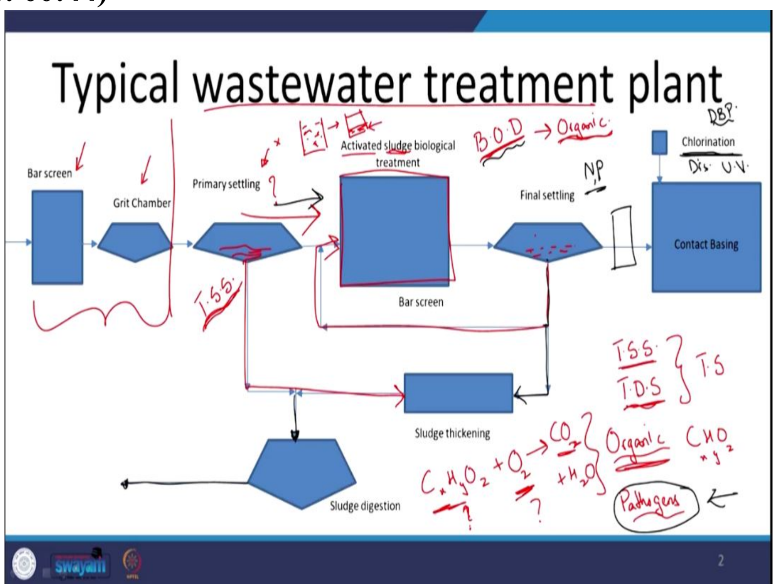
Water and Waste Water Treatment
Prof. Bhanu Prakash
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Lecture - 04
Review of Fundamentals

Hello, everyone, welcome back to the latest lecture session. Let us get into it. We were discussing generic aspects until now we looked at the video of the IIT Roorkee sewage treatment plant, just to get your juices flowing, and now we are going to get into the crux of the issue.

(Refer Slide Time: 00:44)



Wastewater treatment, I have water that is high in total suspended solids, has some dissolved solids, total dissolved solids, the some of which will be total solids, and typically the issue is that it will have a lot of organic content, CHO, xyz stoichiometry, and this when I release into the oceans, what is going to happen to this organic content? The surface water bodies are such, it will undergo degradation.

And how is it is going to use the most common electron acceptor out there, which is oxygen, and then the microbes are going to try to, achieve this particular reaction? Why is that they want to get the relevant energy that will be released from this redox reaction? This is nothing but redox reaction, carbon to be reduced form is now being oxidized or mineralized to carbon dioxide in this process, the compound not compounds, the bacteria are going to get the energy. That is going to happen in nature.

That is what you see, when you throw your waste out or such? If it is aerobic it is going to start to smell too. That is one aspect to keep in mind. But this is an aerobic process being done in the presence of oxygen. If we let it out, or the waste untreated waste into the river or surface water body or such, leave aside, effects on humans, it is going to lead to the collapse of the aquatic ecosystem.

Other than that, the relevant pathogens will be recycled back into our own drinking water supplies, and we are going to be affected , so that is something that we already see. What do I want to remove in general, I want to remove this organic content, I also want to try to kill the pathogens or make them inactive. But here I have organic content in the form of some suspended solids, some dissolved solids also they will be dissolved and some of it can also be suspended, and then you can have inert material also.

Organic content, present both in the form of dissolved organics and suspended organics, and also want to take care of the pathogen. How do I do that? We have a schematic out here, you might have seen at least in India, manholes over flowing other than poor design, one reason that leads to such choking of manholes is that, people dump a lot of inert waste. One example is the dumping of plastics.

And that chokes up your pipeline or storage network, and then you are going to have over flow such so, it is on our hands that is something to note, and so all those bigger particles, branches, leaves. We want to remove using the bar screens, if not, they are going to affect your other machinery down the line in your wastewater treatment plant, and then grit, relatively bigger particles you want to remove them or take care of them out here.

Let us say easy to remove and, then you are going to have particles that will or can settle down by gravity but can take a lot of times so you can add a coagulant and flocculant but in wastewater treatment, typically they do not add coagulant and flocculant but some people do, and then you are going to lead to have or a settling of your relatively heavier particles here at the bottom, and that goes to sludge thickening.

We looked at the video in last session, where at the end of the video I showed you a particular filter press where the sludge that was collected from that aeration tank of that particular sewage treatment plant that it settles down it is heavier it settles down and that goes to this sludge thickener because you want to decrease the volume and to increase the density so it goes to the sludge thickener.

Here what is it that we are trying to do here we are trying to remove as much suspended solids as you can, primarily suspended solids. Along with this process, some of the organic content is also going to be removed. Here we will have maybe 30% DOD, but constable removal of suspended solids. After that you still have a lot of organics, I just used the term BOD. It is biochemical oxygen demand.

It is a way of understanding how much organic content is there in the water sample. But we are trying to look at it in terms of oxygen demand how much oxygen will this particular waste, or the organics in that waste, Oxygen demand? How much would that exerted? How much oxygen will it be consuming and that terms, we are going to look at its biochemical oxygen demand, why is that because if I dump it, they have dumped this waste into the nature, it is going to consume the oxygen.

BOD will give me an idea about how much oxygen can be consumed, biochemical oxygen demand indirect indicator of the organic content leads, we will look at how to conduct this BOD test later. But I just want to mention that, and then we have this activated sludge, biological treatment activated sludge, what is all this, sludge if you remember, I put in a beaker, and this was after aeration, and after some time, you had relatively clear water at the top, and most of the sludge or the bacteria settle down to the bottom itself.

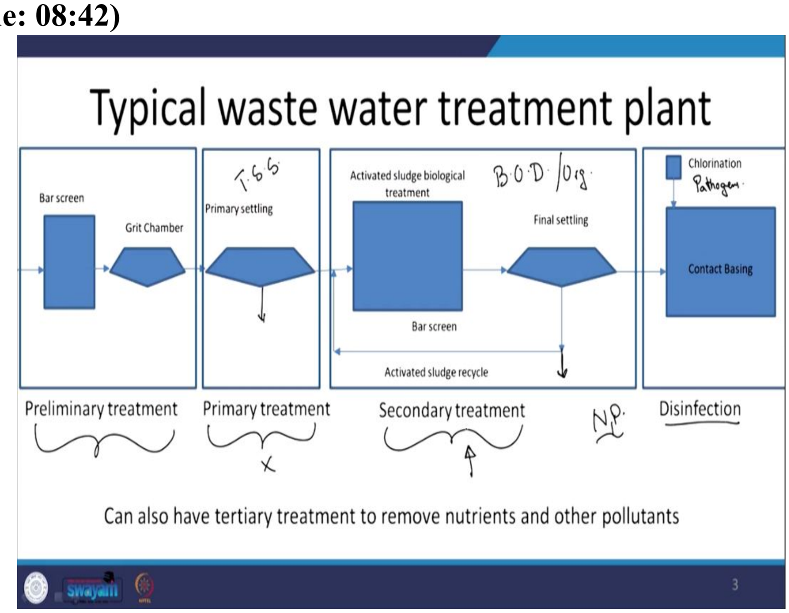
That this is what we are referring to as sludge. What is the role? Or why do we need this sludge? And why do we need to activate it, for example, you see that after this aeration treatment here, or aeration zone, it goes to the secondary settling, and then the sludge is settled down. That is what you saw in the beaker, the settle sludge is some of it is recycled back into what is this, aeration basin sludge aeration tank. Why is that?

Because the waste that is coming in does not have enough microbial content. The kinetics of your particular degradation of organics is going to be relatively slow. You want to increase the concentration of the microbes that are present in your aeration basin.That is why you are going to recycle some of this settled sludge from here back into the aeration tank and the other goes into that sludge thickening.

And after that it goes for sludge digestion or compulsion before being given to farmers or use just fertilizer. This is the biological process out here, where most of the body is degraded, if nutrient removal nitrogen and phosphorus removal is also required that you will have another stage here or you can tinker with this biological process here to remove nitrogen and then chlorination. Typically, now people are moving away from chlorination of at least treated wastewater why is that because you have harmful disinfection by products.

But we will not discuss this now, chlorination or disinfection is carried out why is it you are going to have to take care of the pathogens. That is why you have chlorination you can have a UV for disinfection, so that is something to keep in mind let me just get a give an overview of what we have.

(Refer Slide Time: 08:42)



Preliminary treatment, where plastics, tree leaves, branches are removed out here bar screens and grit chamber will have good pictures later. Primary settling relatively bigger particles, quite a few wastewater treatment plants sometimes do away with this primary treatment, and then you have the biological process again here we have the sludge but for the sake of easier understanding I removed it out here.

Here biological process where most of the BOD or the organic content is removed out here and here most of the suspended solids are removed and here most of the pathogens are removed. As you see primary treatment, secondary treatment and then disinfection sometimes you will have tertiary treatment if you also want to remove nitrogen and phosphorus let us so that is something to keep in mind out here primary and secondary. In India mostly, we have only up to secondary treatment.

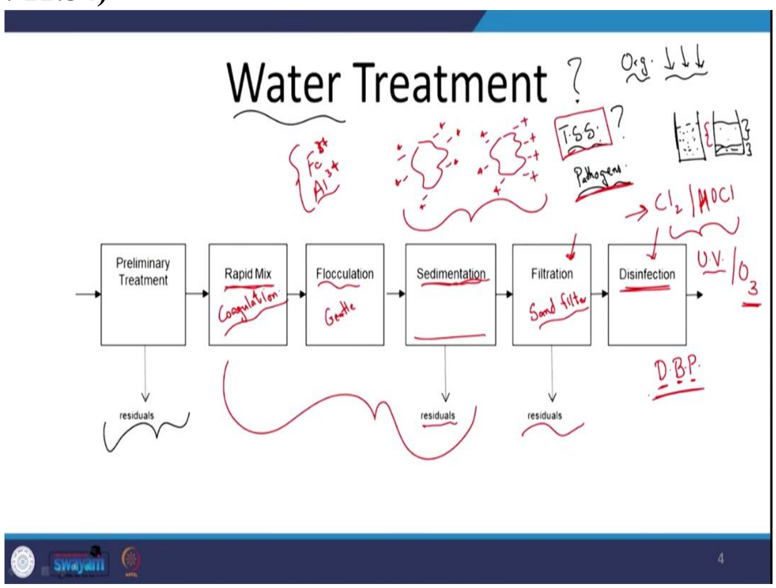
Even if we had a sewage treatment plant in the first case, we only have it until the secondary treatment and typically they are poorly run. Why is that lack of knowledge? People think that , microbes are like machine. You can, treat them poorly during the night and in the morning, they are going to wake up and do the job. That is not how they work. They are similar to humans or any other living organisms, you can take care of them the system thrives, a good, microbial population is going to thrive.

Then you are going to have a well-functioning sewage treatment plant microbes, living organisms. You do not look after them, they are not going to be able to achieve the desired results. That is one thing that we always see in our wastewater treatment plants, and another thing is that, especially in those cases, where industries are connected to the irrelevant common effluent treatment plant, what do industries do?

They are supposed to pretreat it so that at least some of the more toxic and hazardous chemicals are removed, before the waste is sent to the sewage treatment plants not see which common effluent treatment plants in such which are typically based on the same principles that we see. But what do they do in the night, they just let all the toxic, very low pH waste, or high heavy metal laden waste, or, inorganic laden waste invest into the relevant stream that ends up coming in contact with your bacteria.

The bacteria cannot do the job or they die, and it leads to ruining of the plant, and that happens quite often India, but hopefully people will realize that we are shooting ourselves in our own foot, legs.

(Refer Slide Time: 11:34)



Are you people listening to this class will now act as well to be more aware and knowledgeable citizens? We looked at wastewater in water, what is it that I am concerned about? In water, at least in theory, the issue is that we presume that the organic content is relatively less. But this is in theory in India, that does not turn out to be the case, especially when water treatment is from surface body water bodies, like rivers, or lakes.

We assume that organic content is less and then what is it that we are trying to remove, we are trying to remove suspended solids, if there are any, and then we are going to try to kill the pathogens. That is what we are going to achieve. Suspended solids, as I mentioned, preliminary treatment bar screens , we are not going to discuss this. We can have judged particle settling by gravity.

Let us say we had the example of bottle of glass of water and particles or soil, put into that particular glass of water, and after some time, most of it settling down, but some particles will be out there, because they take more time, there are different types of settling, we will come back to that later. Here, we will let gravity do the job for these particles. But what about these particles? Let us see, how do I get rid of?

How do I get these particles which are relatively small in size, but can still be removed? What do we say pulled down by gravity?But we will take a lot of time, what will I do? I have these flocks, and they are going to have a charge on it, and I am going to try to neutralize the charge? Typically, they have a negative charge, and that is why they repel each other.

I am going to add a coagulant typically that will have poised to charge that is going to or can release positive charged ions Fe^{2+} not a Fe^{2+}typically a Fe^{3+} or Al^{3+} charge is going to be neutralized out here.

Then the particles can come together they can coagulate and then bigger particles they can now be removed by sedimentation. First you are going to have coagulate Fe^{3+} or Al^{3+}. You are going to have rapid mixing and coagulation when you are neutralizing the surface charge and then you are going to have flocculation when these particles come together and form flocks. Here you are not going to mix it rapidly because if you mix it rapidly these particles are going to be sheared , they are not going to form flocks.

Here you are going to have gentle mixing and then once you form the bigger particles, you are going to stop stirring and you are going to have sedimentation. You need to treat the residuals and then you are also going to have, relatively other smaller particles which cannot be removed even by sedimentation. You want to have, different filtration.

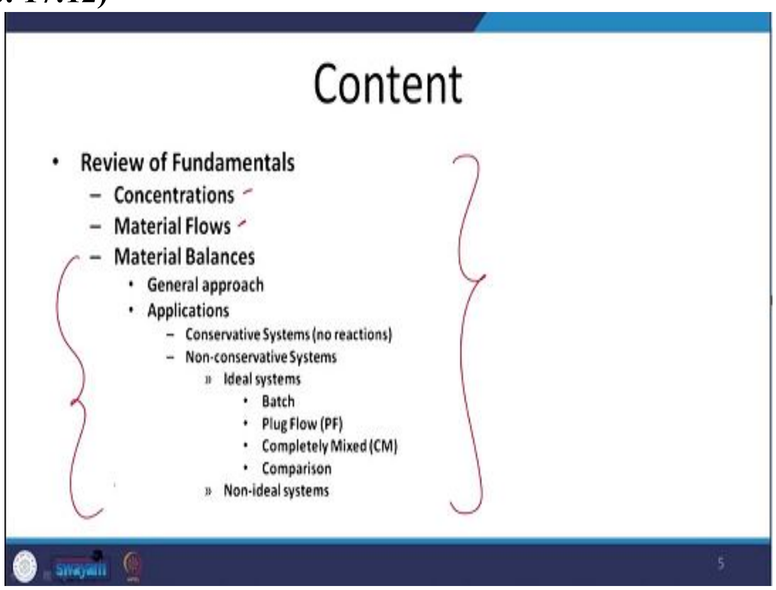
There are different kinds of sand filter relatively common. Again, if you do not do this and use a sand filter directly, yes, you can. But keep in mind that your sand filter is going to be choked very often. What happens is, it is not as if the size is 20 micrometers or 30 micrometers, and everything above 30 will be stopped, everything below 30 will go down, it does not work like that.

You will typically also have a biofilm developing on your sand, and it is not just straining sometimes, the biofilm will absorb and degrade some of the organic content here and the size of this particular pore also decreases, you are going to have straining and other aspects. Relatively smaller particles also can be removed by Sand filtration.

The final step before I send it to the water distribution network is that I have to remove the pathogen. That is why I disinfect it typically either Cl_2 or HOCl source of oxidizing agents, both are oxidizing agents. Nowadays, people are going to UV and rarely also ozonation, ozonation because it can oxidize the organic content present, without leading to formation of harmful or carcinogenic disinfection by products.

With when you use Cl_2 or HOCl you can lead to formation of disinfection byproducts. This is what is general water treatment. But as I mentioned, we will also look at ion exchange, and what else I think different kinds of ultra-filtration, and so forth this is for surface water treatment.

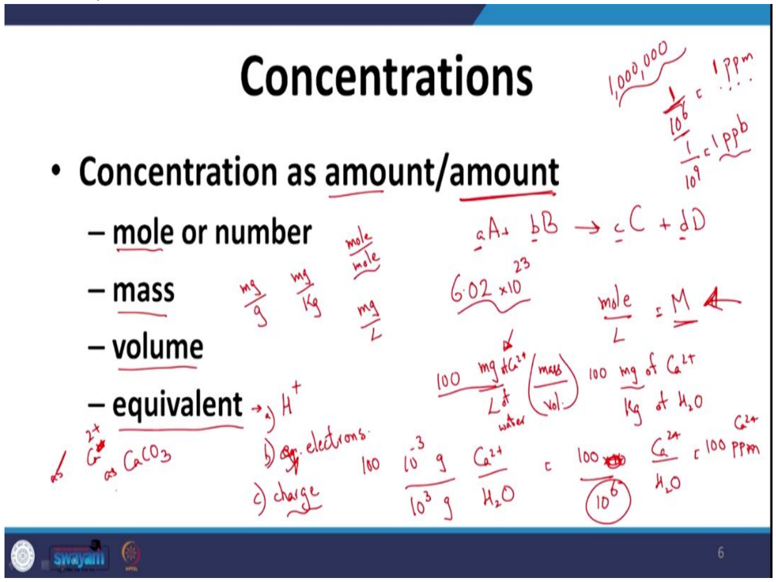
(Refer Slide Time: 17:12)



Let us move on and see what it is that I have out here. The content we are going to discuss over the next couple of sessions. We need to look at and understand concentrations and material flows, we will just touch upon that, and material balance, I request everyone and urge everyone rather, to pay great attention to material balance, you will use this at least environmental engineers will use this a lot.

You know, when you find when they go to pursue Master's or PhD, and at least in this class, also we will be using it a lot in the wastewater treatment related aspects.

(Refer Slide Time: 17:55)



With respect to concentrations, we can express this in different ways. Let us say how this so a moles of A react with b moles of B. I can express , sometimes concentration is at least in a is expressed in terms of mole ratio. That is based on trying to see that the molecular mass and the mass and Dalton's is the same.

$$aA + bB \rightarrow cC + dD$$

Mole, sometimes people use that but typically in water or wastewater another aspect is mass. Either milligrams of the compound per gram, or milligrams per kg, are such or sometimes, though, I have written it as volume here, I will also use it in terms of amount per volume I can have moles per meter. That the unit is molar units.

With respect to mass, sometimes we come across different kinds of units like this milligram per liter, that is a mass per volume, I typically would like to write it as mass per volume, because it helps me to understand it but different ways for different persons. Milligram per liter, and one liter of water if I am dealing with water and assuming the density to be 1 kg per liter, milligram per kg. Here, when I write it this way, people will be confused.

The way I write it is if I am talking about Calcium, so I have milligrams of Calcium. Let us say 100 milligrams of Calcium per liter of water. Mass per volume of water. If I say it is, 1 liter weighs 1 kg, 1 liter of water, so 100 milligrams of Calcium per kg of water. Here milli, milli is 10^{-3} grams of Calcium in H_2O, or in water.

What does this end out to be? This comes out to be 100 into 10^{-6}, or let me write it this way in the denominator 10^{-6}, per H_2O. This unit is 10^6 and a million is also 10^6 so 1 by 10^6 is nothing but 1 part per million 1 part per million. That is something to keep in mind. This unit can also be written as 100 ppm. CO_2 plus concentration, so that is something to keep in mind.

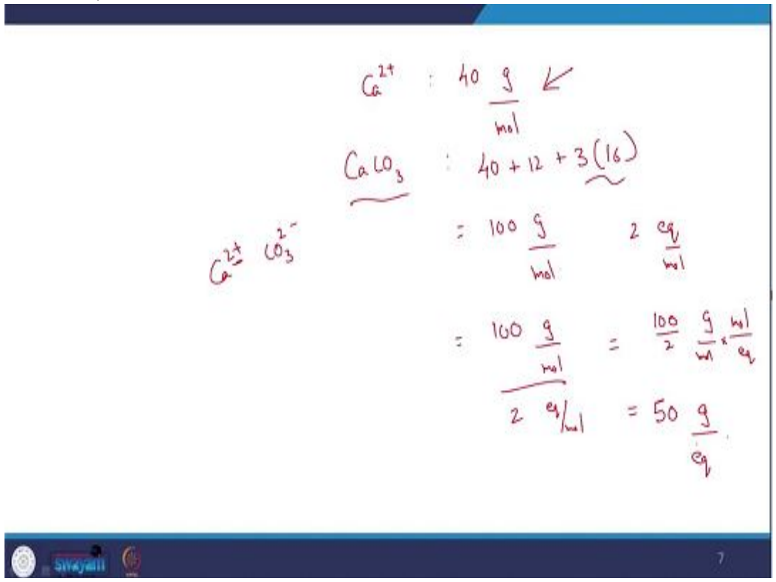
Similarly, instead of 1 by 10^6 if we have 1 by 10^9, so billion, 1 billion is 10^9. It is equal to 1 part per billion, different ways of expressing it. One is with respect to moles, we have molar in typically when we are talking about chemistry and relevant conversions, we talk about molar basis, but for the layman typically they understand it better in terms of mass per volume, and milligram per liter.

Rarely do we express it in terms of volume, sometimes, especially when we are talking about hardness, we express it in terms of equivalence. When we say equivalent, what is it that we are talking about, I have, some apples and you have some oranges, how do I , go about getting the oranges I want and giving you the apples are such that you want, so we need to think of it in terms of equivalents.

One equivalent can be the cost of for the price of a set of apples, we are talking about money here. We are talking about equivalents in terms of money. I will give you 100 rupees equivalent of market value worth of apples and you will give me 100 rupees worth of or equivalent worth of oranges here. We need to explicit in terms of equivalence or some equivalent.

Typically, it can be in terms of how much H+ is given out or can be taken equivalent in terms of H+ equivalent or electrons equivalent in terms of electrons, and most usually used in this with respect to charge alerts, as you would have seen with respect to hardness or such we would have expressed, rather than writing it Ca^{2+}, we write it as this is 2+ we write it as $CaCO_3$ equivalents $CaCO_3$. We will look at these conversions later.

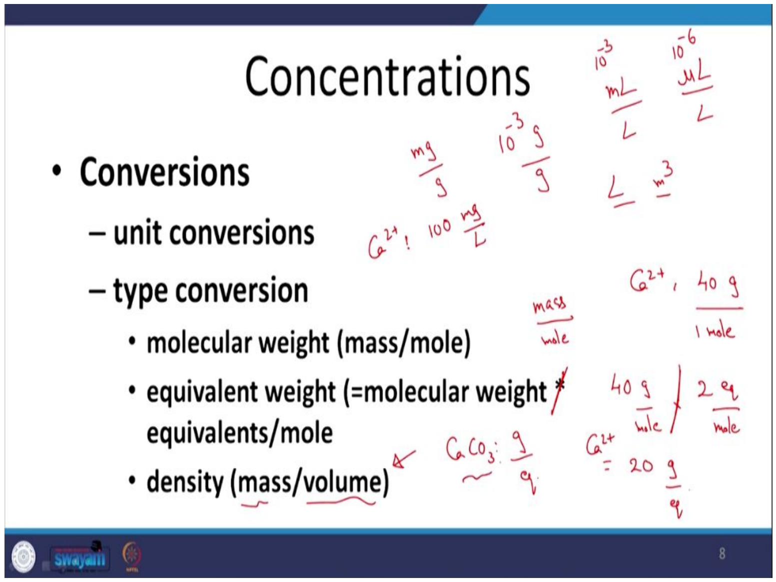
(Refer Slide Time: 23:46)



For example, Calcium, molecular weight, how much is that? 40 grams/mole, and with respect to $CaCO_3$ 40 + 12 + 3 into 16. This is 48 and 16. That is going to be equal to 100 grams per mole . Here, we are looking at it with respect to charge and pause to charge at Ca^{2+} and CO_3^{2-} , so +2 charge out here so based on that, you can calculate the equivalent weight.

If I have , 2 equivalents per mole, what will the equivalent weight be? It will be 100 grams per mole by 2 equivalents per mole so that is going to be equal to 100 by 2 gram per mole into mole per equals, so that is going to be equal to 50 gram per equivalent. I always suggest that you write it in terms of this equivalent. Similarly, you can write it for Calcium, and once you have it in terms of equivalents you can get it done accordingly.

(Refer Slide Time: 25:21)



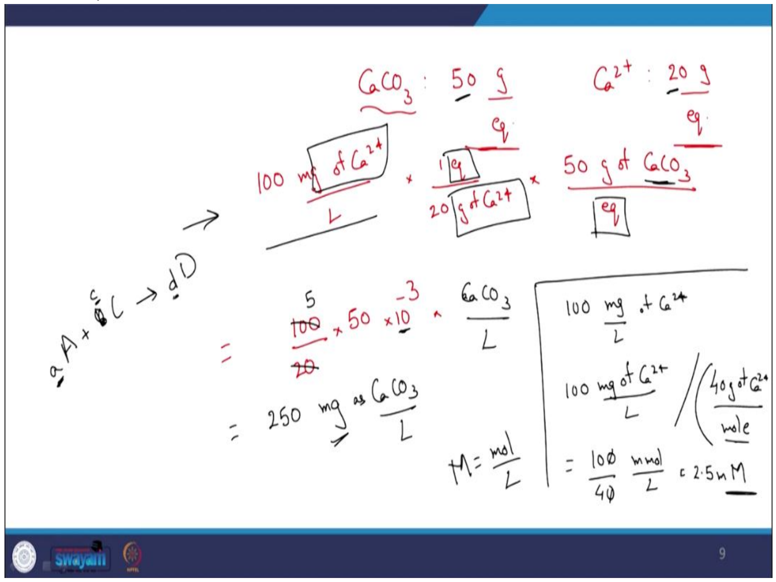
Let us cover the next aspect. Concentrations, we sometimes look at conversion , and one aspect is milli gram per gram. 10^{-3} gram per gram or ml per liter, or micro liter per liter so you have to use these relevant conversions, conversion factors 10^{-3} or 10-6, and so forth, or liter, and meter cube, and different conversions. Then there is the other kind, the type conversion about which I already talked about.

For example, molecular weight, mass or per mole, mass per mole of that relevant compound, for Calcium, we just saw that it is going to be equal to 40 grams of Calcium per 1 mole of that relevant compound. That is something that we already looked at. Similarly, equivalent weight, how will we get that? That is molecular weight, for example, with Calcium 40 gram per mole, let us write into , Calcium to charge here, the equivalents are with respect to charge .

2 equivalents per or divided by, it has to be divided by 2 equivalent per mole . We have the equivalent weight out here 20 grams per equivalent. This should have been divided not multiplied by. Accordingly, you can calculate the equivalent weight and get it done. Density, but we do not use that law, once the units of density or mass per volume typically, we assume that the densities are same with respect to time and space, at least in the aspects that we consider out here.

Let us move on this is with respect to equivalents. Before I move on, about that. We had $CaCO_3$ the equivalent weight was 50 gram per equivalent. Let us see. Now for Calcium, you had it in terms of 20 gram per equivalent. If you have concentration of Calcium to be, 100 milligram per liter. You can convert it into equivalents in the first case and then use that to convert it into equivalents in the form of $CaCO_3$.

(Refer Slide Time: 27:57)



Let us just write that out. I have a $CaCO_3$ the equivalent weight was supposed to be 50 gram per equivalent, and here we are talking about charge, keep that in mind equivalent in terms of charge, and for Ca^{2+}, we said that it was going to be 20 gram per equivalent and the concentration I have is 50 milligrams of Ca^{2+} per liter of this water. Here, I want to convert this into equivalents.

You see the units out here I want it in terms of equivalents, so I can divided by this particular value, this particular value because of Calcium. Into 1 equivalent per 20 grams of Ca^{2+} so now I will have it in terms of milli equivalent per liter, but I want to express it as $CaCO_3$. I will have to multiply it by this value so I have 50 grams of $CaCO_3$ per equivalent. Let us see what the units will turn out to be. I first have 100 / 20 into 50 milli that is 10-3.

Grams of Calcium so grams of Calcium and grams of Calcium they cancel out equivalents, equivalents cancel out. What are the units I am ending up with as $CaCO_3$per liter let us so from that 5 times 50 are 250 because we already took out what is this 250 instead of 10^{-3} I will write milligram as $CaCO_3$ per liter. That is what we have we just converted 100 milligrams of Ca 2+ per liter.

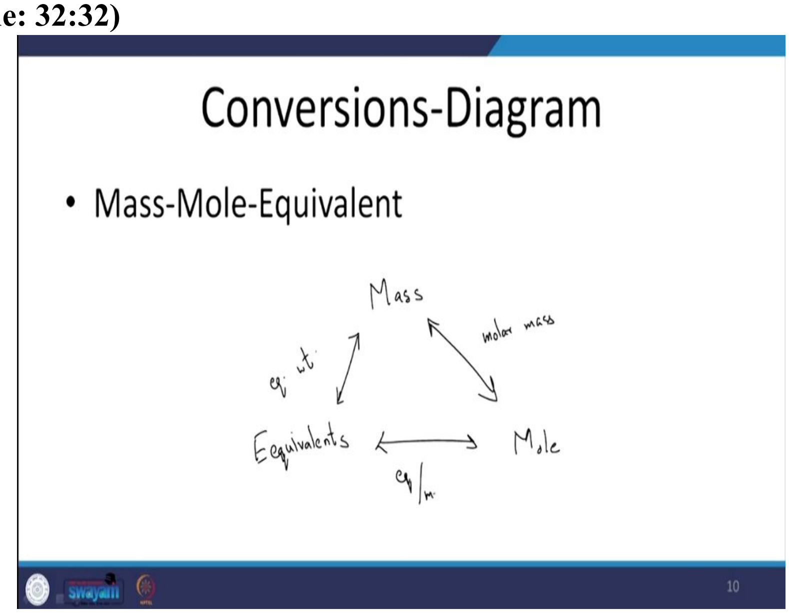
And we expressed this in terms of a $CaCO_3$ or in terms of $CaCO_3$ 100 milligram as equivalent in terms of 250 milligrams of $CaCO_3$. Obviously knowing these equivalent weights, you can also get it done in a faster manner. But I wanted to show you the way to get it done without any confusion or such, especially if you write the units in terms of milligrams of Calcium, 1 equivalent per 20 grams of Calcium.

But if I wanted it in molar units, I have 100 milligrams of liter of Calcium, and I want the units in molar units, molar units what do I do? Molecular weight I know that it is 40 grams of Calcium per mole. I want this to be cancelled out. I have to divide it by the small flow rate, I want the grams to be canceled out and moles in the numerator. 40 milligrams of Ca^{2+} per liter into or divided by the small flow rate.

That will be 100 / 40. This grams of Ca^{2+} cancel out and moles comes to the numerator? Milli moles per liter 10 / 4 is 2.5 millimole per liter is nothing but capital molar units. Molar units, it is nothing but moles per liter. That is something to keep in mind, and one aspect is as we mentioned earlier, when we are talking about stoichiometry or such you have to use now, the molar units.

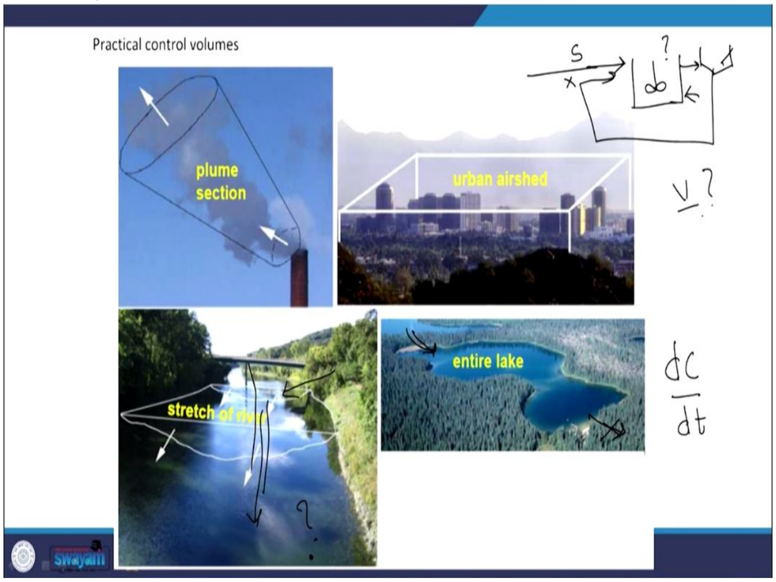
That is always going to make it easier. Why is that here the units, the reactions are in terms of molar units out to you a moles react with c moles to form d moles. If it is per volume, we are going to see that in terms of molar units out there.

(Refer Slide Time: 32:32)



Let us move on what else do we have? Conversion, I will just talk about this diagram and we will move on I have mass I have moles and I have equivalents. How can I interconvert mass to moles, I need to have the molar mass either divide or multiply and here I will have to have the equivalent weight or the equivalent mass. Here I will have to have equivalents per mole, which so in that way, I can convert from one unit to the other. I just wanted to mention that.

(Refer Slide Time: 33:17)



We will move on to looking at mass balances here, I have it at a bigger scale. For example, I want to understand the concentration of a pollutant within this urban air shed which covers the city or if a pollutant or compound is coming into this lake and going out from this way or is not going out, but can be degraded inside this lake, how is the concentration of that compound changing with time or if this river is flowing and the sewage is coming in out here.

If this is flowing in this direction, what is the concentration downstream 10 kilometers? How do I calculate that or more pertinently for your wastewater treatment plant, you saw that you have an aeration tank, what is coming in your organics are coming and typically we use the term substrate, substrate is coming in. You are also recycling your microbes X is also coming in. But that just recycled though that is something to keep in mind, then we are going to have the relevant reaction out here.

How long do I need to , run this system are more or less how much volume is it that I need to design this tank for? How will I get this only by applying mass balance? But I see we are out of time. I do not want to start this important topic now. Once again thanking you for your patience. I will end today's session.