Physico-Chemical Processes for Wastewater Treatment
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Lecture 52
Disinfection – l

Good day everyone and welcome to these lectures on Physico-Chemical Processes for Wastewater Treatment. So, we have come to the end of these water treatment processes. And we have studied a lot of unit operations or processes or methods which are used for water or wastewater treatment and we started with the flow equalization basin and then we started studying the aeration thereafter, we studied coagulation-flocculation and settling.

And in addition, we studied the various adaption and ion exchange processes, which are used for treatment of water. Thereafter, we studied the membrane separation processes including Microfiltration, Ultrafiltration, Nanofiltration, and reverse osmosis for water treatment. And in the previous sections, we studied a lot of advanced oxidation processes for destruction or mineralization of various organic and other type of pollutants present in the water which are very difficult to remove otherwise, now this is the last section that we are going to continue now, which is called as disinfection.

So, in that disinfection, we use techniques which are similar to advance oxidation processes like UV oxidation, and then also we can use a lot of chemicals for removing some of the most of the pathogens which are present in the water and these pathogens may be bacteria virus cyst are any other types of worms and larvae. So, if these pathogens are present, so, they will cause lots of diseases to us.

So, we have already studied various types of water related diseases earlier and if these pathogens are present in the water and we use the water for drinking in particular, then we may get infected and that may cause a lot of problem. So, it is very, very necessary to remove these pathogens before we use the water for drinking.

So, there are a number of techniques which are used for disinfection. So, in these lectures we are going to study regarding these techniques. Generally, there are many chlorines related chemicals which are used for disinfection, in addition, UV radiation etc. can be used, and there are some minor other chemicals also which are used for disinfection.

So, we will try to learn all these chemicals, their chemistry, how it works along with the water, so as to remove these pathogens or mineralize these pathogens, so, and what are the

doses that is required for disinfecting various pathogens. So, all these details will continue in that disinfection lectures that will start from today. So, starting disinfection is used in water treatment to reduce pathogens to an acceptable level. So, this is very very important, but there is a difference we are always whenever the term disinfection comes into our mind.

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So, there is some confusion with respect to sterilization which is used in the Biochemical Engineering and other places. So, sterilization and disinfection is liquid different in the crystallization, we want to distract all the living organisms, whereas in this disinfection we reduce them to within an acceptable level.

So, drinking water does not need to be sterilized to be safe for drinking, we have to only see that all the pathogens we will be human enteric pathogens, which are of concern in drinking water that is bacteria, viruses and cyst and we exist they are reduced to an acceptable level. So, this is the main objective of disinfection and how it works.

And the sense disinfection is capable of destroying all these viruses. We need not destroy those, those microorganisms which are which will be good for our body or otherwise. So, we try to See that we are able to distract the pathogen within an acceptable limit and it is different than sterilization.

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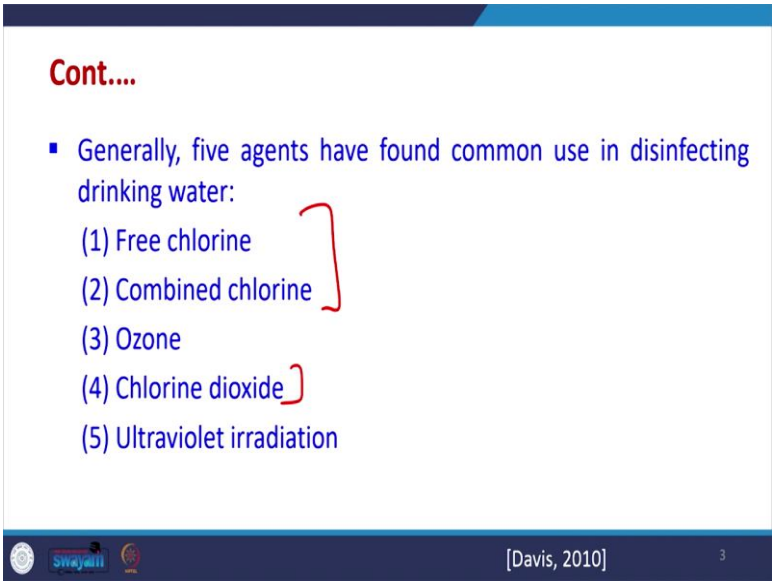

Now, going further, there are different types of agents which are used for disinfecting the water. So, most common agents are related to chlorine. So, chlorine free chlorine combined chlorine or chlorine outside, they are very commonly used for removing pathogens or reducing the pathogens to an acceptable limit. In addition, ozone can be used and Ultraviolet irradiation can also be used for detecting these pathogens in the drinking water going further, other disinfectants which are used for doing different situations for in various conditions they are given here. So, ultraviolet radiation already we have discussed.

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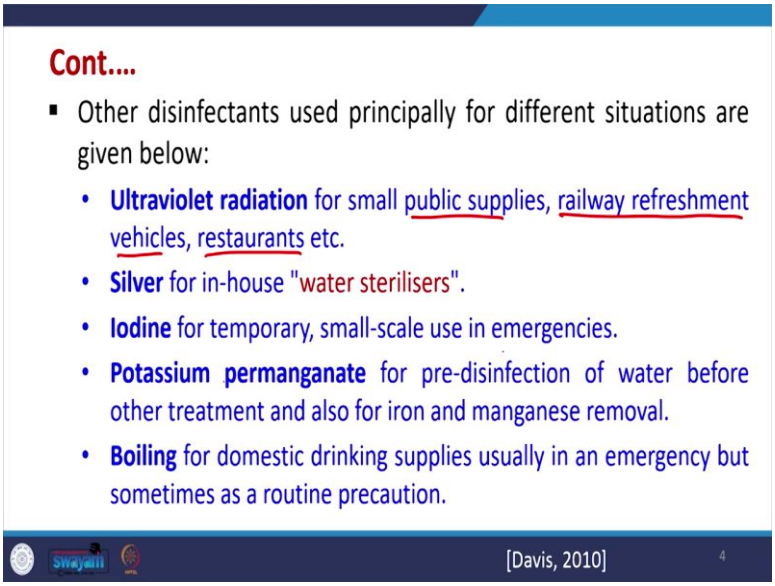

So, they may be used for public supplies, railway refreshment vehicles and restaurants etc. And with the with COVID the use of ultraviolet radiation for virus removal its uses has

increased way beyond the water also. So, anything which is any type of pathogen are virus which is present on the any of the sub surfaces, so, they are being removed using ultraviolet radiation. So, it has become a well-known thing nowadays and it is very similar to like the we have studied photo-oxidation. So, this is very similar to that and a certain difference may be there with respect to the ultraviolet wavelengths that we are using, but this is a similar to photo-oxidation itself. So, this is there now, silver for in house water externalization.

So, many times it is used. So, silver is considered to be highly good in removing or disinfecting the surfaces and water as well. So, this can be used Iodine has also been used it temporarily for small scale using emergency cases. So, for emergency cases and where there has been a tremendous increase in virus and bacteria in the water. So, sometimes it may be used, Potassium permanganate for be disinfection of the water before other treatment strategies can be used. So, this is also possible to use Potassium permanganate.

And also, potential impairment is used for Iron and Manganese removal. So, it works for pathogens Iron and manganese removal all three a petition per magnet is used a boiling of domestic drinking water supply is very very common and it can be used as a disinfection method for using the water for drinking purposes. So, these are the other techniques which are possible for us and they are available for disinfection.

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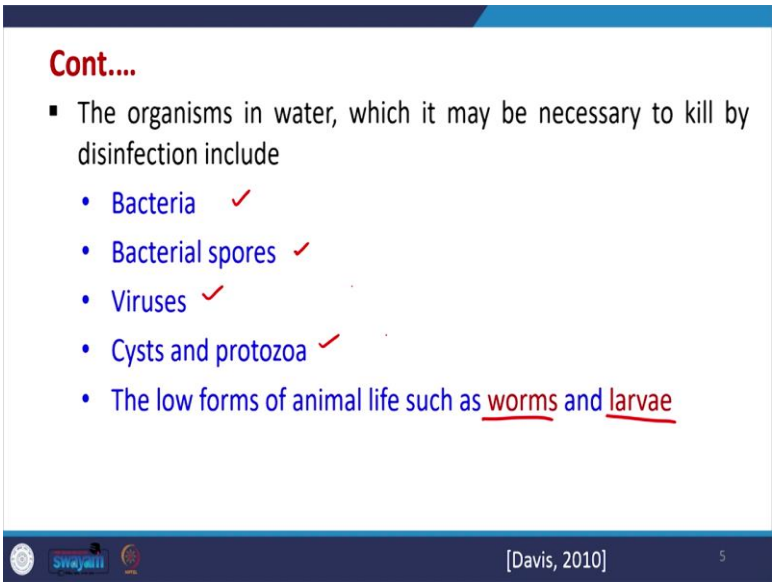

Now, the organisms in water which are very necessary to be removed via disinfection, they include like bacteria, various types of bacterial spores and viruses, cysts and protozoa and the low forms of animal lives such as worms and larvae. So, all these things we always target

them to be removed from the water. So that we can use the water for drinking and they may be removed by using the various chemicals which we have discussed are ultraviolet radiation or some other techniques. So, we have to employ these.

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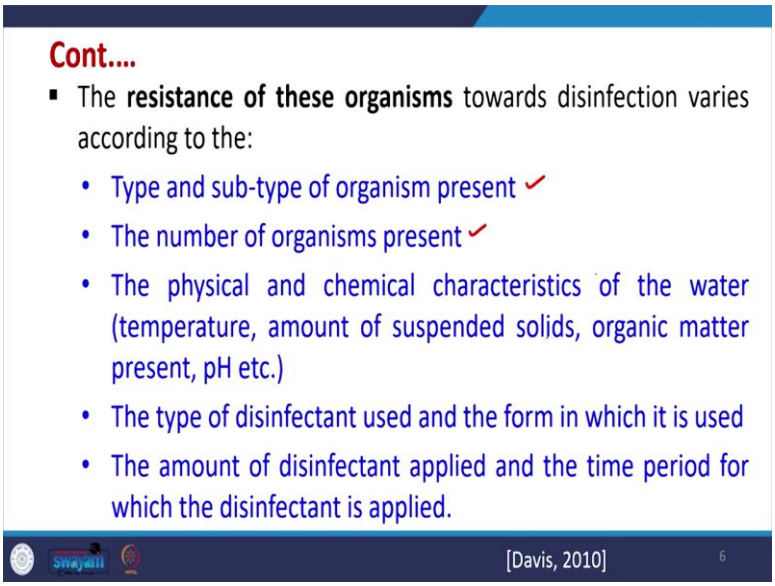

Now resistance of these organisms towards disinfection varies according to different types of situations. So, in the water, we have to see that which type or subtype of organism is present. So, depending on also whether it is bacteria or virus, so, depending upon that, the dose of the chemicals are in the case of radiation, the intensity of radiation may vary also the number of organism.

So, the type sub type of organism present and the number of organisms present, they all change the dose response curve. So, in this way the amount of chemical to be used are the wavelength of the chemical to be used on intensity changes the physical and chemical characteristics of the water.

So, in the water in which these micro these pathogens are present, the characteristics of the water like temperature amount of other solid suspended solids present organic matter present and the pH. So, all these parameters affect the amount of disinfection that will occur at a particular condition also, it will vary depending upon the type of disinfectant that we are going to use, and its chemistry with the water.

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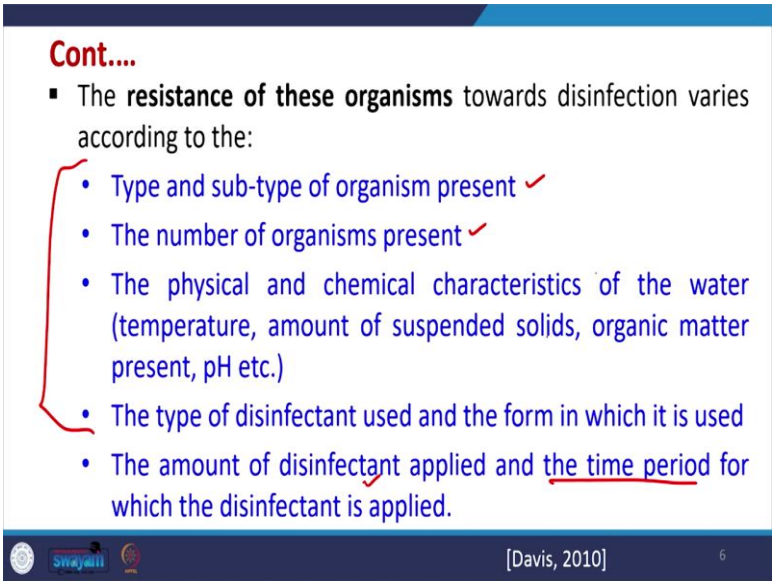

So, that is very important and that chemistry will be highly pH dependent and also dependent upon the different types of organic material and suspended solids that are present inside the water. So, this is there now, we the amount of disinfect tint which is applied and the time period for which this has to be applied that will also depend upon the all these factors. So, depending upon these factors, the amount of disinfectant, that type of disinfectant and the time period for which it is applied, that will vary. So, this is what we have to learn and this is how it is applied in the actual field.

Now, chlorine and their various compounds are one of the most widely used disinfectant to everywhere most commonly, chlorine and their various compounds are used. Now, why they are used, so, there are certain reasons for their very wide use. And these reasons are that these type of worms are they have very, they are easy to use, and they have very good mineralization efficiency with respect to pathogens.

So, they are able to remove the pathogens and destruct the pathogens maximum possible level and this is possible because the chlorine is like a halogen compound, and it has only one electron requirement it towards fulfilling its valiancy now, what happens is that, so, that is the chlorine are any type of halogens compounds are one of the most reactive elements to thus, the chlorine and related compounds are also highly reactive elements.

So, does their if they are present or added in the water, they will react or they will react with the body parts of the pathogens and thus they will distract them. So, and so this is one of the reason because of the high reactivity, high oxidation potential of the species, they are able to

distract the pathogens. Now, these chlorines and their compounds are cost effective, and they are easily available as well. So, this is another reason for their wider use.

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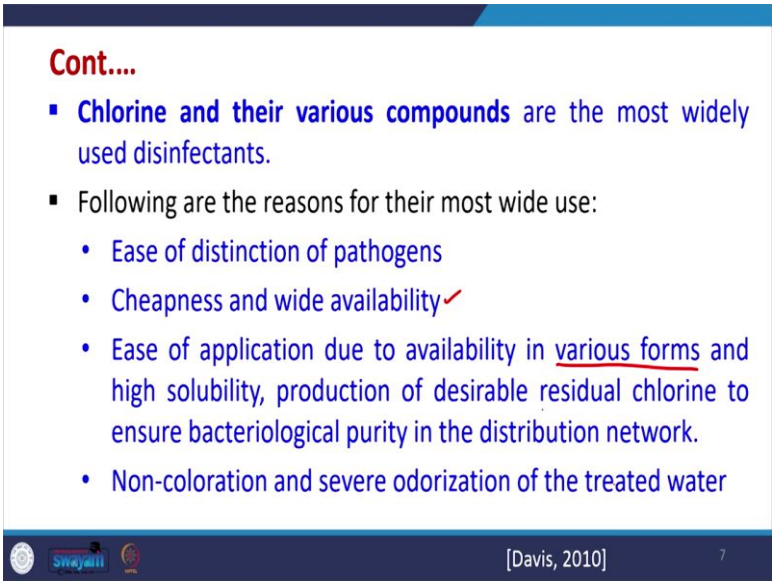

Now, ease of application is also there, because they are available in various forms. So, we can use them in various forms, they are highly soluble in the water and they produce desirable residual chlorine to ensure that the bacteriological purity is there in that distribution network after the treatment is done. And they are non-coloring type and they are severe, they cause odor removal as well.

So, they are able to distract not only pathogen, they are able to distract other types of organic compounds are another thing present in the water. So, that is why they are very very commonly used for disinfection. Now, chlorine has some disadvantage also. And we should be kept in mind while using them, what are the disadvantages that says chlorine is highly reactive. So, it will react it can react if present in the water beyond a certain value to the human body parts as well. So, does it can harm the human beings also it present in a very high concentration in the water.

So, we have to be very cautious with respect to uses of chlorine, because they will be used for distracting the pathogens, but if more amount of chlorine is used, so it will not be used up for disinfection and it will be remaining in the water. So, and if you are using that water so that chlorine will affect us. So, this is the problem. Now, there are in addition, the chlorine may form chlorine gas, which is a toxic and which requires careful handling as well. So, this is another reason.

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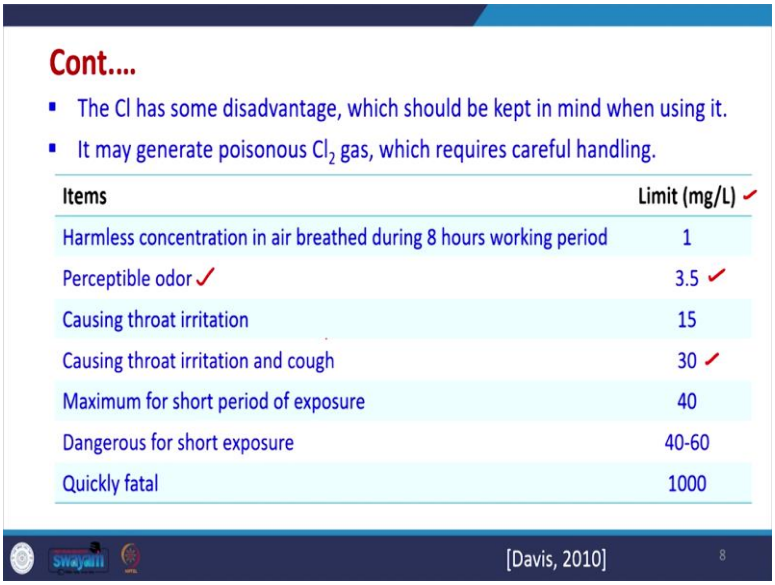

Some of the limits which are given here with respect to chlorine and it is shown that at 1 milligram per liter the chlorine is like harmless in air, if we use breathe it for eight hours, but 3.5 milligram per liter some odor will be we can perceive that some odor if it is there at 15 milligram per liter it was cause throat irritation after throat irritation we can have cough problems if it is present at 30 milligram per liter and if the short period a exposure to 40 milligram per liter are beyond is there, then it will cause a start causing problem to us and it will be dangerous and at around 1000 milligram per liter that means 1 gram per liter it can be fatal also.

So, human beings can die because of the presence of chlorine So, this is just so that is why we had to be cautious with using the chlorine but a chlorine is one of the most commonly used disinfectant. Now, going further will try to learn that disinfection chemistry with respect to different chlorine compounds and some of the disinfection chemistry understanding this chemistry is very important and with respect to that, which type of chlorine species is available at what pH inside the water. So, through that we can come to know whether the pathogens will get removed or not. So, this chemistry will tell you a little bit idea regarding this.

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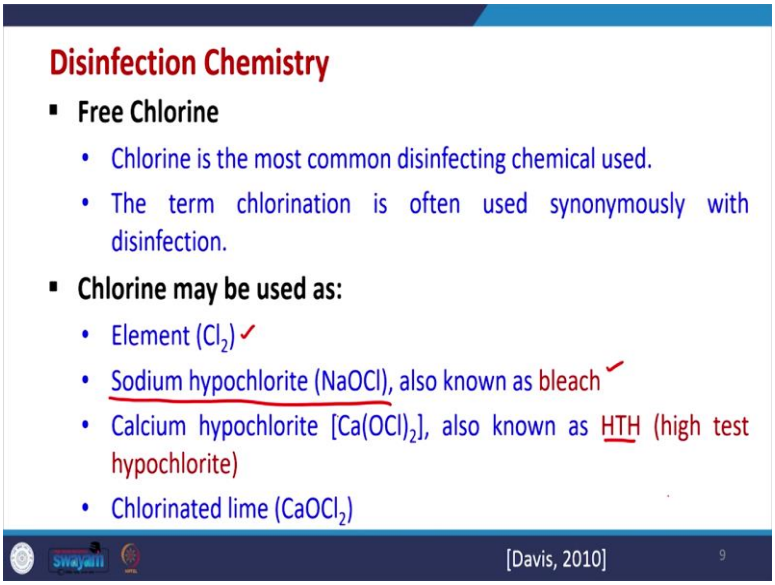

So, free chlorine is one of the most commonly used disinfecting chemicals and the term chlorination is used sometimes very commonly with disinfection. So, in the field people will say sometimes chlorination, so, chlorination means disinfection, so, this is there, now, elemental chlorine, chlorine may be used as elemental chlorine, then sodium hypochlorite which is very common, and it is also known as bleaching agent.

So, this is also used for disinfection, then calcium hypochlorite also known as HTH or high-test hypochlorite. So, hypo common word is if you go into the field, they will tell we are using hypo sometimes the laborer are the person who is using may not know it is sodium hypochlorite or calcium hypochlorite. But hypo is very common word and hypochlorite is used as a disinfecting chemical in the form of water and disinfection. In addition, the chlorinated lime can also be used for disinfection. So, this is there.

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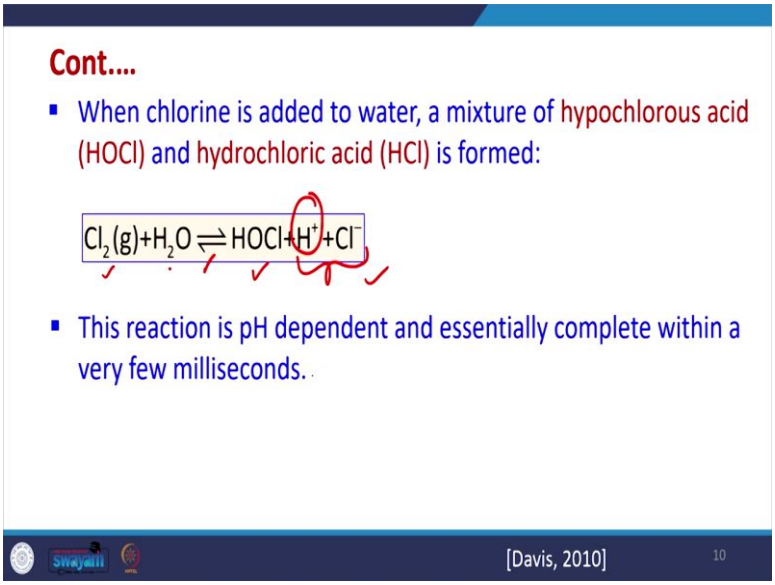

Now, when chlorine hypo hypochlorite which is getting hypochlorous acid as well as hydro chloric acid which are getting form. Now, this reaction is reversible as well and this reaction is pH dependent and essentially complete within a few milliseconds. So, this will happen this will be dependent upon the pH also. And thus, the type of chlorinated compound which is present in the water will depend upon the pH also.

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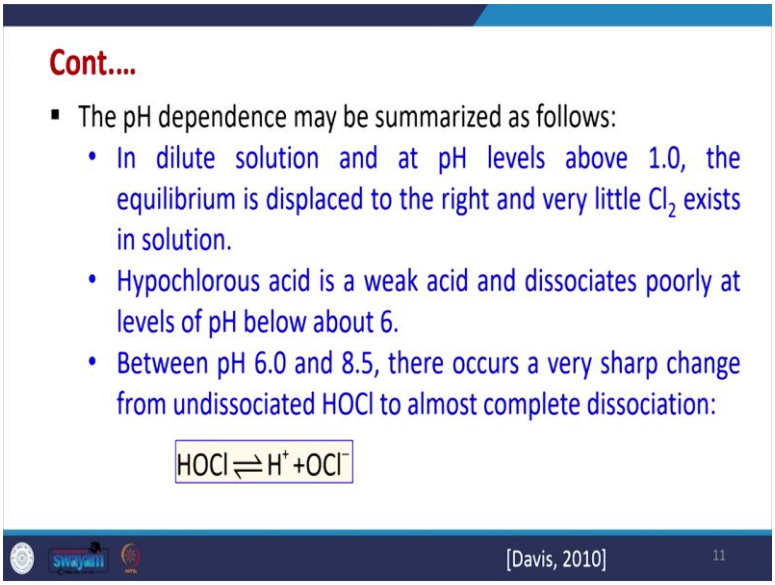

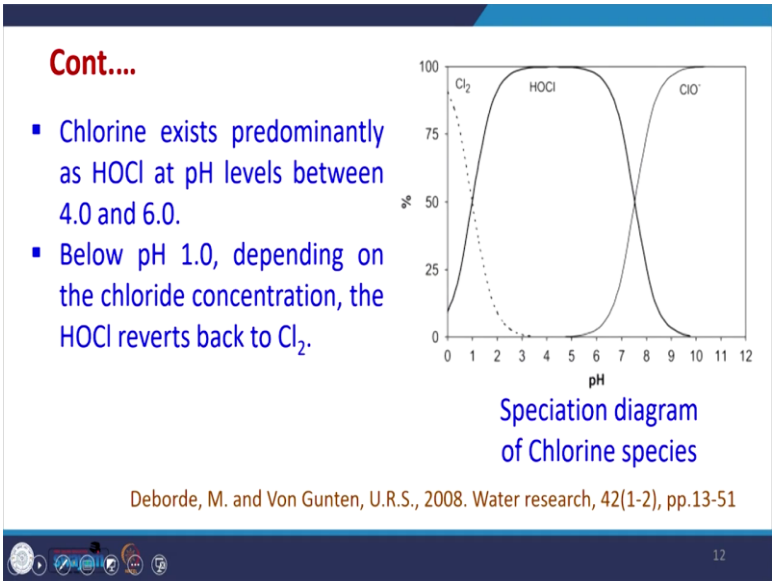

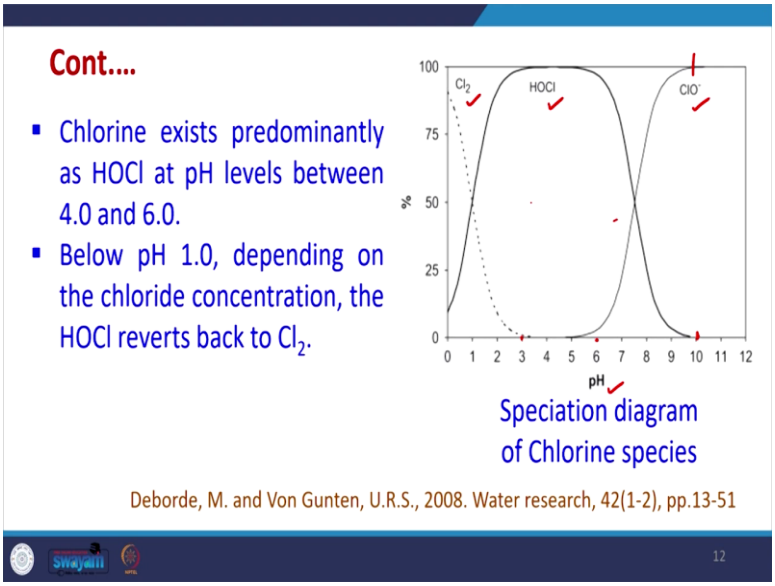

Now, the pH dependence of this chlorine can be summarized here, for the sake of easiness. I am just showing you a graph here and will try to understand this graph via the text which is given here in the slides. So, you can see here if chlorine is present, so, chlorine if it is added, so, it can be in different three different forms.

So, Cl2, HOCl and ClO and whether which type of chlorine is present if it is pure water, then it will depend upon the pH which is shown here. So, we can see it that beyond 10 PH. If chlorine is added it will be in the negative form. And if it is between around 6 pH to 3 pH, everything will be in the hypochlorous acid HOCl form and below like 2 pH or less or 3 pH or less some amount of chlorine will also be present. So, everything will get converted into some amount of that will get converted entered into chlorine also, along with HOCl. So, if pH is less now will try to understand this more.

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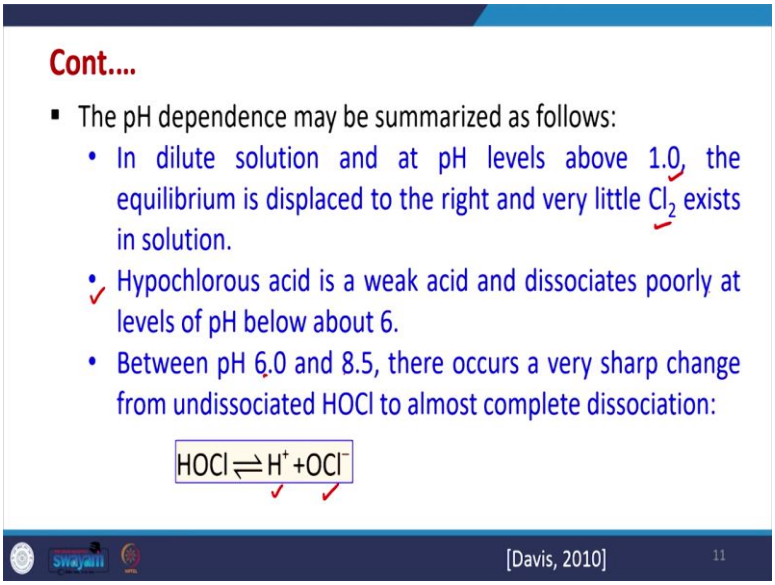

So, in dilution solution and at pH levels above 1 that equilibrium is displaced to the right in this particular equation and very little Cl2 to exist in the solution. So, some amount of Cl2 will be present, if the pH goes beyond 1 and after 3 it will totally change. So, hypochlorous acid HOCl is a weak acid and it will dissociate poorly at levels of pH below about 6. But it will not dissociate that means everything will be in the HOCL form.

So, hypochlorous acid between pH 6 and 8.5 there occurs a very sharp change from a dissociated HOCl to almost complete dissociation. So, between 6 to 8.5 HOCl will dissociate into H plus and OCl minus and in fact, beyond 10, it will be complete dissociation that will happen and because of that, everything will be present in the OCl minus form.

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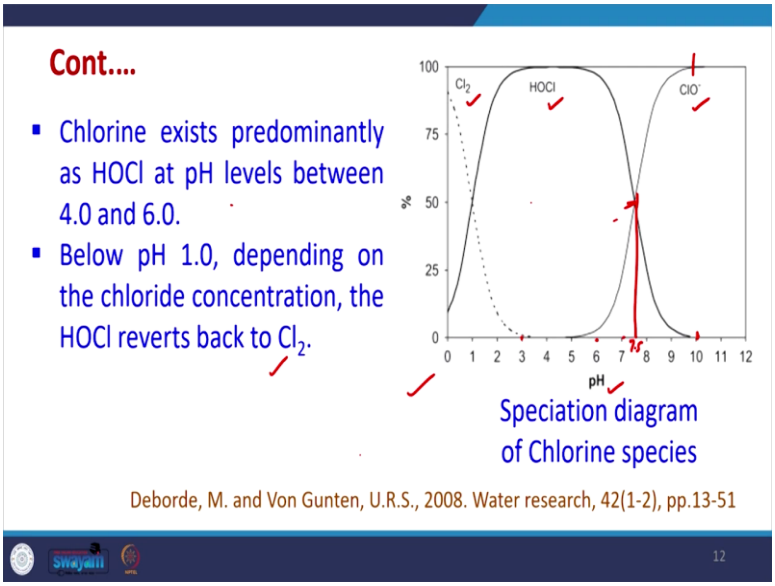

So, this is there. So, chlorine exists predominantly as HOCl at pH levels between 4 to 6. So, everything will be in that HOCl form between 4 to 6 below pH 1 and depending upon the chloride concentration, HOCl will get converted into Cl2. So, this is the So, these are the different forms in which the chlorine will be present in the water under various condition and this diagram it is called as a speciation diagram of chlorine species and this is pH dependent.

So, from this we can understand that also in between some like suppose we have to find out what 7. So, we can tentatively know that at 7.5 tentatively 50 percent of the chlorine will be in the HOCl form and 50 percent will be in the ClO minus form. So, this is the water chemistry with respect to chlorine

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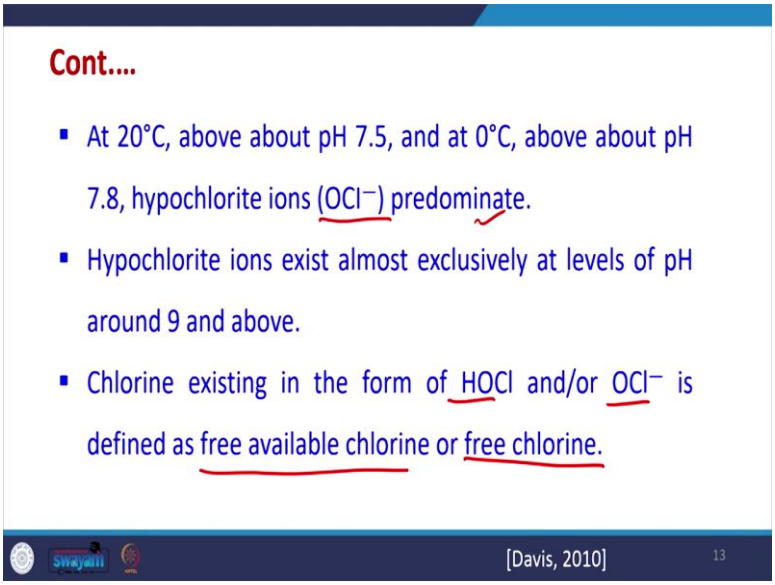

That we can understand at 20 degrees centigrade and above 7.5. And at zero degree centigrade above about pH 7.8, HOCl will always be hypochlorite ions will be present. So, OCl minus hypochlorite ions will be totally be present. So, if the pH is above 8, everything will be in the chloride hypochlorite ions will only be present chlorine will get converted into hypochlorite ions.

So, this is there, now chlorine exists in the form of HOCl are OCl minus, that will be considered as free available chlorine are free chlorine. So, we always want that how much amount of free chlorine is available also the HOCl and OCl minus have different reactivity or oxidizing potential. So, depending upon their potential, they are able to disinfect the pathogens which are present in the water.

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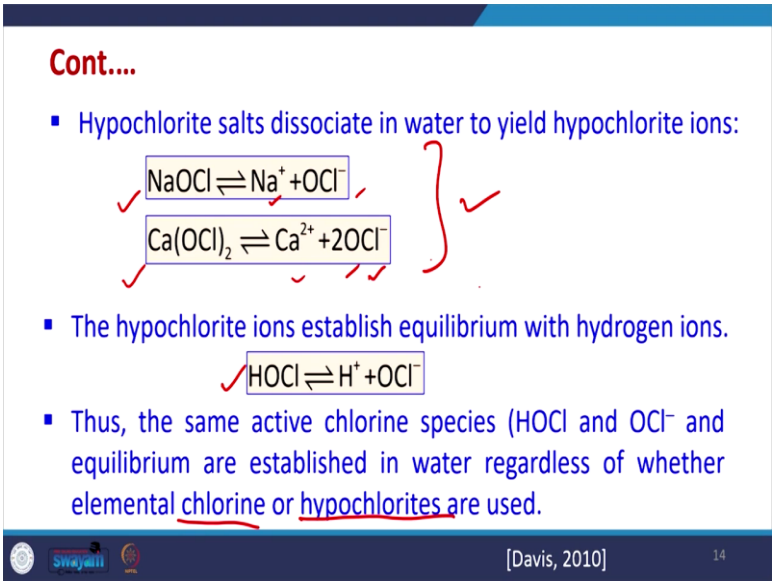

So, this is there now going further the hypochlorite salts if we are adding like NaOCl are CaOCl2 So, whether we are using sodium hypochlorite are calcium hypochlorite. So, they will do dissociate in the water to yield different hypochlorite ions. So, they will dissociate in this manner we can see here the hypochlorite Ions if they are getting added in the water.

So, they will establish an equilibrium depending upon pH whether they will get converted into HOCl so, some amount of that will get converted into HCl depending upon pH. So, if pH is high beyond 8 or 9, so, OCl which has been formed here it will remain as such, but suppose pH becomes six. So, some part of that will get converted into HOCl.

So, this is there the same active chlorine species HOCl and OCl minus and equilibrium are established in water regardless of whether elemental chlorine either hypochlorite is used. So, this is there. So, and these are the most common use the chemicals for disinfection in any water tanks or otherwise. So, they are very, very commonly used.

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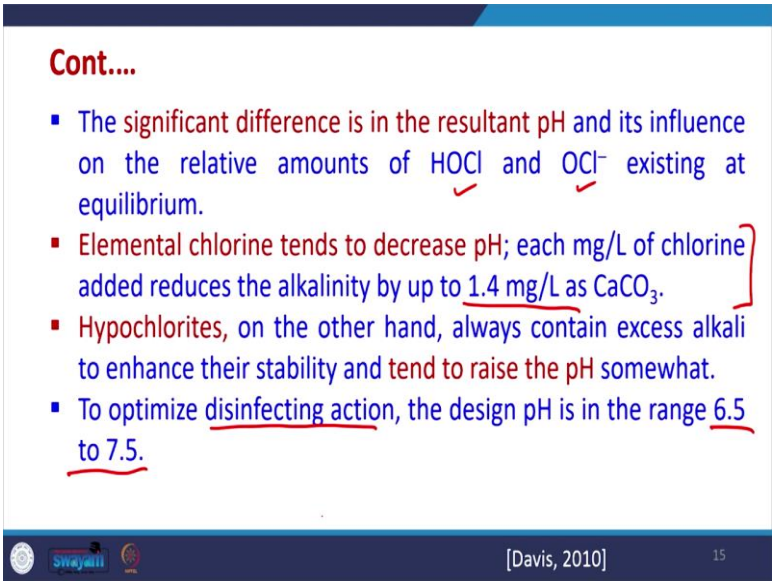

Now, the significant difference is the resultant pH and it influences the under relative amount of HOCl and OCl minus, which are present at the equilibrium. So, that already we have discussed the elemental chlorine tends to decrease PH. So, each milligram of chlorine added reduces the alkalinity by up to 1.4 milligram per liter as CaCO3. So, this is very important information and from this there will always be a pH decrease when we use elemental chlorine hypochlorites if other hand we are using and so, always they contain excess alkali to enhance their stability and they tend to raise the pH somewhat.

So, this is there to optimize that disinfecting action, that design pH is generally in the range of 6.5 to 7.5. So, in this range, we generally get very good disinfection and we are able to disinfect most of the pathogens out of the water if we are using chlorine as ion disinfecting agent now, will try to today understand some of the questions related to disinfection. So, if the first question is given here for better understand,

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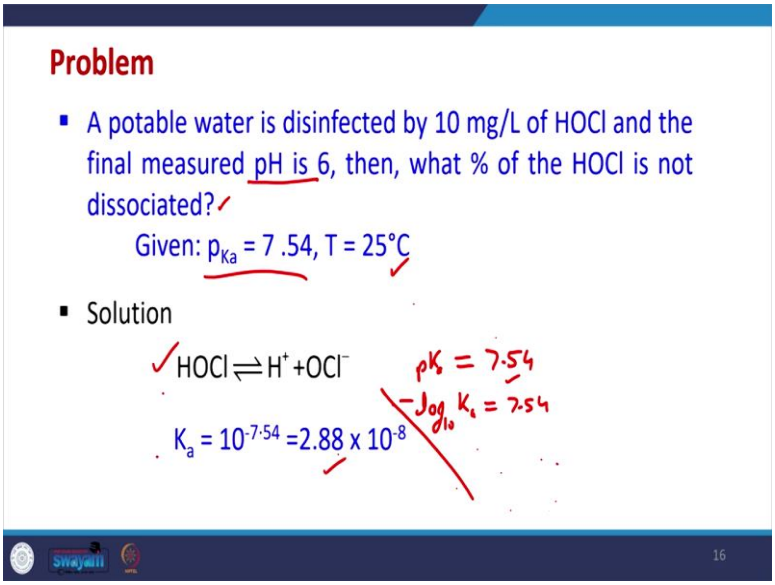

So, a potable water is disinfected by 10 milligram per liter of HOCl and the final measured pH is 6. So, we had to find out that what percentage of HOCl is not dissociated. So, this is there and the Pka value of this particular dissociation reaction which is given here it is 7.54 at 25 degrees centigrade. So, from the literature we can find out the Pka value. So, the Pka value of this particular equation is 7.54 which is available from the literature we can find out experimentally also there are many techniques for that. So, this is there.

So, this is already reported. So, we have to find out that how much amount of HOCl will not dissociate it, if we are adding this HOCl at 10 milligrams per liter at pH 6 this is the question that has been asked. Now, going further if now, since Pka value is 7.54 so, we can find out the equilibrium constant for this particular equation as k is equal to 10 raise to minus 7.54. Because this is log minus log 10k. K so, this will be equal to 7 point 5 4. So, thus we can say that K is equal to 10 raise to minus 7.54 so, this value will be 2.88 into 10 raise to minus 8 if you solve it.

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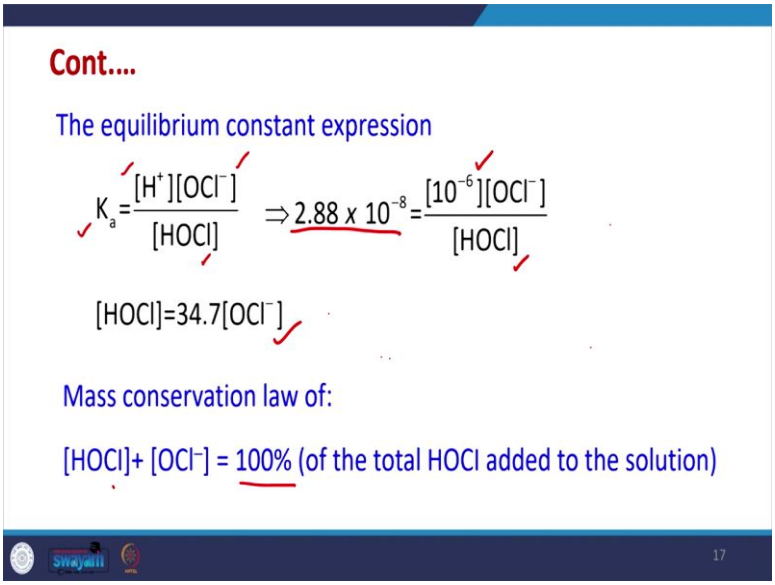

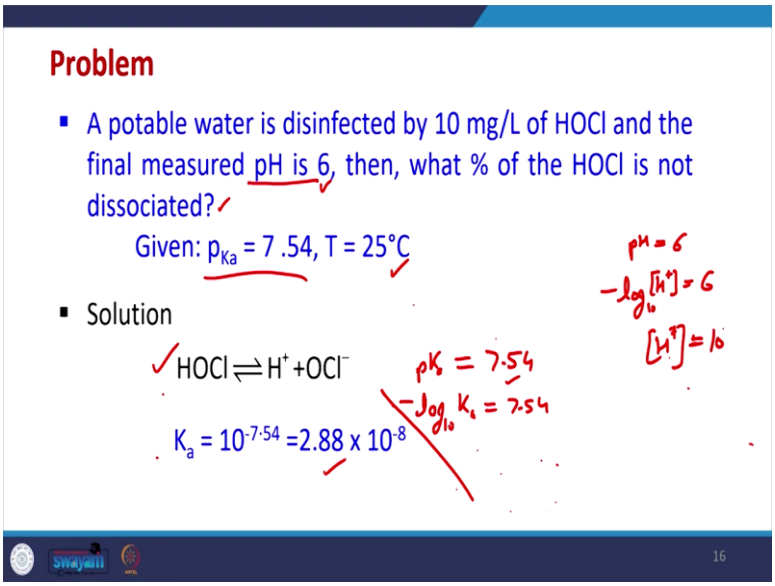

Now, since the value is known, now equilibrium constant expression for this particular equation, which is given here is like k equal to H plus OCl minus divided by a concentration of HOCl. So, these are the respect to molar concentration which are there now, this is already K value already we have found, so, this is written here now, it is the pH has been given, now the pH is 6. So, since the pH is 6, so, that means the pH is equal to 6.

So, that means minus log H plus concentration is equal to 6. So, that means, the H plus concentration we can find out and this is equal to 10 raise to minus 6 this is there. So, this is what is written here 10 raise to minus 6 HOCl concentration, we have to find out and the relationship between both is now known. Now, the total mass conservation law tells us that

HOCl plus OCl minus they should be equal to 100 percent of the total HOCl which has been added into the solution and which is 10 milligrams per liter in the present case.

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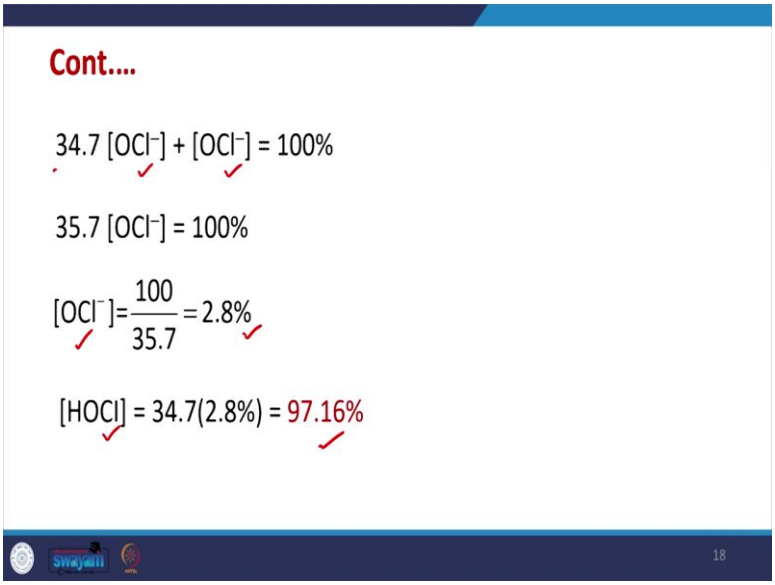

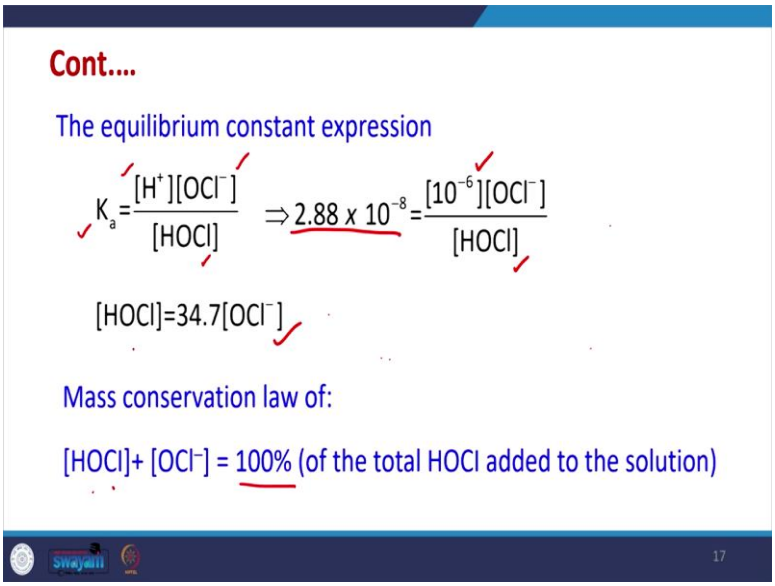

So, from that data, what we do is that we add this relationship here and if you solve it, so, 34.7 OCl minus plus this is equal to 100 percent and if you solve it will be finding it. OCl concentration is now, 2.8 percent So, that means HOCl concentration is 97.16. So, through this, we come to know at pH 6 at pH 6, it is 96, 97 percent of the chlorine are hypo added will be in the form of HOCl.

So, this from this we get to know the different ideas which can be used for calculation of the concentration of this chlorine species from the data that we have. So, now in this lecture we have started that disinfection section and today we learn regarding that what are the different

types of disinfectant which are used some chemistry part of the disinfection and we tried to calculate that how much amount of chlorine and which amount of which type of chlorine species will be present at which pH, so, we perform some calculation of the debt. So, we will continue with that disinfection section in the next lecture onwards. Thank you very much.