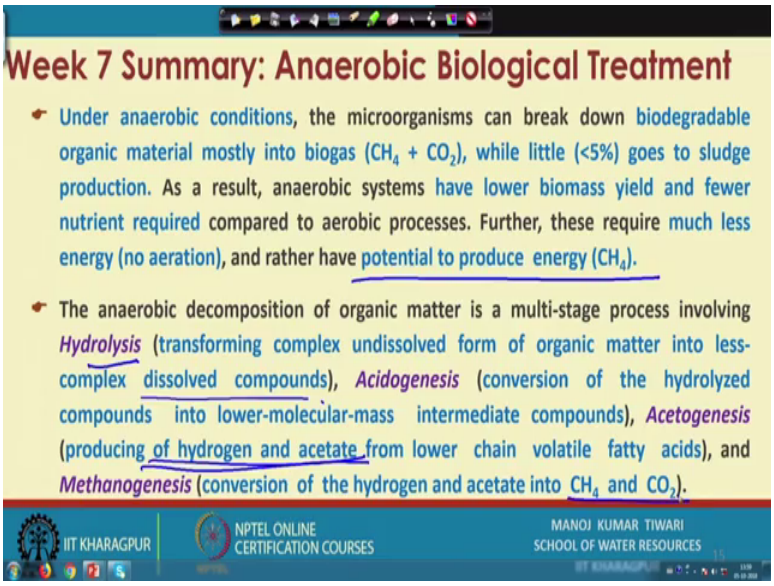
Wastewater Treatment and Recycling
Prof. Manoj Kumar Tiwari
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 62
Course Summary (Contd.)

Welcome back friends. So, you have been discussing the summary of the discussions that we had in this course Wastewater Treatment and Recycling. In the last class, we discussed the summary of the first half of the course from week 1 to week 6 and in this last class we are going to talk about the discussions, we are going to summarize the discussions that we had from week 7 to week 12.

(Refer Slide Time: 00:45)



So, the in the week 7, we did talk about the anaerobic biological treatment. So, week 6 we discussed about the aerobic systems in the activated sludge process rotating biological contactor, and treating of filter those kind of stuff. In the week 7 we discuss the other type of biological treatment which takes place in anaerobic conditions.

Now, anaerobic conditions the microorganisms can break down the organic matter particularly, the biodegradable organic matter into biogas, which is the methane and carbon dioxide of which mostly it is like close to 60 to 70 percent depend although it depends on the characteristic of the waste, but often with the domestic sewage we get 60 to 70 percent of the methane of the total biogas. Only little amount less than 5 percent goes to the sludge production.

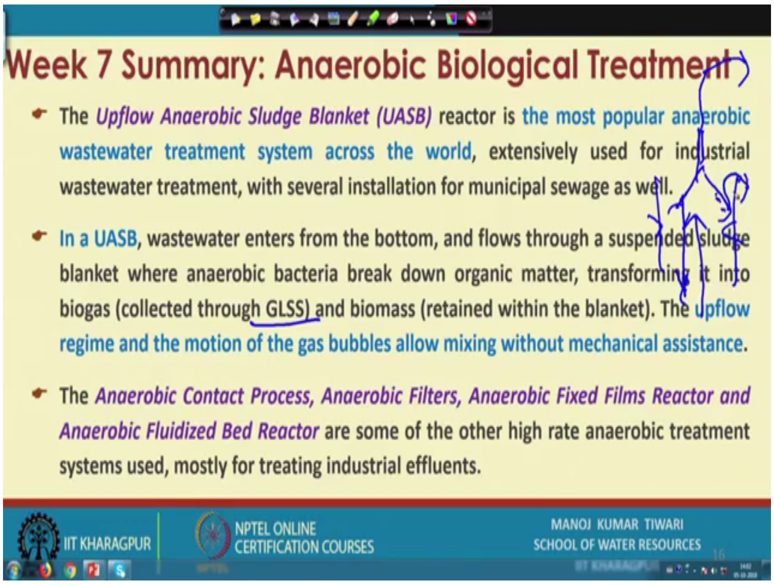
So, as a result the anaerobic system have lower biomass yield ok. Because the sludge production is low and when this sludge production is low; the biomass growth is low. So obviously, the nutrient requirement is also low. So, many times if there are, like for aerobic system we had to supply additional nutrients, if there is a nutrient deficient wastewater, but in anaerobic system we do not need to do that because the nutrient requirement itself is low. On the other hand, we cannot get nutrient removal also, because nutrient requirement is not there; in some specifications we do. So, we had the discussions further in the week later weeks.

So, then further this requires much less energy, because we do not need aeration; it is a anaerobic system. So, there is no aeration no requirement of energy for the aeration purpose and the most advantageous part is that, we can actually produce energy. It has potential to produce energy in the form of methane. This anaerobic decomposition of organic matter is a multistage process. So, there are four stages: the first is the hydrolysis where the complex or undissolved form of organic matter is solubilized ok.

So that are converted to the less complex dissolve compounds, then comes the acidogenesis; where conversion of hydrolyzed compound into the lower molecular mass intermediate compounds various like: volatiles various volatile fatty acids are those kind of a product are formed in here.

Then the Acidogenesis, Acetogenesis which actually uses these lower chain volatile fatty acids, and finally, produces hydrogen, and acetate out of this, and the last one is the Methanogenesis which converts these acetate, and at times even hydrogen into the methane, and carbon dioxide. So, once it converts the acetate it is called acetoclastic methanogenesis, or when it converts the hydrogen into methane it is called hydrogenotrophic methanogenesis. So, that is what happens in the anaerobic processes.

(Refer Slide Time: 03:43)



Then the most common or most popular reactor configuration for this anaerobic wastewater treatment is UASB which is Upflow Anaerobic Sludge Blanket Reactor. So, this have a single tank system where the water is pumped from the bottom; it is up flow system water is pumped from the bottom, and flows through a suspended sludge blanket.

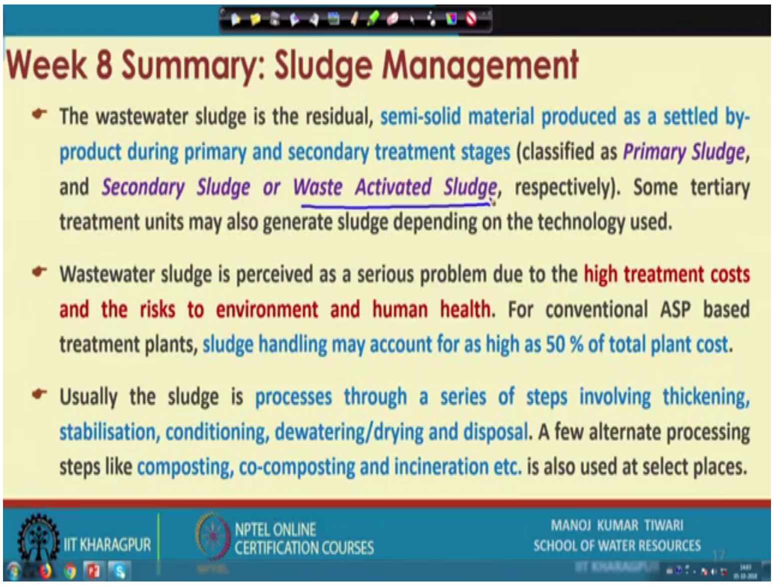
Now, the anaerobic bacteria which remains in the sludge blanket are responsible for breaking down the organic matter, and in the process they are kind of transform it into the biogas. Now this biogas is produced in this sludge bed, but since gas is a tendency to move up; so, it actually moves up, and then after this sludge blanket where were settling zone. So, because some such mass, or some biological organisms also will come along with the gas particles, or the water is flowing up.

So, this up flow regime actually is responsible for the kind of ensuring the motion of the like ensuring if the mixing in the sludge bed itself. So, there is a gas motion there is a upflow regime of the water movement. So, this ensures that enough amount of mixing is there, and we do not need any mechanical mixer in the system, but due to this mixing when the gas moves up are the water moves up there are some biomass also moves up, and then we provide a settling zone where this biomass get settled, and on the top of that there is a GLSS; which is gas liquid solid separator; which is responsible for the separation of all these elements.

So, GLSS essentially, or the gas liquid solid separator is a funnel kind of thing. So, it is if your let us say this is your reactor. So, there is a deflector provided over here, then when water moves up the gas will actually find a path and will be collected from this point on onwards the sludge particles solid particles that is try this the surface of the GLSS will be post back for settling, and water flows in the outflow here.

So, it can separate the gas liquid and solids, and that is why it is called GLSS gas liquid solid separator. There are various other anaerobic systems: anaerobic contact process, anaerobic filters fixed film reactors, and the fluidized bed reactors are some of the other high rate anaerobic treatment systems; which are used, but they are mostly used in the industries ok.

(Refer Slide Time: 06:25)



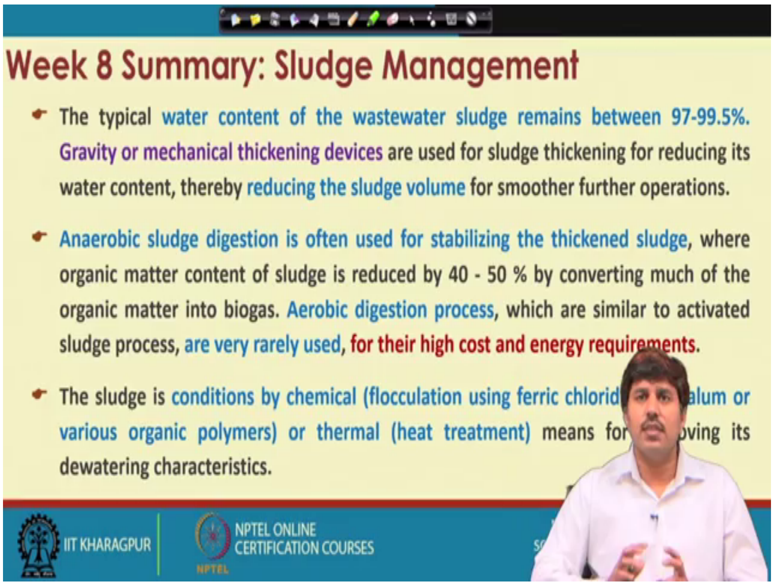
In the domestic effluent the very little application is there. Then we move to the week 8; where we discussed about the sludge management. So, when the wastewater treatment starts we discussed about the primary sedimentation. Now the part case that are settling in the primary sedimentation; they are collected as a primary sludge ok. Then we discussed about the particularly, in the aerobic system the activated sludge process; which is the most common biological treatment units.

So, in activated sludge process, the secondary settling bases, secondary settling tank, which receives water from aeration tanks and let the biomass settle over there. Some part is recycle, but a large part is wastage also. So, the amount of sludge which is being wasted or which is being generated in the second is settling level is called secondary sludge, or we also called that as a waste activated sludge because that is the sludge; which is kind of being wastage from activated sludge process.

So, that way we generate these different types or different categories of sludge some tertiary treatment units may also generate it is sludge depending on the technology used. Then the grid system also generate some grid materials which is a kind of sludge, but that is process separately that usually goes to the landfill because these are essentially the inorganic stuff with very high specific gravity, where as the secondary sludge or primary sludge has lot of organic carbon in this, lot of organic mass in this. So, around up to 60 to 70 percent of these sludge are actually the organic. So, waste water sludge is perceived as a serious problem due to its high treatment cost, and the risk to the environment, and human health. The conventional activated sludge process; have a kind of the 50 percent of the total cost of the plant is attributed towards the sludge handling only.

So, that is what is the importance of sludge handling. Usually the sludge is process through a series of steps which involved thickening, stabilization, conditioning, dewatering, or drying, and then disposal. There are few alternate process like composting co-composting, or incineration for energy production is also kind of being used at few select places. So, that is the status of that way sludge.

(Refer Slide Time: 08:52)



Now, if we see the typical water content of the waste water sludge usually remains between 97 to 99.5 percent. So, that means, there is very little solid content, and may be for 1 k g of solid if your water content is say 99 percent. So, for 1 k g of solid we get a total mass of 100 k g because 99 percent is water just 1 percent is solid. So, instead of for handling just 1 percent solid, we have to process the 1 k g of solid we have to process the total 100 k g of this sludge mass because 99 k g is water similarly that way.

So, this makes it very difficult to processing, and that is why the first unit which is used is the thickening sludge thickening. So, the gravity thickener, or mechanical thickening devices like: centrifuge, or various like a filter beds are used for thickening purpose. Mostly the gravity thickeners are more popular.

So, this is what is used where water contents of the sludge is reduced, and that is how we are able to reduce the sludge volume. We can reduce sludge volume as just to like around 90 percent also. So, if you are let us say just increasing the water content from say 1 percent to 4 percent; we are actually getting significant decrease in the volume; even from this shift.

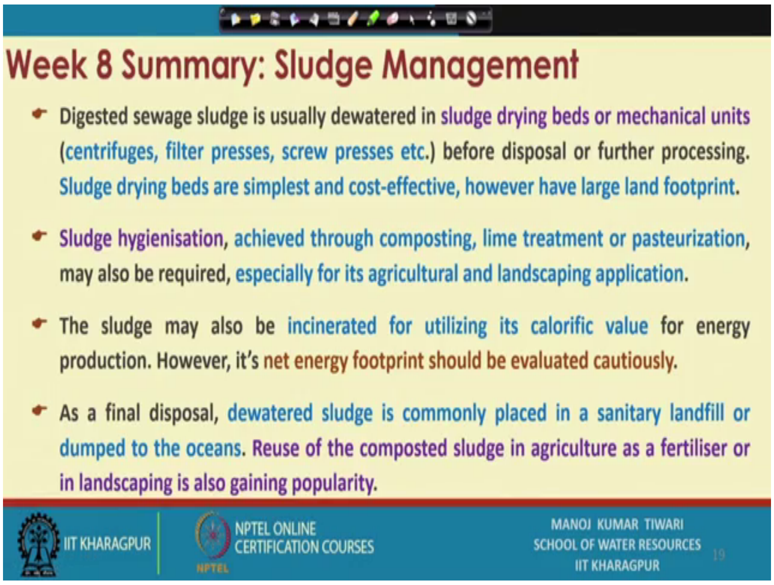
So, the anaerobic digestion is the next process which is used for the stabilizing the thickened sludge. So, once we have done with the sludge thickening; then we go for the digestion process all we call that sludge stabilization process, and for this purpose anaerobic or aerobic digestion process could be used.

Anaerobic digestion process are more common here because of high energy needs, and high treatment cost with the aerobic digestion process which is similar to activated sludge process, and we need to kind of give a large retention time. So, aerating that thickening amount of sludge oxygen transfer also becomes very difficult, and doing that for a large number of days is very difficult very costly.

So, that is why anaerobic digestion is for more popular. The anaerobic digestion actually uses the concept of anaerobic decomposition as we discussed in the week 7. So, and we get: so, all those processes like the hydrolysis, acetogenesis, and methanogenesis will take place, and eventually the 40 to 50 percent of the organic content of sludge is reduced to biogas. So, it gives a potential for producing biogas also, and that way making the process self sustainable.

The next step is usually conditioning which is optional; many like for better dewatering characteristics sludge is condition, and disconditioning can be done in the through by adding chemicals. So, flocculent using ferric chloride, or alum on various organic polymers are used, or the thermal or heat treatment is used, but the heat treatment is far more costly, and the other way we have to have a higher chemical footprints. So, we have to make a choice that which one is the better option for conditioning; that is done for improving the dewater ability of the sludge.

(Refer Slide Time: 12:24)



Then this digested sludge is usually dewatered in sludge drying beds, or mechanical units. So, like centrifuge, filter press, screw presses are there, which are used for the sludge dewatering, but the most popular, or most common is this sludge drying beds which is most simple also. So, here the sludge is laid on a drying bed, and we have under drainage systems.

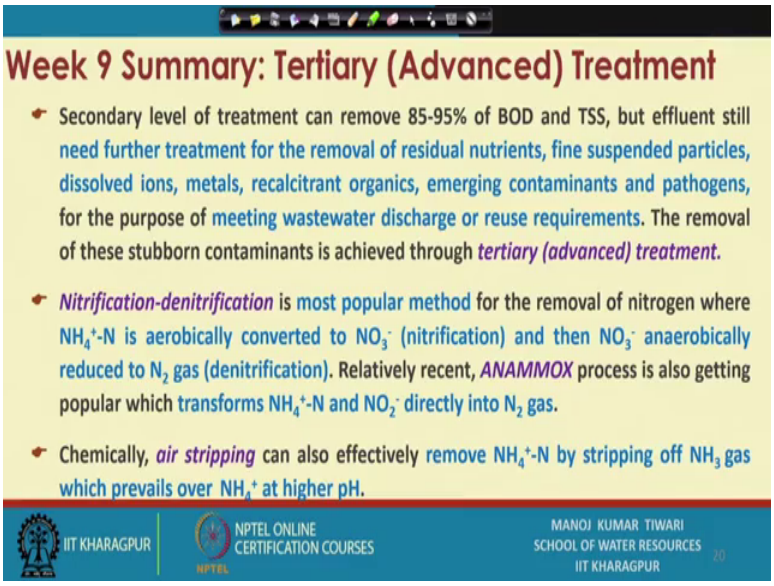
So, the evaporation takes off some water, and the percolation through that sludge bed, or the kind of percolation of water, and collecting it through under in a system is the other mechanism which to works simultaneously. The major removal is through the operation, and because that works for a larger period of time; however, there is a large land for print of the sludge drying bed. So, that is how that is what is the like a problem.

Particularly, when you have to put systems through a with in a limited area in a dense with densed population cities where the area getting a large area is a big issue. So, one can actually go for the mechanical units for the sludge dewatering.

Then the sludge hygienisation which is achieved through composting line treatment, or pasteurization could also be used. Especially for its agricultural and landscaping applications the sludge could be (Refer Time: 13:58) for utilizing its calorific value for energy productions; however, we have to cautiously evaluate the net energy footprint of the sludge because for the purpose of incineration we have to supply also lot of energy, and what net energy gains are there that needs to be properly estimated beforehand.

As a final disposal the dewatered sludge can be placed in sanitary landfills, or can be dumped into the oceans. Reuse options are also coming up. So, reuse of the composted sludge in agriculture, or fertilizers, or in landscaping is also gaining popularity; at few places it is being reused as a building materials as well.

(Refer Slide Time: 14:33)



Then week 9 we discussed about the advanced or tertiary treatment options. So, the second levels of treatments are effective in removal of the BOD and TSS to adequate degree. So, around 85 to 95 percent of BOD and TSS removal could be achieved, but this is still not sufficient if you want to use the water for reuse purpose, or the, we even we want to meet the discharge norms. So for the purpose of meeting discharge norms, or reused requirements; we may need to further process the water which is done usually through the tertiary, or advanced treatment options.

These targets the removal of residual nutrients, the fine suspended particles, the dissolved ions metals recalcitrant, or non biodegradable organic matters, then emerging contaminants, pathogens those are kind of things which are targeted for removal in the advanced stage of treatment. For removal of nutrients we have the biological as well as chemical processes the biological process for nitrogen removal includes nitrification denitrification which is the most popular method where the kind of, through a process sequential aerobic anaerobic process the nitrogen is removed.

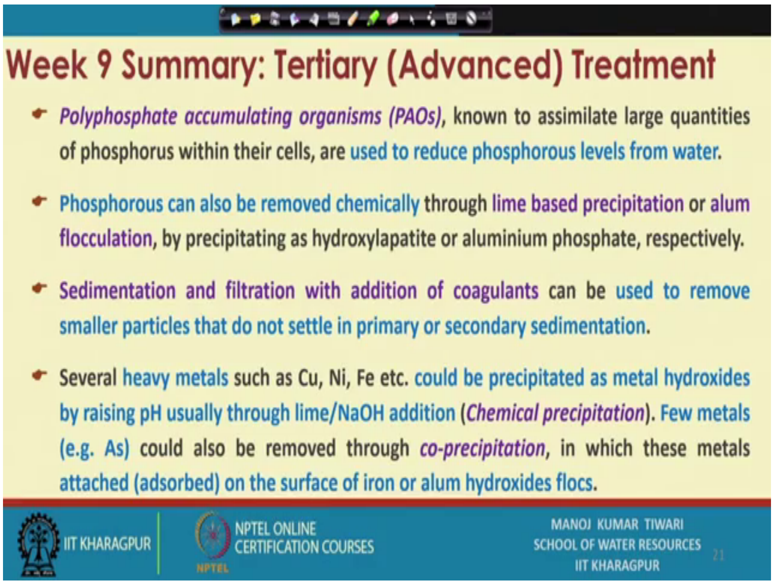
So, first step is the aerobic, where the nitrate where the ammonical nitrogen is converted into the nitrate which is called nitrification and nitrite is the intermediate step here, and then the nitrate is anaerobically reduced to nitrogen gas which is called denitrification, and which takes place in an anaerobic environment.

Relatively, recent technology in the form of anammox has also being developed and is getting more popular; the advantage with the anammox that it transfers the ammonia and nitrite directly into the nitrogen gas. So, the requirement of say aerobic system with aeration for converting ammonia and nitride to the level of nitrate is removed.

So, just with the partial oxidation we can maybe convert ammonia to nitrate, or ammonia itself, and then we can directly convert that into the nitrogen gas in anaerobic system. So, anammox is also done in anaerobic system: there are chemical ways in which the air stripping can be used or this is also called ammonia stripping.

So, it effectively removes some ammonical nitrogen by stripping off. So, what happens when the pH of the system is raised we can add lime, or those kind of thing for raising the pH. So, pH of system is raised. So, ammonical nitrogen converts into the gaseous ammonia phase, and then the gaseous ammonia phase could be stripped off just by simple aeration, or air stripping.

(Refer Slide Time: 17:25)



So, that is what is the chemical approach. For the removal of phosphorus there are biological techniques which kind of take the advantage of certain species which are called polyphosphate accumulating organisms, or PAOs. So, they assimilate large quantities up to 20 percent of the phosphorus within their cells, and. So, this kind of organism could be used for phosphorus uptake from the water.

Then phosphorus can also be removed chemically through lime based precipitation, or alum flocculation where the phosphorus is converts to hydroxyl apatite, or along phosphate respectively, and gets precipitated. There are sedimentation added with filtration in the presence of certain coagulants; so, can be used for the removal of various small particles which they do not settle in the primary or secondary sedimentation.

So, there are very small particles are colloidal particles we can coagulant them using standard iron, or alum coagulants, and then make them settle in a sedimentation basin, or filtration basin are the combination of both. There are various heavy metals which could also be precipitated as metal hydroxide by just raising pH.

So, the, at higher pH the solubility of these metal hydroxide is very low. So, many of these metal hydroxide like: iron nickel copper those kind of metal hydroxides when we increase the pH through adding line or whenever solution they get precipitated, which is called chemical precipitation.

There are certain matters, for example, arsenic they could be removed through coprecipitate. So, for these, what happens that we can have we can add alum, or iron coagulants, and when there hydroxide flocks is formed. So, the arsenic, or these kind of things make get adsorbed on to the surface of these metals. So, and these flocks of a alum, or hy alum, or iron hydroxide flocks. So, since they get adsorb on to the surface of these flocks and the flock settle. So, these metals also settle also precipitate along with this flocks and that is why it is called co precipitation.

(Refer Slide Time: 19:32)

Then, there are adsorption which is a mass transfer process which involves the accumulation of pollutant at the surface of the adsorbent. Mostly activated carbon either powdered activated carbon, or granular activated carbon is used in the wastewater treatment, but it is more common for industrial scale. So, adsorption process is able to remove the various micropollutants, nondegradable organics, and some metal from the wastewater. We also discuss the ion exchange process which could remove the dissolved ionic impurities and hardness.

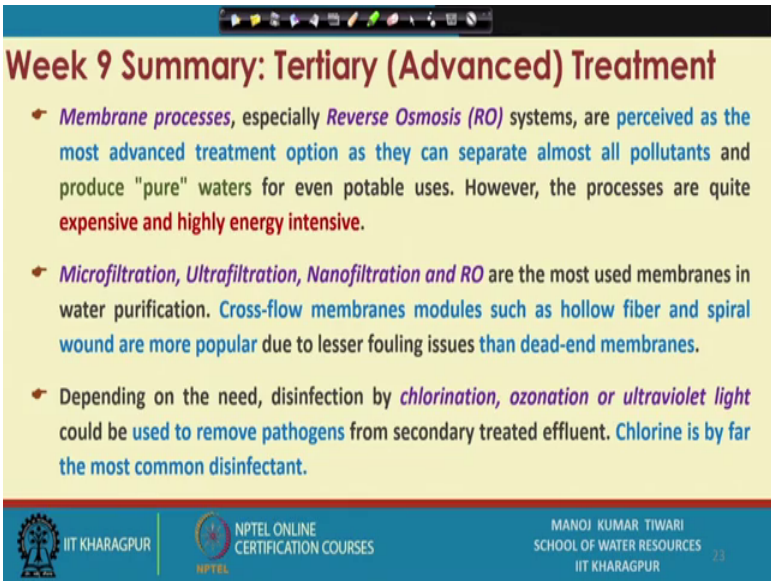
So, how and exchange works: it basically the target contaminant ion is swapped with another ion which is non-objectionable, or much lesser objectionable, but of similar charge. So, there are ion exchange resins which has a polymer backbone and there is a functional group attached along with the ion is attached when it is watery exposed to that.

So, the contaminated ion in water comes attached to the functional group, and the pre-attached ion less toxic or less contaminant ion is released back into the water. So, that is what is, ion exchange process both of them have certain limitation in the form of the both ion exchange; and adsorption in the form of like their capacity can get exhausted. So, they need to be regenerated and then how many cycles we are going to regenerate all those things are there, and then there are issues with the sort of interfering ions.

So, interfering ions are interfering agents are there. So, if there are such things which preferentially get absorbed over the target ion. So, then the efficiency will be decreasing of the systems. Then there are advanced oxidation process which are normally called AOPs which targets oxidation through the highly reactive OH radicals; they used to treat the wastewater having recalcitrant organic ok, and they can actually be used to either treat water either to complete mineralization level, but that is quite expensive because we have to ensure the full level complete oxidation of the compounds, and for that level of OH radical production and supply has to be ensured, or we can use this as a pretreatment because these processes are known to increase the biodegradability enhance the biodegradability. So, if there are recalcitrant organic compounds; they can sort of break them down to biodegradable compounds and from there onwards the standard biological process will take care of that.

So, that way this process could be used as a pretreatment as well.

(Refer Slide Time: 22:10)

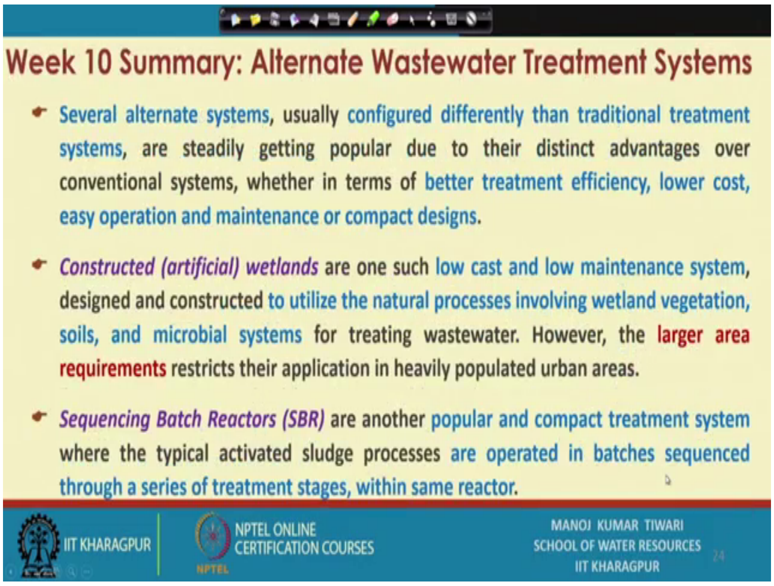


Then there are membrane processes with like: there are microfiltration, ultra filtration, nano filtration, reverse osmosis those kind of membrane process which are most popular membrane systems for water purification. So, these are perceived, particularly the RO systems are perceived as the most advanced treatment options which can separate almost all pollutants ok, and produced pure water even for the potable uses; however, the process are quite expensive and highly energy intensive.

There are cross flow membrane modules like hollow fiber and spiral wound; so these are more popular then the dead end membrane modules because they have lesser fouling issues which are one of the most critical maintenance aspect of the membrane system.

Then depending on the need we can go for disinfection or if the requirement is for disinfection we can go for chlorination, ozonation, or UV light based disinfection which removes the pathogens.

(Refer Slide Time: 23:13)

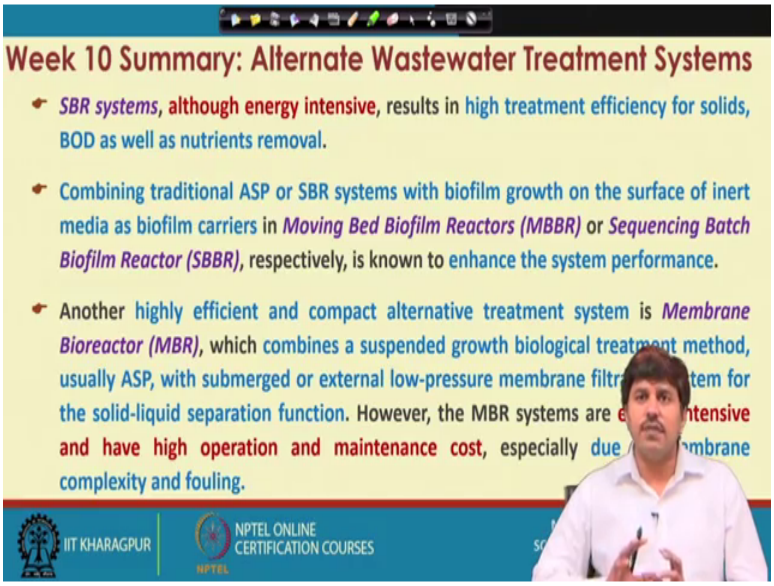


Then the week 10 we discussed the alternate wastewater treatment system. So, several systems configure differently than the traditional systems could be also be used, and there; in fact, getting more popular because of certain distinct advantages over conventional system. These advantages could be in terms of better treatment efficiency, lower cost, ease in the operation, or maintenance, and one of the features is the compact design of the systems.

So, there are wetlands constructed, or artificial wetland, there are which kind of simulates the natural wetland systems. So, they use the power of wetland vegetation, and for the purpose of wetland vegetation then adsorption of that kind of thing. So, soil microbial systems everyone is assembled in a constructed wetland system. These are low cost and low maintenance systems which utilize these natural processes for treating wastewater, but they need a large area, and that is how their application is restricted particularly in the heavily populated urban areas.

There are sequencing batch reactor which are another popular and compact design; where the typical activated sludge process are operated in the batches. So, we these batches are sequence through a series of treatment stages. So, we first fill then kind of allow it to react, then make them settle then decant, and then again keep it on static and go back to the refill system.

(Refer Slide Time: 24:52)



So, that happens in a sequencing batch reactor. So, these systems are although energy intensive, but result in higher treatment efficiency for solids BOD as well as nutrient removal. Then either conventional activated sludge process, or SBR systems could be augmented with the bio-film carriers, and then biomass growth takes place on these surface of these inert media which is which acts as a bio-film carrier, and as a result the biomass growth.

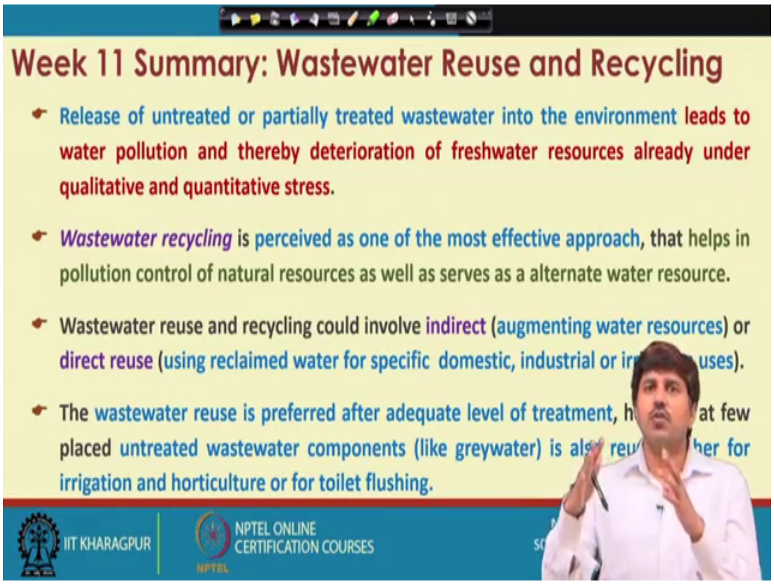
So, we get the advantages of both suspended as well as the attached growth systems. So, these are done in a moving bed bio-film reactors which is MBBR. So, in activated sludge process if you just put in these bio-film carriers will get in MBBR, or sequencing batch bio-film reactors in s b r system; if we add these these bio-film carriers, and biomass growth on the takes place bio bio-film growth takes place on the surface of these career.

So, we call that system as SBBR which is an upgradation of SBR system that way ok. So, these are relatively known to enhance the system performances. There are another highly efficient and compact alternative treatment system in the form of membrane bioreactor that exist.

So, it is actually combines the suspended growth biological treatment systems like ASP with this submerged, or external low pressure membrane systems for solid liquid separation. So, the biological process takes place of the degradation of organic matter, where as the membrane is instead of going for secondary settling basin; the secondary settling basin because of the lesser efficiency we use a membrane which gives us some better filtered quality.

So, the requirement of tertiary treatment could also be omitted here depending on their use application, or if needed we can directly go for a high and tertiary treatment stages. So, that were the MBR system works they are quite costly have high operation and maintenance cost also, but otherwise the efficiency is very good the major problem is the complexity of the membranes and membrane fouling.

(Refer Slide Time: 27:07)

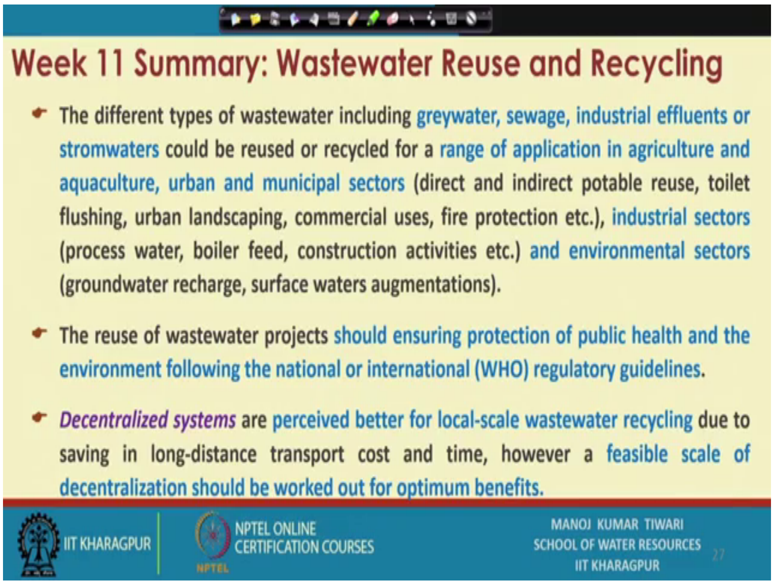


So, in the week 11 we discussed about the wastewater reuse, and recycling the basic aspect. So, release of the untreated or partially treated wastewater into the environment leads to the water pollution, and as a result deterioration of the freshwater resources, and as we are already under the qualitative, and quantitative stress. Our water resources are under qualitative and quantitative stress. So, this kind of enhances the problem further.

So, waste water recycling is considered as one of the most effective solution that helps in the pollution control of the natural resources as well as serve as an alternate water resource. So, this reuse and recycling could involved indirect, or direct reuse indirect reuse means augmenting water resources either groundwater or surface water resources, where is direct reuse is using reclaimed water for specific targeted domestic industrial, or irrigation applications.

The water reuse is preferred after adequate level of treatment; however, a few places the untreated wastewater components like: grey water is directly reused without treatment for some users like irrigation in horticulture, or even for toilet flushing, but again there are certain risk associated as we discussed during the week 11.

(Refer Slide Time: 28:20)



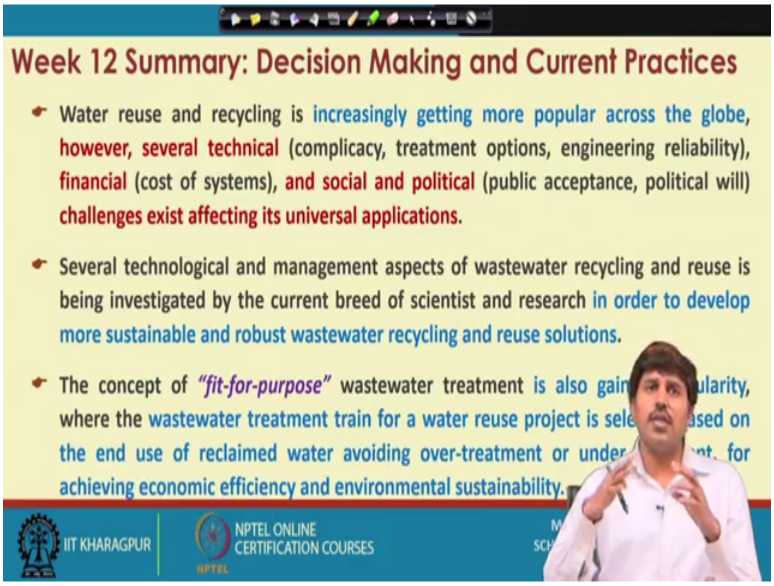
Then if we see the like reuse, and recycling aspect the different type of waste water including grey water, sewage, industrial effluent, strom waters could be reused, or recycled, and we can use this reclaimed water for a large range of applications in the agricultural, aquaculture, urban, and municipal sector, industrial sector, and environmental sectors ok. The reuse of waste water projects should ensure the protection of public health, and environment and follow the national or international regulatory guidelines.

So, international like WHO has put through certain regulatory guidelines for water waste water for waste water recycling system. There are few countries which have own separate regulatory guidelines like USA, and those other countries. So, they have their own separate guidelines for wastewater reuse. The decentralized systems are perceived better for local scale recycling, that is, because we get saving in terms of cost and times by not going for long distance transport of the sewage which is requirement of centralized system.

In centralized processing we have to basically collect the sewage from each part and then bring it to the far off point, and since this transportation things goes off; so, we save lot of cost transport cost and time. So, that is why it is perceived better, but it will be better if there are kind of appropriate reuse options are available in the vicinity.

So, and furthermore there is a feasible scale of decentralization should be worked out for optimum benefits because decentralization can be done at a different scale even from household to household scale, but that probably going to be very difficult to manage, and operate. So, instead of going for that level of decentralization we should work out the optimum level of decentralization for the best benefits.

(Refer Slide Time: 30:26)



In this particular week we had discussed about the decision making and various current practices adopted in the water and wastewater recycling systems. So, water reuse and recycling is increasingly getting more popular across the globe, but there are some technical, social, and political, financial issues that exist.

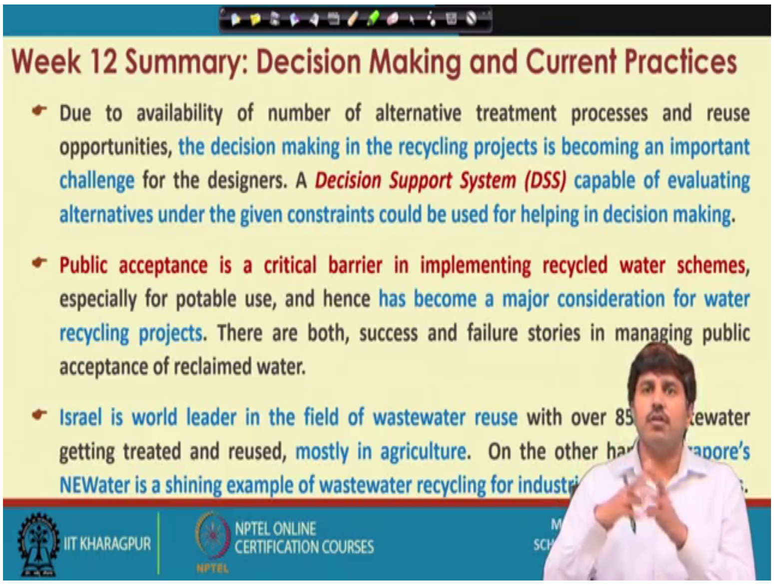
So, like there are technically issues in terms of the complicacy of the system, treatment options, engineering reliability, then the financial issues in terms of the cost of the system. Then social and politically issues in terms of the public acceptance, political will, or trade barriers. These are the major challenges that affect the universal applications of the recycling systems.

So, are several technological, and management aspects of this wastewater recycling and reuse is being investigated, and the current breed of scientist, and researchers are taking care in order to kind of develop more sustainable, and robust wastewater recycling and reuse a solutions. Then there is a concept of fit for purpose is gaining popularity where the wastewater treatment schemes are selected based on the reuse option.

So, that the treatment accordingly treatment is accordingly provided for the reuse option. So, we avoid over treatment or under treatment, and that way achieve the economic efficiency, and environmental sustainability. So, for say some water if it to be used for agricultural application does not need the complete removal of nutrients or treating it to the RO level which is going to be very costly.

So, that may be just treated to the requirement for the irrigation water, and those kind of concept are referred as fit for the purpose treatment.

(Refer Slide Time: 32:17)



Then due to the availability of number of alternative treatment process, and various reuse opportunities; the decision making in this recycling project is becoming an important challenge. So, for this purpose a decision support system which can guide based on the evaluating different alternatives under the given constant that which one is best. So, which can guide and help in decision making system.

So, that kind of decision support system have a lot of value in the wastewater recycling domain. The public acceptance is another very critical barrier in implementing recycled water schemes ok. There are especially for potable uses there are both success, and failure stories. So, we have had several projects waste water recycling projects being stopped in the countries like USA and Australia for this public opposition. So, this becomes a major consideration for wastewater recycling project.

So, towards the end of this we discussed about the kind of global practices, and Israel is actually the world leader in the field of wastewater reuse where over 85 percent of waste water is treated, and reused mostly in the agriculture. If we talk about the industrial and domestic uses. So, Singapore's new water is a very signing example of waste water recycling system; we have another examples from the Orange County California then the Florida in the United States, and many other places in India things are just catching up.

So, we have like the awareness is increasing, but still we do not have a great recycling system in place for the wastewater treatment, and recycling at multiple stages. Although there are some like small scale systems exist the industries are being forced to adopt for 0 liquid discharge policies which kind of ask for the complete recycling of the industrial effluent, but from domestic sector it is still not that attractive. So, this is all that we discussed during this entire course.

So, I hope that this discussion would have been fruitful for you, and thank you for being with us for this entire 12 week duration. I am open to your feedback, comments, queries in the forum. So, if you have any please post in the forum. Although the discussion here has ended, but we will be happy to respond to the, those queries are those concerns in the forum I will be happy to have feedbacks also. So, we end our journey here for the time being, and thank you for being with us.

Thanks.