Advanced Aquaculture Technology
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Lecture 07
Intensive Farming in High Tech Tanks

Welcome everyone, my name is Professor Gaurav Dhar Bhowmick from the agriculture and food engineering department of IIT Kharagpur. So in this lecture module this is the second lecture of module 2 technology of closed aquaculture, so in this course advanced aquaculture technology we have already discussed about in details some basics of aquaculture systems. So, In this particular lecture I will be discussing you about the intensive farming in high tech farms high tech tanks and or farms.

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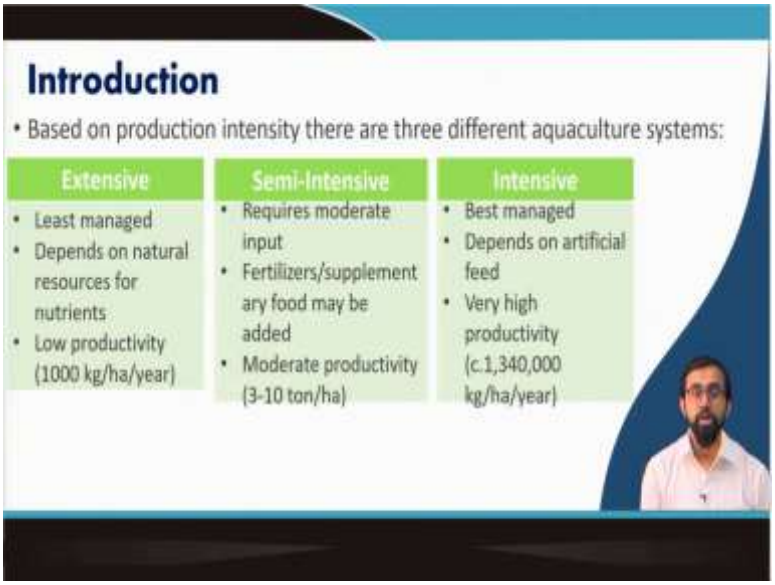

The concept that I will be covering is the comparison between extensive, semi-intensive and intensive aquaculture systems. We have already discussed about it in brief in previous lecture we will be discussing more in scientific terms in this particular lecture. The intensive aquaculture system in general, the intensive farming in high tech tanks and the zero water discharge systems.

We already know what is the difference between extensive, semi-intensive and the intensive aquaculture. In case of extensive the it is the least managed the aquaculture systems, it depends on the natural resources for nutrient, it has a very low productivity of around 1000 kg per hectare per year.

Whereas in case of semi-intensive it requires moderate input fertilizers and supplement may be required, the moderate productivity it has like 3 to 10 ton per hectare whereas in case of intensive aquaculture the based on the artificial feed we normally go for very high productivity in case of intensive aquaculture systems, we get it and it can go approximately say like almost 1.3 lakh kg per hectare per year.

In case of extensive, semi-intensive and intensive aquaculture you can see from the figure itself how it looks like. So in case of intensive aquaculture systems we need to go ahead with the more of anthropogenic developments, the more of a reactors, more number of the tanks or the raceways or the pond whatever we are utilizing.

Whereas in semi-intensive we only have to worry about the feed and the fertilizers some time to time if we can see that the production has some issues with the amount of feed or the

fertilizer requirement is there. In case of extensive aquaculture we don't have to worry about or any one of this.

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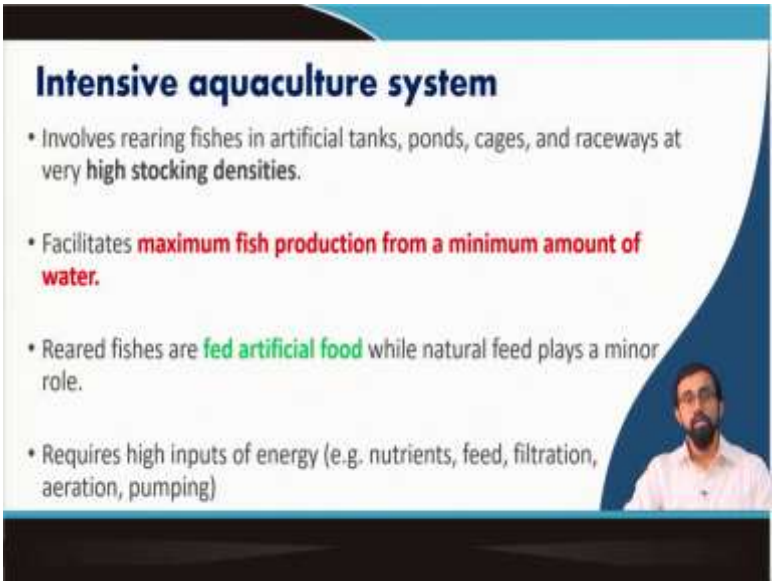

Figure 1: System map of intensive aquaculture systems. GHG: greenhouse gasses

In case of intensive aquaculture systems it involves the artificial tanks, ponds, cages and raceways for rearing the fishes in a high stock intensity. It facilitates the maximum fish production from a minimum amount of water. We are feeding the artificial food whereas the natural food is almost not available in most of the cases, also the main problem incorporated with the intensive aquaculture system is the high input of energy that it requires interms because of the presence of additional amount of nutrients that we have to supply, the filtration unit that is available, the aeration system that we need to utilize, the pumping system that we need to involve for the for all of this we need to actually requires a huge amount of energy and which actually one of the major disadvantages of intensive aquaculture systems.

We have already discussed all those things and let's go through it again briefly, so to go ahead with further idea to get a fresh idea about like how what are the high-tech tanks that we will be discussing soon. How it differs with the all the existing knowledge that is available in the aquaculture systems. It has a very high yield as I discussed involved with the high cost of investment overall return exists the operational cost so it definitely ensures the high profit, low energy losses from the feed input, it has a high feed conversion ratio from the specific artificial feed that we normally use.

In case of input functions we have the supplying water, stocking density, feeding interval, the fertilizing capacity and what are the fertilizers that you will be utilizing, what are the what is the amount of like providing light? This is the input function for the intensive aquaculture systems, what are the treatment functions? The temperature control, the phosphorus control, metal control solid organic matter, nitrogen disease control, ph control and the dissolved oxygen in the carbon oxide.

So if you see the dark ones are actually the one which is kind of must and the one which is like light colors is actually the one which is optional, but actually involves in case of if you want to have a high amount yield from your system.

Output functions always obviously the harvesting of the system other than that processing effluent, processing solid waste, preventing the escape of the catch or escape of the your culture spaces and controlling the greenhouse gas emission. So these are all involved in the intensive aquaculture system and I think to your surprise like intensive aquaculture system actually one of the major culprit of producing the greenhouse gaseous emission in the nature, so how to get rid of it I will discuss about it in details like what are the procedures and all.

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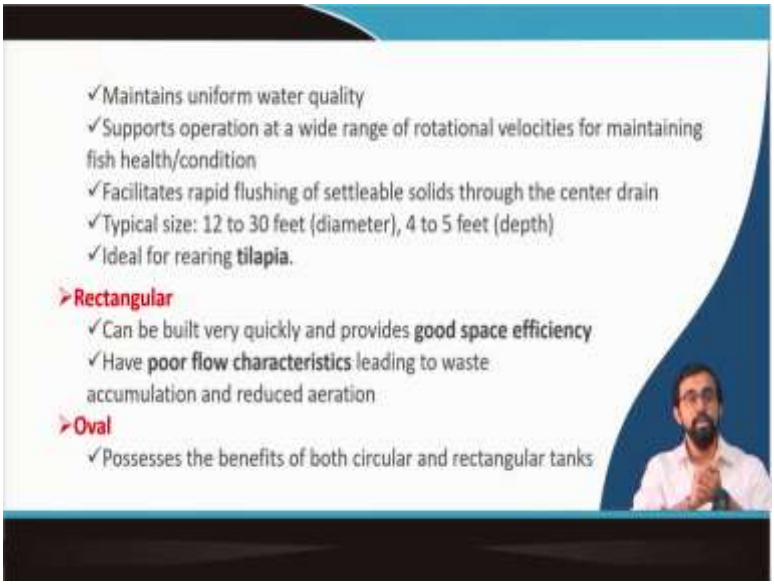

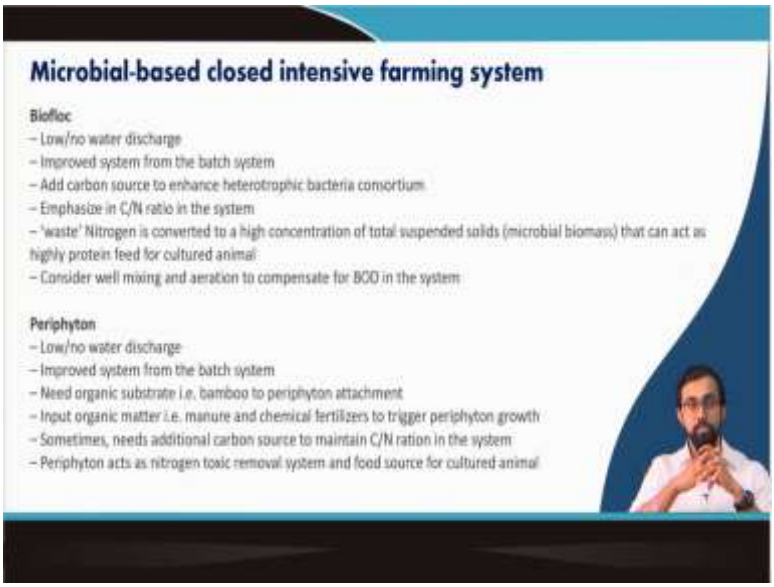

So in general the intensive farming in high tech tanks we go for the culturing the breeds for two to three months into the fingerlings within the tank. Based on shape there are three types of shape circular which is like simple maintenance which are easy for the effective water use and also it facilitates the self-cleaning action.

It also maintain the uniform water quality, it supports the operation at a wide range of rotational velocities for maintaining the fish health and conditions, it can facilitate the rapid flushing and settleable solid through the center drain because it's like a rectangular in a circular in nature and it has a particular slope and which looks like a hoovering structure. So in the middle of it we have this you know the center drain is there so because of this slope; all the settleable solid will actually wash out through this center drain. It has a typical size of around 12 to 30 feet and in diameter and 4 to 5 feet in depth, ideal for rearing the tilapia.

Rectangular tanks are there, we it can be built very quickly but provide a very good space however it has a very poor flow characteristics, so leading to the waste accumulation and the reduced aeration so that's why we normally go for oval or the circular one only. In case of oval it poses the benefits of both circular as well as the rectangular tank.

If you ask me what are the some example of the closed intensive aquaculture systems so let's first discuss about some existing one before going for discussing about the high tech technology that we have nowadays let's discuss about the existing ones, not only existing but even these technologies are actually nowadays evolving and people scientists are actually trying to find out solutions for all the possible cons part of this kind of technologies.

Like, First of all say like biofloc technology it is, it comes with a lot of advantages; first of all it almost low to no water exchange is required, improve system from the batch systems like we can go ahead with the adding of carbon source which can enhance the heterotrophic bacterial consortium in the biofloc itself, it can emphasize the carbon to nitrogen ratio in the system and also the waste nitrogen which is converted to a high concentration of the total suspended solids that can act as a highly protein feed for cultured animals. Okay! How it works?

First of all see we have a aquaculture waste, Okay! which has a carbon and which has a nitrogen compound though we call it a waste for us it is a waste but for them some microorganisms that is a feed, so what they we are doing, we are trying to develop the the biofloc technology is what we are trying to develop the heterotropic microorganisms which will consume this carbon source as a feed, this nitrogen source as a feed and it will convert this carbon and nitrogen into their own biomass. Isn't it? Then this microbial biomass is actually used as a feed for the cultured animal.

So, see it is a win win situation for us we can treat the waste water, we can utilize that treated element again come back to its feeding it is your own cultured animal and all cultural species and all. Other than that, it can help you for well mixing and also having well aeration like if you can supply with the well mixing and well aeration it can compensate for the BOD of in the system as well, the biochemical oxygen demand can also be reduced.

I think you already know what is biochemical oxygen demand, right? so this biochemical oxygen demand it is a very important parameter you need to understand whenever you will be working with any water related activities, any water quality related engineering or water quality related technology or say like any science subjects, you have to understand COD, BOD, what is PH, what is different nitrogen species like total nitrogen, ammoniacal nitrogen, kjeldahl nitrogen. So what are those parameters, how it is defined I am leaving up to you, you need to search for it, go google it and you will try to understand what are these parameters and try to understand this parameter, these are very important parameters.

No matter, because see, if your fisheries graduate student if you are a undergraduate or postgraduate student from fishery, fishery biology, fishery engineering, aquaculture engineering or even if you are a simple aquaculture enthusiastic unless until you do not know these parameters water quality parameters it will be very hard for you to understand the

further development of these subjects or any other subjects related to the this course or like this kind of aquaculture technologies. So, try to understand try to learn these things.

Next is the Periphython technology, it also have almost low to no water discharge required, it improves the system from the batch system like it is much better than the batch, it needs the organic substrate that is a bamboo for the the periphyton to attach to its surface, the input organic matter that is manure and the chemical fertilizer is utilized to trigger the periphyton growth on its on the surface of the bamboo.

Sometimes needs additional carbon source to maintain a proper carbon to nitrogen ratio in the systems, but however, this periphyton acts as a nitrogen removal system and food source for the cultured animal. So here also we have this win-win situation as I discussed in the biofloc technology also.

This periphytons they not only consumes the nitrogen species which is like toxic in nature, you know that even a certain the even very small amount of ammoniacal nitrogen present in the system or if it is a free ammonia gas then even it is more toxic for the fish to survive or any aquatic species to survive in general.

In order to remove the nitrogen however, they are generating that nitrogen itself so you need to remove that nitrogen from the system, how we can remove it which is toxic in nature? You use this kind of technologies like biofloc, periphytons, etc I will be discussing that is the main motto of any treatment you need that we incorporate in aquaculture treatment aquaculture wastewater treatment. Okay!

Then removal of nitrogen that is one of the major thing that we need to think about. And in order to do that for periphyton, see periphyton or any kind of microorganism or any kind of animal say even us, we need a proper ratio. We will not only keep on having water without any food we need food also; even in food also if you are only giving rice like any Bengali like us I do not like to have only rice I need the dal as well. Right?

So it is like you need to provide carbon source as well which to maintain a proper carbon to nitrogen ratio so that the periphyton will find it you know very pleasant to have the food and they will consume it more and they will reproduce and this periphyton will act as a food source for the cultured animal. So you are treating the nitrogen source from the system and you are in the on the other hand you are providing the food source for your cultured animal.

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What are the other intensive aquaculture system that is available is RAS. RAS, I think you guys already have some idea about what is RAS, recirculatory aquaculture system, where practically no water exchange is happening. It involves stages of treatment processes; primary, secondary, tertiary if needed. Initially what is the primary treatment?

Primary treatment means majorly primary treatment consists of the filtering operation, filtering of all the suspended solid present in your aquaculture wastewater. So how it is done we use drum filter, we use different kind of filtering mechanism, screens filter and all we use it accordingly so we try to get rid of using this filter we try to get rid of all the suspended solid present in your system that is the first process.

Second is the biochemical process, we go for secondary treatment, secondary treatment where we actually introduce microbiota in our system; or in say separately in a separate system which will be called as bio filter. So what it will do it will treat the waste water by converting the chemical elements present in the waste water into the biomass. Okay! hat it will do?

Those microorganisms they will consume that carbon nitrogen present in the waste water they consume it and they develop their biomass and it will be converted into a biomass which is easy to separate, in elemental form or in biomass form once it is consumed by the microorganism. Now, we can simply separate out the biomass, we can simply separate out the microorganism that is it the final water that is coming out of the system is like pollutant free that water we can again traverse it back to the tank or our culture media culture say like pond or raceway.

That’s how we treat the aquaculture wastewater in a recirculatory aquaculture system. This microbial compartment we call it biofilter. It has a very defined microbial consortium isolated or the clear water systems we use the main purpose is to biologically secure and hygiene aquaculture product.

Sometimes what we do we also incorporate tertiary treatment unit also as I discussed earlier, the ozonation, UV irradiation or any other advanced oxidation processes. This advanced oxidation processes what it does even if some amount of unwanted microbiota is left out like or some amount of nutrient is still available in your waste water this processes will consume that also and at the end whatever the outcome whatever the output of this tertiary treatment units will be completely void of all the pollutant, so then that is very good it is okay for applying back to the tank again that is what we do in case of recirculatory aquaculture system.

Then there comes the green water techniques; it also has a very low water exchange. It uses the batch system mostly the autotrophic microalgae used as a microbial component in the system. It utilizes the chemical fertilizer and also organic waste to trigger the phytoplankton growth.

We have no control in the microbe community in this particular type of systems. However, the main moto is what? First of all to provide the natural food for the cultured animal this phytoplankton. Second thing this phytoplankton or this microalgae whenever they try to grow what they will do they will utilize they need the nutrition nutrients.

Where they get these nutrients from? From the pond itself, which things they will utilize? The nitrogen and carbon source. This nitrogen and carbon source are the nutrients for the culture species, so they will utilize it and they will grow as a biomass and this biomass is utilized further by the cultured species itself. By this way we have a nice like small scale artificial ecosystem build up in the treatment tank itself in the tank itself.

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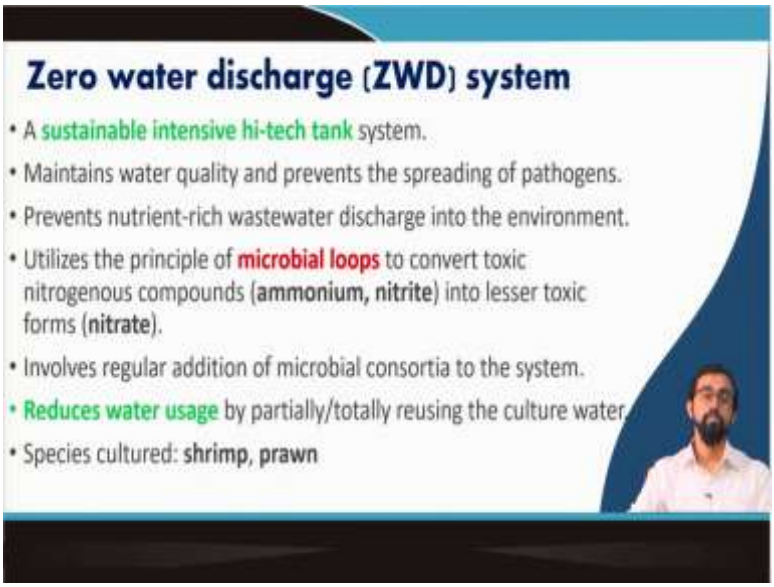

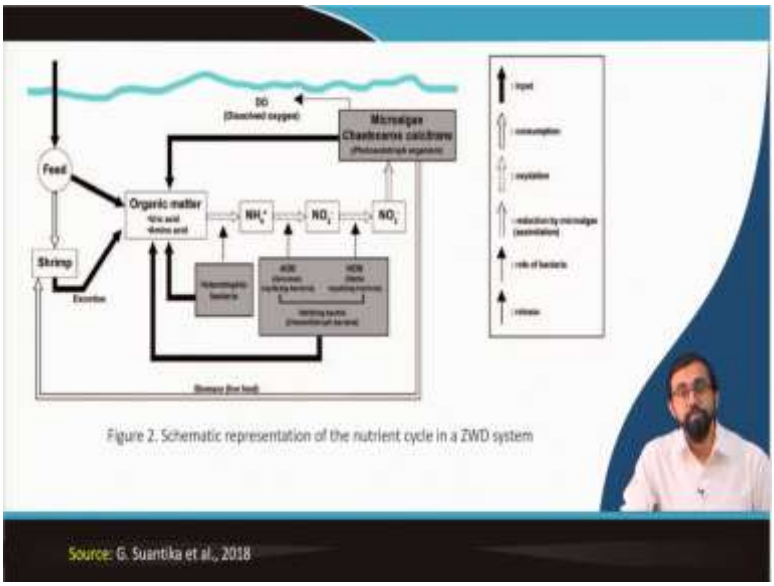

So, these are all the technologies that is already available and people are working on it and still there are advanced level of these technologies are already there, so what are the further advancement that is happening in this kind of systems. We call it there is a technology recently we discussed about; we normally try to go ahead with the zero water discharge system.

It's actually a type , Its a sustainable intensive high tech tank systems where we maintain the water quality, we prevent the spreading of the pathogen, we try to prevent the nutrient-rich wastewater discharge into the environment, we utilize the principle of microbial loops to convert the toxic nitrogenous compounds like ammonium or nitrite into lesser toxic form like say nitrate and this nitrate and even if it can be further utilized by the plant and all if we can

supply with any phytoplankton, if it can supply with micro biota or if you can supply with say like any how to say micro algae and all, so they can utilize it and they can further reduce the overall pollutant load of the system.

It involves with the regular addition of the microbial consortia to the system, it reduces the water uses by partially or totally reusing the cultured water. Species which normally we go ahead with the zero water discharge systems shrimps, prawns etc.

If you see this particular design given by Suantika et al., 2018 in this reference also you can you can see at the end of the lecture video. So the feed is given to the shrimp, uneaten feed considered as a organic matter. The shrimp whatever the excretory product that they are developing going to the converted to the organic matter uric acid or amino acid.

We utilize some heterotrophic microorganism, heterotrophic bacteria what they will do, they will convert this uric acid and amino acid to ammonium ion, Right? NH_4^+, this ammonium ion then be utilized by the nitrifying microorganism. How they work, first the ammonium oxidizing bacteria will start working on it, you you know the example of it, nitrobacter. Okay!

Nitrobacter are one of the examples of this kind of nitrifying microorganism, nitrifying bacteria. So they use nitrosomonas nitrobacter they normally use this ammonia and nitrite for as a feed and they convert it to the nitrate as the end product is the nitrate. This ammonium oxidizing bacteria and nitrite oxidizing bacteria they convert it to the nitrate, so this nitrate is actually utilized by the microalgae.

As I told you like this nitrate is a rich source of how to say uhh food or a rich source of nutrient for the plant to grow any kind of plant to grow. So what is happening this nitrate is actually utilized by the micro algae, this at the same time what microalgae is doing? It not only utilizes the nitrate not only utilizes the nitrate for their respiration process they also give out like some breathe out the oxygen which actually causes the dissolved oxygen level to high in your system.

So it's a complete it's a complete how to say umm not only energy balance it is a nice cycle that we are making, its a nutrient cycle that we are developing inside the system. So that everything will happen you know all the nutrients will be in a same cycle and all the recovery can be also happen, nutrient recovery can also happen and also the reduced amount of water uses can be can also be possible.

After the treatment is done this microalgae may be considered as organic matter even this can be utilized as a feed also for certain type of aquatic species and this see microalgae it will go directly as a biomass for light feed for the shrimp. So this is how in general the nutrient cycle of a zero waste disposal system of say any aquaculture process looks like.

In general if you ask me there are procedures of there may be certain changes in the procedures, there may be certain variations we can do in these procedures by which sometimes we may not need the heterotropic microorganism at all, sometimes we may enrich the growth of heterotrophic microorganisms in the tank itself by utilizing some particular type of stones, particular type of rocks there.

So they will develop the heterotropic mechanisms by themselves somehow if you can make some anaerobicity there; there are ways, there are scientific explorations there are explorations there, n number of research papers are there. If you are interested we can you can go and we can learn more about it; in the just google it with all these keywords and you will get a very nice research papers. Even from IIT Kharagpur itself we are also working on this kind of technology a lot for like last couple of years and that also will be a very beneficial for all of you, so this is how zero waste disposal system it looks like. Okay!

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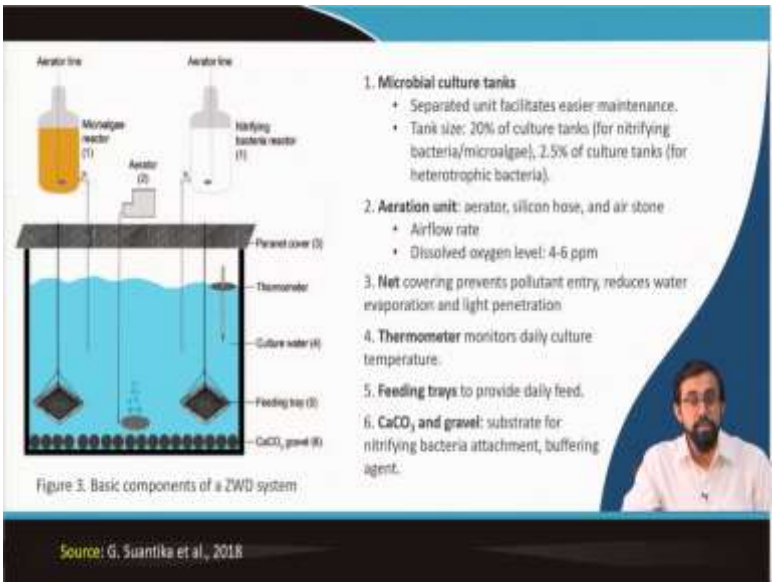

So, in general this is a very standard practice that you see in this standard practice in this standard method that is given by Suantika et al., 2018. You see the aerator line is given in each of the segments like say it has like four segments, first reactor is nitrifying bacteria reactor, second is micro algae reactor, fourth is this the whole tank itself where the cultured water is there, fifth is this aerators are there.

If you see the micro algae if you see the first the tank in the tank you have a feeding tray, you have a culture water, you have a aeration going on, you have a thermometer is there to control the environment, you have a paranet covers. In the bottom you have this this calcium carbonate calcium carbonate gravels are present, so these substrates are given for the bacterial attachment and the buffering agent it is used and also this actually helps the treatment that water then it goes to the nitrifying bacteria chamber which is like you know where there is nitrifying bacteria reactor is there.

So this nitrifying bacteria what they will do whatever the ammonia that is generated from this waste water they will convert it to the nitrate; nitrite and then nitrate. This nitrate then goes to the micro algal reactor, the micro algal reactor they will utilize that nitrate and the final water which is completely void of any nitrogen element nitrogen species it will come back to the culture tank the final tank I mean the itself for your target species.

What are the units microbial culture tank as I already discussed it a separate unit facilitates the easier maintenance, the tank sizes are almost 20 percent of the culture tanks for like the nitrifying bacteria or the micro algae and 2.5 percent of the culture tank is required for the heterotropic bacteria grow to grow.

Aeration unit in general aerators, silicon hose or air stones are used, air flow rate you have to maintain based on the volume of the reactor and the expectation and the intensity like stocking intensity, etc. Dissolved oxygen level has to be maintained 4 to 6 ppm. The net covering is given for to prevent the net pollutant entry and reduce the water evaporation and the light penetration. Thermometer is used to monitor the daily culture temperature and feeding trays are provided to the daily feed and I already discussed the process and the requirement of the calcium carbonate and the gravel.

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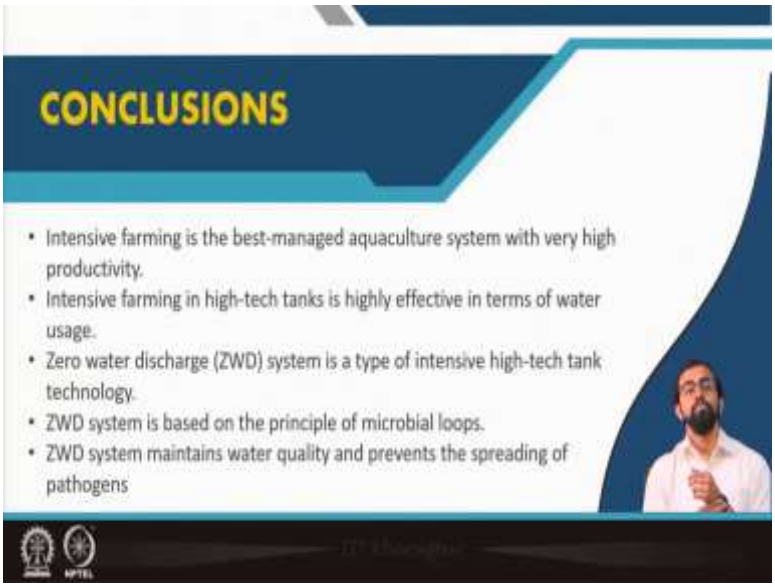

So this zero water discharge or zero waste disposal type of system what it does, it actually helps us to device the very high like high-end intensive aquaculture systems. In general the intensive farming is the best managed practice for its, its very much practiced all over the world for its high productivity other than that it is very much active in terms of the water uses also and it can be further developed to the different level when we go for designing this kind of zero waste disposal or the zero water discharge systems.

In this kind of ZWD system is based on the principle of microbial loops as I already discussed in the last slide. It also maintain the water quality and prevents the spreading of pathogens all together because in general whatever the amount of pathogens that can be

present in the system it is possible for them being like for them to utilize by the heterotrophic bacteria. Okay!

I am giving you one very fine information in this particular case how the spreading of pathogen is possible to control, possible to prevent. When we go for the heterotrophic growth of microorganisms which will consume and use this urea and urea and uric acid to convert it to the ammonia we try to go for some friendly heterotrops like bacillus, in general what they will do they are the friendly heterotrophic microorganisms and the presence of them, actually they actually have a quorum sensing mechanism by which they can somehow outlay all the unwanted pathogens present in the system.

This system this quorum sensing is a very specific methods kind of I am not going to details in this method they actually try to they communicate between each other by this process they can get rid off, if you know or if you search for this term this keyword quorom sensing in google and read its very interesting thing you will be very surprised to know this technologies in this quorom sensing thing that is available in that how we are actually utilizing this quorom sensing fundamentals for the microbial communication for our own purpose and it is being very famously like very like profoundly used in the research field nowadays in microbial research field nowadays. Anyway, so they actually help prevent the spreading of the pathogens so by this way we can get rid of the pathogens as well using this heterotrophic growth of microorganism in the this ZWD or zero water discharge systems and all.

So that is how the system will looks like, so I am giving you just a very brief introduction and very brief idea of only one specific type of zero water discharge system. Okay! There are ample amount of examples available in the literature even we are also working on different type of ZWD systems in IIT Kharagpur and we have worked on previously also.

So there also you can find the literatures available in the internet which involves, which will give you more in-depth idea about how it looks like and what are the different treatment benefits, what are the different system benefits that it will offer when you go for the designing any aquaculture farm and all.

So these are the references that I have utilized for preparing this material for this lecture material. So we will go ahead with the details soon with more in-depth engineering design and drawing of advanced aquaculture systems in coming lectures, so that’s all for now. Thank you so much.