogen sulphide is released. In this process; H_2O, H_2S, NH_3, H_2S and energy is released.

If anaerobic conditions persist in a particular area, it means that there is no oxygen. The decomposition happens via anaerobic process, which leads to some bad odour which is primarily, because of H_2S and CH_4. Thus, these are two biological processes that are employed in any sewage treatment plant.

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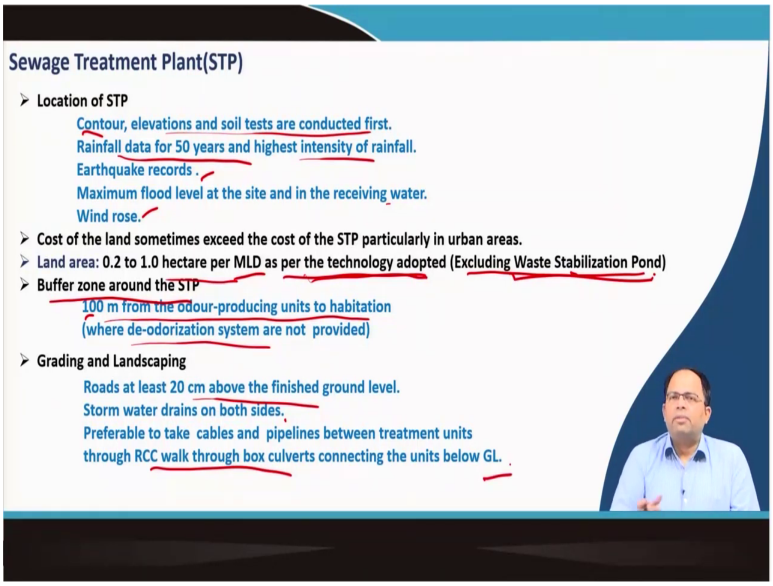

Sewage Treatment Plant

As urban planners would always like to reserve certain area for sewage treatment plant, two things needs to be understood, i.e., the water quality and the type of treatment required. In addition, if there is a need to change the treatment quality. Based on this, what type of units should be there and what would be the size of those units and accordingly what would be the size of a plant needs to be determined. It is difficult to say that exactly what amount of land area has to be reserved at what location. As per thumb rule, a location of STP is determined by analyzing the contours of that area, elevations, soil type and rainfall data for 50 years.

Also, the highest intensity rainfall during that period also needs to be determined which will give the total quantity of runoff generated in the given area which gives an idea about the flooding potential of the area. In case of sewage treatment plant one has to be very careful about flooding. If the area gets flooded, the sewage will be mixed with the flood water. The stabilization ponds, large-scale basins or sludge drying tanks may get inundated that will lead to contamination of the entire area.

In addition, earthquake records, maximum flood level at the site and in the receiving water body should be checked. Wind rose should be checked because sometimes there is smell from odour from the sewage treatment plants which also needs to be controlled.

In many cases, cost of land is determined because sewage treatment plants has to be set up in an urban area, particularly in case we want to reuse the water; the sewage treatment plant is set up within the urban area. If we have the sewage treatment plant far away, then the sewage will first go there and again return from that plant. So, the length of pipelines increases the cost and pumping energy. It is thus better to have the sewage treatment plant in the urban area itself. But because it is in an urban area, the cost of land sometimes exceeds the cost of the STP itself.

So, how much amount of land area needs to be reserved?

As per thumb rules around 0.2 to 1 hectare per million litres per day of sewage treated should be reserved as per the technology adopted. In case waste stabilization ponds are installed, a huge amount of area is required. As these are natural basins where waste is put for a certain amount of time to be automatically acted upon by the natural elements it requires a huge area.

If we go for more artificial treatments then we do not require that amount of space, but 0.2 to 1 hectare per MLD is required as a broad thumb rule as per the technology adopted for this particular treatment.

In addition, we should have reserve area for the sewage treatment plant for future. Also, buffer zones are provided around the sewage treatment plant.

If de-odorization systems are not provided, 100 meter buffer is provided from the producing units to habitation or residential areas. If de-odorization systems are provided, this distance can be reduced.

Proper grading and landscaping has to be done and roads have to be at least 20 centimeter above the finished ground level. Storm water drains has to provided on both sides so that flooding can be prevented in the given area. Also, it is preferable to lay cables and pipelines between the treatment units underground through RCC walk through box culverts connecting the units below ground level.

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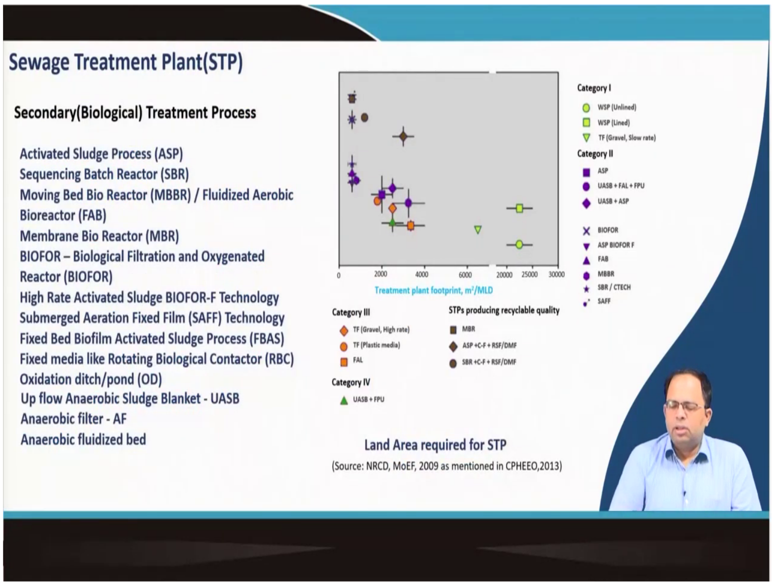

The Figure shows the land area required for an STP as per the different technologies as given in CPHEEO. These technologies are provided in combination. For example, a sewage treatment plant including trickling filter will require around 2500 square meter of area per million litres per day of sewage.

Similarly, for waste stabilization ponds(lined or unlined), the maximum required area is 20 to 23000 square meters of area per MLD of sewage treated.

These are the secondary or biological treatment process which could be adopted such as activated sludge process, sequential batch reactor, moving bed bioreactor or fluidized aerobic bio reactors, membrane bioreactors then, bio for biological filtration andhigh-rate activated sludge bio for F-technology.

There are various technologies with different variations. If it is an activated sludge process or filter, certain media is used. Then, air is added or media is transformed to a fluidized state like sand or brick bats through which the sewage passes and they float in the particular sewage media.

There are many processes that could be adopted for biological treatment of sewage. The space required for these processes are given below. For example, SBR and dual media filtration. It requires very less space.

Membrane bioreactors require the least amount of space. The quantity and quality of discharge using these technologies are different. Also, the space required for these technologies are different. The costing and the operation procedures are also different.

There is a need to develop understanding of provision of these fundamental technologies in given context. Whenever these are designed, feedback of the people should be incorporated. Also, willingness to pay for the given technology, and pros and cons of these should also be evaluated.

The basic processes, costing, space requirement and other parameters should be understood to make a decision.

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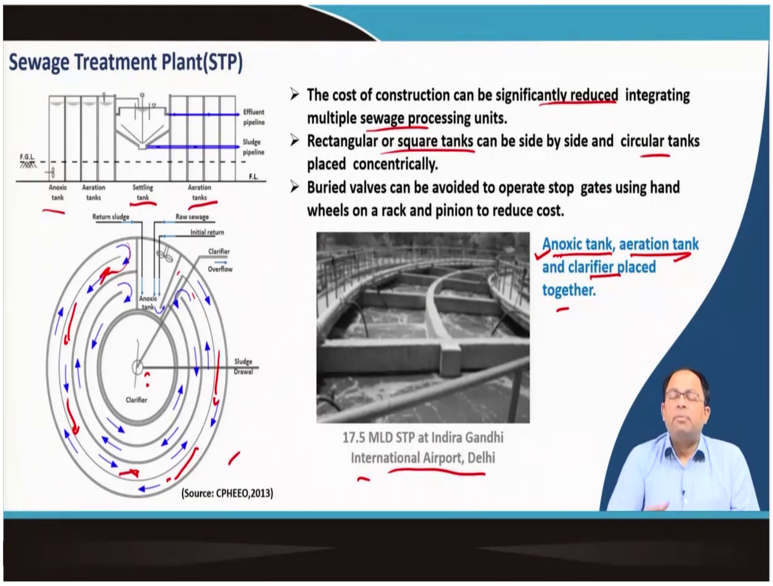

The case study shows the design of a 17.5 MLD sewage treatment plant at Indira Gandhi International Airport in Delhi. There is an anoxic tank, aeration tank and a clarifier placed together as a compact unit. In clarification tank, sludge is scrapped during sedimentation. In aeration tank, oxygen is added. In anoxic tank, nitrification happens in the absence of oxygen. These processes are combined together in one plant.

Thus, the area and the cost of construction can be significantly reduced by integrating multiple sewage processing units. The tanks are rectangular or squared shaped that can be placed side by side with the sewage moving from one tank to another. Circular tanks could be placed even concentrically.

The given STP has the anoxic tank at the beginning with a mixer. Raw sewage is mixed and then nitrification happens. The water actually passes through the given pathway and comes at the centre. The sludge is gathered at the clarifier. Followed by this, aeration is performed.

Buried valves can be avoided. Stop gates can be operated using hand wheels on a rack and pinion to reduce cost as well.

As a decision maker, the details in such extent may not be required. However, one should have an understanding about the area requirement so that the available resources can be optimised.

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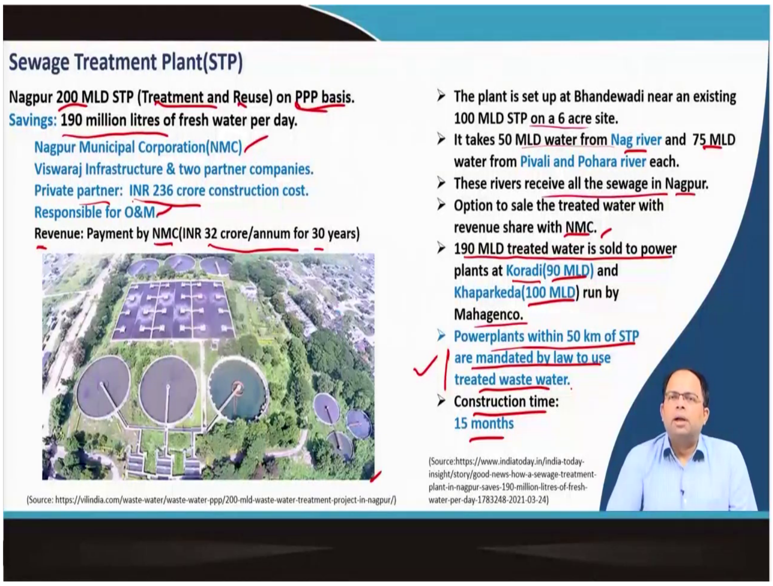

The case study shows the design of a 200 MLD sewage treatment plant in Nagpur. In this case, the treated wastewater is being reused. This was developed on PPP basis. This plant led to savings of 190 million litres of fresh water per day. This project was developed by Nagpur Municipal Corporation and the PPP model was implemented via Vishwa Raj Infrastructure and two partner companies which formed a special purpose vehicle.

The private partner invested around 236 crores as construction cost and they were also responsible for operation and maintenance as well. The payment has to be made by Nagpur Municipal Corporation. This is the revenue that the private consortia will get and that comes to around 32 crores per annum for 30 year period. This is the money the municipality will keep on paying the company for keeping this plant operating.

The plant is set up in Bhandewadi near an existing 100 MLD STP on a 6-acre site. It takes 50 MLD of water from the Nag river and 75 MLD water from the Pivali and Pohara river each.

Thus, total 200 MLD is taken form river sources. These sources receive all the sewage from Nagpur. STP takes the water and discharge in it after cleaning it.

This contract has an option to sell the treated water with revenue share with Nagpur Municipal Corporation. If the water is reused, then the money that would be generated by selling it has to be shared with NMC. So, out of the treated water that is 200 MLD, 190 MLD of treated water is sold to power plants at Koradi and Khaparkeda.

First one takes around 90 MLD of water and the next one take around 100 MLD of water and both these thermal power plants are run by Mahagenco. Power plants within 50 kilometers of STP are mandated by law to use treated wastewater.

The project is very successful. The feasibility of treating the sewage is possible because the provision for reuse is mandated by law. That is why a PPP model could be set up for this kind of treatment process. The construction time for this project was 15 months. Similar projects can also be set up in other parts of the country as well.

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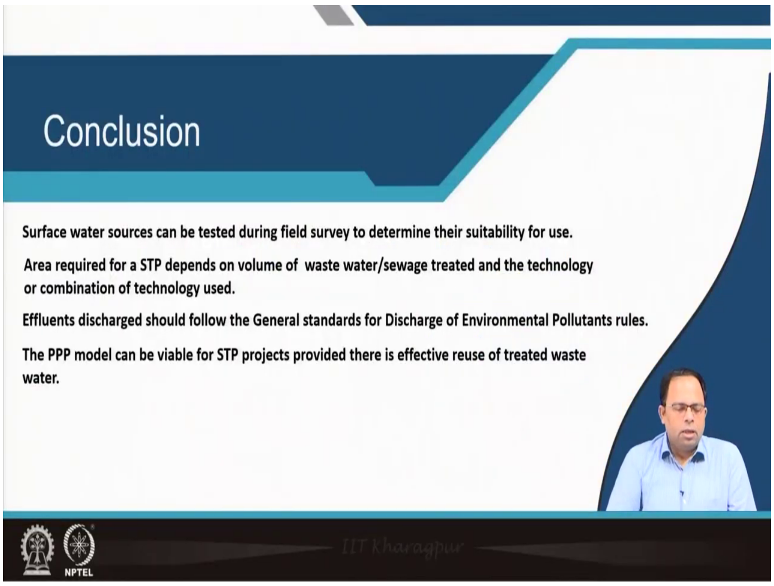

Conclusion

To conclude, surface water sources can be tested during field survey to determine the suitability for their use. Area required for a STP depends on volume of waste water or sewage and the technology or combination of technology used. Effluent discharge should follow the General standards for Discharge of Environmental Pollutants Rules. The PPP model can be viable for STP projects provided there is effective reuse of treated wastewater.

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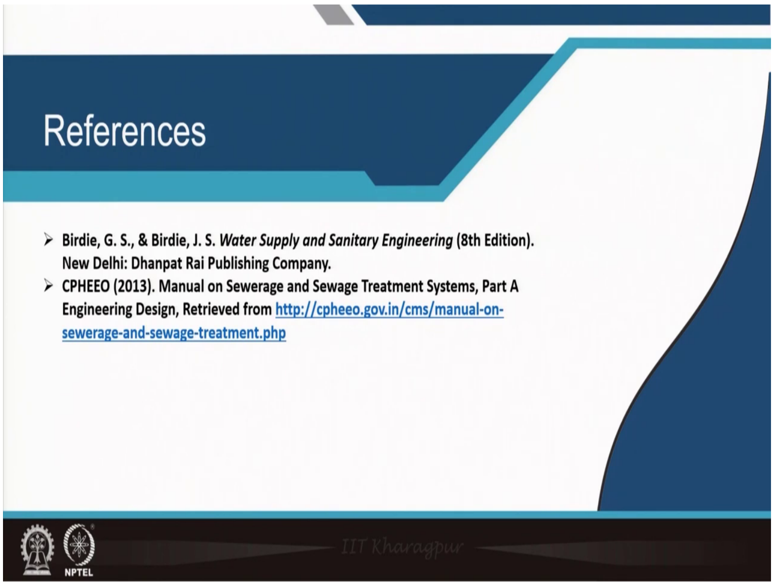

References

These are the references that can be followed.