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**Lecture-37**
**Other Disinfection Method Ozone and UV Disinfection**

Welcome friends we will continue the discussion from our previous class. We were discussing about the disinfection methods and in the last class we had an elaborated discussion on the chlorination process. Now in this class, we are going to talk about other disinfection methods which in will be basically focusing on the ozone and UV disinfection and then we will conclude with kind of a comparison of the different disinfection methods, the major disinfection methods of course okay.

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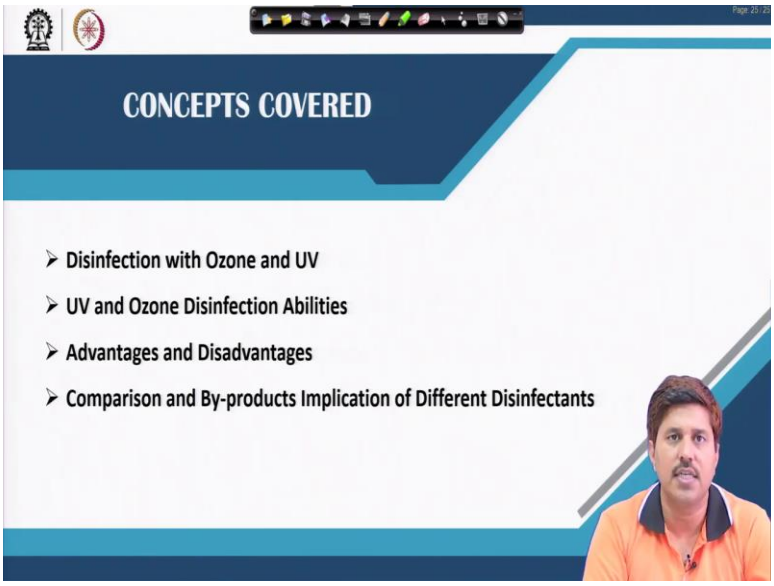


So what we are going to cover in this class is the UV and ozone disinfection and what are their abilities what are their mechanism their advantages and disadvantages and then we will compare these different disinfection methods based on the their by-product implications and the applicability and other advantages and disadvantages.

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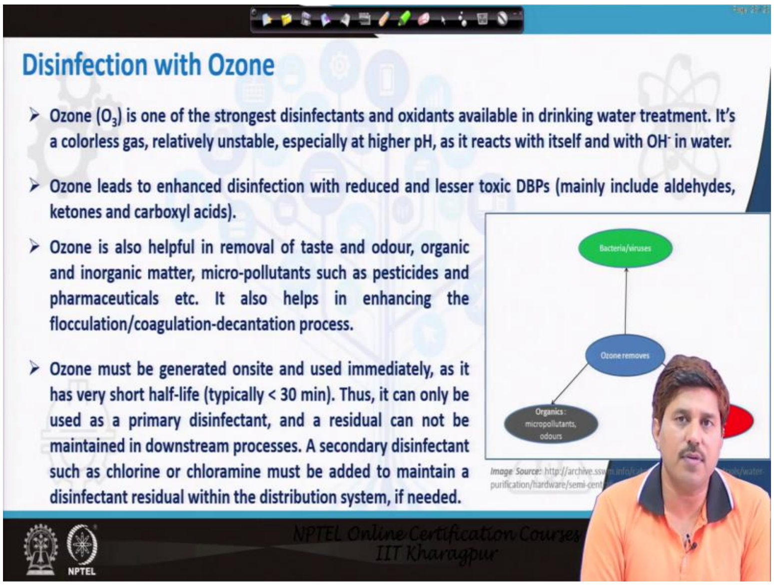


So, another like apart from chlorination the other method which is being used for the disinfection for drinking water systems is the ozone. Ozone is basically the strongest disinfectant and oxidant available in the drinking water treatment. It is a colourless gas but very unstable it is very unstable if you compare it with the chlorine it is quite unstable and especially at higher pH.

It can react with itself and with OH and in the water which can produce the hydroxyl radicals and which kind of act as a very strong in fact, stronger oxidant than the ozone itself. So, Ozone lead to enhance disinfection with reduced and lesser toxic DBP's the DBP is mainly includes aldehydes, ketones, carboxyl acid. So, it does produce DBP's but not like hallow acetic acid or trihalomethanes it generally produced aldehydes, ketones, carboxylated kinds of DBPs which are far less toxic as opposed to the DBP is produced by the application of the chlorine.

There are added advantages with the with the ozone system that it is helpful in the removal of taste and order. It can remove the organic and inorganic matters, it can remove the micropolitan such as pesticides and pharmaceuticals etc and it can also help in enhancing the flocculation coagulation detention process. So, that is the reason many times ozone is provided before coagulation flocculation process.

But again in that case also we, this act as just primary disinfectant and we have to use as a secondary disinfectant after that okay. So, ozone will remove the bacteria viruses it will remove the various in organics like arsenic, iron, manganese kind of substances and it will remove the various organ organics like micro pollutant and other stuff. The issues are that it because of its unstable nature, it, it needs to be kind of generated on site and used immediately as the half-life is very short approximately just less than 30 minutes okay.

So that is why it can be used as a primary disinfectant and unlike chlorine it cannot leave a residual that can go into the distribution system and ensure the post treatment safety. So, that is one of the unique advantages of chlorine system that they leave a re they leave a residual in the system which ensures the future safety as well whereas the ozone or for that matter UV or ultrasonic ways of this disinfection they will disinfect very effectively, but the disinfection lasts only till they are in the contact okay.

After that if any regrowth occurs or if any which is like potential of regrowth is very little or almost negligible. But recontamination may occur and if some recontamination occur it is not going to help in any way. So, for that we need secondly disinfectants such as chlorine or chloramines, we can add to maintain a disinfectant residual within the distribution system. so we can go for primary disinfection with the ozone and then use the chlorine compound for secondary disinfection.

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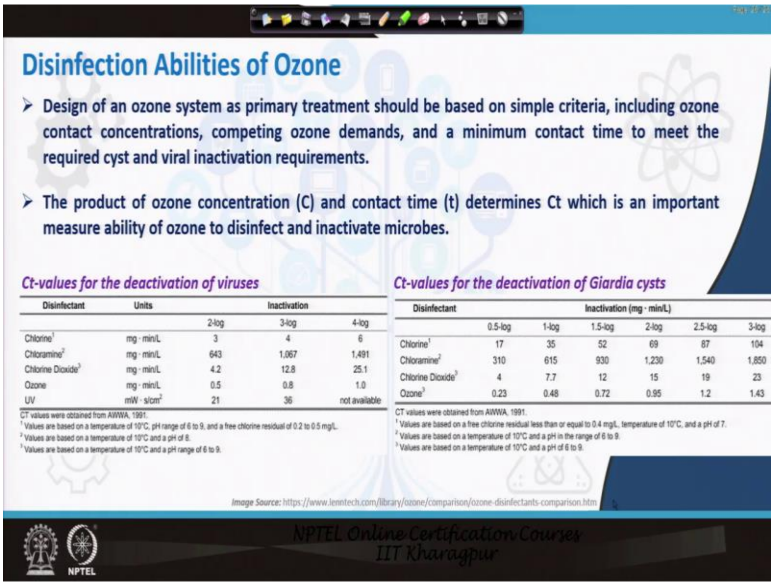


We use CT concept for design of the ozone doses okay. So, if you see the CT value for deactivation of the viruses, so like, the this is the chlorine compounds they have C T in the range of like chlorine has for too long reduction three chloramine has 643 and chlorine dioxide has 4.2 four log reduction it is in this range. Ozone, has just one okay. So, one milligram per minute per liter dose is good enough to ensure four log reduction just 0.5

milligram per minute per liter is good enough to ensure almost two log reduction of the various viruses.

For Gardea which is say difficult to remove compound again, if you see the chlorine compounds so for, for say two log reduction the doses required are 69 15 or 1230 very high doses whereas ozone requirement is just around one milligram per minute per liter. So, you can see that what how effective it is in comparison to the chlorine compounds. So, that is why it can be used as a primary disinfectant and if needed residual chlorine maybe like produced by adding some chlorine compounds for the secondary disinfection purpose.

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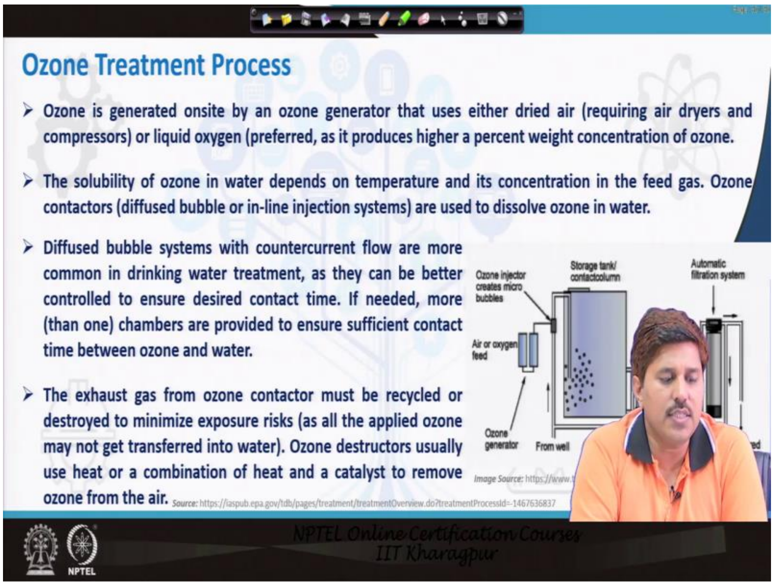


The other attributes of the treatment process is how we apply it okay. So, as we just discussed that ozone is generated on site by ozone generator. And this ozone generator either use uses kind of dry air. Now for purpose of producing dye air, we need air dryers because the air that we get in the atmosphere might have the humidity so we need either air dryer okay or compressor so that we can use dry air from the atmosphere or we use dry air cylinder right away.

Or we use liquid oxygen liquid oxygen is rather preferred because it produces better quality of the ozone in terms of like the which is being produced will have a higher percent weight concentration of the ozone. So, that is why it might it is in fact more preferred liquid oxygen is more preferred over using just simple dry air the solubility will depend on the temperature and its concentration in the feed gas okay. So, whatever like feed gas we are providing either we are providing liquid of the oxygen or we are providing dried air and that will generate ozone and how much what is the solubility of ozone at that particular temperature at which we are operating will kind of guide how much soluble it is.

The Ozone contractors are generally of two types. So, we can have the say diffused bubble contractor or inline injection system which is used for dissolving ozone in the water. The diffused bubble system may be of the counter current flow okay. Generally, it is of counter current flow counter current means will pass water from the top and the ozone will be basically because it is a gaseous element so it will be moving up.

So, the direction of the flow is different the water moves from top to bottom the gas moves from bottom to top or ozone moves from bottom to top so that is called the counter current flow. So, this is more common for drinking water treatment as it kind of provides a better contact time okay. If needed we can go for more than one chambers and then we can have like ozone sub flow in the subsequent chamber as may be counter current or Co current where both are passing in the same direction.

Water is also a flow and the ozone is also a flow or we may have a flow through system also where we are not adding any ozone, we are just allowing the water to stay for some time so that the contact period is enhanced. So, we may have that kind of different chamber as well. The one of the issues with ozone system that because the efficiencies of the like ozonation process or whatever ozone we are generating and how much is it is getting dissolved in the water it may not be hundred percent.

And then we may get exhaust gas which might contain ozone and it can basically lead to the exposure risk of the ozone.So, that is why proper safety must be taken care and the ozone destructors which usually use heat or a combination of heat and catalyst may be used to reduce ozone to kind of remove the ozone from the exhaust air which is coming out of these systems.

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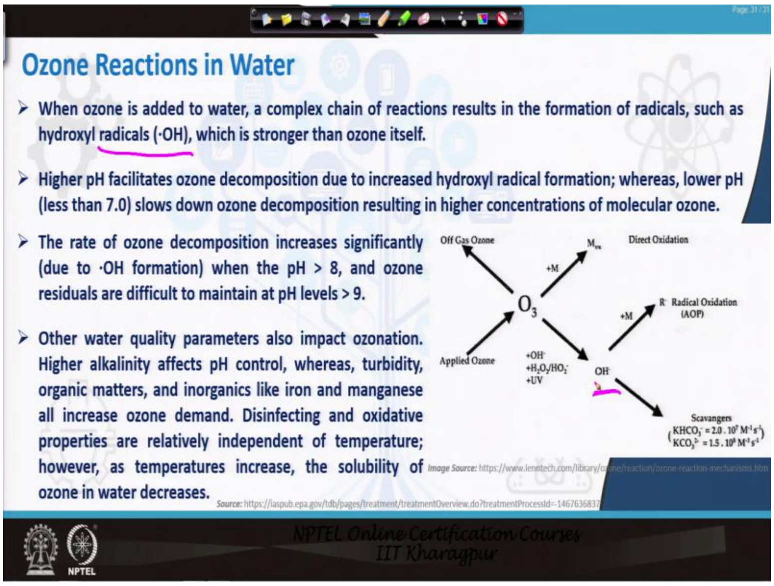


If you see the ozone reaction in the water so, when ozone is added in the water, basically a complex chain of reaction results and there there are different radicals can be formed. The OH radical or hydroxyl radical is the one of the most reactive and most common. But if there are like, many times H 2 O 2 and those kinds of things are also added alongside, so that more like strong oxidant can be formed, at times. So, the hydroxyl radical is stronger than ozone itself.

The higher pH facilitates the ozone decomposition so that is why the reaction at higher pH will increase the hydroxyl radical formation. And it will be more effective at higher pH lower pH less than 7 slows down the decomposition of the ozone so that will have higher concentration of molecular ozone and lesser concentration of the hydroxyl radicals. So, the rate of ozone decomposition that way increases significantly due to wedge formation, hydroxyl radical formation when pH is greater than 8.

And ozone residuals are difficult to maintain at pH levels greater than 9. So, if you are having a pH greater than 9 then ozone will not remain in the water. all ozone will actually react and we will form the hydroxyl radical. And this hydroxyl radical are because of their very high reactivity, they can actually lead to different kind of oxidation reaction including the disinfection process as well.

Apart from this there are other water quality parameter that also impact okay since we are talking about pH so ultimately itself becomes very important okay. We must ensure that there is adequate alternative to pH control. pH is not falling rapidly so if alternate is higher it will have better pH control. If turbidity organic matters or inorganics like iron and manganese are there present in the system, so they will increase Ozone and demand similar to chlorine demand okay.

So, like there is chlorine getting react to these compounds we call that chlorine demand. So, similarly if these kind of agents are present so ozone will basically oxidize them and in the process some zone will get consumed. So, that will basically caught cause to the ozone demand in the water. So, more of these compounds higher is the ozone demand and more ozone, we need to supply so the process like becomes more costly.

And the disinfecting and oxidative properties are relatively independent of temperature though okay. However, as temperature increase the solubility of the ozone in water will decrease. so, this is the effect of temperature.

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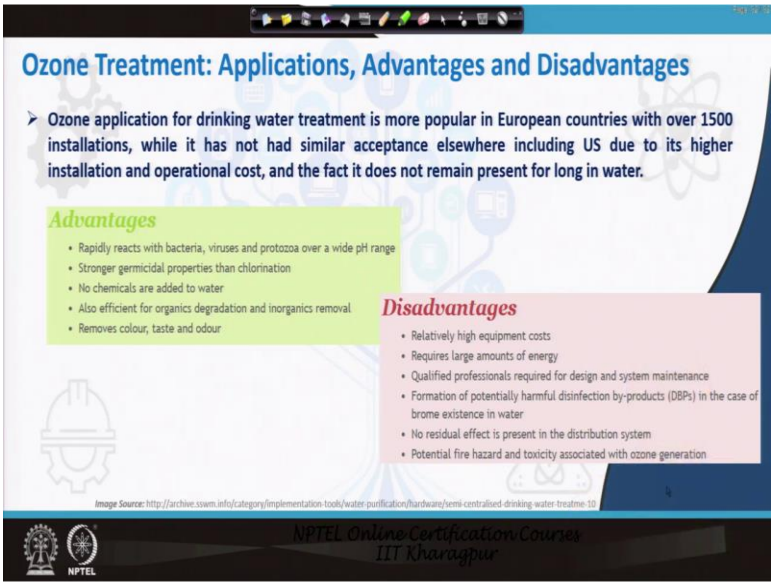


Ozone application is more popular in the European countries. There are over 15,000, 1500 installation in various European countries and this data is also not up to date okay. This is around say mid around 2014 or 15 data so there might be more number of installation that has come up. In US, there was around a similar time there was around 250 installations okay so far less as opposed to the European countries.

European countries are by far the most like most popular user or more they use ozonation for the great extent as it appears from the number of installation itself. But this process has not had similar acceptance elsewhere. The main reason is the higher installation and operational cost and the fact that you need to have a secondary disinfectant in the system, if you want to ensure the post safety.

So, in developing countries where the health risks are high they anyway prefer chlorine because of their because of its ability to ensure the long lasting disinfection abilities by insuring the chlorine residuals in the treated water. So, on advantage side the Ozone actually rapidly reacts with the bacteria okay and virus protozoa or a white pH range. It is a strong germicidal properties then chlorination there is like apart from ozone of course we are adding ozone.

So, apart from ozone no other chemical is being added to the water which is also a gas and can leave the system very short left and the amount is also low it is also efficient for organic degradation and inorganic removal it removes color taste and order as well. On the flip side the cost is quite high requires lot of energy it requires qualified professional for design and system maintenance ok. Some DB P's will still be formed but of course lesser than that and it has no residual present in the distribution system.

That is one of the major demerits because it does not lead to any residual protection okay and it may cause potential fire hazard and toxicity associated with the ozone generation system okay.

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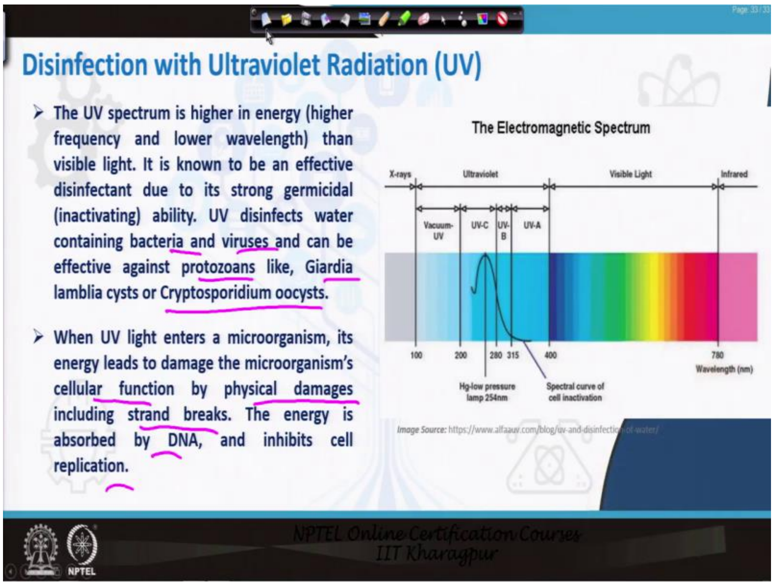


The other disinfectant is UV so disinfection with UV radiation is also getting more popular. In the UV spectrum is generally higher in energy than the visible spectrum okay. So, visible spectrum has higher wavelength and low frequency as compared to the UV spectrum, UV spectrum that may have higher energy than the visible spectrum, but lower than the x-ray okay. X-rays are x-rays have even more even higher energy than the UV spectrum okay.

And they have further kind of lower wavelength and like higher frequency. So, because of higher energy UV disinfectant in water that contains bacteria and viruses can be very effective. It kills the bacteria it kills the virus it is also effective against the protozoa like Giardia, lamblia cysts and Cryptosporidium etcetera. So, when UV light enters a microorganisms its energy leads to the damage of microorganism cellular function okay.

It will damage its cellular function and this damage could be because it could be by sheer physical damage. It can basically include the sand strand breaks. The energy is absorbed by the DNA and it inhibits the cell replication okay. Now, if you see the electromagnetic spectrum it is generally the if you see the spectrum curve for cell inactivation so this is the wavelength range, which basically is good for Saline activation.

So, around 254 nanometer or some differences say around 264 nanometers in fact okay so around this range, around 254 in between somewhere this range 254 to 264 nanometer range, we see the peak here, appearing and if we put the exposure of UV light in this range, it can lead to very high degree of Selene activation. If you are putting exposure in other light ranges it is not that effective okay. So, the like the curve shows here that this could be the ideal range for in activating the microbes.

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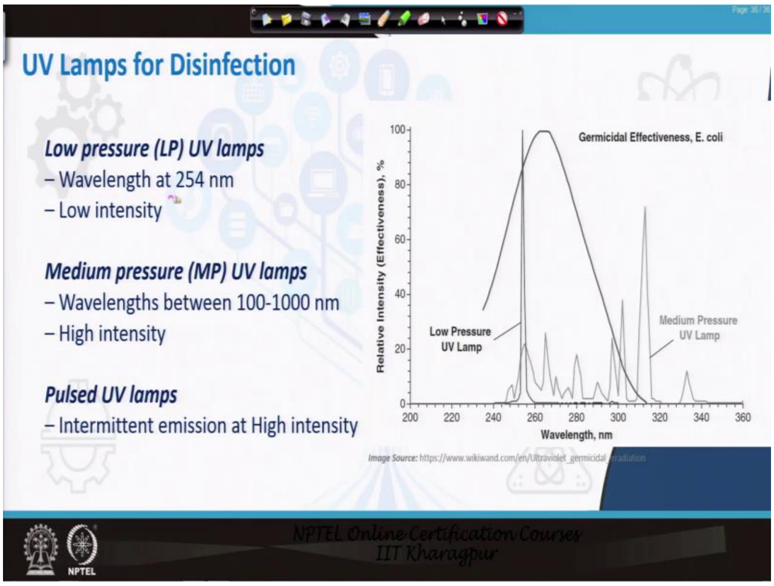

So the lamps that are used for disinfection purpose there are low-pressure UV lamps which is generally made of mercury. And then, medium pressure UV lamps again made of mercury are there. So, low pressure range low pressure UV lamps target the wavelength at 254 or 264 or somewhere in between where the efficiency is highest generally 254 is the target okay. So, the lamp I have a wavelength out of 254.

And if you see this is the low pressure UV lamp so it will lead a lighter at this wavelength which is having very good disinfection abilities. This is the germicidal effectiveness for E.coli for same. The medium pressure lamps have high intensity as opposed to the low pressure lamp which works at a low intensity. The medium pressures have high intensity and they work at a wavelength which is far more wider.

So, generally like they can work in a wavelength range higher wavelength range okay in these means we can get of different types. So, they may work in a higher wavelength range and a cumulative effect of this is appeared and the intensity is also very high. We may have pulsed UV lamp which is intermittent emission of the high intensity.

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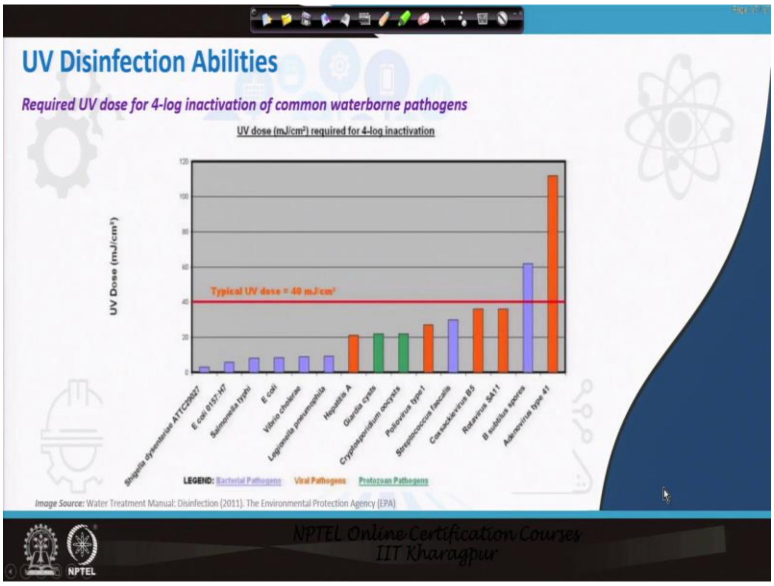


So, instead of like regular emission of the either low or high intensity intermediate pumps may lead to intermittent lamps may lead to the like impulse emission okay the disinfection abilities are also quite good okay. If you see the required UV dose for for login activation of the common waterborne pathogens, so, typical UV doses are in the range of 40 milli Joule per centimeter square and this is sufficient enough to take care of majority of the microorganisms okay.

However some like some couple of this species may require high so that is there okay. If you see, these are the bacterial pathogens, all taken care of more or less okay apart from just one spores. This is the the orange one are viral pathogens. Again these are taken care of some might still persist and the protozoa like Cryptosporidium and Giardia cysts are very well taken care of okay.

So, that way UV is considered very effective because it can basically consider the it can take care of the Giardia and Giardium kind of species which are difficult to remove from the simple chlorination systems.

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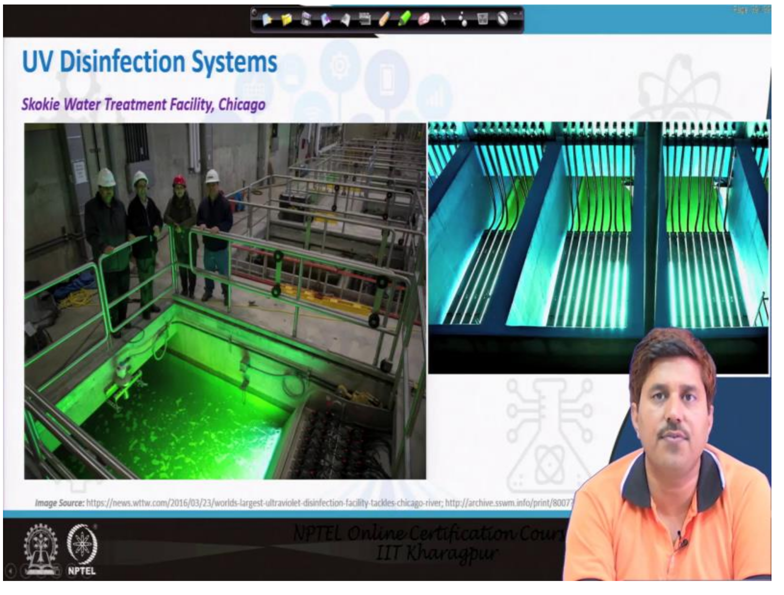


This is a couple of examples of the UV disinfection systems okay. So, eventually process is simple we need to just make the light expose to the water, UV light exposed to the water and as the energy or the light beam incident on the cell, it will disrupt that, it will be basically through physical damage or the process just we were discussing it can lead to the like deactivation or inactivation of the microbial species.

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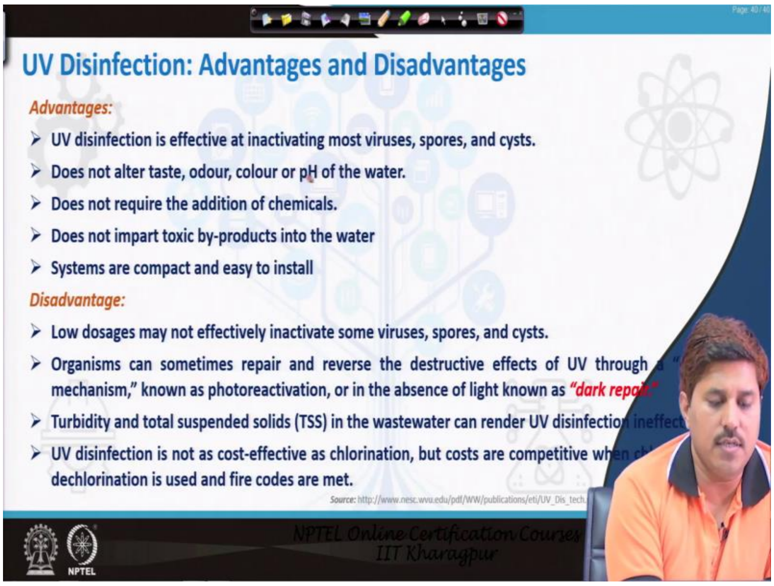


So, advantage side, UV disinfection is effective against inactivating most viruses spores and cysts. It do not alter taste order color pH of water. It does not require addition of any chemical okay even there like ozone or gas form chemical is also not required here. It does not impart any toxic by-product to the water. So, that is another very important advantage. It does not produce the by-products. Systems are compact and easy to install.

On the disadvantage side, the low doses of UV may not like effectively inactivate some viruses spores or cysts. So, we have to see like we may need adequate doses and but that might make the system costly. Organ is the another risk in fact is that the organism can sometimes repair and reverse the destructive effect of the UV. So, whatever destructive effect that UV is causing on the organism they can actually repair that known through a repair mechanism which is the photo reactivation.

And this happens in the absence of light as and known as dark repair. Through this dark repair process there is a possibility of microorganism reactivating themselves okay. But again the evidences are very little for this. On the other hand, the turbidity and total suspended solids in the water also render UV disinfection in effectiveness. So, like if there are turbidity or total suspended solids present in the water, then UV disinfection might not that be very effective.

Also it is not a cost-effective option okay. The requirement of the cost and energy is relatively higher as opposed to the chlorination. However it may be actually competitive with chlorination if we consider the complete chlorination de chlorination process and like put a system which follows all fire codes and other things, then, it may be actually come to the comparative to the chlorination process.

The point that it is ineffective against the turbidity and total suspended solids it is let us say because you see the UV or in fact the similar mechanism is adopted in the ultrasonic exposure as well okay that is even less use. Ultrasonic exposure is not a method for disinfection which is very popular these days. These days still like chlorine UV and ozone are by far the most popular mechanism for the disinfection. UV is very effective in smaller treatment facilities okay.

So if you see like many of you might be having the purifiers in your households okay. So, the RO system and many other systems come with a UV lamp for disinfection purpose. or you might be seeing advertisement on the television. So, UV is that way is quite popular for a smaller system and that helps in because there is no addition of the sort of chemical is needed all right. And generally these systems have ultra filtration or in some cases even RO treatment beforehand.

So water quality is reasonably good and just a little exposure of UV ensures safety from the pathogens on any sort of microbial contamination. So, they work well at a smaller system. At a larger system we need lot of like lot of arrangements to ensure that the penetration of UV is covering the entire mass of the water. And moreover, we were just we were discussing if you are having the turbidity and suspended solids present in the water, so what happens that these microorganisms may like if you have say UV lamp here and it is putting a light beam and it is striking to suspended particles and microorganism is behind this.

So, in that case, this microorganism may not get exposed to the UV light or may not actually the UV light cannot directly penetrate to the microorganism cell and disrupt that or physically damage that. So, if there are more turbidity and more suspended solids so more such protection can be like there for microorganisms. And like the efficiency of the disinfection would decrease substantially. So, that is one of the risks with the, these kind of processes.

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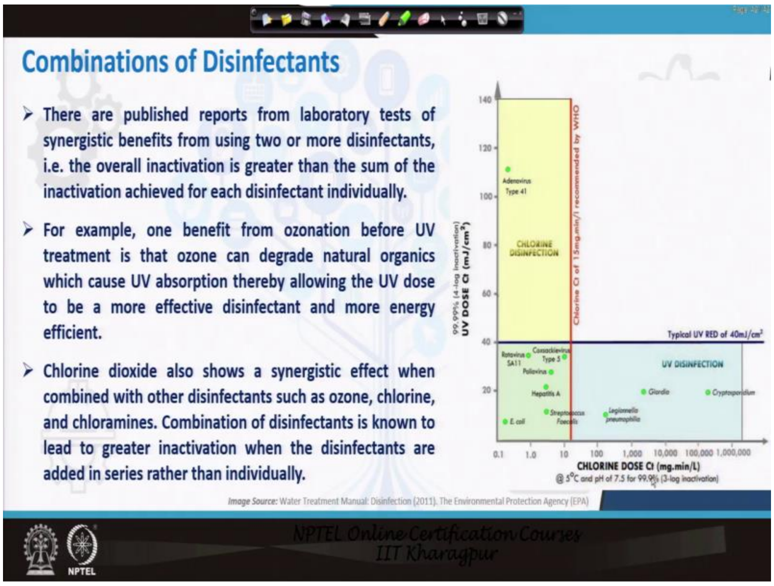


Many times the combination of disinfectant is also recommended but very rarely used okay. The people have shown that particularly, the laboratory tests have shown, that they have the synergetics, they have the synergistic benefits for using two or more disinfectant together so that overall inactivation can be higher than some of these two independent systems okay. For example, like the ozonation, before UV treatment is shown that ozone can degrade natural organics okay which can cause the absorption of the UV light and thereby allowing UV dose to be more effective disinfectant.

So if let us say organic compounds are there which is absorbing UV light. You put a UV light and the you light is getting adsorbed by the organic compound it is not actually fulfilling the purpose purpose of disinfection. But if you provide ozonation beforehand it can actually degrade or decompose those organic matters so that UV also becomes much more effective. Then, the similarly like chlorine dioxide have also shown the synergistic effect when combined with the ozone or chlorine or chloramines.

You see one such example. Like this is the deactivation through UV disinfection for the different species now this particular species requires like if you see the UV dose requires huge amount of UV dose. So if you want to remove this and this together so you need to actually cover whole spectrum with the UV okay. Similarly, if you are putting chlorine so chlorine is very effective in removing these all these compounds at a less dose.

But if you want to remove Cryptosporidium you need to add chlorine doses up to here or say up to here okay. So, then you are actually like you need to add this much amount of chlorine.

On other hand, for complete removal you need to add this much amount of say UV exposure you need to ensure this much amount of UV exposure. If you are using this together so which this particular species which needs a lot more energy for removal, so in only for removal of this species you may need to add this much of extra power in the UV which can be very easily removed with the just disinfection like with little dose of the chlorine okay.

And whereas this particular thing which needs lot of chlorine for removal might get removed with a very less dose of the UV, so, instead of putting a like instead of going for chlorination with this much amount or instead of going for chlorination up to up till this much amount or going for the UV exposure from here to here, it is advisable to use let us say, lit UV light only from here to here. So, saving lot of energy from UV and chlorine dose only from here to here, so, saving lot of chlorine and achieving removal of all the target microorganisms okay.

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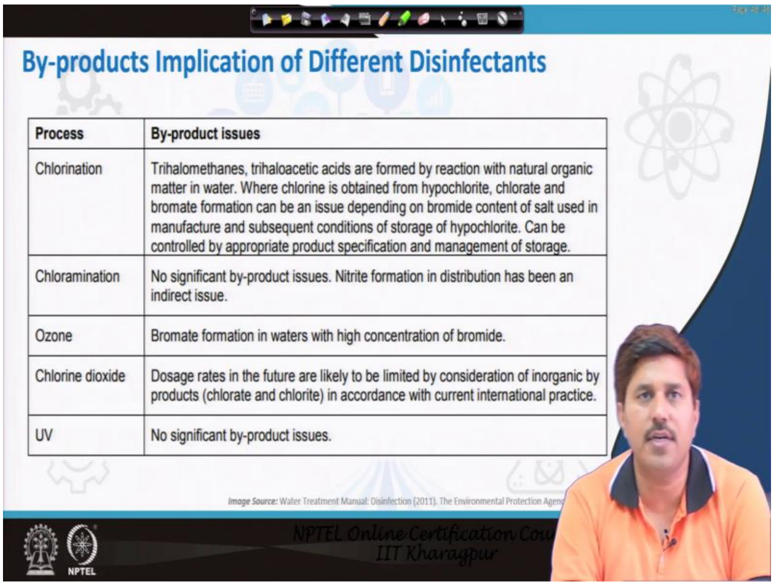


So, that way like we can see that combination of disinfectant may also up giving the better results at times. Now, if you see the by-product implication of the different disinfectant what we have seen so far, so chlorination again as we discussed is one of the most risk in terms of by-product formation. It produces trihalomethanes, it produces the hello acetic acids which are carcinogenic okay. So, that is that risk is there where chlorine is obtained from hypochlorite, Chlorate or say bromide formation can also lead.

So, these are like some of the challenges with the chlorination process. Chloramination process no significant by-product issues okay. Nitrate formation in distribution has been an indirect issue though because in distribution nitrate formation may be there. There are some by-product formations in chloramination as well but far lesser. Ozone will lead to bromide formation in water with high concentration of bromide which could be an issue.

Chlorine dioxide again dosage rate in kind of controls the formation of the many of the by products okay. But still some products are found and UV does not produce any significant by-product.

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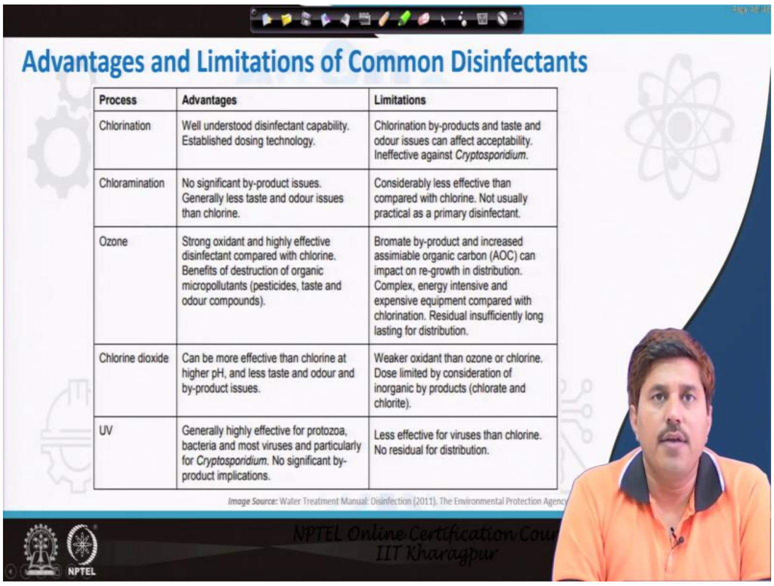


If you see the advantages and limitation of these common disinfectant methods, so we already have discussed that, the chlorination have advantages that well understood and relatively simple method established technology okay, produces residual chlorine, whereas limitation is there are by-product, there are taste issues and it might be ineffective against Cryptosporidium. Chloramination again it is less effective than even the chlorine okay.

So that is one of the issues whereas and the advantage side the byproducts are far lesser that taste and order issues are generally less than that of the chlorine. Ozone is very strong oxidant very effective disinfectant compared with the chlorine. It can remove a variety of other substances including the organic micropolitan space taste and order creating compounds or it can oxidize iron, manganese kind of substances and then they can be removed.

The flipside it may lead to the bromated  by-product okay and it is an energy intensive process, cost intensive process and it does not lead any residual in the aqua system. Then, chlorine dioxide is again more effective than chlorine with typically at higher pH and has less taste and order issues, less by-product issues, whereas again it is a kind of flipside it is costly great needs great technical expertise and comes with a risk as well.

And UV as just we discussed okay is very effective especially against the Cryptosporidium and giardia kind of compound it does not lead to the any by-product okay. But again, it is less defective for viruses then the chlorine and it also does not lead any residual chlorine for distribution and may be actually requiring higher amount of cost and energy, for the installation purpose and of course the operation purpose as well.

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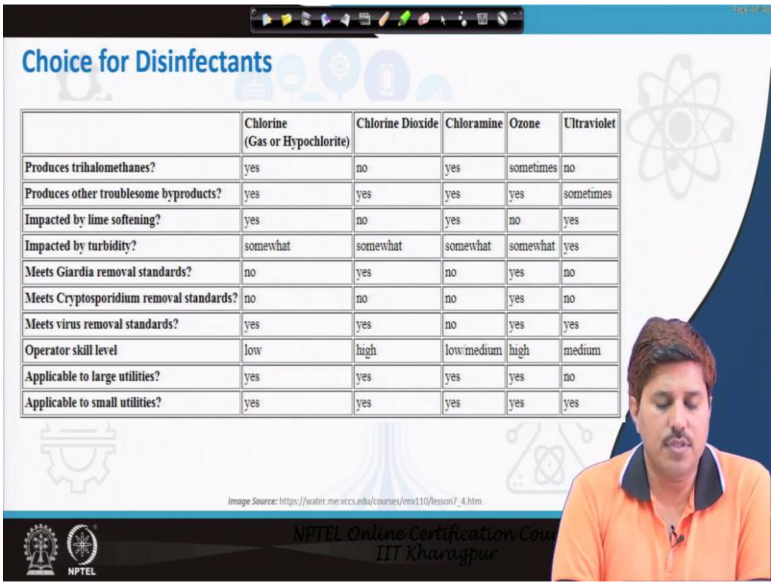


| | Chlorine (Gas or Hypochlorite) | Chlorine Dioxide | Chloramine | Ozone | Ultraviolet |
|---|---|---|---|---|---|
| Produces trihalomethanes? | yes | no | yes | sometimes | no |
| Produces other troublesome byproducts? | yes | yes | yes | yes | sometimes |
| Impacted by lime softening? | yes | no | yes | no | yes |
| Impacted by turbidity? | somewhat | somewhat | somewhat | somewhat | yes |
| Meets Giardia removal standards? | no | yes | no | yes | no |
| Meets Cryptosporidium removal standards? | no | no | no | yes | no |
| Meets virus removal standards? | yes | yes | no | yes | yes |
| Operator skill level | low | high | low/medium | high | medium |
| Applicable to large utilities? | yes | yes | yes | yes | no |
| Applicable to small utilities? | yes | yes | yes | yes | yes |

So, for choice of the disinfectant these are the common disinfectant. Let us say we have we can use chlorine gas in the form of hypochlorite, chlorine dioxide, chloramines, ozone, ultra white and based on like which produces trihalomethanes, so we can see based on our requirement okay whether we want to apply it to large utilities. So, large utilities again you see that ultraviolet is not an option has just we discussed or ultrasonic or any such method are not an option.

For small utilities all may be applied the operator skill required what kind of this thing meeting the bacteria, meeting the Giardia, Cryptosporidium and virus removal standards so how would they are, what is the impact of turbidity, so of these are the questions which can guide on to the selection of the appropriate disinfectant. So, with this we conclude the class here, we have discussed about the disinfection processes.

Now, we will move to the next part on the sludge management. And then, subsequently we will be discussing the advanced the water treatment systems in the remaining lectures of the week. So, thank you for joining I see you in the next class.