Water and Wastewater Engineering
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Wastewater Disposal and Reuse
Lecture # 32

Last class we were discussing about effluent disposal. We have seen that the treatment plants can remove a certain amount of the pollutant present in the waste water. We design the treatment plant in such a way that whatever is the maximum extent possible will be removed in the treatment plants. But hundred percent efficiency is impossible in any of the treatment plants so definitely some amount of the pollutant will be left over in the effluent whatever is coming out of the treatment plant. What we will do with this effluent? This effluent has to be discharged somewhere. Most of the time we discharge these treated effluents in existing water bodies or in land. So what is the principle behind this effluent disposal is whatever treatment is taken care by the treatment plant is okay and whatever is left over the nature will be taking care and it will be completing the treatment process. So when we discharge this effluent to existing water bodies what all are the important factors we have to consider.

We should be aware of the self cleansing capacity or the carrying capacity of the stream because the stream is having high dissolved oxygen and it will be having large volume of good quality water flowing through that one so when we discharge the effluent to the stream whatever organic matter that is present in the effluent will be undergoing bio degradation in the presence of micro organisms and it will be utilizing the oxygen in the stream and at any level the dissolved oxygen concentration in the stream should not fall below the critical concentration.

For example two milligram per litre is the dissolved oxygen concentration required for aquatic life and if you are bothered about very very sensitive organisms then the dissolved oxygen concentration should not fall below four milligrams per litre. These things we have seen in detail in the last class. And we have seen that though the oxygen diffusion is taking place in the river there are other mechanisms by which oxygen is getting added to the stream. For example, the river water is contact with the atmosphere so definitely it will be increasing the dissolved oxygen content of the stream. Another mechanism by which oxygen is entering in the stream is by algal photosynthesis. that also contributes significant amount of oxygen/ but if it is a fast flowing river then algal growth will be very very negligible because in turbulent condition algal growth is very less. So in such cases the oxygen replenishment is because of the re-aeration from the atmosphere.

So if you want to see what is the oxygen profile in a stream or what is the quality of the stream with respect to the pollution or effluent addition we can use dissolved oxygen model. Today we will see in detail dissolved oxygen model. This dissolved oxygen model was developed by Streeter and Phelps in 1925.

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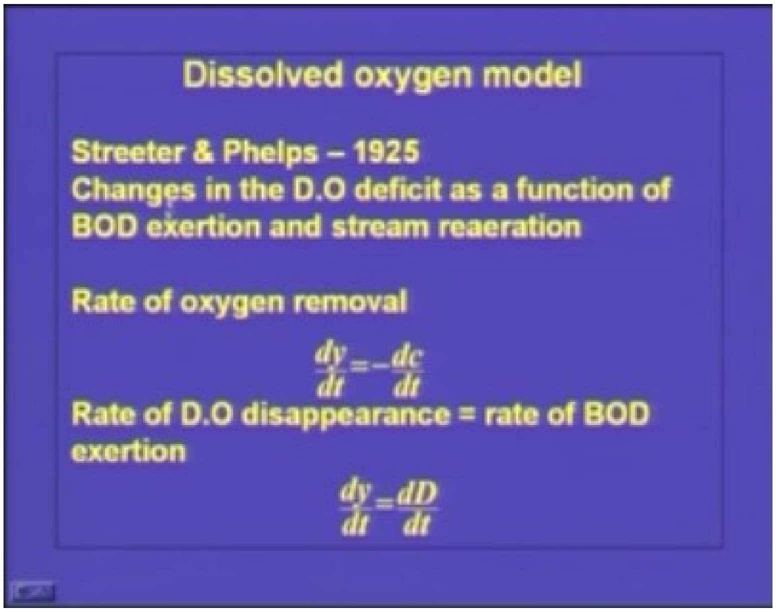

This model is used to predict the changes in D.O deficit as a function of BOD exertion and stream reaeration. So this dissolved oxygen model is not taking into account the photosynthesis. As I have already mentioned in the streams because of the high turbulence algal growth with will be negligible.

This one we have seen in the last class also, the rate of oxygen removal or dy by dt is proportional to the concentration of organic matter present in the system. And we know that as the oxygen consumption increases the concentration of the pollutant will be decreasing with respect to time so that is why this negative sign is coming. And rate of D.O disappearance is equal to rate of BOD exertion because BOD is nothing but bio chemical oxygen demand. So as the BOD exertion increases the rate of D.O disappearance also will increase as it is written here dy by dt where y is the BOD exertion so rate of change of BOD exertion is proportional to the rate of change of D.O disappearance dD by dt.

So BOD exertion we have seen in detail when we were discussing about the water or waste water characteristics. So BOD exerted is nothing but whatever is the difference between the ultimate BOD what was the initial organic matter concentration present and what is the organic matter concentration present at time t. So if you take the difference that is nothing but the BOD exertion. That means this much amount of organic matter is being utilized by the micro organism and correspondingly that much of oxygen is utilized.

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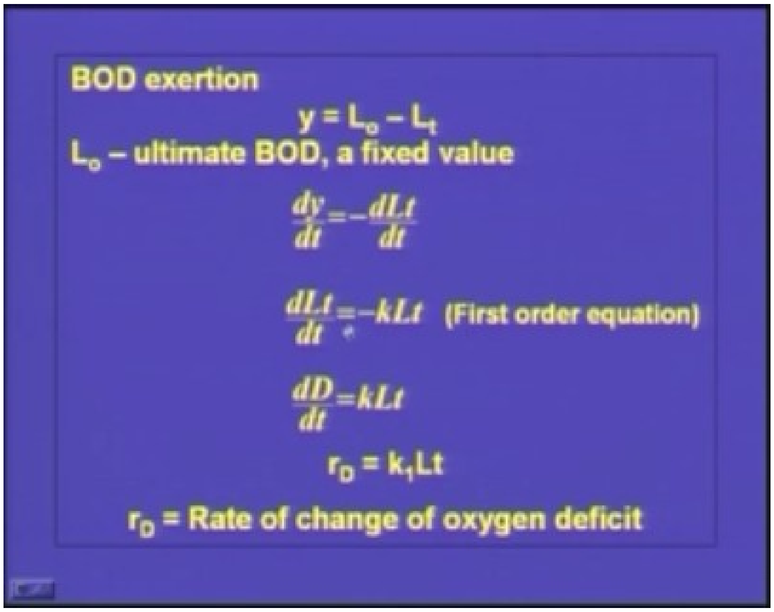

Here L0 is the ultimate BOD and ultimate BOD is a fixed value and Lt is the BOD or the organic matter left over at any time t. Or we can write like this; dy by dt the rate of BOD exertion with respect to time or rate of BOD exertion dy by dt is equal to minus dLt by dt because we know that L0 is a constant so if you take the derivative of that one it will be 0 so dy by dt will become minus dLt by dt and this dLt by dt you can replace by minus k into Lt because we have seen that BOD exertion is a first order equation so the rate of change of concentration of organic matter is proportional to the concentration of organic matter present in the system.

Or in other ways we can tell that the rate of D.O depletion dD by dt is nothing but k into Lt or this dD by dt we can replace it by another term rD, rD is equal to K1 into Lt where rD is the rate of change of oxygen deficit.

I will explain once again.
The y is the BOD exerted, it is the difference between ultimate BOD and the organic matter concentration whatever is left over or the rate of BOD exertion dy by dt is proportional to the concentration of organic matter left over in the system. Or we can write it as minus dLt by dt and dLt by dt is equal to minus kLt because we are assuming that the BOD exertion is a first order reaction and this this dy by dt is nothing by minus dD by dt so we can write like this dD by dt is equal to k into Lt or this dD by dt term we can replace by rD where rD is rate of change of oxygen deficit that is equal to K1 into Lt that means it is equal to a constant into whatever is the organic matter left over in the system.

Now we will see how we can find out the rate of oxygen addition.

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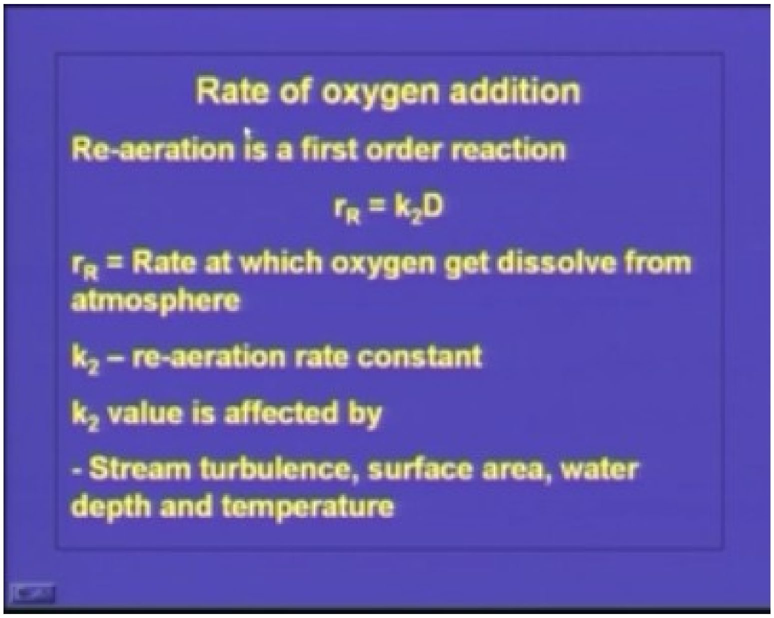

The re-aeration is also assumed as a first order reaction. So rR the rate of re-aeration is equal to k_2 into D, rR is rate at which oxygen get dissolve from the atmosphere or and k_2 is the re-aeration rate constant and k_2 value is not a constant, it is affected by stream turbulence surface area, water depth and temperature. If the stream turbulence is high definitely this k_2 value will be very very high. The reason is, when there is turbulence and when oxygen has to dissolve in the stream then the mass transfer will be much easier so stream turbulence increases the k_2 value; and if you have more surface area more contact surface will be available so definitely it will be increasing the k_2 value; and if the water depth is high definitely the k_2 value will be decreasing.

If you take, for unit volume, since the surface available for the re-aeration or oxygen transfer is less and as the temperature increases the dissolved oxygen concentration will be decreasing because solubility decreases with increase in temperature. So at low temperature the solubility will be high and high temperature the solubility will be less. These are the parameters that affect k_2. So whenever we find out the k_2 value it should be considering all these factors or we have to apply proper correction for these changes.

We have seen that oxygen concentration is varying because of deoxygeneration and re-aeration. So if you want to find out the oxygen concentration in the river it will be a function of this re-oxygenation. So if you combine these two curves then the resultant curve whatever we are getting is known as oxygen sag curve, oxygen sag curve is nothing but the summation of re-aeration curve and the de-aeration curve of the stream.

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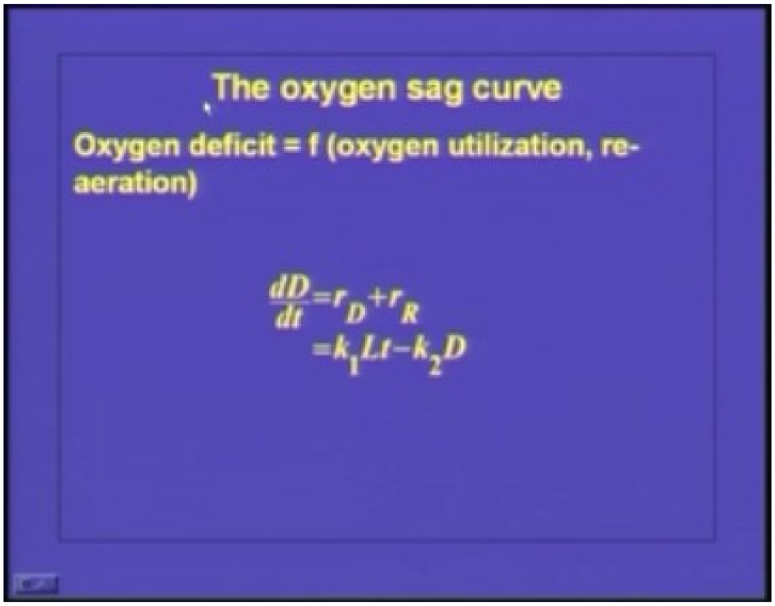

Or in other ways the oxygen sag curve we are calculating oxygen deficit. It is a function of oxygen utilization and re-aeration. Or we can write in other ways dD by dt is equal to rD this is the de-aeration rate and this is the re-aeration rate or we can write like this; K_1 into Lt because this will be increasing the deficit and k_2 into D is minus because it will reduce the deficit because if more and more oxygen gets into the system the deficit will be increasing so that's why we are writing like this; dD by dt is equal to rD rate of de-oxygenation plus rate of re-aeration that is equal to K_1 into Lt minus k_2 into D. So if you plot the curve separately you will get something like this.

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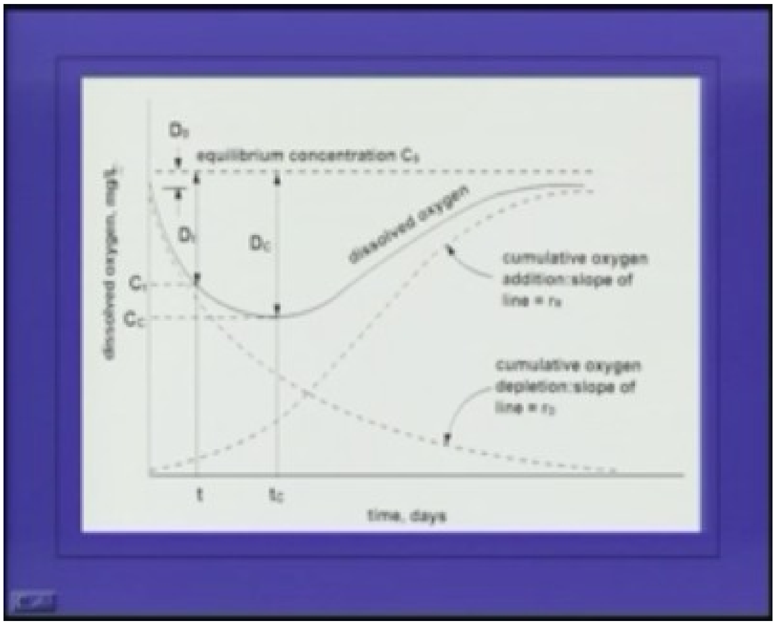

Here this curve (Refer Slide Time: 11:55) is the cumulative oxygen depletion with a slope of rD so what is happening here is here we are discharging some waste water so with respect to time whatever organic matter that is present in the waste water will be utilized by the micro organism so with respect to time the oxygen concentration will be decreasing. Therefore we are taking the cumulative oxygen depletion so you will be getting a curve something like this and finally it will become asymptotic or almost nil. And at the same time what it is happening is the oxygen will be entering into the system because of the re-aeration. So this is the cumulative oxygen addition to the system the slope of the line is rR at any point and this line slope is rD.

If you combine these two curves then you will be getting a curve something like this so this will give you dissolved oxygen concentration in the system. And here the x axis represents time in days or it can be the distance in the stream and here you will be getting the dissolved oxygen. here you can see that in the oxygen sag curve (Refer Slide Time: 13:05) this is the maximum tip available, this is known as critical deficit and this is known as the critical concentration and the time corresponding to that one is the critical time. So the critical time or critical deficit will not be occurring immediately after the waste discharge, it will take some time for the critical deficit to occur. So we can find out the critical time or the distance at which critical deficit will be occurring and this information can be used for the management of the effluent discharge. This is the use of this dissolved oxygen model. We will be able to predict the critical deficit and the location where it is occurring and what is the corresponding dissolved oxygen concentration.

This line here (Refer Slide Time: 13:50) shows the saturation oxygen concentration. That means at a particular temperature this is the maximum dissolved oxygen concentration the stream can have so that is Cs. Now we will see the derivation of the dissolved oxygen model.

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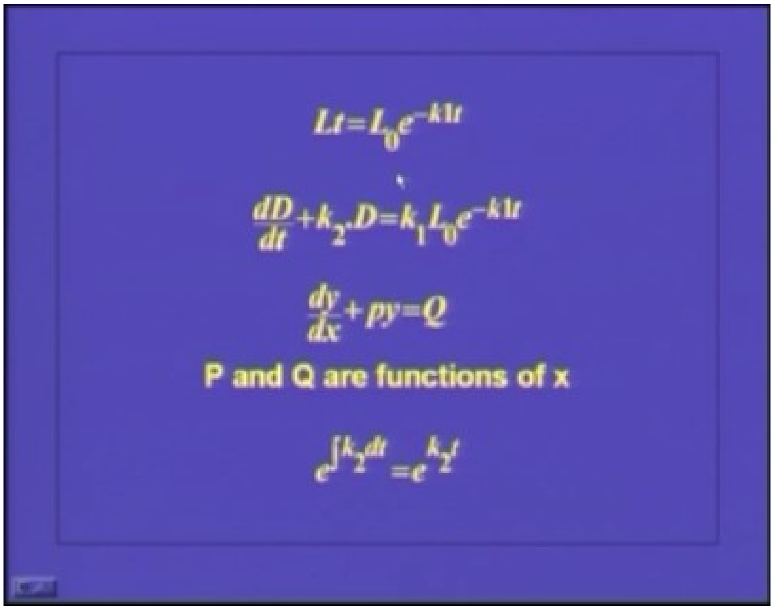

We know that Lt any time means the left over organic matter equal to L_0 into e raised to minus K_1 into t where K_1 is the BOD exertion rate. Or we have seen earlier that dD by dt is nothing but K_1 into Lt minus k_2D so this one we can write like this; dD by dt plus k_2D because that term is coming this side is equal to K1 into L_0 into e raised to minus k1t because that is equal to K_1 into Lt and Lt we are substituting by this value L_0 into e raised to minus K_1 into t so equation is in this form; dy by dx plus p into y is equal to Q where P and Q are functions of x. So we can integrate this using this approach.

This is the standard format: e raised to integral k_2dt is equal to e raised to k_2t. So how can we integrate this equation? What we are doing is we are multiplying all the terms by e raised to k_2t so the equation will become e raised to k_2t into dD by dt plus k_2 into t into the same term e raised to k_2 into t is equal to k_1L_0 into e raised to minus k_1t multiplied by e raised to k_2t then we will be getting k_2 minus k1t. So this term if you see it is e raised to k_2t into dD by dt plus k_2D into e raised to k_2t which is nothing but d by dt of D into e raised to k_2t.

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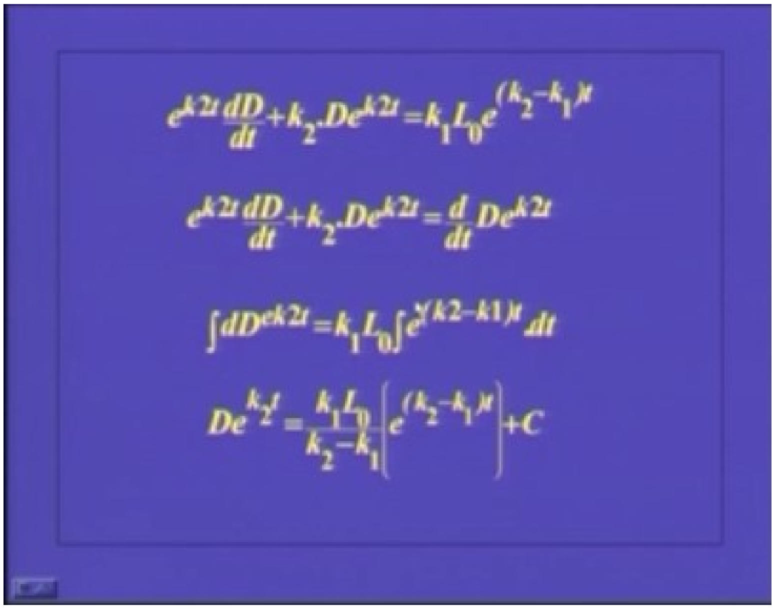

So we can write like this integral d of D raised to e raised to k_2t is equal to k_1 L_0 into integral e raised to k_2 minus k_1t into dt so we are integrating this one because we got it in this standard format so if you integrate this step you will be getting D into e raised to k_2t is equal to K_1 L_0 by k_2 minus K_1 into e raised to k_2 minus K_1 into t plus C this is the constant of integration.

How can we find out the constant of integration? We know that t is equal to 0; D is equal to D_0 that this is the initial deficit so D_0 is equal to K_1 L_0 minus k_2 minus K_1 plus C; you substitute.

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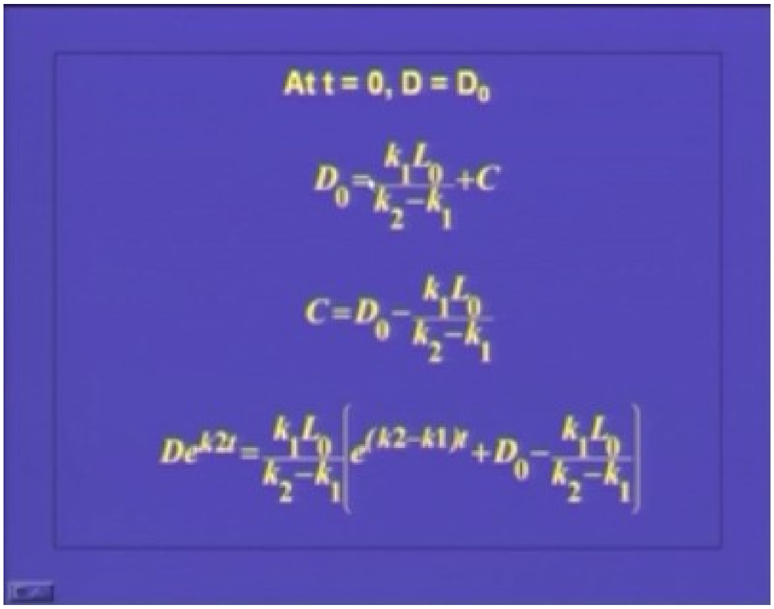

Here t is equal to 0 then we will be getting this term D0 is equal to K_1 L_0 by k_2 minus K_1 plus C or C is equal to D_0 minus K_1 L_0 by k_2 minus K_1 or and we can substitute this C value in the earlier equation this equation (Refer Slide Time: 17:06) so we will be finally getting D into e raised to k_2t is equal to K_1 L_0 by k_2 minus K_1 into e raised to k_2 minus K_1 into t plus D0 minus K_1 L_0 by k_2 minus K_1 where K_1 is the de-oxygenation constant and k_2 is the re-aeration constant and L0 is the ultimate BOD and D0 is the initial deficit so we know all these terms. From this we can find out what is D so you divide this expression (Refer Slide Time: 17:43) with e raised to k_2t so you will be finally getting the deficit at any time t equal to K_1 L_0 by k_2 minus K_1 into e raised to minus k_1t minus e raised to minus k_2t plus D_0 into e raised to minus k_2t.

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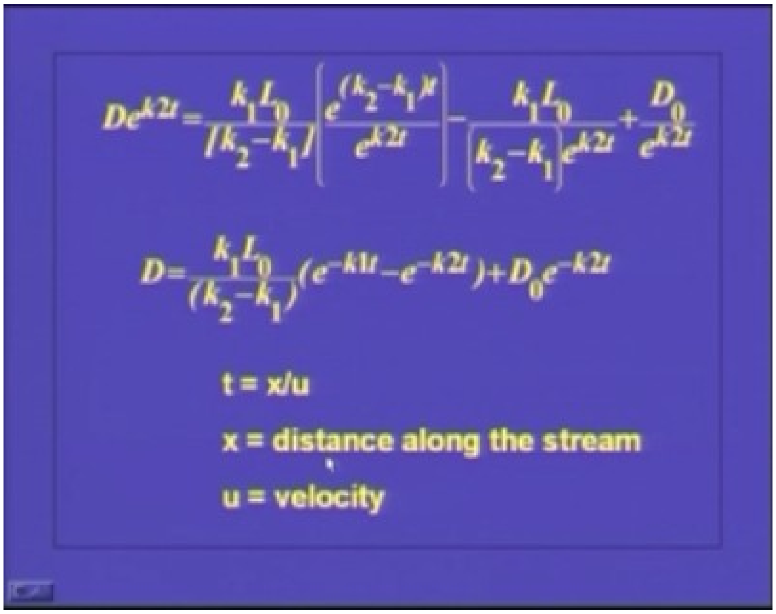

Therefore in the stream if you substitute any t value we can get the oxygen deficit so we can plot the dissolved oxygen or oxygen sag curve for the stream. Hence this t is nothing but x by u where x is the distance along the stream and u is the velocity. So from this expression we can make the oxygen sag curve.

But for the management purposes this oxygen sag curve itself will not be enough because we are interested to find out what is the minimum dissolved oxygen concentration available and what is the maximum deficit and at what distance it is occurring so this is the most important thing. So how can we find out those information from this expression is what I have written here. the most important point in oxygen sag curve are the point of lowest D.O, critical deficit Dc and critical time tc because at any point the lowest D.O should not be below the specified limit either four milligram per litre or 5 milligram per litre depending upon the class of the stream or depending upon the use of the river water.

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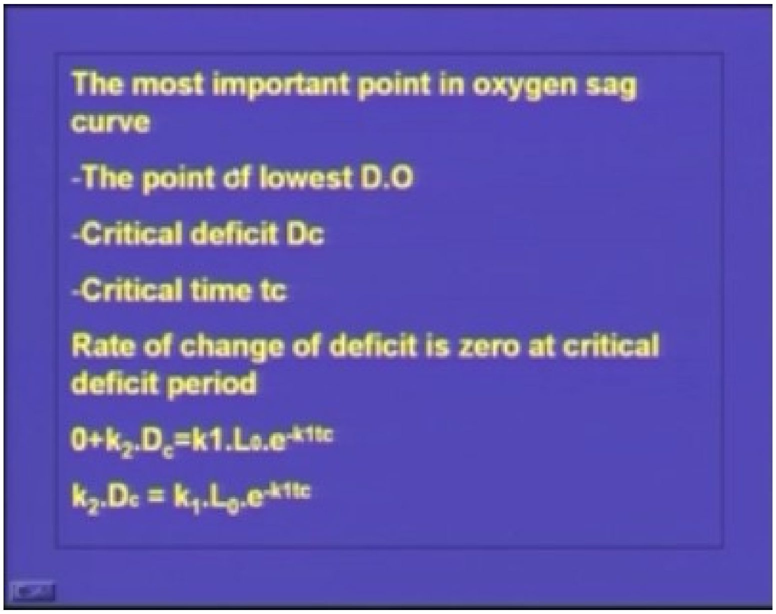

We also know that at critical deficit you can see that the slope is 0 or rate of change of deficit is 0. so we can use that information for finding out what is the Dc and corresponding tc as I have written here; rate of change of deficit is 0 at critical deficit period so we can write the expression like this; 0 this is nothing but dD by dt plus k_2 into D. Thus we know that the deficit at that time is Dc the critical deficit that is equal to K_1 into L_0 into e raised to minus K_1 into t and here the t is corresponding to the critical time so we are replacing the t by tc. So our original equation will become 0 plus k_2Dc is equal to K_1 into L_0 into e raised to minus K_1tc or k_2Dc is equal to K_1 L_0 into e raised to minus K_1tc.

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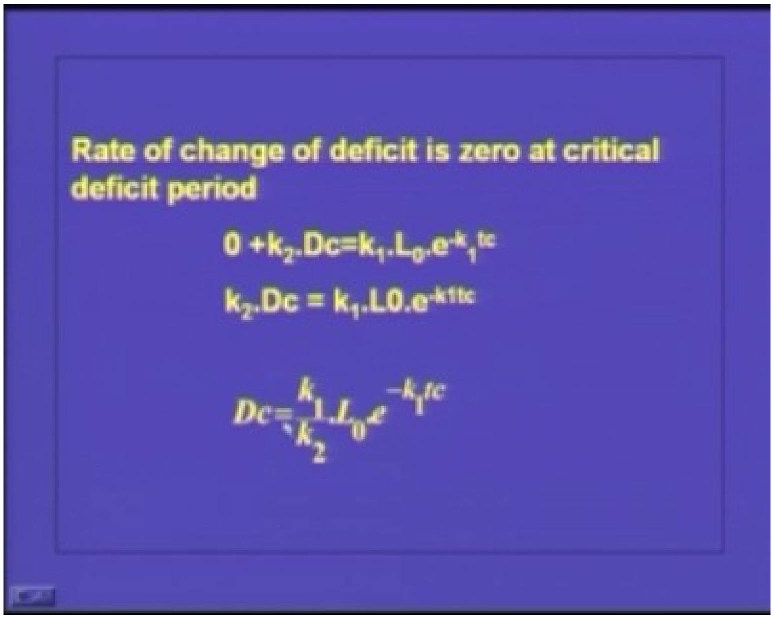

Therefore now we can find out the Dc value. The Dc is equal to K_1 by k_2 into L_0 into e raised to minus K_1tc. So if you know tc value we can find out the deficit Dc at that point. So how can we find out the tc value? Unless you know the tc value it will be difficult to get the Dc value. So in order to find out the tc what we have to do is differentiate the equation for D with respect to t and equate it to 0. So we know the expression for D and we know that at the critical deficit the rate of change of deficit is equal to 0 that's why we are differentiating the equation for D with respect to t and equating it to 0.

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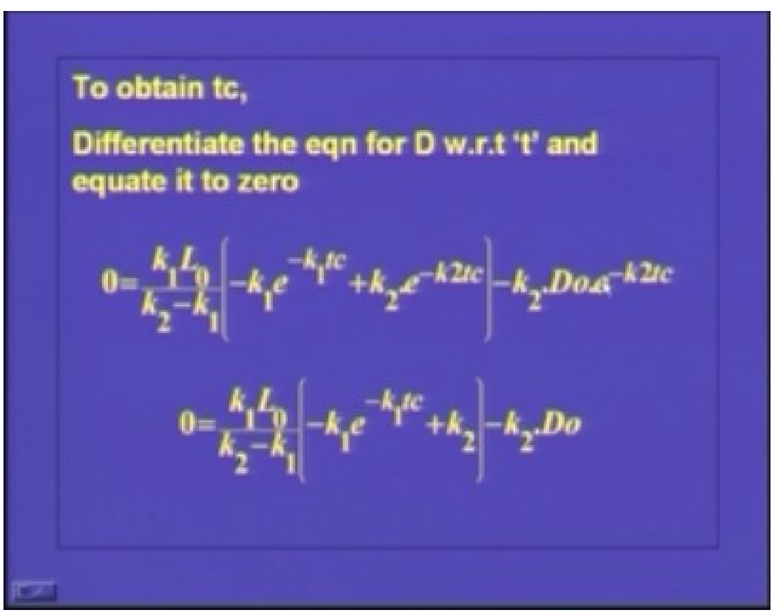

This is the expression for D (Refer Slide Time: 21:15) K_1 L_0 by k_2 minus K_1 into minus K_1 into e raised to minus K_1 tc plus k_2 into e raised to minus k_2 tc minus k_2 into D_0 into e raised to minus k_2 tc.

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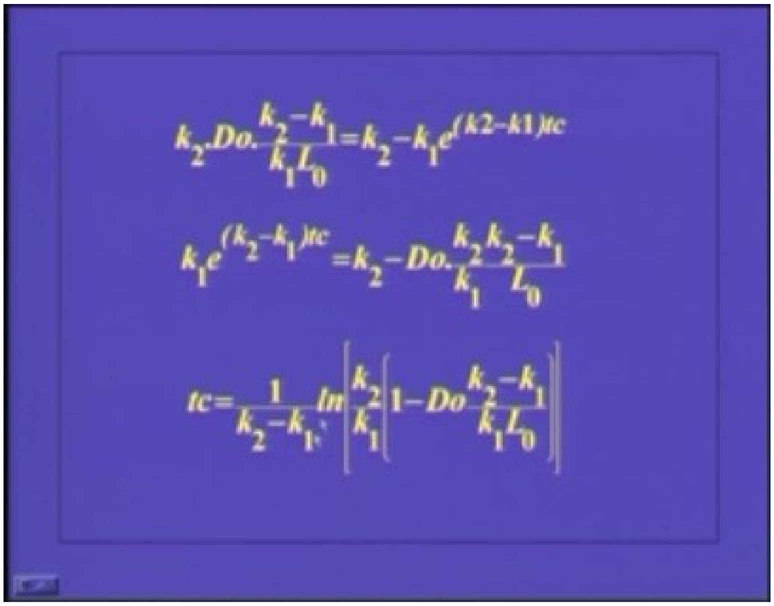

So we are differentiating it and equating it to 0 so you will be getting tc is equal to 1 by k_2 minus K_1 into ln k_2 by K_1 into 1 minus D_0 into k_2 minus K_1 by K_1 L_0 or the time can be calculated based upon K_1 value, k_2 value, D_0 value and L_0 value. All these values are known to us so we can find out what is the tc or the critical time at which the minimum dissolved oxygen concentration can occur in the stream.

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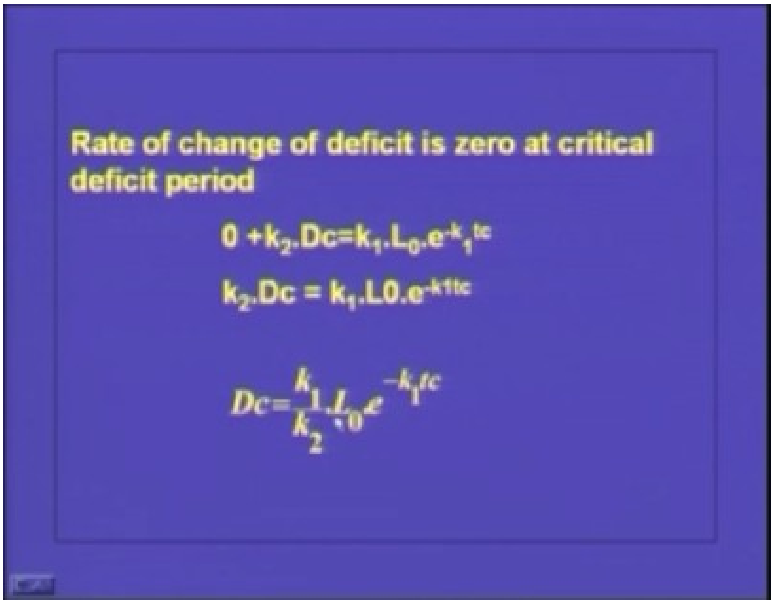

So once we know the critical time we can substitute this tc value here and we can find out what is the Dc value or the critical deficit and we can also find out the concentration corresponding to that one because we know what is the critical deficit and we know what is the saturation concentration so Cc or the critical concentration is nothing but Cs minus Dc. So by using this dissolved oxygen model we can find out what is the maximum organic load we can discharge into a stream so that the dissolved oxygen concentration of the stream will not be going below the specified minimum value. That is the most important use of this dissolved oxygen model but there are certain disadvantages of this Streeter Phelps equation because they have considered only one discharge point for the waste. But we know that if you take a stream it will be having many point sources of waste water coming to the system so we have to make the oxygen sag curve for each discharge point and you have to superimpose that one then only we will be getting the actual oxygen sag curve.

This dissolved oxygen model has not taken care of the algal respiration or the re-aeration due to photosynthesis. But if the river velocity is very very less then photosynthesis will contribute significantly to the dissolved oxygen concentration. That is another problem. and we know that apart from the organic matter other constituents like organic nitrogen, organic phosphorous etc will be exerting some amount of oxygen demand because if organic nitrogen in the form of ammonia is present we have seen that one mole of ammonia oxidation require around 4.52 moles of oxygen that means ammonia has to convert that to nitrite and nitrate so it requires lot of oxygen. Therefore, these things are not taken into account in the Streeter Phelps equation the simplest model available for predicting the dissolved oxygen profile of a stream.

So if you want to get the actual dissolved oxygen profile we have to taken into account all these other reactions and other parameters like photosynthesis, organic nitrogen, organic phosphorous and algal, decay etc. nowadays many commercial packages are available which takes care of all these aspects and we can get the dissolved oxygen profile of the stream.

Now we will see how to discharge the waste water to the streams. Either we can put the discharge point like this. That means it is below the water level in high water level period and it is above the water level during summer or low water level period. This is the example.

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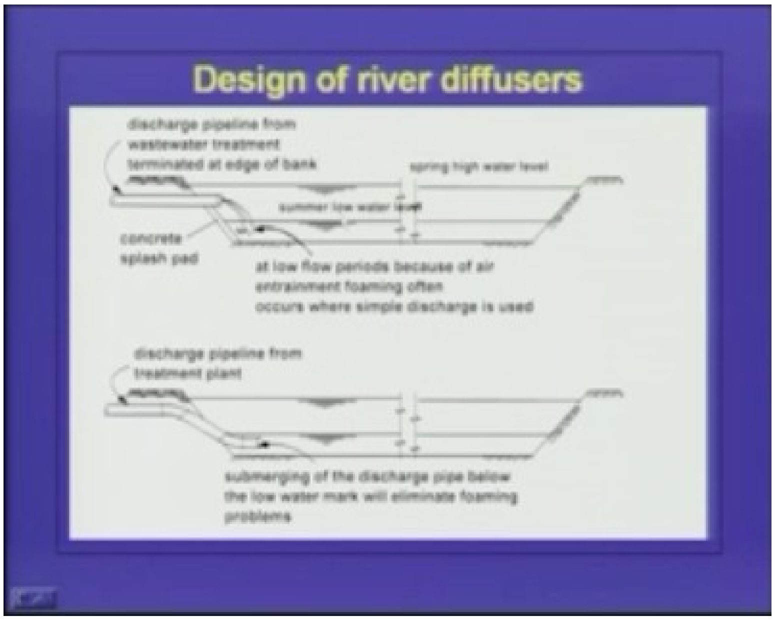

So this is the discharge pipeline from the waste water treatment plant and here we usually give a concrete splash pad to avoid the erosion and at low flow period because of air entrainment foaming often occurs where simple discharge is used. That is another drawback of this system. Because in summer or in low water level the water is falling from such a height so because of turbulence and air entrainment foaming can take place here. So if you want to avoid the foaming it is always advisable to put the pipeline in the bottom most of portion of the stream. That is what is shown here.

Discharge pipeline from the treatment plant submerging of the discharge pipe below the lower water mark will eliminate foaming problems. So, according to the requirement we can put either this way or this way and whenever we discharge the treated effluent we have to use proper diffusers and to avoid the foam we have to submerge the discharge pipe.

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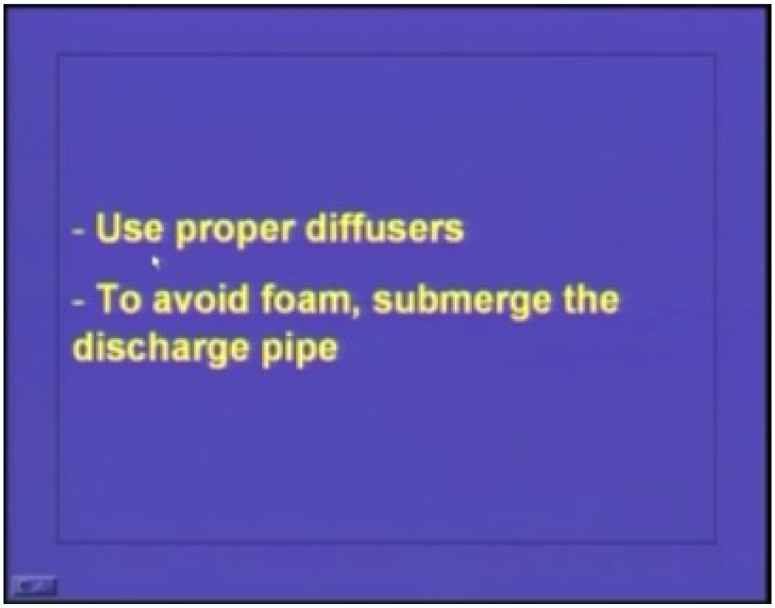

Another water body usually the waste water is being disposed into estuaries. Estuaries is the zone where the river meets the sea. And in estuaries because of the tidal action increased dispersion will take place and because of the dispersion there will be the dilution of the waste water of dilution of the pollutant will be taking place.

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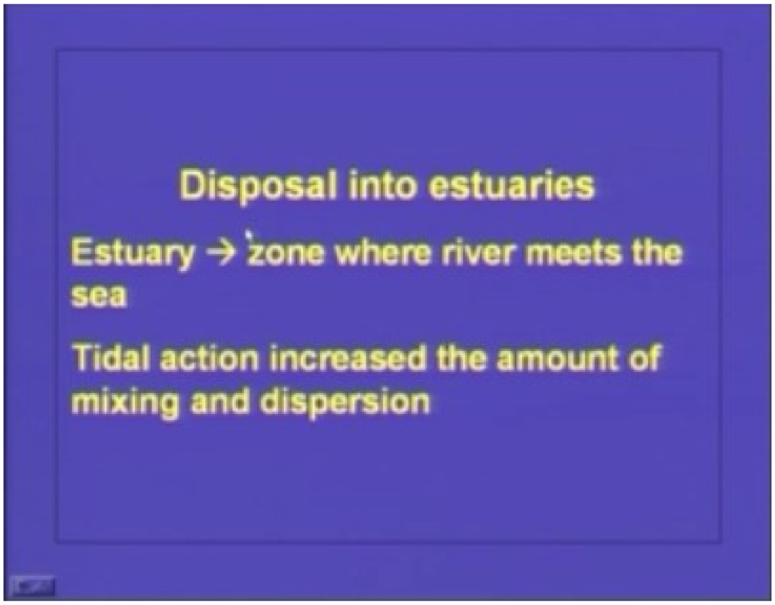

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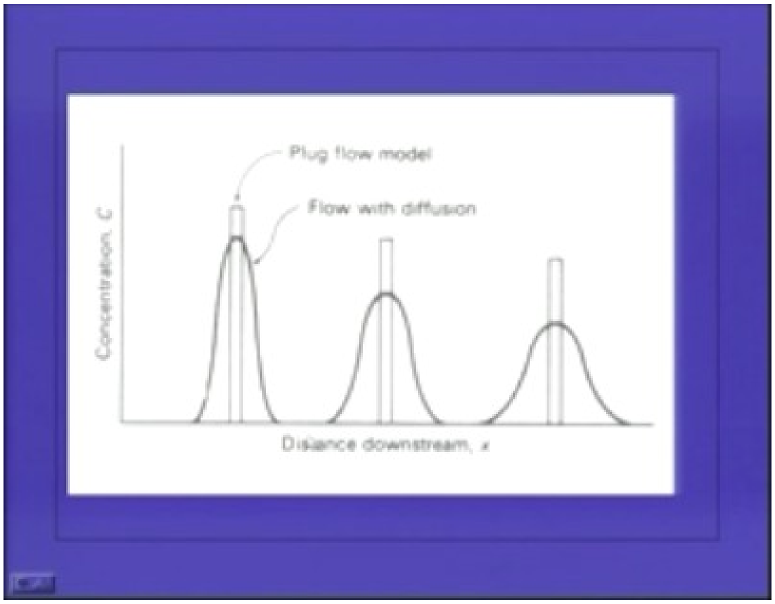

This is the concentration and distance in the downstream, this is the plug flow model. If it is a completely plug flow you will be getting this type of concentration. but because of the diffusion what will happen is this will be getting diluted like this (Refer Slide Time: 27:24) and as the distance increases the concentration will be coming like this and coming like this so it will be almost uniformly getting this after a particular distance.

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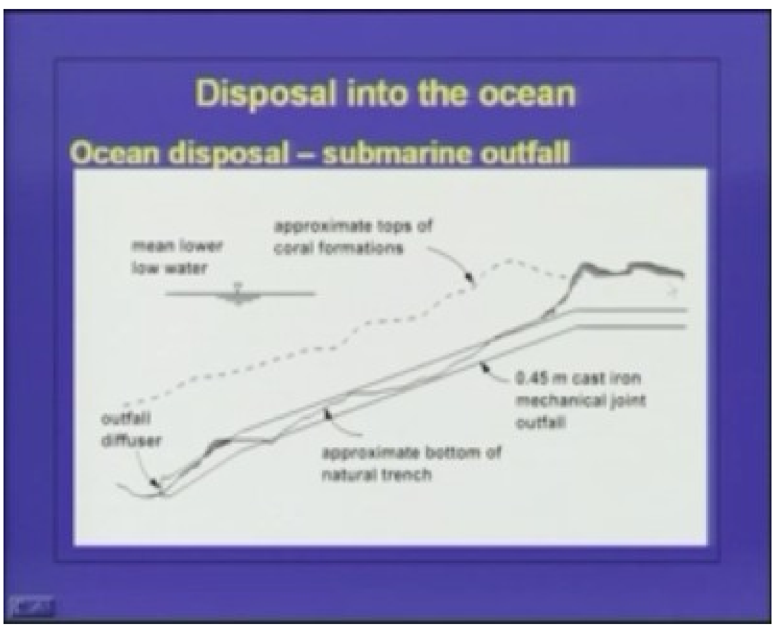

Another water body where disposal is possible is ocean. in ocean disposal usually submarine outfalls our use. This is the waste water coming from a treatment plant and this is the outfall disposal and this is the mean low water level and whenever we put the ocean out falls it is always advisable to keep around 500 m from the beach.

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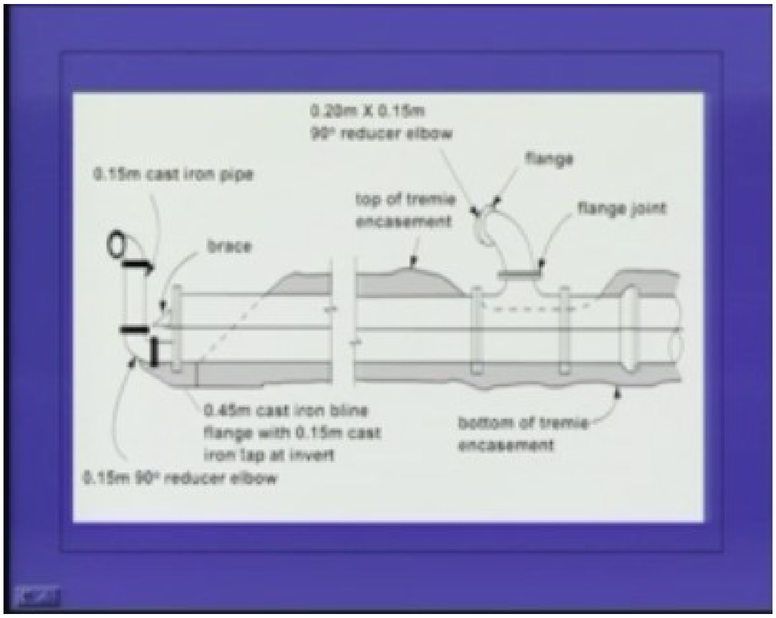

This is a typical cross section of an ocean out fall and we will see how the waste water mixing is taking place once we discharge the waste water either in the ocean or in the estuary. The two phenomena which are responsible is one is advection and another one is diffusion. There is certain amount of bio degradation that also takes place in this region. So whenever we design outfalls the receiving water standards on dissolved oxygen, bacteria, floatable material, nutrients and toxicants should be satisfied because at any case all these water bodies will be having lot of aquatic organisms so the dissolved oxygen concentration should not fall below the specified minimum dissolved oxygen concentration.

Another thing is pathogenic bacteria. If the pathogenic bacterial concentration is more the aquatic organism will be getting affected by the micro organisms so the effluent discharge standard should be met even when we discharge the effluent to the existing huge water bodies.

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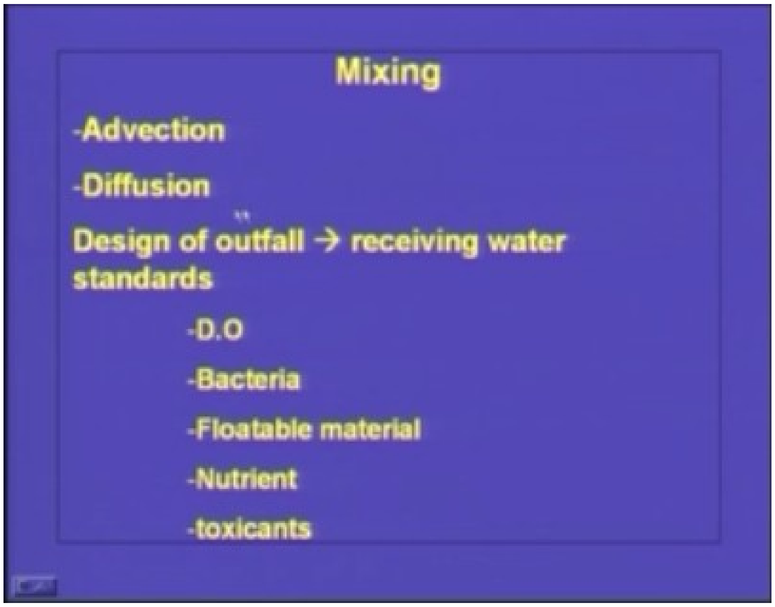

Floatable material: if floatable materials are there the treated effluent will be making obscene scenes so it is always advisable to remove all the floatable materials. And if the nutrient concentration is high what will happen algal blooms will be taking place. that means the essential nutrients like nitrogen and phosphorous if it is more than the minimum requirement then the algal growth will be very very high that will be affecting the water quality and the effluent whatever is coming to these water bodies should not contain any toxicants or the toxicants concentration should be within the specified limit otherwise it will be affecting the uses. So each and every water body will be having a specified standard. This standard is made based upon the beneficiary use or the use of that water because if the stream in the downstream end is used for drinking water purpose then definitely the standard will be more and more stringent and if it is only used for navigational purpose then standard will be little more relaxed. Therefore, depending upon the downstream use of the water body the receiving water standards have been put up and we have to satisfy that standard after this advection, diffusion and bio degradation. Whatever is ultimate concentration coming should be within the permissible limit.

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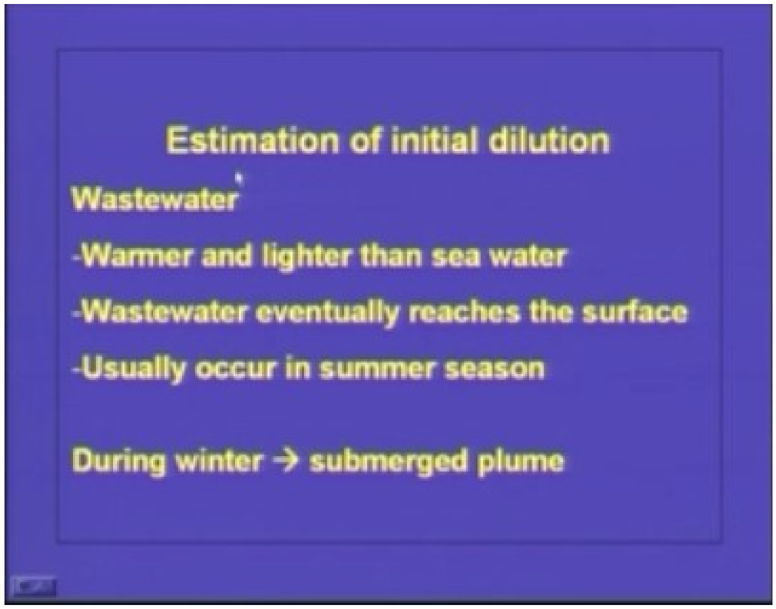

How can we estimate the initial dilution whenever we discharge it into the ocean? It is depending upon the climatic conditions. So what will happen when we discharge the waste water into the ocean? the waste water will always be warmer and lighter compared to the sea water so what will happen is even though your ocean disposal point is much below the low water level the wastewater eventually reaches the surface because as it comes out of the disposal point some velocity will be there so with that velocity or with the momentum it will be rising and compared to the surrounding water in the ocean this water temperature will be higher and the density will be lighter so this water will be having a density to push apart the ocean water and come up so it will be forming a layer over the ocean water. Usually this occurs in summer time because in summer time most of the time the waste water temperature is much much more than the sea water or the ocean water temperature. During winter the waste water temperature will be less compared to the sea water but the density is density is also less so it will not be able to come up to the top of the ocean so it will be getting submerged in between the ocean water.

Therefore during winter most of the time you will be getting a submerged plume whereas in winter the sea water will be coming into the top of the ocean and forming a floating layer. So it is always advisable to avoid the floating layer because if the water is floating on the surface of the sea water then during tides and because of the waves all these pollutants will be coming to the beach and that will be adversely affecting the people whoever is going to the beach or using the beach for swimming purpose.

We have seen how we can dispose the effluent coming from the treatment plants but not only water bodies can be used for that purpose sometimes we can go for land disposal also. In the land if you put the waste water it will be acting as a water source for the land moreover waste water will be having lot of organic matter, nutrients etc present in the system so what will happen is these nutrients can be utilized by the plants and a high degree of treatment can be achieved. This itself is known as land treatment systems.

Land treatment systems or phytoremediation: Use of plants, the soil surface and the soil matrix for wastewater treatment. This is what is known as land treatment system.

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Land treatment of wastewater can be done either using irrigation or by rapid infiltration or by over land flow.

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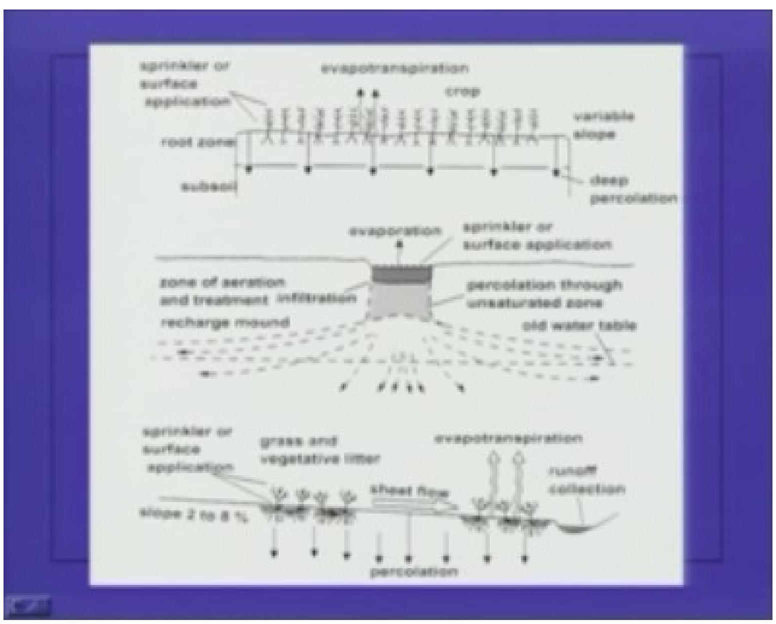

These are the schematic of each and every process. This is the irrigation. This is your land and these are the plants (Refer Slide Time: 34:20) so you are sprinkling the water on the surface either by using sprinklers or by surface application you can supply the water here so the water will be percolating. this is the root zone and in the root zone the soil will be loose and lot of micro organisms will be there so those micro organisms will be taking care of the organic matter and the other nutrients whatever is present in the system and it will be getting removed and the left over water whichever is relatively clean will be coming through this soil or it will be percolating and finally it will be reaching the down water.

This is the other thing (Refer Slide Time: 35:00) that is rapid infiltration. What we are doing is we make a drench and here the waste water or the effluent whatever is coming from the treatment plant is applied so infiltration is taking place and percolation through the unsaturated zone. This was your existing water table so because of this infiltration recharge is taking place, we can see that the water table is increasing like this.

This is the example of over land flow (Refer Slide Time: 35:33). What is happening is this is the grass under vegetative flitter so they will be utilizing the organic matter and the nutrients whatever is present here so the water will be getting relatively clean and finally it will be coming to the existing water bodies this is relatively cleaner than whatever we have applied to the land. These are the different methods of land treatment.

There are different aspects. If you want to go for irrigation we can apply using sprinklers or surface irrigation and for rapid infiltration usually surface application is used. For overland flow usually sprinklers or surface applications can be used. And another treatment method is wetland application. Here also sprinklers or surface application can be used and for subsurface application subsurface piping is used. These are the different methods used for the water treatment using land.

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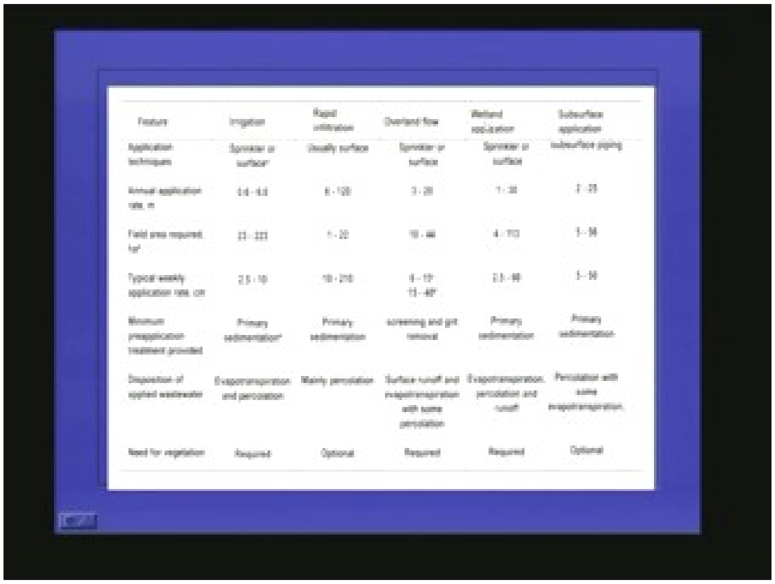

Feature	Irrigation	Rapid infiltration	Overland flow	Wetland application	Subsurface application
Application techniques	Sprinkler or surface*	Usually surface	Sprinkler or surface	Sprinkler or surface	Subsurface piping
Annual application rate, m	0.6 - 6.0	6 - 125	3 - 20	1 - 30	2 - 25
Field area required, ha*	23 - 223	1 - 22	10 - 44	4 - 113	3 - 56
Typical weekly application rate, cm	2.5 - 10	10 - 210	6 - 15* 15 - 40*	2.5 - 60	5 - 50
Minimum preapplication treatment provided	Primary sedimentation*	Primary sedimentation	Screening and grit removal	Primary sedimentation	Primary sedimentation
Disposition of applied wastewater	Evapotranspiration and percolation	Mainly percolation	Surface runoff and evapotranspiration with some percolation	Evapotranspiration, percolation and runoff	Percolation with some evapotranspiration
Need for vegetation	Required	Optional	Required	Required	Optional

Nowadays the wetland applications and subsurface applications are gaining more and more attention. If you want to go for this land treatment the waste water whatever is coming from the treatment plant should be meeting certain conditions. the BOD should be less than at least 15 mg per litre and suspended solids if you go for overland flow should be less than 20 and if you are going for irrigation should be less than 5 mg per litre and ammonia nitrogen should be less than 2 mg per litre at any case and total nitrogen should be less than 5 to 8 mg per litre and total phosphorous should be less than 0.03 mg per litre in case of irrigation and for rapid infiltration it should be less than 5 mg per litre and overland flow it should be less than 6 mg per litre.

The reason is if you put the waste water high pollutant concentration the land will not be able to take care of the pollutants properly so some of the pollutant will be left over after the land treatment and it will be percolating and it will be going and meeting the ground water so even the existing ground water whatever is there will be getting contaminated.

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Constituent	Irrigation[a]		Rapid infiltration[b]		Overland Flow[c]	
	Average	Maximum	Average	Maximum	Average	Maximum
BOD	< 2	< 5	2	< 5	10	< 15
Suspended solids	< 1	< 5	2	< 5	10	< 20
Ammonia nitrogen as N	< 0.5	< 2	0.5	< 2	0.8	< 2
Total nitrogen as N	3	< 8	10	< 8	3	< 5
Total phosphorous as P	< 0.1	< 0.3	1	< 5	4	< 6

And in overland flow the wastewater will be flowing over the land and plants are supposed to take care of all the left over pollutants in the water. But if the pollutant load is very very high the plants whatever is present in the system will not be able to take care of all the pollutants so the left over pollutants will be going and meeting the existing water bodies along with the water that will contaminate the ground water and the surface water sources. We will see each one in detail for example irrigation. Irrigation is the application of effluent to the land for treatment so the purposes are to meet the plant needs and it will also give physical, chemical and biological treatment to the effluent and application can be done by sprinkling or by surface techniques which we have already seen.

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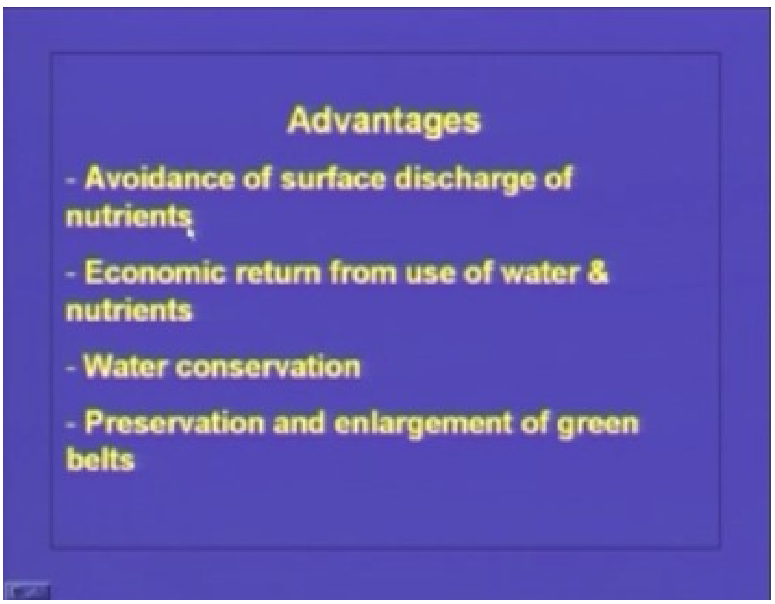

The advantages of irrigation is avoidance of surface discharge of nutrients because if you discharge it to the existing water bodies lot of nutrients will be going to the existing water bodies and that will be increasing the algal growth and it will also give economic return because the irrigation water quantity the pure water can be reduced and whatever is the nutrient present in the waste water or the treated effluent can be used by the plants so the fertilizer requirements can be reduced considerably.

The next one is water conservation. We are not wasting the water.
Preservation and enlargement of green belts: When we have lot of water available with high nutrient content naturally the preservation and enlargement of green belts happen.

Whenever we apply the effluent for irrigation the loading rate is important. The place where water scarcity is there we can go for 2.5 to 7.5 centimeter per week and when water availability is not a problem then we can go for maximum hydraulic loading of 6 to 10 cm per week. Therefore, it is 2.5 to 7.5 cm where the water scarcity is there and when water availability is not a problem you can for a higher loading.

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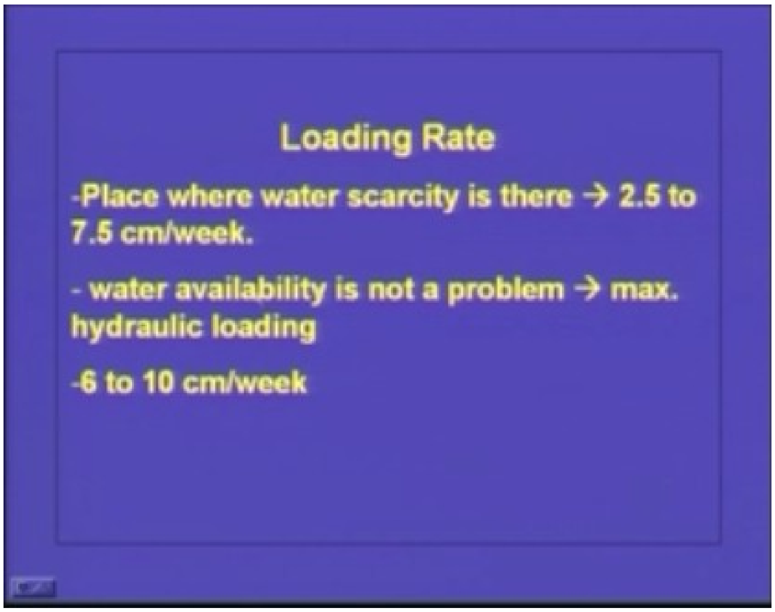

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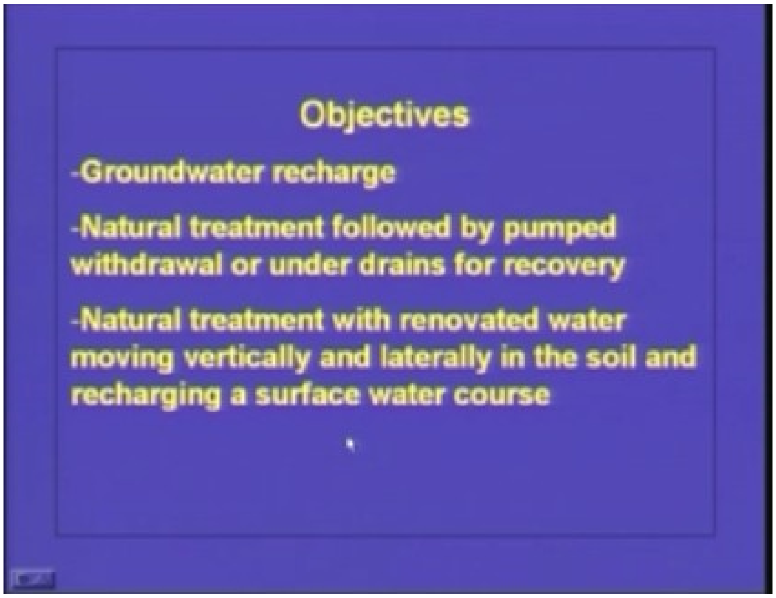

The major objectives are groundwater recharge and natural treatment followed by pumped withdrawal or under drains for recovery. After irrigation if you can place a proper drainage system we can collect the water for reuse.

The other objective is natural treatment with renovated water moving vertically and laterally in the soil and recharging a surface water course. That is also possible because of this method. Now we will see what is happening in overland flow.

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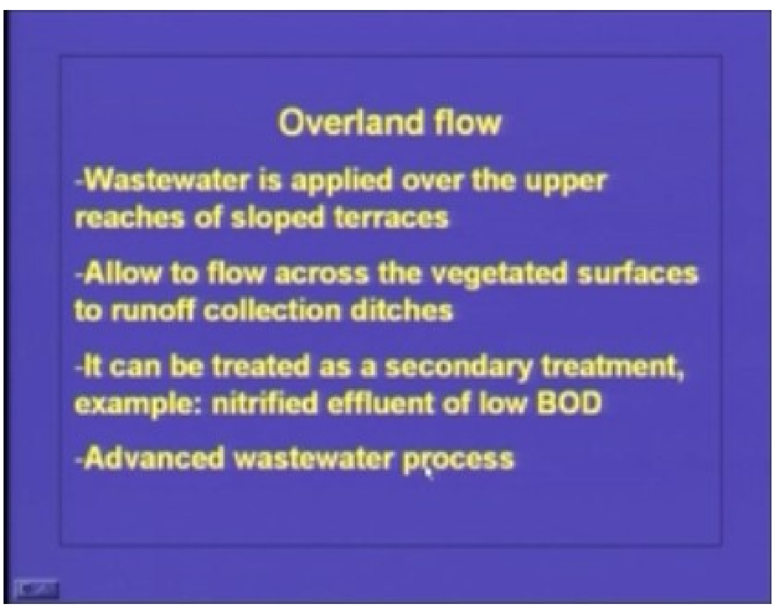

1) The wastewater is applied over the upper reaches of the sloped terraces
2) Allow to flow across the vegetated surfaces to runoff collection ditches

3) It can be treated as a secondary treatment, for example some degree of nitrification will be taking place if the BOD of the wastewater is low and
4) Advanced wastewater treatment can also take place

The reason is the soil will be acting as an absorbent so it will be taking care of most of the other organic matter present in the system.

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What are the fundamental considerations when we go for land treatment?
The wastewater characteristics and treatment mechanisms are very very important. For example, if the organic matter content, this organic matter whatever is present in the effluent will be utilized by the micro organisms whatever is present in the soil. So if the organic matter content is less it's fine the soil micro organisms will be able to utilize the organic matter but if the organic loading is high what will happen is the oxygen available will be limited and the micro organism will try to utilize the organic matter so anaerobic condition will prevail in the soil so as a result what will happen is lot of odorless gases will be generated and the entire place will be place will become non usable.

Similarly if the nitrogen concentration is within the permissible limit it will be acting as a nutrient for the plant but if the nitrogen concentration is very very high what will happen is the ammonia nitrogen has to be converted to nitrate. But if sufficient oxygen is not there nitrification will not be proper, similarly for phosphorous also.

Another one is the presence of exchangeable cations. If large quantity of these exchangeable cations are present in the system that will be changing the permeability of the soils or the soil characteristics will be changing. So this one we can measure in terms of SAR, this is noting but sodium absorption ratio. This can be calculated using this formula Na divided by root of Ca plus Mg by 2.

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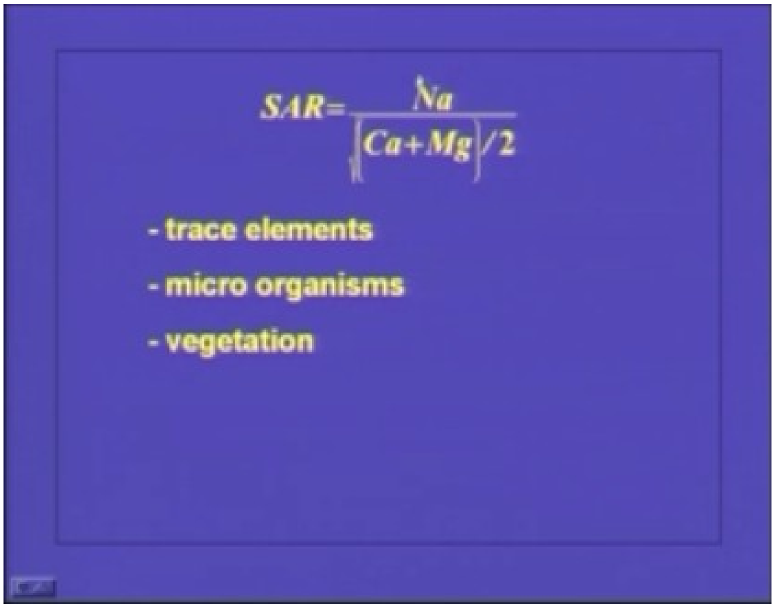

All the concentrations are expressed in terms of milli equivalents per litre. If SAR is more than 9 it is not advisable. We should be careful about trace elements like heavy metals. If it is present in the soil we cannot destruct them so what will happen is if heavy metals are present the root zone will be absorbed in those heavy metals and it will be getting accumulated in the plant. So when we consume any part of the plant what will happen is it will be coming to us.

Similarly the micro organisms, many pathogenic micro organisms may be present in the effluent coming from the treatment plants and if we use that water for the irrigation purpose and use the vegetable in the raw form it might be harming the health of the people whoever is using that vegetable as these micro organisms may be present in the raw vegetables.

Another important thing is the vegetation, the type of crops or the type of plants present in the system. Because if the plant is able to take care of lot of nitrogen, phosphorous and if it requires lot of water then that type of a plant or the vegetation is preferable for land treatment.

Another important aspect we have to consider is the public health because the treated water will be containing lot of bacteriological agents so it can cause diseases and if the land treatment is not proper what will happen is the groundwater quality will be getting affected because partially treated water will be percolating to the ground water and entire groundwater quality will be getting affected. Another one is the crop quality. It will also be getting affected.

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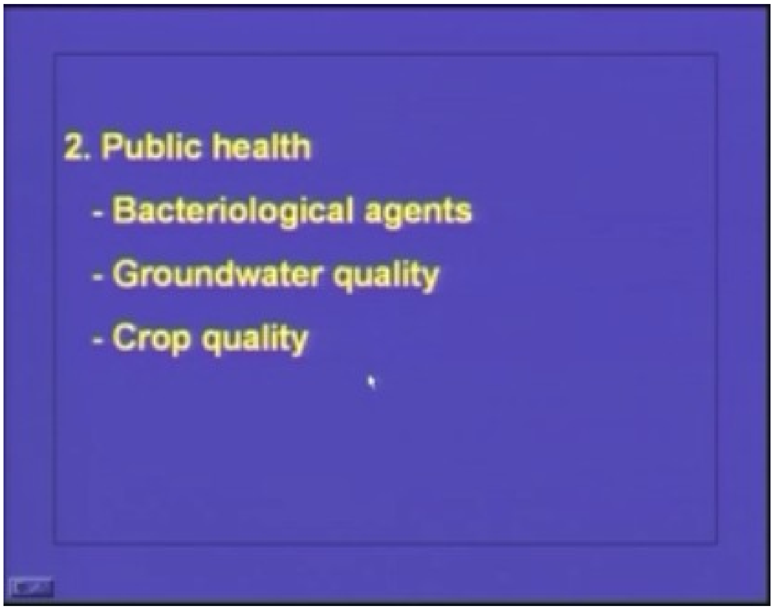

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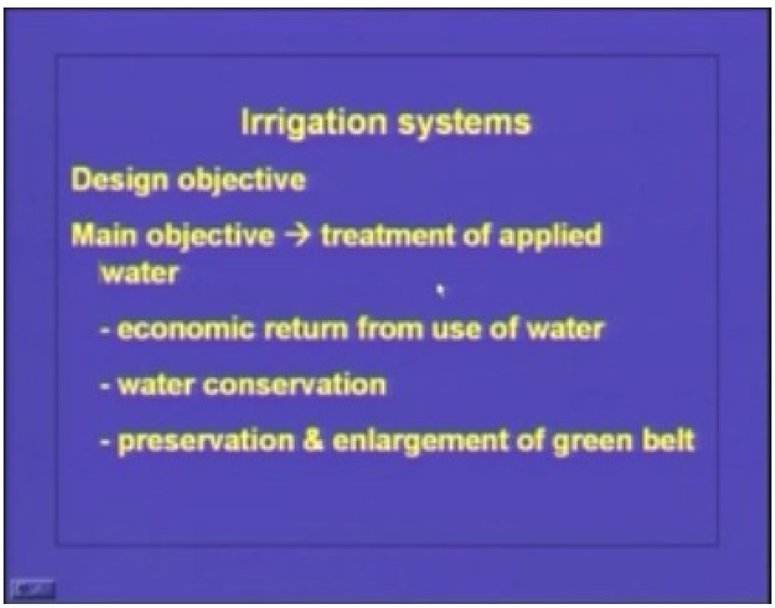

And when we go for the irrigation systems what all are the design objectives we have to consider? The main objective is the treatment of applied water as how much treatment we can provide. This is very very important.

The other one is what is the economic return from the use of water?

The third one is what is the extent of water conservation we are doing and what is the extent of preservation and enlargement of green belt possible?

For the objectives of treatment the hydraulic loading is very very important and is limited to the infiltration capacity of the soil. If the hydraulic loading is more than infiltration capacity the water stagnation will be taking place and under drains can increase the allowable loads. Because whatever is percolating through the soil if we can collect it and pump it up then the loading can be increased.

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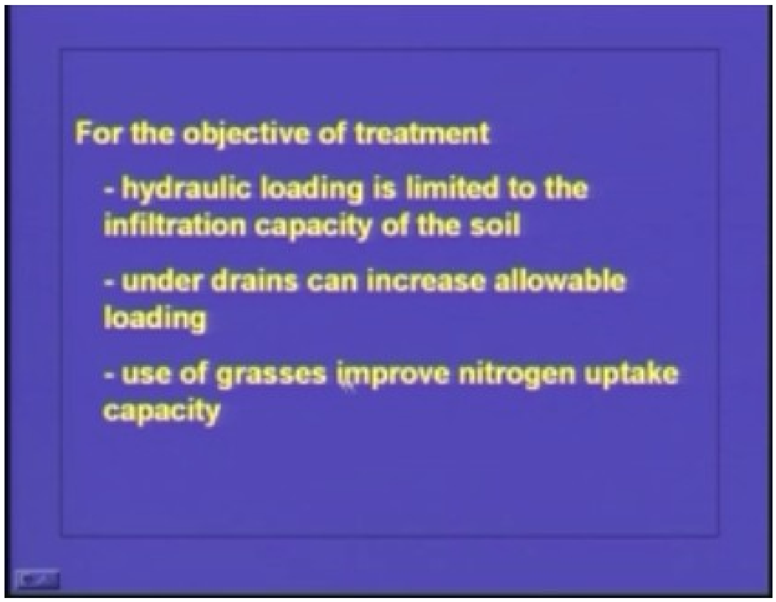

The use of grasses improves the nitrogen uptake capacity.

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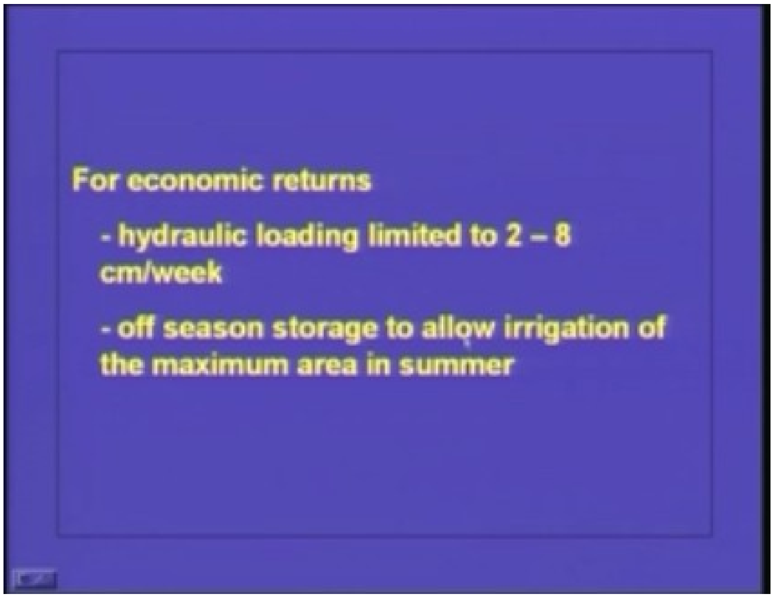

For economic returns a hydraulic loading of 2 to 8 cm per week is recommended and off season storage to allow the irrigation of maximum area in summer is essential. This is because in winter the water consumption will be less so we may have to star the effluent for the irrigation purpose in summer.

What are the pre-application treatments required?

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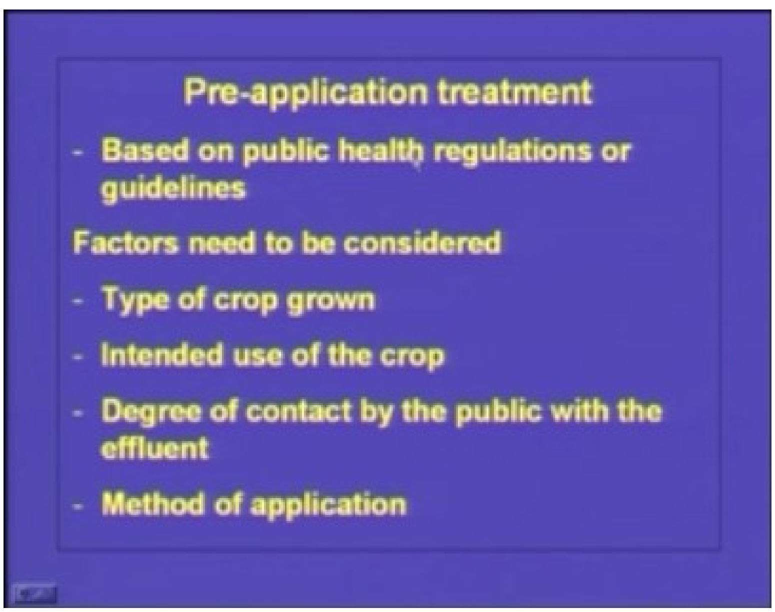

It is based on the public health regulations or guidelines. So based upon the regulations we have to achieve the treatment.

The factors need to be considered for this irrigation are;

- type of crop grown
- intended use of the crop
- degree of contact by the public with the effluent and
- method of application

All these things are very very important. So if you are going for food crop naturally we have to be very very careful because the bacteriological agents whatever is present in the waste water can affect the crop quality and that will invariably affect the health of the public.

The degree of contact by the public with the effluent: If the plant needs continuous attention then those plants have to be treated so people will be getting into the land to treat those plants which will lead to more chances of diseases being caused to the plants which will affect the life of the plants which is not good for the plants. The other one is the method of application.

Again, we have the climate and storage which is also an important factor. Wastewater application is restricted only to the growing season because then only the plants can utilize the nutrients and storage of one to three months is moderate in moderate climates and four to seven months in cold climates are required.

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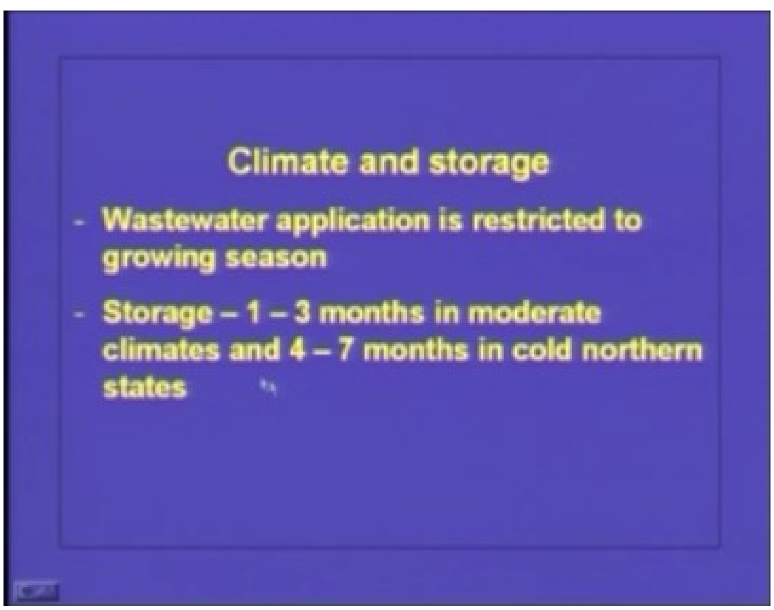

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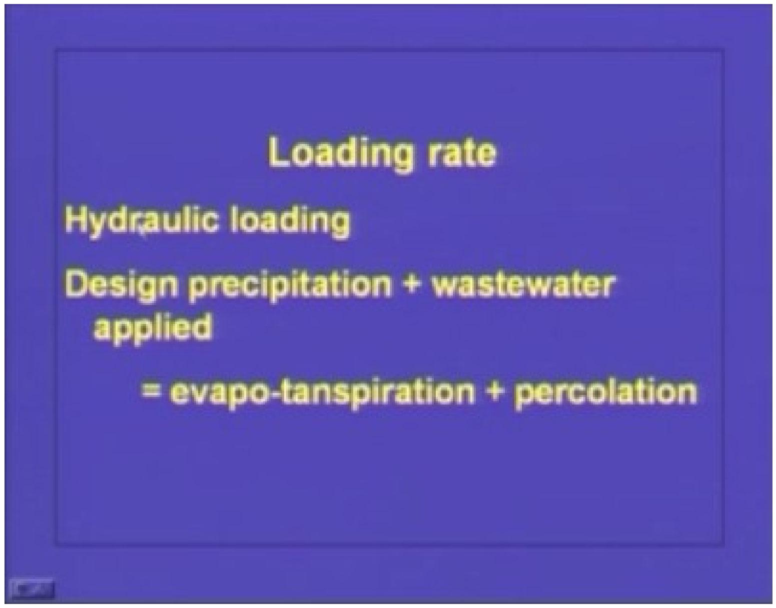

We have already seen the loading rate and hydraulic loading rate be such that the design precipitation plus wastewater applied should be equal to the evapo transpiration plus percolation, this is very very important. If you add more water
Then water logging will be taking place.

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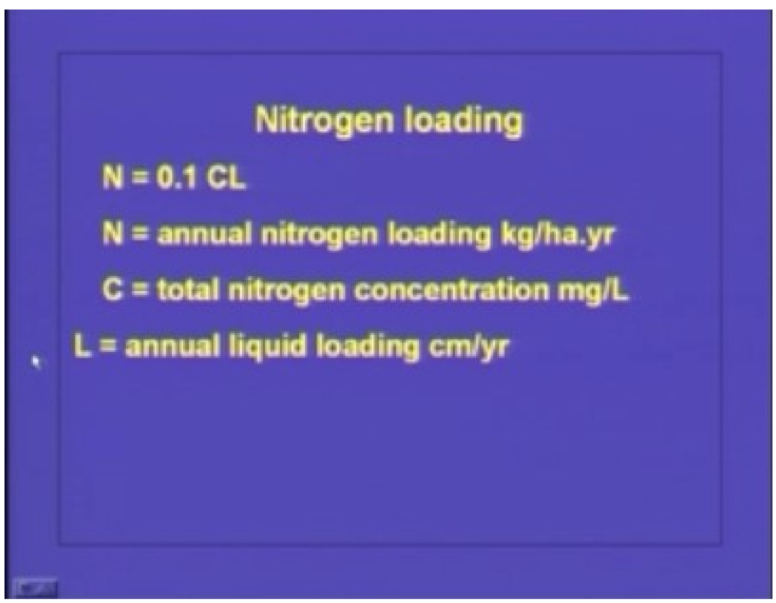

This is the nitrogen loading because nitrogen loading will be based upon the nitrogen uptake capacity of the plant. So N equal to 0.01 into CL where N is the annual nitrogen loading kg per hectare year and C is the total nitrogen concentration in the effluent that is given in milligrams per litre and L is the annual liquid loading centimeters per year. Similarly for phosphorous also we can calculate up to what extent of phosphorous we can give.

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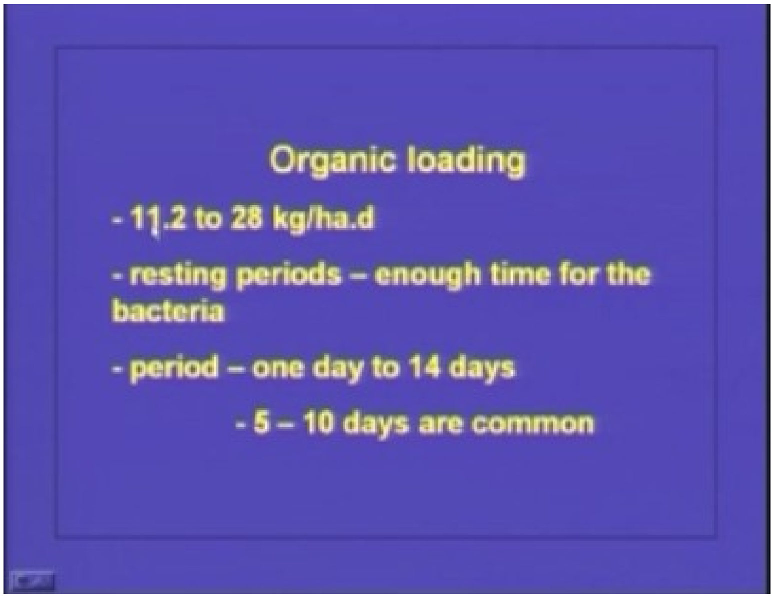

This is the organic loading. The recommended organic loading is 11.2 to 28 Kg hectare per day. And land requirement is based upon the organic loading, we can find out the field area required. It is equal to 3.65 Q by L where Q is flow rate in meter cube per day and L is the annual liquid loading centimeters per year and field area will be getting in terms of hectares.

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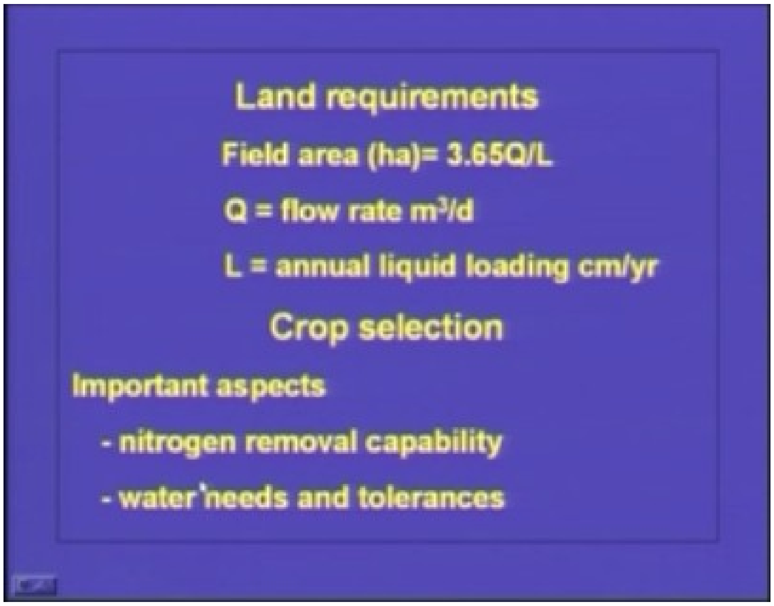

Whenever we take the crop the important aspects are nitrogen removal capability and water needs tolerance. Other systems are wet lands and aquaculture.

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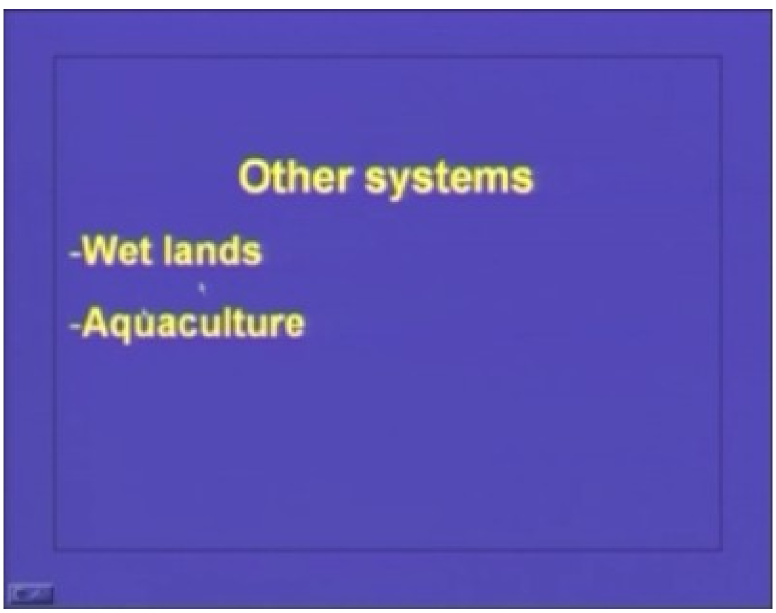

Now we will see the direct and indirect reuse of wastewater.

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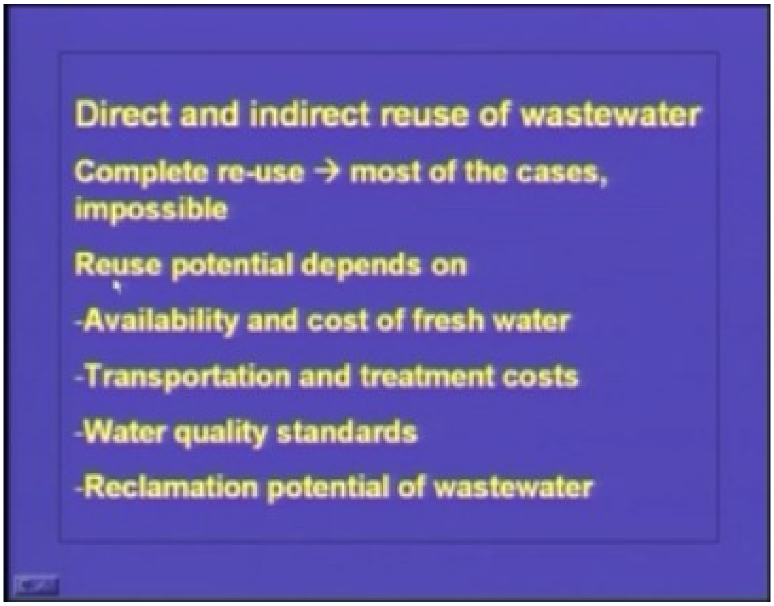

Nowadays this reuse of water is gaining much more attention. But we all know that complete reuse of water is impossible in most of the cases. The reuse potential depends upon;

- The availability and cost of fresh water
- transportation and treatment costs
- Water quality standards and
- Reclamation potential of wastewater

Why we have to go for the reuse?
The need is to meet the increasing water demand. It is because we know that the water is not available in plenty in all the locations so we have to meet the increasing water demand.

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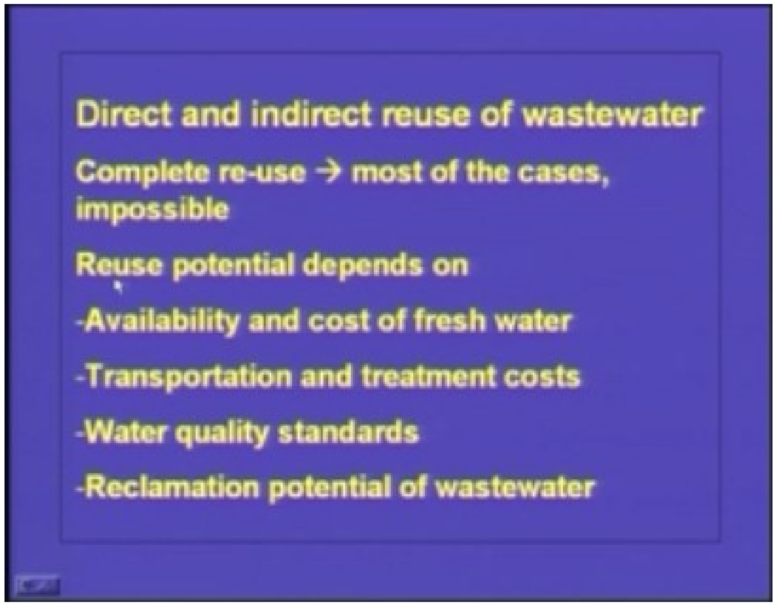

The second one is to protect the water bodies. We know that the effluent whatever is coming from the treatment plant will be having some amount of pollutant. But if we can treat that one and reuse it the pollutant whatever is going to the existing water body will be limited so we can protect the water bodies. These are the two major objectives.

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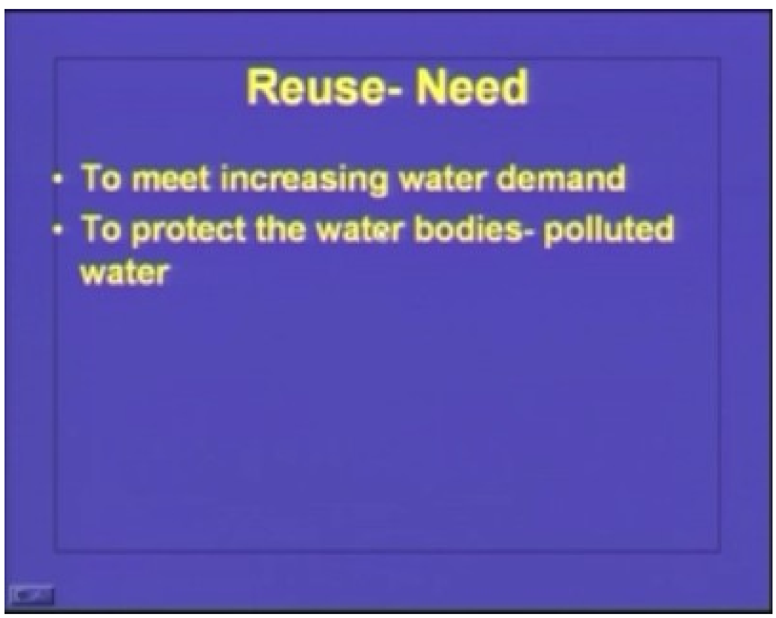

What are the different ways of water reuse?
The first reuse is sewage farming which is what we have seen till now. And when we talk about the water reuse what are all the public health and environmental issues of water reuse. First one is the constituents because there will be conventional pollutants, non conventional pollutants and emerging pollutants. In conventional pollutants it is organic

matter, nutrients and microbes. We know that the land can take care of this one.

Non conventional means volatile organic compound, surfactants, refractory organics etc. To a certain amount these are bio degradable but some are really refractory organics.

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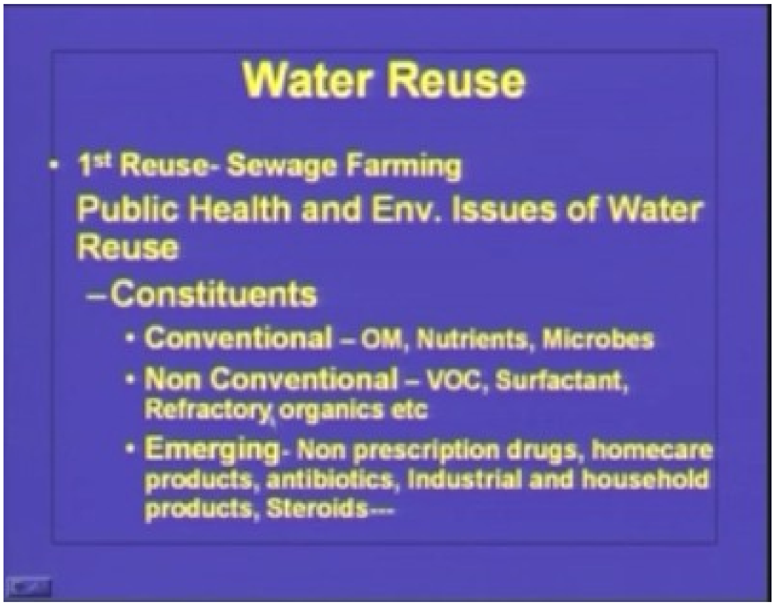

Emerging compounds creates maximum problem. Those include non prescription drugs, homecare products, antibiotics, industrial and household products, steroids etc. So in most of the cases these compounds will be coming out after the treatment also. So when we go for the reuse we should be aware of these compounds and what are the various effects of these compounds.

Another one is public health issues because of the emerging compounds and acute and chronic health effects of these emerging compounds. This acute and chronic health effects depend upon the concentration and exposure pathways.

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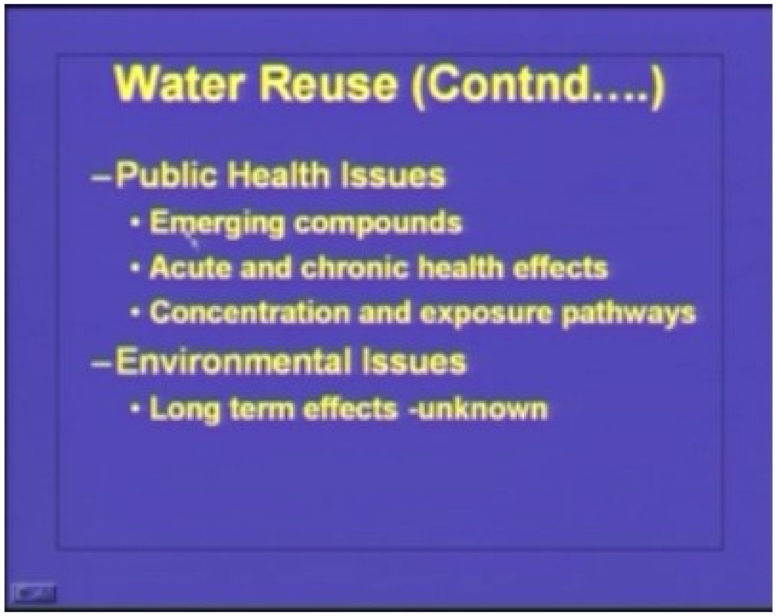

The third one is environmental issues because nobody knows what are the long term effects of this emerging compounds as most of them are very very new to the system. Hence these are the concerns. So if you want to go for this one, if you have to go for a risk assessment what type of a risk assessment we can do for the water reuse.

One is the hazard identification. Whenever we want to go for a reuse how to find out what are all the hazards involved in that process and second one is exposure assessment. So if you reuse the water what are the possible exposures because of the reuse? The third one is dose response assessment. We know what all are hazardous and what is the potential exposure so if you know these things then we can find out what is the dose response of the pollutant. If this much of concentration enters in the body we should know what will be effect in the body then we can find out what is the risk. Once we know the risk we can go for the risk management. This is very essential.

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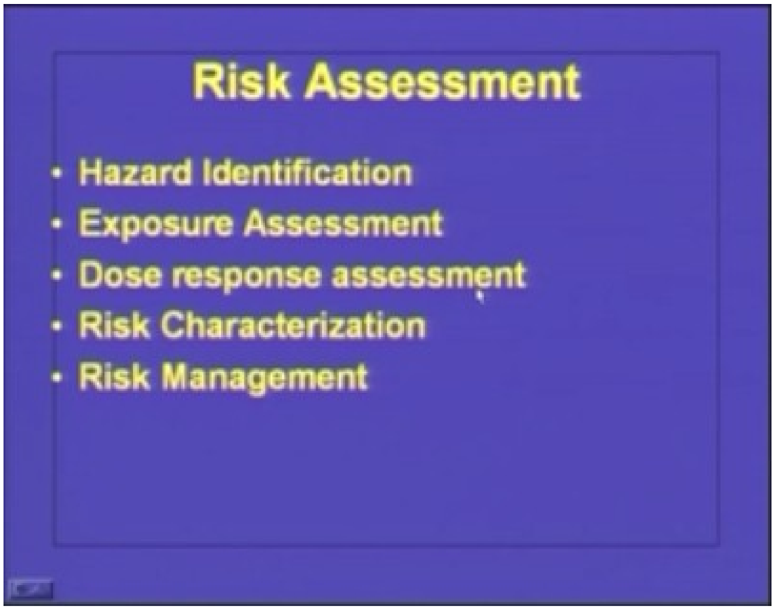

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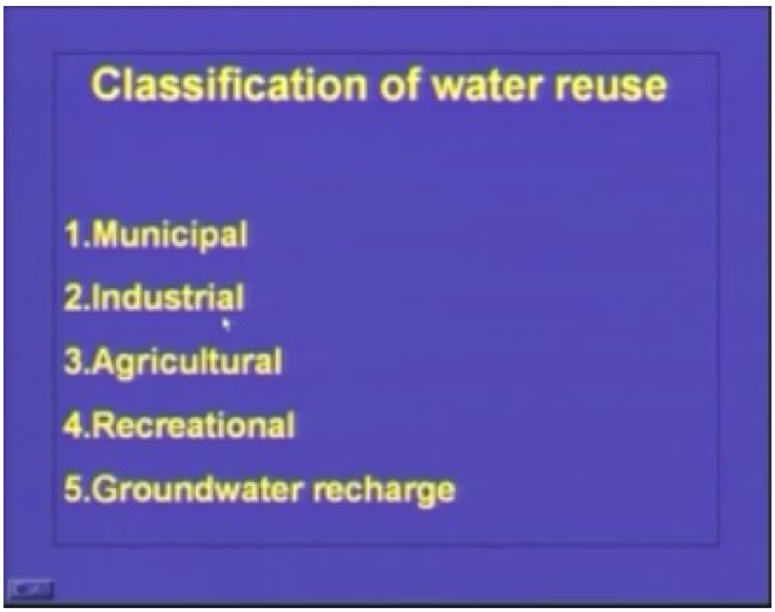

Whenever we go for a water reuse project, the risk assessment is very very essential. Now we will see the different ways by which we can reuse the water as follows:

- Municipal
- Industrial
- Agricultural
- Recreational
- Groundwater recharge

In municipal reuse the dilution in natural waters to the possible extent is taking place and afterwards the same water body is used for drinking purpose. We give treatment like coagulation, filtration, disinfection, adsorption etc. And most of the time this is practiced in emergency basis. Desalination and demineralization is also new to be done to remove all the compounds or all the molecules present in the water. This is technology feasible but the cost involved is very very high.

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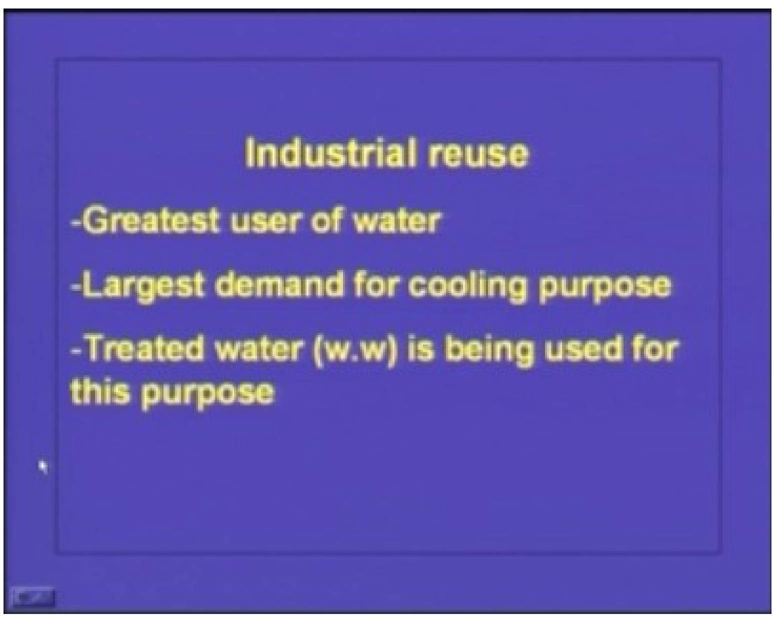

Industrial reuse:

The greatest user of water

The largest demand in industry is for cooling water. So, treated waste water can be used for cooling purpose. But the problems associated with this one are the scale formation, metallic corrosion, biological growth and fouling. The treatment required after the conventional secondary treatment are denitrification, lime soda softening, filtration and disinfection. Even after this treatment sometimes these problems are occurring in the cooling water circulation pumps.

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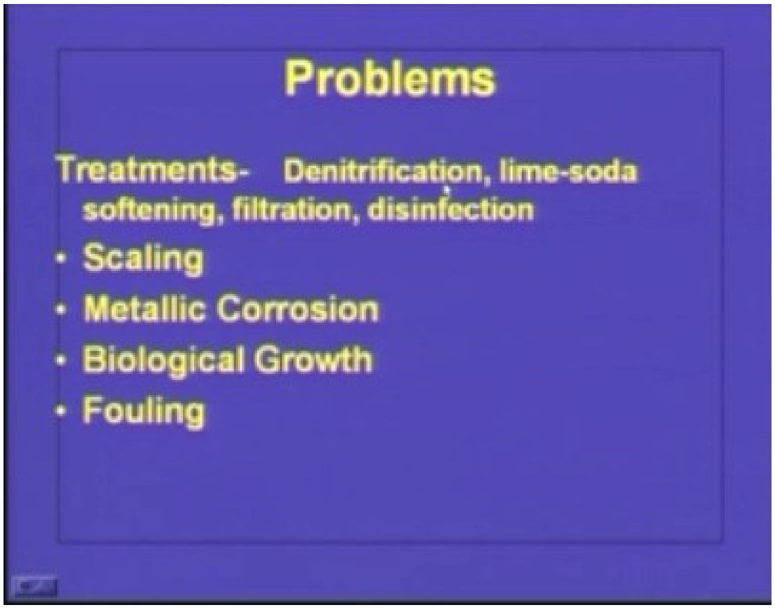

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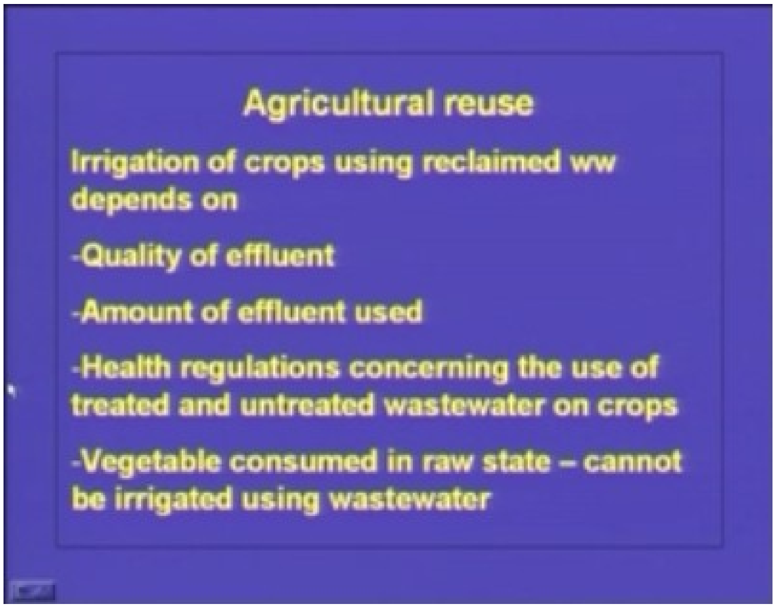

We have seen agricultural reuse in detail. The quality of effluent is very very important and the amount of effluent used is also important and we have to see the health regulations concerning the use of treated and untreated wastewater on crops. And vegetables consumed in raw state cannot be irrigated using wastewater because of the potential health hazard.

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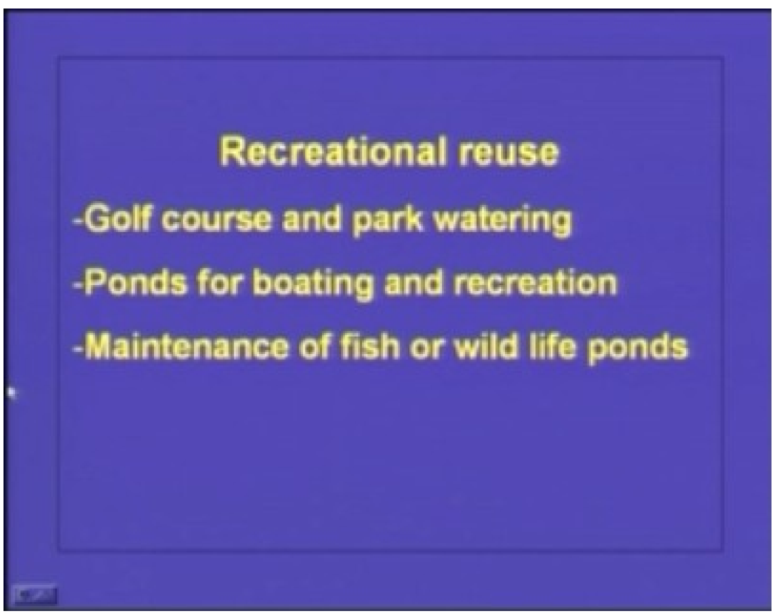

Now coming to the recreational reuse we can use the water for;

- Gold course and park watering
- Ponds for boating and recreation

- Maintenance of fish or wild life ponds

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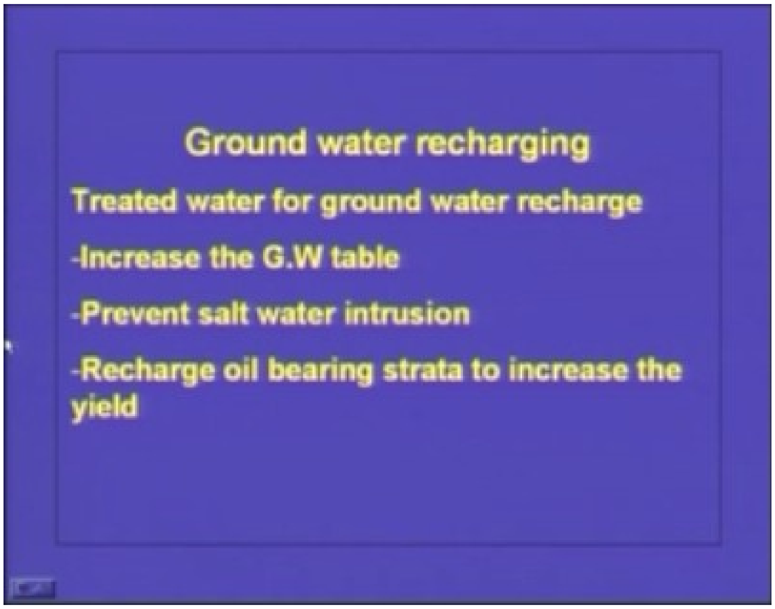

We can also use the effluent for ground water recharging.

- The treated water for ground water recharge
- Increase the groundwater table
- Prevent the salt water intrusion and
- Recharge oil bearing strata to increase the oil yield

But whenever we go for the groundwater recharge we have to see that all the pollutants whatever is of importance in terms of health is removed from the system otherwise entire ground water will be getting polluted because of the pollutant present in the system. That's why nowadays the land treatment is not advocated much. It is because in the land treatment earlier what was assumed is in the water zone or the root zone where the root of the plants are there lot of microbial activities will be there so that region will be able to take care of all the pollutants whatever is present in the system. But the traces study shows that the water will not be distributed evenly throughout the soil surface it will be taking some particular paths and coming to the groundwater so the groundwater will be getting polluted.

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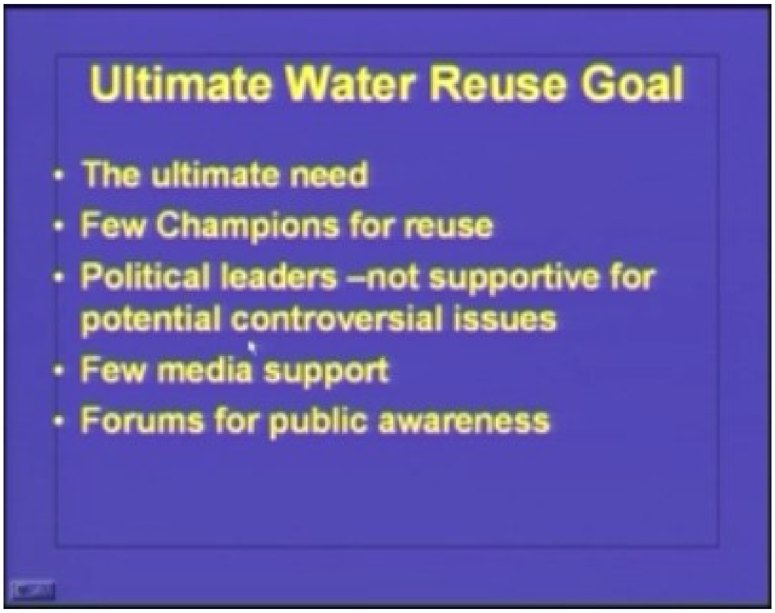

So if you want to go for the ultimate water reuse we have to do this we have to plan in the following way.

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First we have to;

- Assess the wastewater treatment and disposal need
- Assessment of water supply and demand is required
- Assessment of water supply benefits based on water reuse potential is essential

- Analysis of reclaimed water market
- Environmental and economical analysis
- Implementation plan financial analysis
- Public information program

All these things are essential before going for any wastewater reuse program. Though the technologies are available or many technologies are feasible even now the wastewater reuse especially for drinking water or domestic purpose is not gaining much attention because the cost involved is very high and public awareness is very very important for this purpose.

Now we will come to whatever we have seen today. We were discussing about dissolved oxygen model. We have seen that using that model we can get the dissolved oxygen profile of that stream and we will be able to find out what is the maximum deficit and the location where it is occurring. So based upon this we can manage the wastewater discharge into the stream. Then we have seen other disposal points estuaries and oceans then another method of handing the effluent whatever is coming from the treatment plant is land treatment. But nowadays land treatment is not advocated because of the partial treatment that is occurring in the system because many many non conventional pollutants and emerging pollutants are present in the wastewater most of the time the land is not able to take care of that one. And we can go for water reuse based upon the economy and the requirement of the reuse water.