Urban Utilities Planning: Water Supply, Sanitation and Drainage
Prof. Debapratim Pandit
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Module - 11
Sewage treatment
Lecture - 54
Artificial Sewage Treatment Part II: Secondary Treatment

In lecture 54, Artificial Sewage Treatment - part II will be covered.

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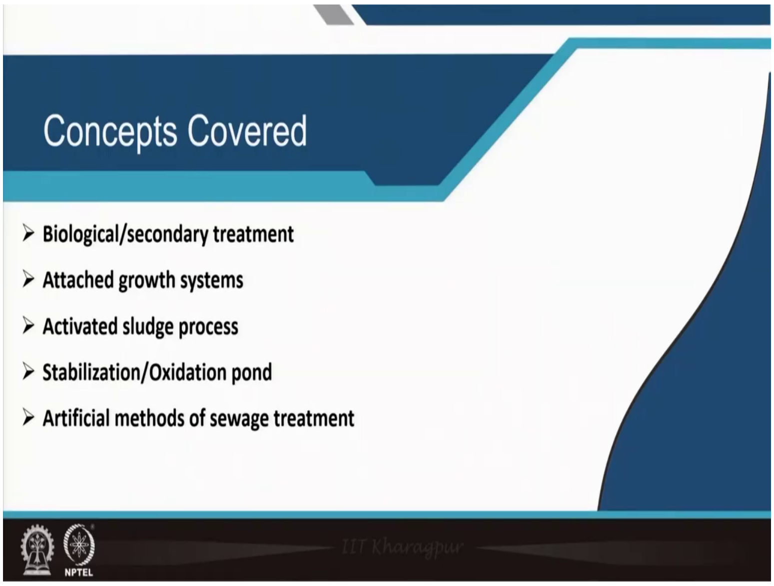

The different concepts that will be covered include:

- Biological or secondary treatment
- Attached growth systems
- Activated sludge process
- Stabilisation and oxidation ponds and finally
- Artificial methods of sewage treatment.

Biological or secondary treatment

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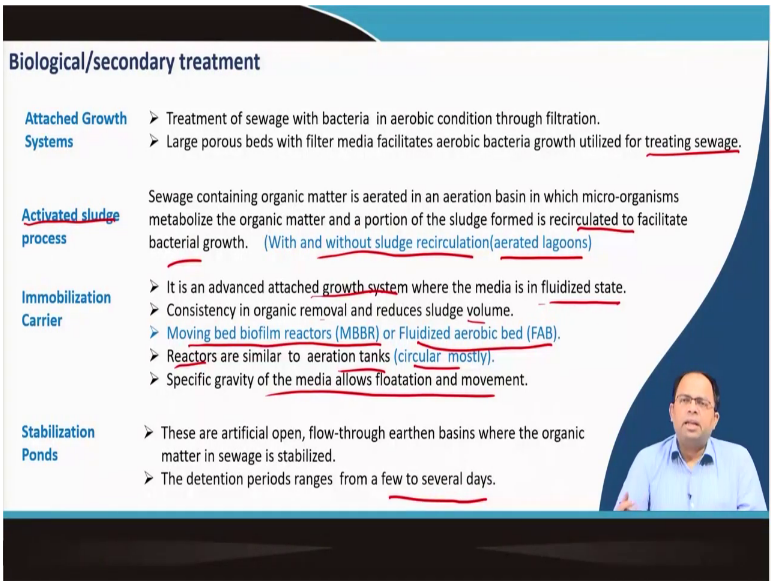

Biological or secondary treatment involves the action of both aerobic and anaerobic microorganisms. There are different types of biological treatment and is broadly categorized into 4 types.

Attached Growth Systems – The sewage gets treated by the action of bacteria in aerobic conditions through the process of filtration. Similar to how the sewage was spread over soil and the solid materials get trapped in the soil pores (as explained in the previous lecture), large porous beds with filter media is involved in this case. The filter media can be sand, brickbats, plastic media etc. Aerobic bacterial growth is facilitated and a film of aerobic bacteria is formed over this media. The bacteria acts upon the sewage as it passes through the media and the sewage gets treated.

Activated sludge process - Here the sewage containing the organic matter gets aerated first by allowing compressed air inside a basin (aeration basin). The aerobic conditions facilitate the growth of microorganisms and help metabolise the organic matter. The organic matter gets stabilized by the microbes and forms flocs (a mix of organic matter and bacteria). This can be reused by introducing some amount of sludge to the influent so that bacterial growth is initiated. Recirculation may be skipped sometimes as in the case of *aerated lagoons* (tanks with aerobic conditions). In general, the activated sludge process refers to systems where some amount of sludge is used to initiate the growth of microorganisms and thus the decomposition process.

Immobilization carriers - are advanced systems where media is in a fluidized state instead of being in a fixed state such as in filter media beds. Here, the filter media is spread all across the volume of sewage and increases the consistency in organic removal thus helping in reducing the sludge volume. The different types include the moving bed biofilm reactors (MBBR) or fluidized aerobic bed (FAB). The reactors/chambers are similar to aeration tanks and the movement involved is mostly circular (air helps in movement). The specific gravity of media (HDP or plastic media) allows for rotation and movement.

Stabilization ponds - are artificial open, flow-through earthen basins where the organic matter in sewage is stabilized. Natural processes are involved and a few to several days are required for detention.

Attached growth systems

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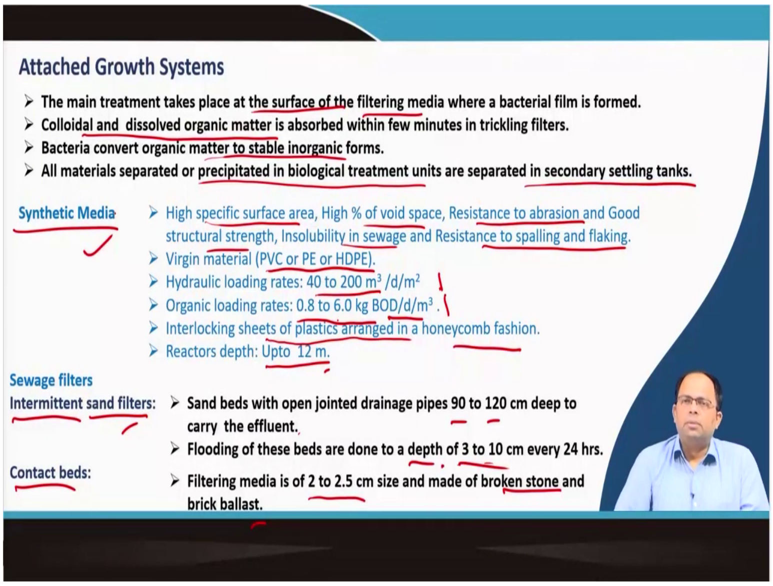

The treatment takes place at the surface of the filtering media where the bacterial film is formed. Colloidal and dissolved organic matter is absorbed within a few minutes in trickling filters. Bacteria convert organic matter into stable inorganic forms. All materials separated or precipitated in biological treatment units (the biological flocs) are separated in secondary settling tanks and this we have discussed earlier.

Synthetic media:

- Synthetic media is used. This has a very high specific surface area (fastens the treatment), a high percentage of the void within that media exists and these are resistant to abrasion and have good structural strength, insolubility in sewage and resistance to spalling and flaking.
- Virgin materials such as PVC, PE or HDPE are used.
- Hydraulic loading rate - around 40 to 200 meter cube per day per meter square; This gives the amount of sewage that can be loaded based on the surface area of the film.
- Organic loading rates - 0.8 to 6 kg of BOD per day per meter cube. (BOD estimation has been addressed in the previous lectures).
- Interlocking sheets of plastic arranged in a honeycomb fashion acts as the surface where the film gets formed
- Reactor/chamber depths – up to 12 meter.

Sewage Filters:

- Instead of synthetic media, *intermittent sand filters* can be employed. This involves sand beds with open jointed drainage pipes 90 cm to 120 cm deep to carry and filter the effluent as it comes down. The organic matter gets acted upon in the pores of the sand and then the effluent gets collected in the under drainage pipes from where it is conveyed to the disinfection tanks. Flooding of these beds is done to a depth of 3 to 10 centimeter every 24 hours.

- Other filter media such as broken stone, brick ballast can also be used. It is known as *contact beds*. Filtering media is of 2 to 2.5 centimetres size.

Sand filters and contact beds are widely in use earlier. Nowadays, synthetic media is mostly used.

Trickling filters:

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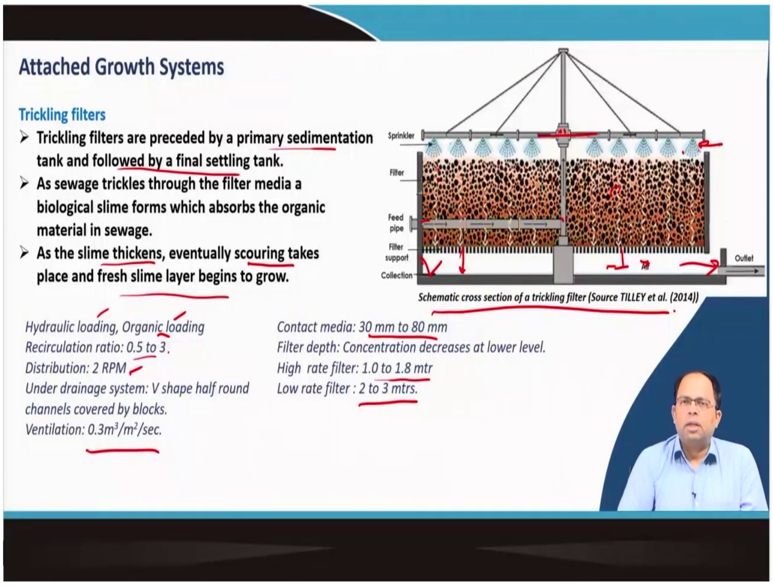

The different components of the system are shown in the above figure. The spraying of sewage by the rotating arm helps in the aeration of sewage; the sewage then goes through the filter media downwards and gets collected at the bottom and the pipe conveys the sewage to the next chamber. Trickling filters are preceded by a primary sedimentation tank and followed by a final settling tank. The effluent that comes out has a significant quantity of scum or biological slime. This slime is formed when bacteria on the filter media absorbs the organic material in sewage. As the slime thickens, scouring occurs eventually and a fresh layer begins to grow. A secondary clarifier is needed to remove these.

Both hydraulic loading and organic loading has to be considered in order to know the rate of wastewater application and the BOD application.

Recirculation ratio - 0.5 to 3 percent

Distribution of this sewage can be done at a rate of 2RPM

Under drainage system V shape half round; It is covered by a large block to prevent the entry of smaller filter media.

Ventilation could - 0.3 $m^3/m^2/s$

Contact media is 30 mm to 80 mm in size

Filter depth - concentration decreases at lower levels; For a high rate filter, depth is given as 1 to 1.8 meters and for a low rate filter, the depth is 2 to 3 meters. More wastewater can be treated in the case of a high rate filter. In the case of a low rate filter, higher depth is given and the movement of water is also slower.

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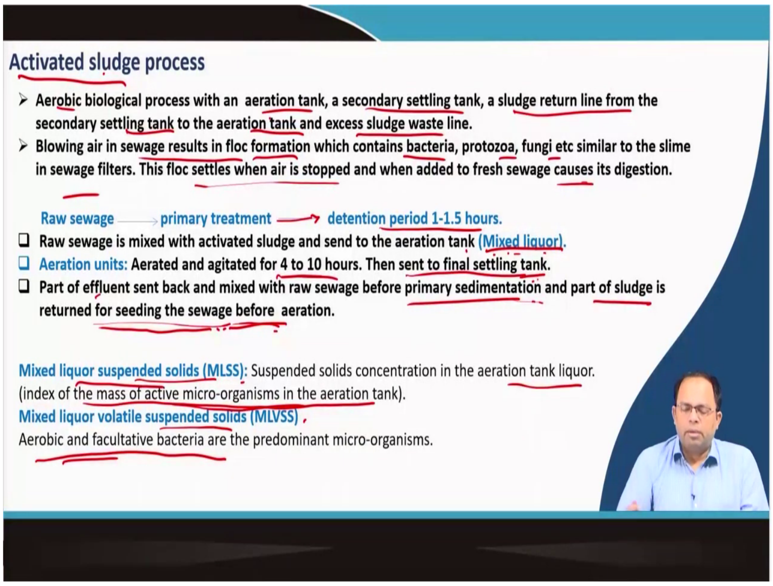

In this process, some amount of sludge is recirculated which activates the decomposition process. The aerobic biological process involves an aeration tank, a secondary settling tank, a sludge return line from the secondary settling tank to the aeration tank and an excess sludge waste line. Blowing of air in the sewage or aeration results in floc formation which contains bacteria, protozoa or fungi. The floc settles when air is stopped. The BOD gets removed and the floc that is formed is separated via a secondary settling tank and is conveyed to the sludge digestion tank. Some part of the sludge is sent back to the initial aeration tank to initiate the digestion process in the fresh sewage.

Raw sewage after primary treatment is mixed with the activated sludge and detained for 1 to 1.5 hours. The raw sewage after being mixed with the activated sludge is called *Mixed liquor*.

In the aeration tanks, the sewage is aerated and agitated for almost 4 to 10 hours. This time also depends on the shape of the tank.

Part of the effluent/sludge is sent back and mixed with raw sewage before primary sedimentation and part of the sludge is returned for seeding to the sewage before aeration.

Mixed liquor suspended solids (MLSS) – refers to the suspended solid concentration in the aeration tank liquor. This gives this index of the mass of active microorganisms in the aeration tank.

Mixed liquor volatile suspended solids (MLVSS) – indicates the amount of aerobic and facultative bacteria present which are the predominant microorganisms.

These are used to determine the quantity of bacteria that is required for the stabilization of this organic matter.

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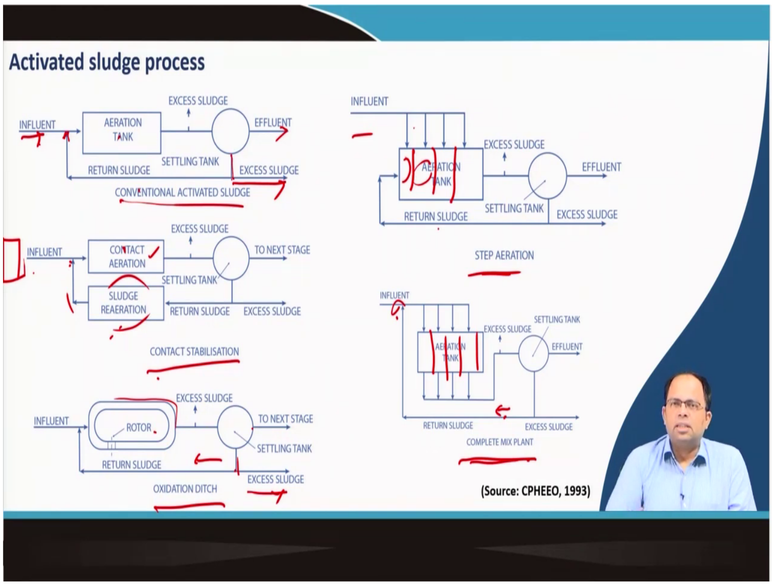

<u>Conventional activated sludge</u>

The influent reaches the aeration tank from where it is conveyed to the settling tank from where the effluent and the excess sludge is removed. Some part of the sludge is recirculated back to the effluent inlet.

<u>Contact stabilization</u>

The primary sedimentation stage is not required in this process. This process is similar to the previous one. However, the return sludge which gets added to the influent is reaerated. This causes the further stabilization of the organic matter thereby reducing the quantity of sludge. The suspended matter and organic matter gets deposited in form of sludge in the secondary sedimentation tank.

Oxidation ditch

Here, the sewage is contained in an earthen basin (oxidation tank) where it gets mixed with the air in the atmosphere. Aerobic bacteria act upon the upper surface of the sewage, and the anaerobic bacteria act upon the bottom volume. So, instead of employing mechanical aeration, aeration happens naturally. The excess sludge from the settling tank is taken to the influent; Some amount of sludge is taken to the landfill site.

Step aeration

Here, the influent flow through multiple channels to the aeration tanks. Return sludge is allowed inside the aeration tank on one end. At that end, the mixing volume is higher and in the next channel, the mixing volume is lesser and so on. Here, the entire flow can be considered as multiple channels and the mixing happens more effectively.

Complete plant mix

Here, both the influent as well as the return sludge is channelled in separate (multiple) channels. Similar to the previous systems, some amount of sludge is sent back to the influent. More mixing happens in such systems.

Stabilization / Oxidation tanks

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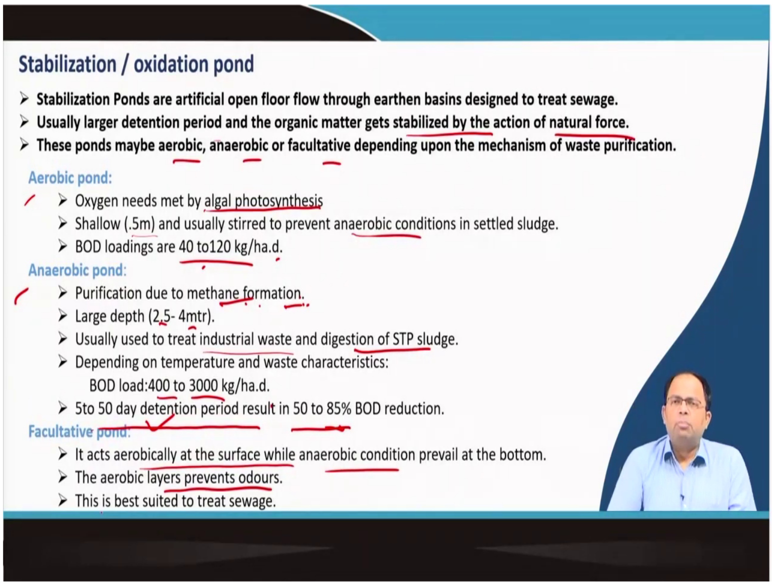

- These are artificial open flow through earthen basins and they are designed to treat sewage
- Usually, the detention period is larger and organic matters get stabilized by natural forces, not by mechanical aeration, but very natural you know aeration you can say.
- These points could be both aerobic, anaerobic and facultative depending on the mechanism of water purification.

Aerobic ponds

- Oxygen needs met by algal photosynthesis
- Shallow (.5m) and usually stirred to prevent anaerobic conditions in settled sludge.
- BOD loadings are 40 to120 kg/ha.d.

Anaerobic ponds

- Purification due to methane formation (and CO_2 because of the action of anaerobic bacteria – creates bad odour)
- Large depth (2.5 - 4mtr).
- Usually used to treat industrial waste and digestion of STP sludge.
- Depending on temperature and waste characteristics:

- BOD load: 400 to 3000 kg/ha.d.
- 5to 50 day detention period result in 50 to 85% BOD reduction.

The effectiveness in terms of BOD removal may get improved if the above two systems are combined as in case of the Facultative pond

Facultative ponds

It acts aerobically at the surface while anaerobic conditions prevail at the bottom. Gases such as CH_4, CO_2 is H_2S and CO_2 are formed and plants, algae etc consume the CO_2 and release oxygen which further helps in photosynthesis and thus the aerobic stabilization.

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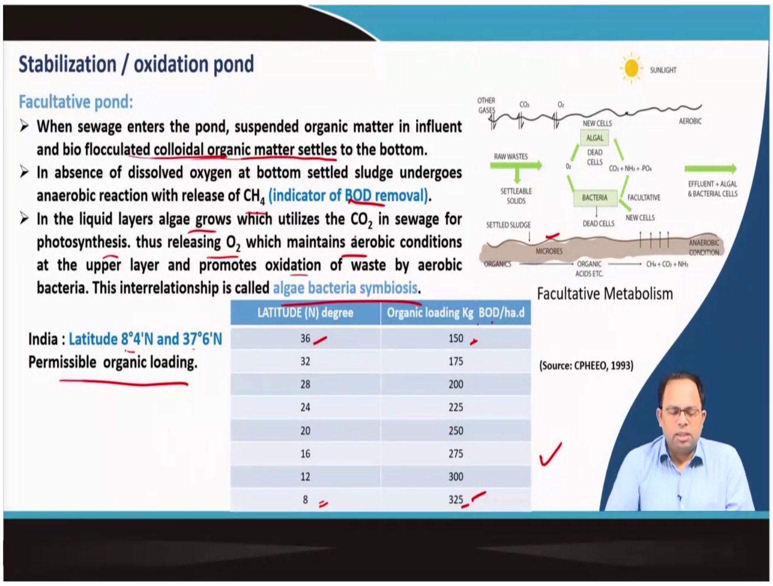

The sewage enters the pond, suspended organic matter in the influent and bio flocculated colloidal organic matter settles to the bottom.

In the absence of dissolved oxygen at the bottom, anaerobic reactions take place and CH_4 is released indicating BOD removal

In the upper layers of the liquid (sewage), algae grow which utilizes the CO_2 for photosynthesis and releases O_2 which maintains aerobic conditions in the upper layers and promotes oxidation of waste by aerobic bacteria. This interrelationship is known as algae bacteria symbiosis. (refer to the illustration given in the above figure)

Temperature, sunlight etc. plays a big role in self-purification processes. The permissible organic loading is higher for locations receiving more sunlight as in the case of India (8.4° North to 37.6° North) than the colder countries at higher latitudes.

The corresponding organic loading is given in the table for different latitudes has been listed. This helps in understanding the organic loading which can be handled in stabilization ponds.

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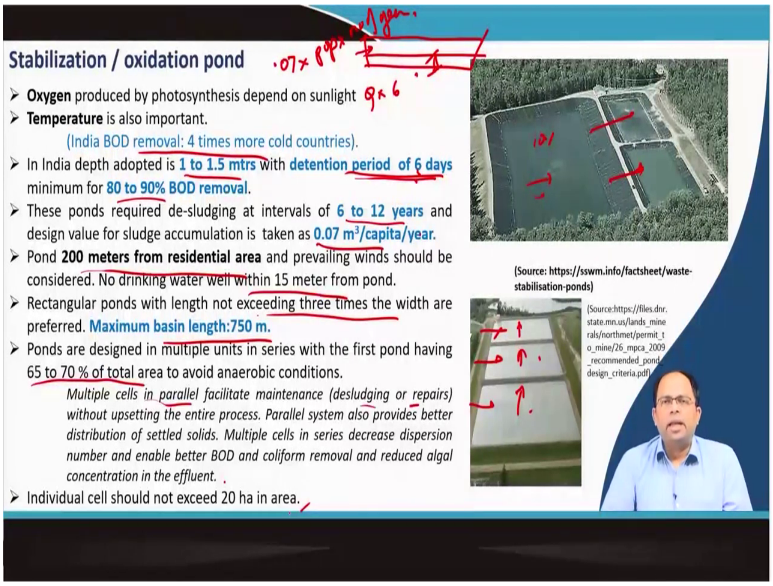

- Oxygen produced by photosynthesis depend on sunlight
- Temperature is also important. (India BOD removal: 4 times more cold countries).
- In India, the depth adopted is 1 to 1.5 mtrs (in between aerobic and anaerobic ponds) with a detention period of 6 days minimum for 80 to 90% BOD removal. The design should consider the volume of incoming sewage for 6 days.
- These ponds require de-sludging at intervals of 6 to 12 years and the design value for sludge accumulation is taken as 0.07 m^3/capita/year. Waste generation as per the population, no. of years, and the sludge accumulation rate can be considered to calculate the volume of sludge that gets stored (lower part of the tank). Thus, both the

volume of incoming sludge based on the detention period and the total sludge that gets stored can be added to determine the volume of the tank.

- Pond, 200 meters from the residential area and prevailing winds should be considered. No drinking water well within 15 meters from the pond.
- Rectangular ponds with lengths not exceeding three times the width are preferred. Maximum basin length: 750 m.
- Ponds are designed in multiple units in series (can be designed otherwise as well) with the first pond having 65 to 70 % of the total area to avoid anaerobic conditions.
- Multiple cells in parallel facilitate maintenance (desludging or repairs) without upsetting the entire process. The parallel system also provides better distribution of settled solids.
- Multiple cells in series decrease dispersion number and enable better BOD and coliform removal and reduced algal concentration in the effluent.
- The individual cell should not exceed 20 ha in area.

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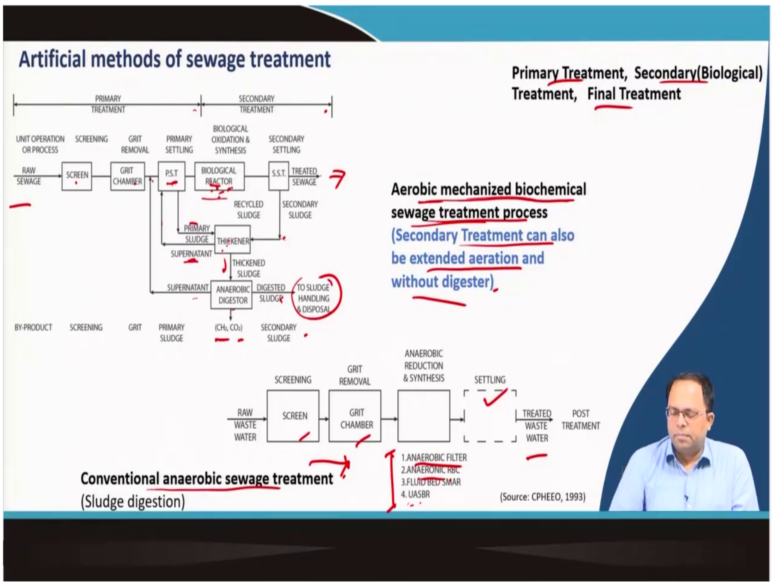

The different treatment units (primary treatment, secondary or biological treatment, final treatment) can be arranged in various ways to effectively treat the sewage for a particular area. The top image given in the above figure shows the processes coming under the primary and secondary treatment. Allowing more aeration will reduce the quantity of sludge produced and the need for digestion.

The different arrangements are determined based on various factors including the type of sewage

Arrangement 1(refer to top image): Involves the Raw sewage inlet, Screen, Grit chamber for grit removal, primary settling tank (PST), biological reactor where biological oxidation and synthesis happens (Could be an aerobic mechanical system), a secondary settling tank (SST) from where the treated waste goes out (It can be either disposed off or reused), thickener which thickens the primary sludge from PST and secondary sludge from SST. The supernatant (clear liquid part) is conveyed back to the PST, and an anaerobic digester to digest the thickened sludge (CH_2 and CO_2 gas is produced as a result of digestion). The digested sludge is taken to the sludge handling unit or is disposed off. This is an example of an attached growth system. An aerobic mechanical biochemical sewage treatment process can also be employed instead where return sludge is involved and conveyed to the aeration tank.

Arrangement 2 (refer to bottom image) - A conventional aerobic sewage treatment is involved. It consists of *screen, grit removal, anaerobic reduction and synthesis* (eliminating the primary sedimentation tank) achieved with an anaerobic filter or anaerobic RBC or fluid bed SMAR or UASBR which is an up-flow sequential batch reactor, and the *settling process* where the suspended solids and the excess deposited sludge from the organic matter gets separated. Here, only biological treatment is involved.

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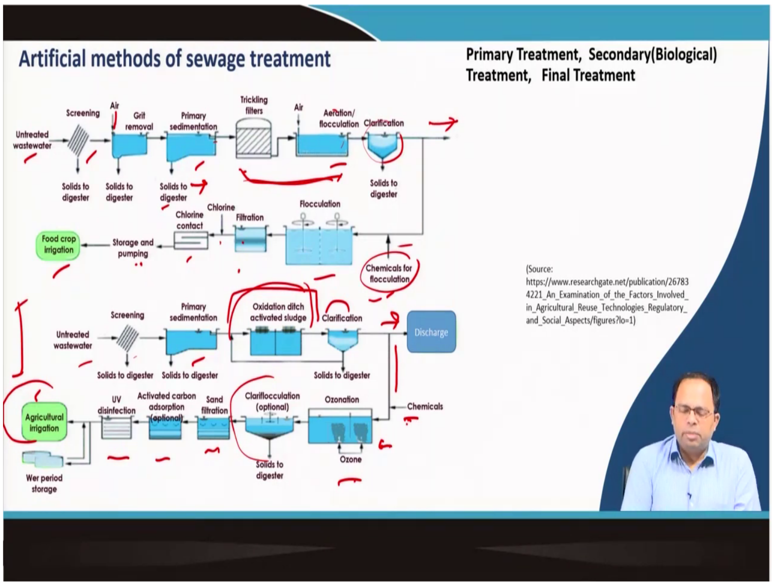

The next two arrangements correspond to the reuse of treated wastewater for food crop irrigation

<u>*Arrangement 3*</u> – This involves screening to remove the solids, grit removal which involves aeration, primary sedimentation (solids deposited is conveyed to the digester), trickling filter, aeration/flocculation, secondary clarification where solids are deposited (some part of the partially treated sewage is discharged), flocculation using chemicals/chemical coagulation, filtration, disinfection with chlorine, and lastly storage and pumping for irrigation use.

Arrangement 4 – This involves screening to remove the solids, primary sedimentation, oxidation ditch activated sludge process (instead of employing trickling filter or other artificial biological treatment options), clarification, after which some amount of water is discharged, ozonation involving the disinfection of the water to be reused using ozone, clariflocculation, sand filtration, activated carbon absorption and UV disinfection. Following the process, the water can be reused for agricultural irrigation.

Conclusion

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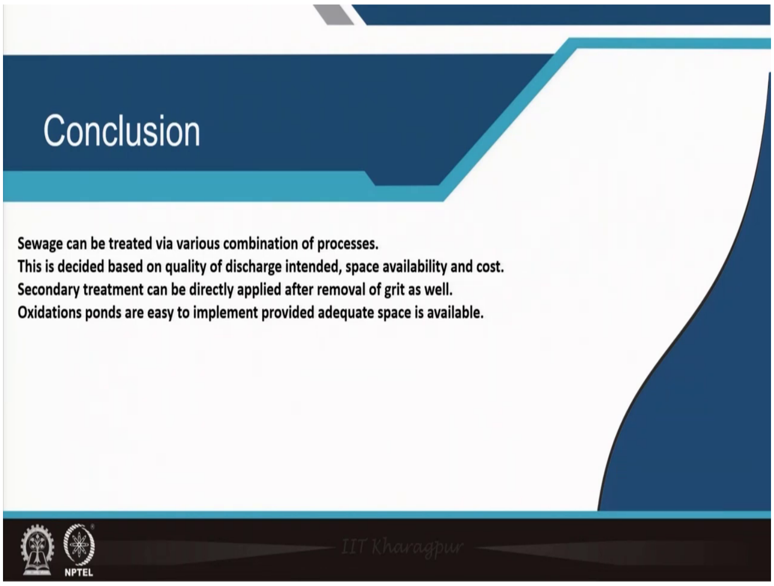

- Sewage can be treated via various combinations of processes.
- This is decided based on the quality of discharge intended, space availability and cost
- Secondary treatment can be directly applied after removal of grit as well
- Oxidation ponds are easy to implement provided adequate space is available.

References

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