

Water Quality Management Practices
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Week – 05
Lecture – 22
Neutralization, Dissolved Air Floatation

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar Bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. So, in this particular module continuing with the earlier discussion will be continuing with different primary treatment units. And this particular lecture I have selected neutralization and the dissolved air floatation or in short we call it DAF. We will discuss about it and we will try to understand the concept and also we will design one neutralization basin and also we will design how the different type of DAF systems and all.

So, this is the this is the different the contents as I was mentioning the neutralization and the dissolved air floatation that I will be covering. So, neutralization to start with why do we need neutralization unit? So, from the name itself we can understand in the wastewater there is a chance that there will be a pH imbalance. It may have some component because of which the pH can go very low or very high. However, if the pH imbalance is there what will happen that wastewater one it will come to the secondary treatment units specially the biological treatment units. Those living organisms will definitely die because of the pH imbalance. Forget about the living organisms there is a chance of having some additional chemical and different kind of chemical processes which will start begin on that systems because of this changes in pH and which will definitely have a very quite a bad effect on the nuisance to I would say in your treatment design and as well as finally, your efficiency will also be altered. So, that is the reason we need to provide one neutralization basin where we normally try to nullify this and try to adjust the pH level and we try to adjust it to the level at which actually your follow up treatment units can actually work better. So, in general the sewage normally have a pH value somewhere around 5.5 to 8. So, we try to maintain that range. If possible maintain at around 7 pH. So, that where most of the treatment plant performs its in its maximum or optimum. So, any fluctuations below 5.5 or above 8 requires a certain action and this action is what we call it the neutralization action.

So, in we add some chemical or we do some mechanical we introduce some mechanical unit by which actually we can reduce this fluctuation. So, normally it is a the acidic waste water if it is there you can see then we use either if it is a acidic waste water that it receives. So, we use mixing with alkaline waste water, we use a lime stone or the lime slurry or we use a soda ash or the caustic soda to increase the pH value. If it is a alkaline waste water what we do we added with the sulfuric acid obviously, the concentrated sulfuric acid we blow the waste water blow the waste boiler flue gas. The waste boiler flue gas which normally it can cause problem to the air pollution that that because that flue gas anyway has the carbon dioxide methane all this components.

So, if somehow that additional carbon dioxide which anyway which create nuisance to

the atmosphere we can somehow be put it back into the alkaline waste water. So, what will happen because of the because of introducing the carbon dioxide it will form different type of acids which will reduce the alkaline the pH of the alkaline waste water isn't it. So, we are doing is like circular we are actually using one type of waste to treat another type of waste you understand. And then we sometimes do the we mix it with some acidic waste water if it is available. One of the best way of treating the acidic waste water is to introduce the lime stone chips you can see this is how it los like.

In this lime stone chips there is a normally what we do we it reacts with the acidity and produces the calcium salt as a product. And this reaction occurs on the surface of the lime stone chips and have because of high surface area with adequate contact time it is normally can have a very efficient for neutralizing the waste water acidic waste water. And this limestone bed neutralization is very effective for waste water having reasonably constant acidity. So, it also has some it also has some limitations. And what are the disadvantages of lime stone? Majorly it in an occurrence of unintentional reactions as I was mentioning requirement of high surface area of the lime stone.

So, you had it has to be as you have to make those chips as smaller as possible. So, because that the smaller it is the higher the specific surface area for a unit gram of product or unit weight of product. What happen after a while the calcium salt will deposit on the surface of it as it reacts with the acidic waste water and it produces the calcium salt. So, once it produce a calcium salt on surface of it, it becomes inert it is not non reactive at all after that. So, that is one major problem it also increases the TDS total dissolved solid and also the suspended solid in the waste water because of introducing this calcium salts.

And no control over the process if there is a variation of characteristics of neutralized waste water which is introduced to the system. Another important one is the lime slurry which normally made by crushing the dry lime with powder with water and this exhibits a higher reaction rate than the lime stone bed. However, this reaction in the lime stone with the waste water can be accelerated by providing heating and some additional amount of agitations. In general the reaction can be computed around 5 to 10 minutes a quick lime. So, calcium oxide is generally used with around 8 to 15 percentage of lime slurry for the neutralization of acidic waste water that is the standard practice.

What are the advantages of lime slurry? Due to the low solubility of waste water it is difficult to handle the lime slurry. Lime slurry it is not soluble in waste water in general it is very little like solubility is very low. The slurry also leads to the generation of high amount of sludge which needs to be de watered and disposed of and which also takes a lot of additional power requirement. Lime based chemicals are cheap, but less convenient due to the slower reaction rate. Therefore, sodium hydroxide, sodium carbonate, calcium carbonates are used either completely or in combination with lime for treating the acidic waste water.

So, flue gas as I was mentioned you can see the normally this flue gas which are exiting in the to the atmosphere via a flue. Flue means nothing, but a pipe or channel from a fireplace or open furnace or say like boiler or steam generator. It often refers to the exhaust gas of combustion of the in the power plant as well. So, blowing this excess this flue gas into the alkaline stream or alkaline waste water it will actually be a very economical neutralization technique. It comes out as a very economical one because this carbon dioxide it reacts with the waste water to neutralize the alkalinity present in the waste water.

And in general the carbonation concentration content in flue gas can be as high as 14 percentage. However, if we have to get rid of the other impurities which may also come with these flue gases like sulphur dioxide, hydrogen sulphide, other unburned carbon particles that need to be filtered before it is introduced to the alkaline waste water. When we do the design there are certain design recommendations that we need to follow. First of all your tank should be designed with a very high quality anti corrosive material because what you are doing you are playing with the pH. So, there is a high chance your first thing that will be affected by this is the tank itself the material of construction right.

So, that material of construction has to have a very high anti like made of with a very high quality anti corrosive material. And we also either or otherwise we have to make a protective lining on the inner side of the tank for with this corrosion resistance materials and all. In case of small scale treatment you can have a batch scale operation with the flow less than 350 meter cube per day. In case of larger scale you should have a continuous flow operation. So, your addition of chemicals will be continuous there or the gases flue gases.

Knowledge of waste water characteristics and the laboratory experimental results are necessary to design the flow. So, the first step normally pH correction is done in waste water in 2 steps. We correct the pH up to 6.5 then remaining pH correction is happening with the sodium or calcium bicarbonate channel. So, in general it prevents the waste water from suiting to an alkaline range.

Air flow that it requires as I was discussing it is somewhere around 0.3 to 0.9 meter cube per meter square per minute per and also the depth should be around 2.7 meter for proper air mixing and proper mechanical mixing of the inside the treatment unit. And also the mechanical mixer capacity of around 0.

40 to 80 watt per meter cube is good enough. So, let us go let us do one let us do one numerical. So, it will be easier for us to remember. What is asked here? An acidic waste water is generated from paraboil rice processing unit or paraboil rice processing unit with a flow rate of 12 meter cube per hour is to be neutralized to a pH of 7.0 using lime to make it suitable for further biological treatment.

The titration for this waste water in the laboratory showed a total lime requirement of 1780 milligram per liter. A two stage controlled neutralization system is proposed to be used the first stage requiring 1600 milligram, second stage requiring 180 milligram. So, 1600 1780 can be achieved. So, design the neutralization tank. First the average lime dose in the first stage is how much? 12 meter cube per hour multiplied by 1600 milligram per liter or gram per meter cube same milligram per liter can be written as gram per meter cube.

So, now, meter cube meter cube can be cancel this gram can be converted into kg by 10 to the power minus 3. So, it will become 12 12 into 1600 kg per hour and now multiplied by 24. So, it will become kg per day. So, you will get say 460.

8 kg per day. Now, average lime dose in the second stage same multiply instead of 1600 multiply with 80, 180 you will get the 51.84 kg per day. So, for with with this doses the each basin should be designed with the detention time of 7.5 minute in general that is the standard practice. So, flow rate we know 12 meter cube per hour and if it will stay there if it has to stay in some tank for say like 7.

5 minute. So, how what will be the total volume? 12 meter cube per hour multiplied by 7.5 divided by 60 to make it to the hour. So, that is the total time that it requires the total I mean the from there only you can from the time multiplied by the flow rate you can get the volume you understand. So, from there you can get the volume, volume is 12 into 7.

5 divided by 60 is equal to 1.5 meter cube. Then use the 2 tanks with the total height of 1.3 meter and the liquid depth of 1 meter and the diameter of around 1.4 meter. How we can calculate this? Suppose we first take the diameter take the depth of 1 meter.

If you take the depth of 1 meter at a total liquid depth and 0.3 meter additional buffer the what is it called this free bolt and what will happen how you can calculate the diameter is as easy as that from 1.5 divided by 1 equal which is equal to πD^2 by 4 from there you can easily find out the D value.

The D value will come around 1.4, 1.403 something like that. So, this is the diameter, diameter of the neutralization tank and also to ensure the proper mixing. So, in general 0.04 to 0.08 kilowatt per meter cube of power required.

So, say we take 0.06 kilowatt per meter cube. So, we can provide. So, if it is like 0.06 meter cube kilowatt per meter cube of here and total meter cube is we know already that this is like 1.

5. So, from there you can easily find out what is the total capacity of treatment unit that it the each tank mixture that you require for the each tank. So, and also we can also find out also you can provide 1 or 2 standard wall buffers 180 degree apart with that almost one twelfth one twentieth of the width of the tank diameter around 10 centimeter from apart from each other. So, from there you can easily find out that we need a 100 watt of mixture. So, this is how actually we design a neutralization basin, neutralization basin and its diameter the tank dimensions and all. I hope you understand it is not it is very easy this neutralization tank designs and all, but you have to be very much careful with the dosing of the chemicals like there you have to know that how much more of chemicals that you need to dose like at one point one what point of time to come to the to check with the pH level drops to a certain value.

So, next important technology that we are going to discuss is called the is called the dissolved air flotation or the DAF in short. DAF is becoming very popular nowadays. So, what we do here it is a unit operations where the finer suspended solid oil and greases are removed by making it to float in the free surface free water surface by rising the air bubble through the water column. So, what we are doing we are pressurizing the waste water or the sewage in a pressurized pump and then we keep it in a tank and then we release it and once we release it forms the micro bubbles. So, because of this micro bubbles and along with the waste water what happen all the solid particles will go along on the surface makes it a scum like structure.

This scum can be easily removed by some skimming mechanism by some scrappers and all we can easily get rid of the scums. So, in general design parameter factors which affect the efficiency of DAF the concentration of the suspended solid definitely the quality quantity of air that you are releasing particle rise velocity and the solid loading rate and the air to solid ratio. Please remember the air to solid ratio that is the most effective most critical parameter for DAF system. In case of DAF systems it is normally the ratio of volume of you can already understand from air to solid ratio is the ratio of volume of air released to the

flotation to the mass of suspended solid. So, from there you can easily find out the A by S ratio.

The required value of A by S ratio depends on the type and the concentration of the suspension it must be determined by laboratory flotation cell before actually designing before actually introducing it to the real field scale design. So, the quantity of air that releases from the solution of the atmospheric pressure can be estimated by this equation A is equal to A is nothing, but the air released at atmospheric pressure per unit volume at 100 percent saturation which is in say centimetres cube per liter and then equal to $A = s_a \frac{P}{P_a} - S_a$

So, this 'Sa' is nothing, but the air saturation at atmospheric pressure in centimeter cube per liter P is the absolute pressure at in kilo Pascal and 'Pa' is the atmospheric pressure in kilo Pascal. How we can find out the solubility in general solubility of air normally less in the waste water than the water that is why we need to introduce one correction factor in this equation.

So, in the same equation, but we need to introduce this correction factor f because the solubility of air is less in waste water than in actual water is not it. So, because of the impurities and all the other factor. So, this correction factor has to be introduced. So, after this you can easily find out the A by S value the air to solid ratio by like this the same way

$$\frac{A}{S} = \frac{1.3s_a((f \times P) - 1)}{S_i}$$

So, what is this 1.3 coming into the picture from where it is represents the weight of the air in milligram in 1 ml of air under higher than atmospheric pressure and what is this S i? S i is the influent oil or the suspended solute concentration. This is the influent oil and suspended solute concentration remember this one. Now when we perform the performance of DAF it normally related to the air to solute ratio from this equation if we write it in when it is having a say like how to say it is present in the influent water, but it has a certain recycle ratio. So, the pressurized recycling is happening without recycling this is the equation.

Please remember when there is a recycling is not mentioned in the numerical or you do not have to provide this recycling mechanism you use this equation $\frac{A}{S} = \frac{1.3s_a((f \times P) - 1)}{S_i}$

. However if you are having the recycle if you are if you are consider that pressurized recycling is required. So, there you need to introduce this term R by Q where R is the pressurized recycling and Q is nothing, but the waste water flow rate. So, as this equation we already know this from the in case of recycle flow as I told you when the only the recycle flow is pressurized and this P capital P capital P is nothing, but the absolute pressure right.

So, this absolute pressure can be easily can nothing, but is nothing, but the gauge pressure plus 101.35 divided by 101.35. So, from there you can easily find out the absolute pressure if the gauge pressure is the gauge pressure in kilo Pascal. And also remember in this equation the value of absolute pressure is given with is provided with the unit of ATM atmospheric pressure very good.

So, now, hydraulic loading rate in general with the increase of hydraulic loading rate suspended solid concentration in the effluent obviously, reduce the more you increase the time for your waste water to stay there in the system. Obviously the final suspended solid

concentration will slowly reduce and also the floating sludge layer becomes more concentrated as the particles are constantly transported from the to the scum layer by removing the air bubbles. In case typical design value for hydraulic loading rate please remember this value 30 to 120 meter cube per meter square per day with a retention time of around 3 to 5 minutes. And what is happening the easy this is this is how the recycle pump mechanism like you know when there is a some amount of flow is recycled how it loss like when that time only we have to introduce this value R and Q in the air to solid air to solid ratio calculation. And in case of solid loading rate in general we it is the mass of the suspended solid present in the effluent per hour per unit surface of area what does that mean if you remember it in the very early modules I think in module 2 or module 3 we discussed about how we can actually calculate the solid loading rate.

Solid loading rate means amount of suspended solid that is coming into your reactor along with the influent you understand. So, the influent has suppose total suspended solid concentration of say 100 milligram per liter and your flow rate is say like 100 meter cube per 100 meter cube per hour. So, based on that you can easily calculate the what is the total solid loading rate. So, the Q the value of x from there you can easily calculate the total solid loading rate in your in your systems per unit surface area so, divided by A. So, Q into x divided by A so, from there you can easily calculate the solid loading rate.

Let us do one numerical. So, it will be much more clearer to you like how actually we can design a dissolved air filtration. Please make sure to repeat this numerical couple of times in your home use the calculator and try to understand the concept how it is how we are doing it. Because it is it is it is very difficult for like me to do it in like say like next 10 to 15 minutes whereas, it would be nice to have it like practice it by yourself normally what we do normally do it in the blackboard it makes it and we take at least couple of hour for this discussions. But due to limited time availability I can only show you how the process is done and I would request you to actually go through it one couple of time by yourself to make it clear to you. So, in general design of dissolved air filtration this DAF unit in wastewater with a flow rate of 0.35 meter cube per minute. So, we know the initial flow the Q value is given 0.35 meter cube per minute to be operated at maximum temperature of 30 degree Celsius. The wastewater contains non emulsified oil non-substitable suspended solid with a total 110 milligram per liter of concentration. It is intended to reduce the oil to less than 15 milligram per liter using the DAF. Laboratory suggests that the alum dose requirement is 30 milligram per liter for effluent oil for effluent oil and grease concentration of 15 milligram per liter the optimum air to solid ratio is 0.05 that is also found during this laboratory study. And the required surface loading rate is 0.08 meter cube per minute per square meter per meter square meter. So, the absolute pressure is also given 3.5 atm and was used to pressurizing the recycle flow to dissolve air during the laboratory test. The alum sludge requirement production is 0.64 gram per gram of alum used and the sludge scum concentration of the solid is almost 2.5 percentage. At 30 degree the weight solubility of air is 20.9 milligram per liter and the value of f shall be considered which is nothing, but the correction factor is 0.5. So, now, we are asked to design the DAF with and without the recycle the esteem. So, let us first do the with without recycle esteem then we will do the with recycle system and also we need to find out the estimate the area required for the floatation unit and the quantity of sludge that is being generated. So, to start with we can easily estimate the required pressure because A by S value is given to us.

So, once A by S value is given to us as 0.05 and also the 1.3 S A S A solubility is also given where the solubility of air is also given 20.9 correction factor is also given 0.5 P is not known to us S i the initial concentration is also given 110 milligram per liter. So, using all these values

we can easily find out the P in atm the absolute pressure is coming as 2.4 atm. So, please try to remember this is this is 2.4 atm is when it is not recycled. So, when the recycle flow is not available recycle system is not available with recycle system the absolute pressure is 3.5 atm much higher, but without recycle. So, this is this this value will be required when we need it when we will designing with the with recycle system. Now, we are doing without recycle without recycle the absolute pressure is coming 2.

4 atm. So, if it is like 2.4 atm how we can find out the relative pressure or the gauge pressure. See you remember this equation P is this small p plus 101.35 divided by 101.35 this value is given 2.43. So, 2.43 multiplied by 101.35 minus 101. So, this P value is known to us 2.4. So, 2.4 multiplied by 101.35 it will go this side then P minus. So, this this part will go to the left side again. So, it will become minus. So, 2.4 into 101.35 minus 101.35 will give us the value of gauge pressure or the relative pressure. So, 243.73 minus 101.35 we get the relative pressure as 142.38 kilo Pascal. So, the surface area that is required we know the initial flow rate 0.35 meter cube per minute and we also know the surface loading rate as 0.8 meter cube per minute per meter square. So, from there if you just simply divide 0.35 meter cube per minute divided by 0.08 meter cube per minute meter square by meter square. So, we will get the surface area of the flotation as 4.376. So, this is the surface area of the flotation for system which having without any recycle system.

So, let us do it for with recycle system. So, with recycle system the equation will become air to solid ratio 1.3 into S_i F minus F into P minus 1 by S_i into R by Q . So, this R is coming into the picture. So, we need to find out this R value recycle rate right because Q is also known to us 0.35 meter cube per minute minute to make it to day you have to multiply it with 60 to make it hour to multiply with 24 to make it to day. Rest of the things are as same as the earlier one here also air to air to solid ratio is same 0.05. So, we can easily find out the value of R the value of R is coming as 1 point if you do it with the calculator you will see the capital R it will coming it will be coming as 138.29 meter cube per day. So, once we know this value we can easily find out the area required surface area that is required total surface area is the total flow rate plus total flow rate plus the recycle flow total flow rate is 0.35 plus the recycle flow is how much 138.29 meter cube per day to make it to the minute divided by 16 into 24 this much minute plus this much meter cube per minute this much meter cube per minute we already know and the loading rate is also given as 0.08. So, so from there surface loading rate you can from you can easily calculate the value of area the area area is 5.575 meter cube. So, from there we know the area now we can have to estimate the total sludge quantity sludge quantity initially how much 110 initial sludge initial total surface and solid and oil and suspension solid concentration was 110 and finally, it has to be reduced to 15 right.

So, initial is 110 10 final is 15 and also we know the flow rate 0.35 meter cube per minute and so, how we can find out the initial oil and sludge concentration 110 I mean total sludge that is that is generate because 15 is the outlet effluent and 110 is influent. So, if you minus this. So, that is the amount of sludge that is generated there it is inside the chamber inside the DAF unit. So, 110 inlet inlet oil and suspension solid 15 outlet oil and suspension solid you substrate it multiplied with the flow rate multiplied with the 1440, 1440 where it is coming from to convert the day into minute 60 into 24 60 into 24 how much 1440. So, this way you can convert the minute into day multiplied by 10 to the power minus 3 to convert the this gram per meter cube milligram per liter means gram per meter cube.

So, meter cube meter cube will cancel, but this gram if you multiply by 10 to the power minus 3 it will become kg. So, you will get the final value as 47.88 kg per day. So, that means, this

much of oil and solid sludge we are generating what is the alum sludge? Alum sludge is also given see alum sludge production is 0.64 gram per gram of alum used. So, what is the total sludge how we can find out? So, 0.64 gram multiplied by 30 milligram per liter it is given you see the total alum dose requirement is 30 milligram per liter if the alum dose requirement is 30 milligram per liter. So, what would be the total sludge 0.64 percentage of total sludge. So, total alum sludge total alum sludge is 0.

64 or 64 percentage of total alum that is introduced. So, 0.64 into 30 milligram per liter multiplied by the flow rate obviously, because flow rate that also matters. So, multiplied by same reason 40 into 10 to the power minus 3 to make it to kg per day. So, now, the total alum sludge is 9.68 that is the additional sludge because of the alum that you introduced to the system.

So, now, total sludge generation oil and solid sludge is 47.88 and alum sludge is 9.68. So, total sludge is 57.56 kg per day. If the sludge contains around say 2.5 percentage solid 2.5 percentage means how to convert percentage to milligram per liter 0.1 percentage means 1 milligram per liter 1 gram per liter sorry 0.1 percentage is 1 gram per liter. So, 2.5 percentage means 25 gram per liter or gram per if you gram multiplied 10 to the power 3 in the both the numerator and denominator it will become kg per meter cube. So, 0.1 percentage means 1 gram per liter. So, from there 2.5 percentage means 25 gram per liter or 25 kg per meter cube. So, that is the total that is the sludge that is the amount of solid that your sludge contains. So, now, we know the total total sludge we know how we can identify the total sludge volume. So, this is the total sludge total sludge content and we can easily find out total sludge volume.

This is the solid part divided by 25 you will get the 56 57.56 kg per day divided by 25 kg per meter cube you will get the value in 2.3 meter cube per day this is the total sludge volume. So, out of this 2.3 meter cube that means, 2300 liter per day you will get around 57 kg of solid sludge you understand. So, this is the total liquid sludge I mean sludge I mean the liquid portion of the sludge is total in general liquid plus solid total volume is 2.3 meter cube per day out of there 57.56 is the solid portion of it. So, you understand. So, this is how actually we can easily calculate the estimate we can easily estimate the sludge quantity as well. So, please go through it another time this video only you can repeat it and you can actually learn it more in details. Then the conclusions we already identify we already understood different ways of designing the neutralization tank as well as the dissolved air flotation tank. I think hopefully it will give you a very good understanding of these two technology and which are nowadays used like anything. So, please have a very go through this lecture video if possible another one or two times and do those numerical by yourself to be more confident about the design that you can do by. So, that the design you can do by yourself. So, this is the reference you can go through and I hope you got to know some important information knowledge about the neutralization technique and neutralization tank design as well as the DAP design. So, we will see you again in the next day. Thank you so much.