Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 11
Sewage treatment
Lecture - 55
Artificial Sewage Treatment Part III: Advanced Methods

In lecture 55, Artificial Sewage Treatment Part III - Advanced Methods will be covered.

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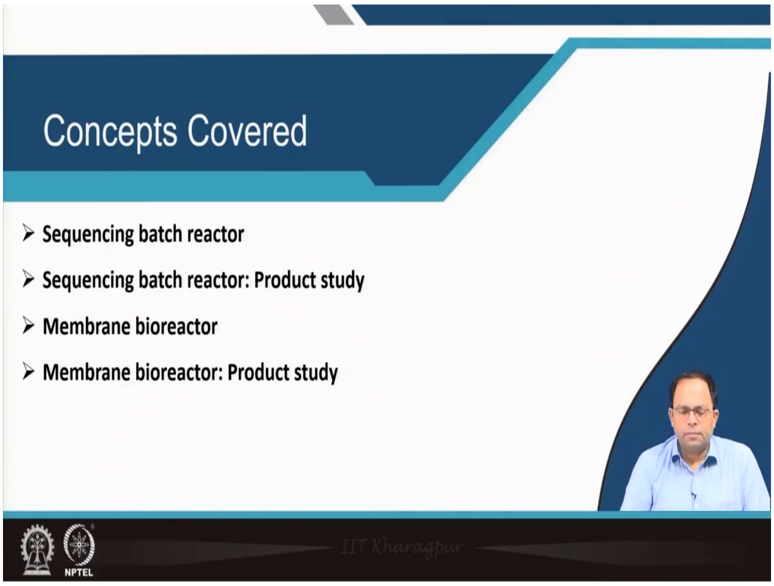

Concepts to be covered includes Sequencing batch reactors, Membrane bioreactor, and Product study for Sequencing batch reactor and membrane bioreactor

Sequencing batch reactor

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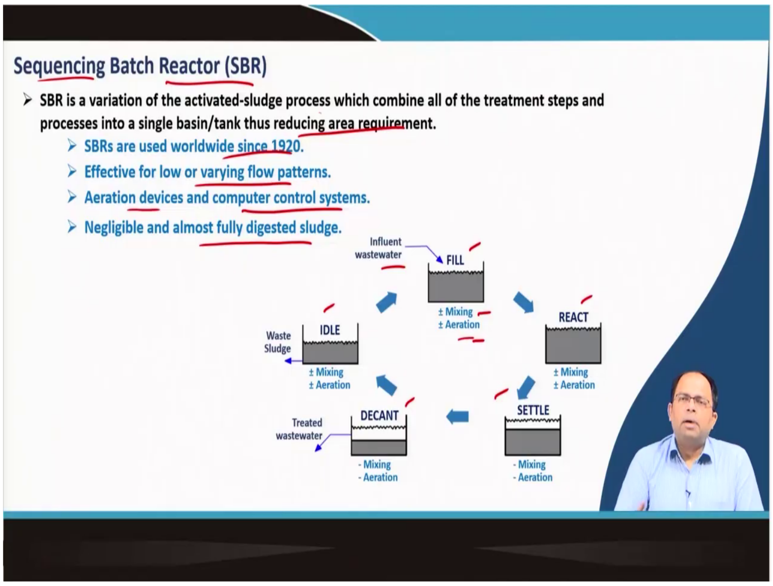

Sequencing batch reactor is a variation of the activated sludge process. It involves a single chamber where the different processes involved happen in a sequence; As multiple processes occur in one chamber, the area required for the tank/basin is high.

- SBR has been used worldwide since 1920.
- Effective for low and or varying flow patterns (suitable for decentralized treatment such as for large residential complexes)
- Devices controlling aeration, opening and closing of certain valves etc can be computer-controlled making it an automatic process
- Negligible and almost fully digested sludge.

The image shows the different stages involved such as *fill, react, settle, decant* and *idle*.

REACT - Mixing and aeration occur in this stage. Wastewater is mixed with the existing sludge, which holds the bacteria. Air is allowed inside the chamber for aeration. It forms an activated sludge process and existing sludge is used to start the biological reactions in aerobic conditions.

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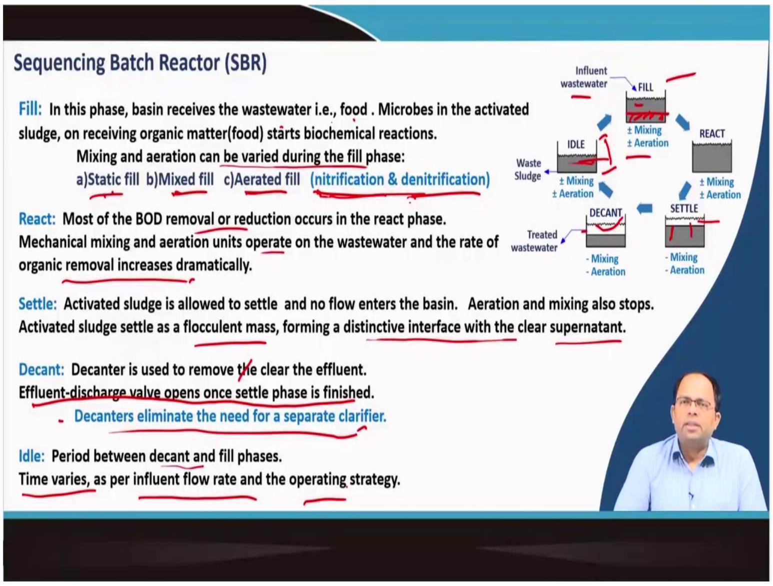

<u>FILL</u> - the basin receives the wastewater that is food for the microbes which is present in the activated sludge already there in the chamber. The microbes start consuming the organic matter which in turn causes further microbial growth. The organic matter in the wastewater is reduced. Different processes can be involved with regard to mixing and aeration.

Static fill - Neither mixing nor aeration takes place. Mechanical mixtures or fans in the chamber causes mixing. Anoxic conditions (absence of oxygen) and de-nitrification occurs.

Mixed fill - Mixing happens and aeration doesn't occur in this process. Anoxic conditions exist and denitrification occurs

Aerated fill - Aeration leads to activities by the aerobic bacteria and thus nitrification.

Thus, in SBR, along with the decomposition or the stabilization of organic content, nitrification or denitrification can also be done effectively.

<u>REACT:</u> During this step, most of the BOD removal or reduction occurs. Mechanical mixing and aeration units operate on the wastewater and the rate of organic removal increases dramatically. Because the more amount of food is consumed, the more is the number of bacteria that is formed. This increases the BOD removal rate.

SETTLE: where activated sludge is allowed to settle and no further wastewater is allowed to enter into this particular basin. The activated sludge settles as a flocculant mass, forming a distinctive interface with clear supernatant which gets formed at the top.

DECANT: A decanter is used to remove/clear the effluent (A decanter is a device that scoops the clean water from the top). Here, valves (effluent discharge valve) are used which is placed such that the upper clear liquid moves out through it from the particular chamber. The effluent discharge valve opens once they settle phase is finished. This eliminate the need for separate clarifiers. As there is constant aeration involved the sludge gets almost fully digested. Sludge is taken out from this particular chamber when required.

IDLE: This is a period between the decant phase and the fill phase. Some time is allowed for stabilization of sludge. This time varies according to the influent flow rate and the overall operating strategy.

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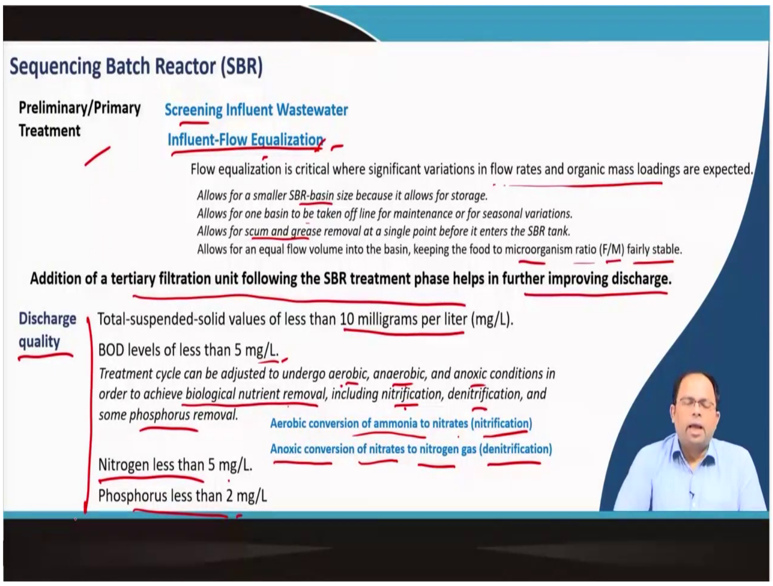

Preliminary or primary treatment is done to strain the influent wastewater to remove plastics, floating matter into the SBR chamber.

Flow equalization is also necessary because SBR cannot handle very high flow or varying flow. (ie, organic loading has to adhere to a particular quantity). This also helps in reducing the size of the SBR basin. Maintenance work concerning SBR basin is possible as the incoming wastewater can be stored in the equalisation tank for a required time. It also allows scum and grease removal at a single point before the wastewater enters the SBR tank. It also allows for an equal volume flow into the basin keeping the food to microorganism (F/M) ratio.

Sometimes a tertiary filtration is done following the SBR treatment as part of the post-treatment in the tertiary filtration unit along with the SBR treatment to improve the discharge point quality

<u>Discharge quality:</u>

- Total-suspended-solid values of less than 10 milligrams per litre (mg/L).
- BOD levels of less than 5 mg/L.
- The treatment cycle can be adjusted to undergo aerobic, anaerobic, and anoxic conditions to achieve biological nutrient removal, including nitrification, denitrification, and some phosphorus removal

When aerobic conditions prevail, Aerobic conversion of ammonia to nitrates (nitrification) occurs. When anaerobic conditions prevail, Anoxic conversion of nitrates to nitrogen gas (denitrification) occurs. Finally, the amount of nitrogen is less than 5 milligrams per litre and phosphorus is less than 2 milligrams per litre.

Sequencing batch reactor – Product study

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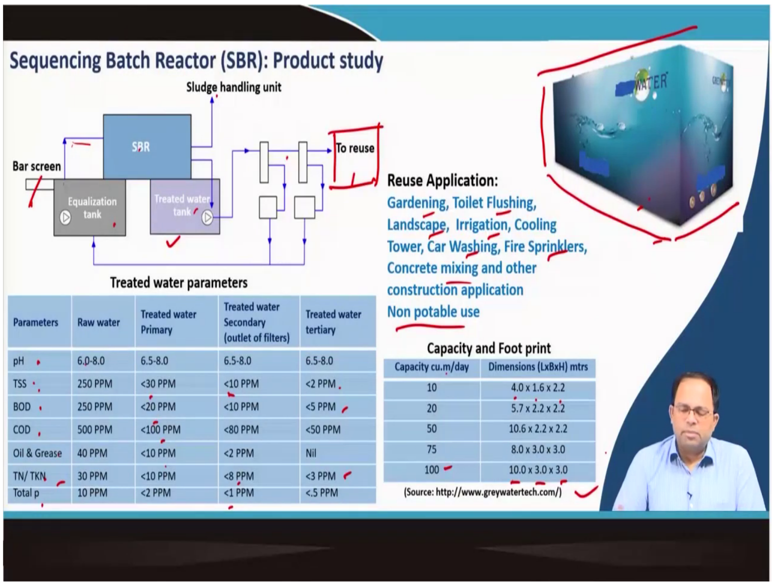

It has a compact design. The incoming wastewater first enters the bar screen before it is allowed to the equalization tank, from where it is conveyed to the SBR. From the SBR, some amount of sludge is taken to the sludge handling unit as some amount of sludge requires to be removed. The treated water is conveyed to the treated water tank.

The various parameters indicating the effectiveness of treatment are listed in the table for Raw water, treated water after primary treatment, treated water after secondary treatment, and treated water after tertiary treatment. It can be observed that a significant reduction of TSS (total suspended solids), BOD, COD, oil and grease, Nitrogen, Phosphorus happens after each stage of treatment. This enables reuse applications such as for gardening, toilet flushing, landscape, irrigation, cooling tower, car washing, cooling tower for air conditioners, fire sprinklers, concrete mixing and other construction application. It is mainly meant for non-potable use.

Footprint based on capacity given in the table (refer to the above figure) indicates that the treatment units are very compact in form.

Membrane bioreactor

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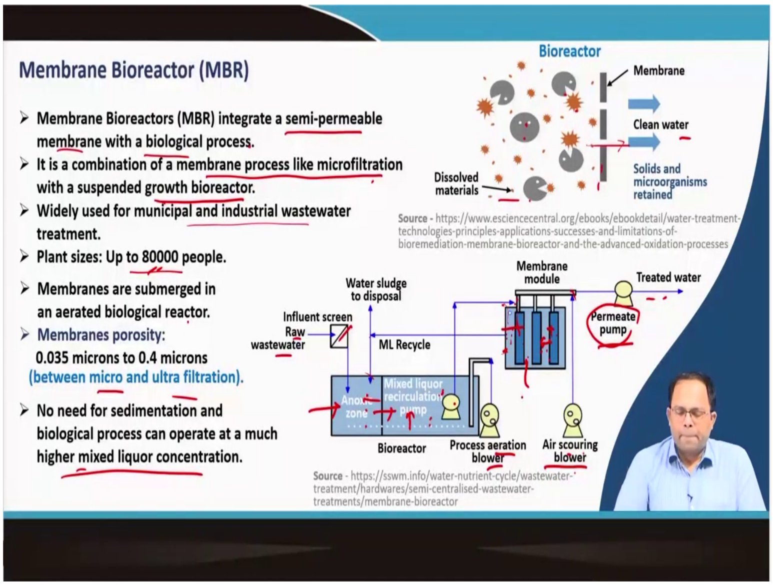

MBR integrate a semi-permeable membrane with a biological process that filters the wastewater as it passes through the membrane and allows clean water. The wastewater is initially mixed with bacteria leading to the consumption of wastewater. It is a combination of a membrane process like microfiltration with a suspended growth bioreactor. It is widely used in municipal and industrial wastewater treatment. The plant sizes can be designed such that they can treat for around 80000 people. Membranes are submerged in an aerated biological reactor. It may be either attached or separated from a bioreactor. The membrane porosity is around 0.035 microns to 0.4 microns (which is between micro and ultra-filtration).

The process is illustrated in the above figure. The raw wastewater is allowed to the first zone, an anoxic zone through the influent screen. As it is an anoxic zone, denitrification takes place followed which the wastewater is conveyed to the mixed liquor recirculation zone in the bioreactor where sludge is present. The organic matter gets consumed under aerobic conditions as air is blown into the tank by the aeration blower. The mixed liquor recirculation pump, pumps the wastewater after digestion into the membrane module within which the wastewater is pushed through to pass treated water out. A permeate pump creates a vacuum and sucks the water through the membrane as there is no pressure difference created otherwise. So, permeate pump creates negative pressure, which sucks in the water via the filter unit. As this process continues, more sludge starts forming and some amount of it can be used as the return sludge. The entire system becomes a cyclic process. The air scouring blower blows air through the filter such that the pores of the filter remain unclogged. There is no need for sedimentation and the biological process can operate at a much higher mixed liquor concentration.

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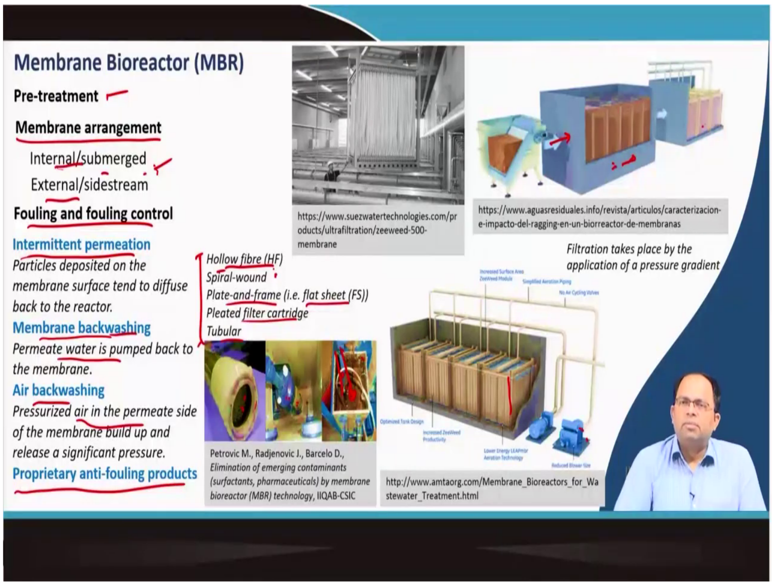

Pre-treatment involving screening and flow equalisation is required as similar to the SBR system.

The membrane arrangement can be either internal/submerged external/side stream

In the previous example (shown in the illustration in the previous slide), an external arrangement is involved where separate chambers were involved for the bioreactor where organic stabilisation happened and the filtration chamber which is the membrane module. Unlike this, the membrane module can be placed in the same chamber itself where the mixed liquor is contained.

The right bottom image in the above figure shows how membranes are arranged. Two pumps are involved. The permeate pump sucks in the water, and the other pump blows in air to unclog the pores of the filter. Fouling refers to the pores getting filled. Unclogging of pores of the filter is known as fouling control. This is achieved in multiple ways.

Intermittent permeation: where particles deposited on the membrane surface tend to diffuse back into the reactor. When water is sucked from the filter, particles deposit on the membrane and as the permeation process stops, it falls back in the mixed liquor.

Membrane backwashing: Permeate water is pumped back to the membrane to clean it. water is pumped back to the membrane.

Air backwashing: Pressurized air in the permeate side of the membrane build-up and release a significant pressure thus cleaning the pores.

Proprietary anti-fouling products: made by several companies, is also used for cleaning up filters.

The filters are of different shapes. Plate filters were shown in the previous examples. Hollow fibre filter can also be employed which encloses multiple filter components within a circular chamber as shown in the figure. This can be inserted inside the reactor to treat high density mixed liquor.

Other ones include the spiral wound systems, plate and frame systems (resembles a flat sheet system), pleated filter cartridge, tubular systems etc.

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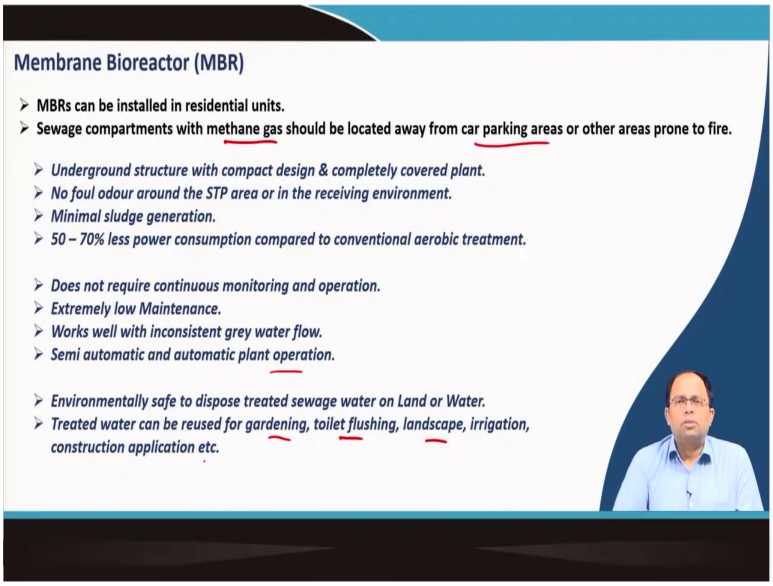

MBRs can be installed in residential units. Sewage compartments with methane gas should be located away from car parking areas or other areas prone to fire.

- Underground structure with compact design & completely covered plant.
- No foul odour around the STP area or in the receiving environment.
- Minimal sludge generation as most of the sludge gets digested.
- 50 – 70% less power consumption compared to conventional aerobic treatment.
- Does not require continuous monitoring and operation.
- Extremely low Maintenance.
- Works well with inconsistent grey water flow.
- Semi-automatic and automatic plant operation; so, remote monitoring is possible.
- Environmentally safe to dispose of treated sewage water on Land or Water.
- Treated water can be reused for gardening, toilet flushing, landscape, irrigation, construction application etc. because of good discharge quality.

Membrane bioreactor – Product study

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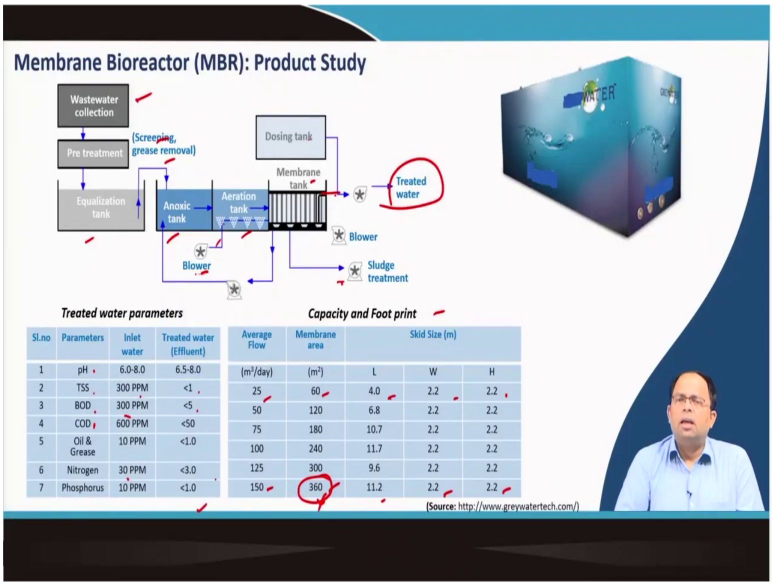

The sequence of treatment is shown in the above figure. The first step involved is wastewater collection. Pre-treatment involving screens, grease removal etc is done in the next step, following which the sewage is contained in the flow equalisation tank. Sewage from the equalization tank is sent to the anoxic tank, aeration tank, and then the membrane tank. Sludge from the membrane tank is collected for treatment and some amount of sludge is recirculated back to the anoxic tank. The blowers involved ensures aeration where required. The treated water is taken out from the membrane tank and collected in the dosing tank where disinfection happens with the action of chlorine and other chemicals.

The parameters including pH, TSS, BOD, COD, oil and grease, Nitrogen, Phosphorous is listed for the inlet wastewater and the treated water. It can be observed that the treated water quality has significantly reduced amounts of TSS, BOD, COD, oil and grease, Nitrogen and Phosphorous and thus becomes fit for most reuse applications.

The membrane area required as per the average flow is given in the table. As large membrane areas are required, it is important to organize such that the surface area of contact is increased. The membranes have to be cleaned and also replaced at certain intervals. These systems form compact units and are very effective in wastewater treatment.

Conclusions

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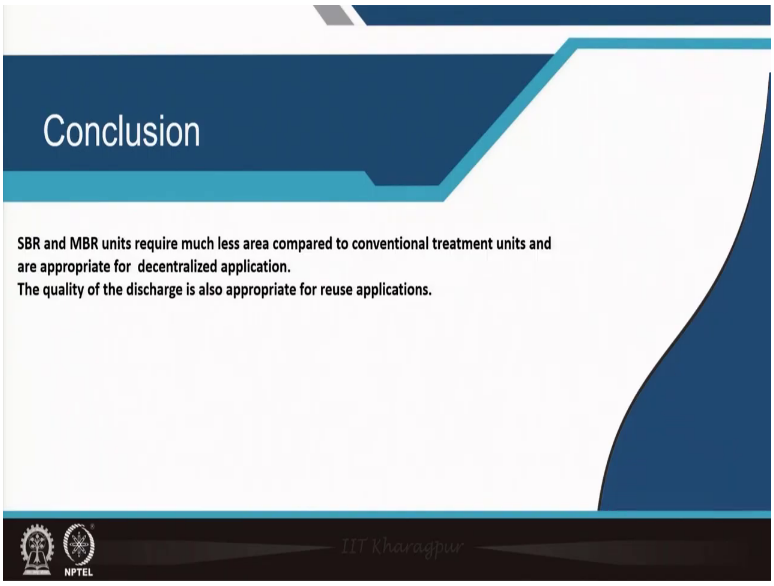

SBR and MBR units require much less area compared to conventional treatment units and are appropriate for decentralized application. The quality of the discharge is also appropriate for reuse applications.

References

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