Course Name: Industrial Wastewater Treatment

Professor: Sunil Kumar Gupta

Department of Civil Engineering, IIT(ISM), Dhanbad

Week - 01

Lecture 03: Wastewater Management

Hello everyone. So, today we are going to deal with a completely new topic that is on the various tools and techniques important key elements of industrial wastewater management. So broadly the tools and techniques which are used in management of huge volume of industrial wastewater that involves volume reduction, strength reduction, equalization, neutralization, proportioning and then treatment. Basically, if we see there are three R principles that we use, reduce, recover, recycle. So, if we talk about these techniques like the first one if we talk about the volume reduction, so that basically we try to reduce the huge volume of the wastewater generated from different operation by using changes into the process, into the operation, segregation of waste, classification of waste. There are various techniques that we can employ in reducing huge volume of the wastewater that is being generated from different process and operations.

So, this employing these techniques we can basically reduce the huge volume of, huge cost of handling, transportation and treatment and finally disposal of the huge volume of wastewater. So, this can significantly the volume of the wastewater which will be more easier to handle, more easier to treat and then to dispose, or reuse and recycle within the industrial operations so as to get the zero discharge concept. Then we have strength reduction, this mostly implies to recover and reuse of various types of metals, precious metals, precious chemicals which are present into the various types of process and manufacturing process of wastewater which may contain various valuable metals like chromium, we may have gold, we may have silver, we may have huge volume of nickel depending upon the pollution load, the strength of the wastewater that we can reduce using various advanced tools and techniques that we are going to discuss under strength reduction. Then we have equalization, as we know we in the industry we have different process, we have different operations which they generate different type and different amount of wastewater throughout the day, some process they run in batches, some are continuous, so they generate sometimes the huge volume of wastewater is generated when one batch is completed.

So, there is no uniform characteristic which are reaching to the treatment plant and any treatment plant what we design that need to be designed for a average composition and average flow rate. Equalization of wastewater basically involves equalization of flow, equalization of its composition, equalization of pH, equalization of its COD, COD so as to get an uniform composition at a uniform rate for which we can design a treatment unit, treatment process. So, for this equalization, neutralization we have different process that we will be dealt in the subsequent slides, what are the various tools and techniques, what are the impacts of equalization, how we can equalize the wastewater, equalize its characteristic, equalize its pollution load. Then is neutralization, this is one of the important tools and techniques which are adopted like there are some waste streams which are acidic in nature, some waste streams they are alkaline in nature. So, by mixing these two different types of waste stream, one in alkaline and the other one acidic, we can neutralize their pH of the wastewater which is mostly required for its further treatment and disposal.

Then we have proportioning process, proportioning is basically done from treatment point of view like there are various types of physical process, chemical process and then biological process and some of the biological process they need proper ratio of CNP that is carbon, nitrogen and phosphorus. So, proportioning of the wastewater is done in such a way that the waste stream coming from different operations are mixed in such a way that we can get a typical C by N ratio water, C by NP ratio in the combined wastewater which can be sent for biological treatment system. And then finally, the adoption of appropriate treatment techniques that we will be dealing in detail for each and every industry, the conventional process, the advanced treatment process, the recycle and reuse process that should be adopted for attaining the zero discharge in different industries. As I told this, three are operations, three are principles that like reduce, recover whatever the valuable chemicals, metals present, recover them and then treat it and then recycle, reuse into the different integrated process requiring water. This is the examples of volume reduction techniques.

Like in the volume reduction techniques, what we do, we try to classify the different types of waste stream generated from the industries like we have process water which are mostly generated from the manufacturing process, then we classify the water which is used in the industry as a cooling agent for cooling operations, that water comes under cooling tower water and that is mostly does not contain much of the chemicals. So, it can be recycled and reused within the operation to reduce the ultimate volume of the wastewater. Then we, every industry, we have domestic activities, we have residential quarters, we use lot of water for our own domestic uses, so that generates a lot of sanitary wastewater. So, that wastewater also we can segregate like domestic wastewater, we can have separate treatment system for municipal wastewater so as to overall volume of the wastewater reaching to the effluent treatment plant system is reduced. And then similarly, we have lot of area involved within the plant which may receive the precipitation rainfall and as we know after precipitation a part of water which does not get evaporated, which does not get infiltrated that is generated as a surface runoff and this runoff when it flows through the open surface area, it may again contaminated with the various types of foreign impurities which are there in the catchment area during its flow, a lot of pesticides, lot of fertilizers, unused diols, hydrocarbons, organics, chemicals, they are mixed into this surface water and that water along with lot of inorganic impurities have a different pollution load, so that can be segregated in order to reduce the total volume of the waste water.

And then similarly, there are different pipes, networks, fittings, some pipes they get faulty connections and there is a lot of volume of water that gets wastage, so we need to identify those leakage and collect those water separately so as to recycle and reuse this water that goes as a waste. So, these are the few examples of classifying different water like processed water and cooling water, domestic water, the water obtained from workshop facilities which may contain various types of oil and grease. So, these different waste streams we need to identify, we need to segregate and then accordingly we have to decide the process of their treatment, their transportation, recycle and reuse. For strength reduction, strength reduction basically the total amount of impurities that are present in the dissolved form. So, those impurities, those pollution directly indicates the amount of dissolved solids which are present into the waste water.

So, these solids may be organic, they may be inorganic and that can be reduced by having changes into the process, changes into the equipment and segregation of various types of waste, equalization of waste, proportioning of waste and monitoring and management of different waste streams in a way to have lesser strength of wastewater ultimately generated from this system. So, let us start with the concept and design of equalization flow. As the name indicates equalization tank, the tank which equalize the flow and the characteristic of the wastewater coming from different sources to a particular tank at different time duration, so as to obtain the constant flow and a more uniform composition of the wastewater which is basically required for design of a plant. The analysis of this equalization process basically determination of mass loading rates which is basically defined as mass load per unit time. The analysis of equalization tank involves determination of various types of mass loading rate which is defined as the product of volumetrical flow rate and the strength of the wastewater.

Mass loading rate basically this is the mass load per unit time which can be obtained by the formula $M_i = Q_i \times C_i$ where Q_i is the flow rate at i^{th} time and C_i is the constitute concentration at i^{th} time. So, this basically mass loading rates if you see from time to time it varies to determination of different types of mass loading rate is extremely essential for analyzing the effect of equalization process in a equalization tank. So, weighted average concentration that is another parameter which is used to determine equalized concentration over a period of 24 hour which is obtained by using this formula $\boldsymbol{C_w = \frac{\sum_{i=1}^{n} C_i Q_i}{\sum_{i=1}^{n} Q_i}}$ where C is the concentration, C_w means weighted average concentration which is equal to the summation of the product of C_i into Q_i divided by summation of flow where C_i is the basically the average concentration at i^{th} time and Q_i also the flow rate at that particular i^{th} period and this C_w gives us the weighted average concentration. Similarly, we can get the weighted average mass load which is used to determine the mass loading of the constituent after equalization is done. So, now let us talk about the other loading rates that is the peak mass loading rate that is used to determine the peak loading of the wastewater constitute over a period of 24 hour.

This basically represents the maximum loading rate that occurs within a period of 24 hours in a equalization tank. So, this peak mass loading rate gives us the maximum loading rate of the constituent present in the wastewater. Similarly, we have another parameter that is called as minimum mass loading rate and which is used to determine the lowest loading rate which is observed in an equalization tank over a period of 24 hour. So, this represents the minimum value of the mass load at different period of time. So, this is basically the different mass loading factors we determine like peak to average mass loading factor then peak to minimum BOD mass loading factor then average to minimum mass loading factor. Average to minimum BOD mass loading factor= $\frac{average\ BOD\ mass\ loading\ rate}{minimum\ BOD\ mass\ loading\ rate}$ So, these factors when we talk about peak to average this gives the ratio of peak loading to the average loading rate. Peak to average mass loading factor = $\frac{peak\ BOD\ mass\ loading\ rate}{average\ BOD\ mass\ loading\ rate}$ Similarly, the peak to minimum mass loading factor gives the value of peak to minimum DOD mass loading rate. Peak to minimum BOD mass loading factor = $\frac{Peak\ mass\ loading\ rate}{minimum\ BOD\ mass\ loading\ rate}$ So, these are different mass loading factors we determine to see the variation in the loading rates that is observed in the equalization tank at different period of time. This slide shows the location of the equalization tank in a typical wastewater treatment plant. So, here we can see this is the entire flow diagram.

So, here if we see after the effluent enters into the screen and communicators the second unit is called as the grit chamber. Immediately after grit chamber this equalization tank is provided. Here this is the offline flow equalization process provided. So, this location for this equalization tank is just immediately after the grit removal system and this is provided before the primary settling tank. So, this is required because from this point onwards whatever the system are designed they are designed for a particular flow rate for a uniform composition.

So, equalization tank becomes very essential in a wastewater treatment plant in order to get a uniform composition, uniform flow rate for which the next unit treatment systems whatever are proposed in a wastewater treatment plant that can be designed for that particular flow rate. This is like the types of the equalization tank we can classify broadly like inline arrangement and offline arrangement of the equalization tank. In inline arrangement what we can see immediately this is provided in inline system like within the line the tank is provided in continuous mode. So, this equalization basin receives all the incoming wastewater into the tank and thus it requires more of pumping volume. So, this may cause more of pumping cost but this kind of provision will provide us the very uniform mixing.

But in case if we need to have the economy in the plant so we can go for offline arrangement this figure shows the offline arrangement of the grit chamber wherein the entire wastewater which is coming to this grit chamber if it is having the average flow rate it will directly go to the next treatment unit. In case of excess flow only that will be diverted to the grit chamber and from here this will be coming to the pumping station and here it will be pumped again in case of any deficiency if the flow rate is less than the average flow rate. So, basically in this case what happens there is limited wastewater which is coming to the grit chamber so its size is reduced as compared to inline arrangement and also the requirement of pumping of the wastewater that is greatly reduced. So, this becomes little bit more economical as compared to inline arrangement but does not provide more uniform mixing of the wastewater thus the equalized concentration that becomes little bit higher in this case compared to the system that we provide in inline arrangement. So, this is a numerical we have taken to describe you how this equalization tanks makes an impact on to the concentration and mass loading rates that is subjected to the equalization tank after the equalization.

So, this numerical basically if we read this is an chemical industry which generates domestic wastewater whose flow and characteristic are given in this table. Now what we have to do is analyze and find out the mass loading factors weighted BOD and suspended solids after the equalization tanks. So, here if we see in the first column there are the time duration starting from 0 to 24 hours. So, for different time period the flow rates are given BOD is given suspended solids are given similarly for other time period the flow rate BOD and suspended solids are given. In this if we can analyze the flow and analyze the concentration what we get the flow rates that are not uniform throughout the period.

So, sometimes very high flow like 16.5 sometimes up to 12.4. So, this flow rate every hours that is varying and similar is the variation in the concentration of BOD and suspended solids. So, this variation may cause difference and variation in into the mass loading rate that reaches to the equalization tank.

So, what we try to do here is to equalize this flow and also to the concentration so as to achieve a more uniform characteristic more equalized loading rate to the next treatment system so as they can perform efficiently. So, this is the solution of the given problem like again we have to write the time period and for different time period this is the flow rate we have to mention as per given in the table. So, here is the BOD level then we have the COD level here if we see the BOD level that is given in mg/L and so we can write it also as g/m^3 because mg/L and g/m cube they are equivalent unit. So, no need to have any conversion factor to convert in gram per meter cube. Similarly, for suspended solids then we estimate here the mass loading rate that is basically, m_i is equal to Q_i into C_i.

So, this m_i basically gives us the mass loading rate which is obtained by multiplication of the flow rate and the concentration. So, what in this table what we have done in these two tables we have calculated the mass load due to BOD and similarly the mass load due to suspended solids. So, here if we multiplied the flow and the BOD say so it will give us the value 16.5 into 171. So, this the unit if we see so this is g/m^3 this is m^3/hr.

So, if we multiply we get the value in g/hr but again if we divide with the 1000 so it will get converted into kg/hr. So, whatever the mass loading rate we are determining here in this table that is in terms of kg/hr. So, that is why this multiplication factor of 1 by 1000 is taken in this calculation. So, now if we want to calculate the mass loading rate of BOD in kg/hr for zero duration, zero time period so this flow multiplied this BOD level and then divided by 1000 this will give us the value of 2.82 and similarly if we multiply this flow with the suspended solid concentration and divide by 1000 so it will give us the mass loading rate due to suspended solids in terms of kg/hr.

So, this is basically the type of calculation we perform for all time period is starting from 0 up to 24 hour using this formula. So, here this is for 0 to 12 hour similarly we have done the calculation for other time period up to 24 hour 13, 14, 15 different time periods with the flow rate data with the BOD level data and the suspended solid data. So, in this table we have calculated this mass load due to BOD here this is similarly the mass load of suspended solids. So, now after this calculation now what we have to analyze from the beginning again what is the maximum mass loading rate due to BOD and what is the maximum mass loading rate due to suspended solids, what are the minimum load, what is the average load, what is the equalized concentration, what is the equalized mass loading rate. So, all these analyses we have to perform in a equalization tank.

So, here if we see what is the peak value if we see in the table of mass loading rate so here the maximum value comes to around 4.282 in this page while the other page if see the maximum peak loading comes at 6.048 which is the highest value of the mass load due to BOD. So, this is taken as the peak loading rate. Similarly, we also analyze the minimum loading rate.

So, minimum loading rate if we see that is the value what we get out of this 24 hour if we look upon for mass load of BOD. So, this value is 0.643. Similarly, if we see for the mass load of suspended solids so the peak value if we see that comes around 5.762 while the minimum value comes around 0.0744. So, this value we denote here and then we find out the sum of all the flow which is equal to 404 m^3 out of this 24 hour. So, if we divide 24 with this total flow so we get per hour flow which is equal to 16.85. Similarly, for BOD also this is the total BOD summation of all the BOD values and then if we divide by 24 so this will give us the simple average value that is 173.25 mg/L. Similarly, for suspended solids we can get and the mass loading rate of BOD also similar way by dividing the total mass load of BOD for all 24 hour divided by 24 we can get the average mass loading rate of BOD and average mass loading of suspended solids. So, now the question comes after this 24 hour whatever the effluent comes into the equalization tank that is being mixed and after mixing there is weighted average concentration which is equal to C_w value which can be determined by using this equation $C_w = \frac{\sum_{i=1}^{n} C_i Q_i}{\sum_{i=1}^{n} Q_i}$. So, this is the formula we use so for this C_w value that we have got here that is 182 which is basically the ratio of summation of mass loading rate that is 73.719 and similarly the total flow rate which is equal to 404. Similarly, for the suspended solid the equalized concentration for the suspended solid that will be equal to total sum of the mass loading rate for all 24-hour divided by the total flow rate which is equal to 0.198 kg/m^3 which can be converted into mg/L as by multiplying 1000. So, this will equal to 198 mg/L. Now, this is the graph which plots the flow rate BOD, COD with respect to the time.

So, time is plotted here on the x axis whereas on y-1 and y-2 axis the BOD, COD suspended solids and flow rates are plotted. So, here if we plot for different time hour the flow, the suspended solid and the BOD concentration we will see that during the morning hours you see there is a minimum flow during like from 8 to 10, 11, this during the daytime there is a maximum load and then again during the evening hour from starting from 6 to 9 pm this is having again a peak there can be seen like there is a lot of variation in the flow rate in the BOD concentration in the suspended solids. So, these variations are basically dampens in case of providing this equalization time. This is the analysis of various types of mass loading rates what we have calculated that is the peak load if we see due to BOD that comes to 6.048 while it is due to suspended solid that is 5.762 which is observed at 22^{nd} hour. Similarly, if we see that minimum load of BOD that comes to 0.643 and while it is due to suspended solid that value comes to 0.744 kg/hr and if we calculate the average load of BOD that is equal to 3.072 and similarly for average load of suspended solids that is 3.30 as we have calculated already here this 3.072, 3.330 while based on equalized concentration if we calculate this value also comes near about simple average value and then this is 3.067 and 3.336 and then this is the mass loading factors as per the numerical we need to determine the mass loading factor, the ratio of peak to average BOD loading rate, similarly the average to minimum BOD mass loading rate. So, here in the first calculation if we see that is the peak mass loading rate divided by the average BOD mass loading rate which occurs at 22nd hours which is equal to 6.04 divided by 3.072 which is equal to 2. Similarly, peak to minimum ratio that comes around 9.4 similarly average to minimum BOD level that comes to around 4.55. So, if we analyze that we see that the peak loading rate that becomes around two times higher than the average mass loading rate and if we compare with the minimum loading rate it is around 9 to 10 times that is 9.4 times. Similarly, if we compare the average and minimum BOD mass loading rate this value comes around five times. So, these are lot of fluctuation in the mass loading rate and you know that biological treatment system they are designed to offer a more uniform concentration. So, if there is a lot of fluctuation in the loading rate they are not working properly their process efficiency gets reduced. So, now this is similarly the peak to average suspended solid loading ratio. Similarly, peak to minimum suspended solid loading ratio which is 7.74 average to minimum suspended solid loading that comes to 4.476. So, these are all the variations in the suspended solid in the BOD loading rate and in the flow rate. So, this is an example which refers that the after equalization whatever the values comes that gets equalized and a uniform equalized loading rate is subjected to the next treatment unit system whatever we designed after the equalization time. So, this helps in dampens the fluctuations that occurs in a wastewater treatment plant because of variation in the characteristic variation in the flow rate.

So, this is all about the design of equalization tank how this dampens the characteristic and the variation in the flow rates. So, this completes about the concept and determination of mass loading factors which are used in design of equalization tanks. Now, rest of the things few of the new vehicles which are based on the how to find out the capacity of equalization tank, how to design the size of the tank and then what are the various tools and techniques used in neutralization and proportioning these tools which are adopted in the wastewater management that we will be learning in the next lecture. So, these are the references that you can refer to have these numerical, various types of numerical are given on equalization tanks.

Thank you.