Course Name: Industrial Wastewater Treatment

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Week – 07

Lecture 32: Treatment of wastewater produced from Distillery and Dairy Industries

So welcome you all. Today I am going to deliver lecture 2 of module 7 which is on treatment of wastewater produced from distillery and dairy industry. So, if we see, we remember in the previous lecture we have covered about the different processes which are used for fermentation of alcohol in the distillery industry, the batch process and the continuous process. So under this we are going to cover the basic introduction on the wastewater generation from the distillery industry and then we will be also looking upon the various sources like spent wash, spent glee, the various types of waste streams which are generated from the distillery industry and then we will be also looking upon the characteristic, various physiochemical characteristic, biological characteristics of the wastewater streams which are generated from the process and finally we are going to look upon the various alternatives which are proposed for the treatment of wastewater and among this the most commonly used process that is the diaphasic, anaerobic treatment system and the UASB and hybrid reactor configurations which are used for the treatment and disposal of the spent wash that we will be describing in more details and then on the bioenergy potential of the distillery effluent in our country and finally we will conclude upon the basic numerical problem based on the amount of energy which can be generated from the treatment of the wastewater and also on different alternatives.

So here if we see the basic introduction about the wastewater which is generated from the distillery industry, so as we know this distillery industry produces alcohol by the way of fermentation and distillation of sugar cane molasses which is basically the byproduct of sugar industry and this generates huge amount of wastewater in the tune of about 15 to 20 liters of wastewater that will be generated out of 1 liter of alcohol produced and mostly if we see as we have seen like two types of waste streams are mainly generated there are number of streams but mostly we see upon the spent wash and spent lees which are high strength wastewater generated from the end of seas and if we see in terms of its characteristics so we find that this contains very high concentration of dissolved solids, very acidic in pH, a colored effluent and is classified as a high strength wastewater and in terms of temperature this is around 70 to 80 °C temperature of the effluent which is very hot, highly acidic and in terms of color if we see that is having a dark brown color and contains high concentration of inorganic and organic materials. So high concentration of this organic matter is mainly responsible for high concentration of BOD and COD present in this wastewater.

So let us see more details about the various streams, various sources where from the wastewater is generated. So, we see mainly there are four types of sources like and the wastewater which are generated. The first one if we see that is the spent wash which is the very high strength wastewater and then this is spent leaf which is generated from rectification column whereas the spent wash that is generated from boiling column and similarly because this is lot of water is used as the cooling water so that gets condensed and this condensed water is also produced as one of the waste stream and then we have cooling water. So, these are the major waste streams which are generated from the silver industry.

And this is the flow diagram of the different sources where from the different types of waste streams are generated. So, if we see this is like pre-fermenters where fermentation process is carried out. So here what we do basically we use this distillery molasses and this molasses is fermented using the particular type of yeast culture. So here fermentation will be done and then after fermentation we see this carbon dioxide is produced and finally we will left with the fermented wash that will contain lot of fermented alcohol and then this fermented liquid will be sent to the analyzer column where alcohol which is in dissolved form that will be separated from rest of the water. So this is done by heating the fermented wash at a temperature of around 70-90°C depending upon the type of process we use and here what happens basically at this temperature the alcohol vapor goes up and then this water vapor being highly dense compared to the alcohol, so alcohol vapor floats goes towards the top and this water vapor gets settled down and from here it is taken out in the form of spent wash along with the fermented wash which is separated from rest of the alcohol. So, from top if we see this both water vapor and alcohol vapor will be generated and then this will be sent again to the rectification column where this the alcohol vapor will be completely separated from the water. So, this is done again by density separation techniques so water vapors they will go down and this alcohol vapors that will be taken out from the top of the column and this basically produces rectified spirit which is around containing more than 99 %, 100 % of the alcohol. So, from this two columns like one we say that is analyzer column and then another column which we say rectification column where separation of water and alcohol vapor is done. So, from here this spent leaves are generated so these are the major based streams which are generated from the distillery wastewater.

So now if we see what are the characteristics of the spent wash and the spent lees which are generated from the fermentation process. So, here if we see in terms of flow if we see the flow of the spent wash there are two process one is like batch process and another is biostil process. So, this we also know that is the continuous process whereas the batch process the fermentation process is done into number of pre-fermenters and then it is taken as to the main fermenter. So, this process is carried out in batches whereas this is biostil process that is basically the continuous process. So, here in terms of flow if we see around two times of the spent wash is generated compared to the biostil process. In bioprocess if we see that is 14 to 15 liter of spent wash will be generated per liter of alcohol whereas in biostil process this amount is around 50 % reduced so that is around 7 to 9 liter per liter of alcohol and in terms of color if we see that is having the dark brown color and the same color we will also see in the biostil process and in terms of pH also if we see the pH of the spent wash which is generated from the batch process that is very highly acidic having the pH range 3.7 to 4.5 whereas in the continuous process the pH of the spent wash which is generated that is around 4 to 4.2 and in terms of organic matter if we see BOD, COD those COD here if we see in batch process that is around 90,000 to 110,000 if we see its BOD so it contains around 50 % of the total COD so that is around 45,000 to 50,000 whereas in case of this biostil process if we see that contains the COD up to the 1,60,000 to 2,10,000 whereas in case of BOD this concentration is around 70,000 to 1,10,000 and overall if we see the two process so here if we see BOD and COD concentration that is generated in biostil process that is about 2 times than the BOD and COD concentration which is generated from the batch process. And in terms of total solids also if we see that contains around 90,000 to 1,10,000 total solids in batch process whereas in biostil process also if we see that is around 2 times that is 1,80,000 to 2,20,000 and similar is the case for volatile solids that is 50,000 to 60,000 in case of batch process whereas this concentration in biostil process that is around 60,000 to 80,000 mg/L and in terms of inorganic if we see that contains lot of chloride, nitrogen, phosphorus and potassium. So here if we see chloride and sulfate that is around chloride if we see that is 5,000 to 6,000 whereas in this biostil process again it is 2 times that is 10,000 to 12,000 mg/L in case of sulfate this is relatively 4,000 to 8,000 mg/L whereas in case of biostil process relatively 2 times than the batch process and found in the range of 8,000 to 10,000 mg/L in terms of total nitrogen also if we see it contains 1000 to 1200 mg/L of nitrogen whereas in case of this biostil process this concentration is very high that is around 2000 to 2500 mg/L and similar is the case for potassium here if we see that the concentration is 8,000 to 12,000 in case of batch process whereas it is around 2 to 2.5 times in case of biostil process and similar is the case for phosphorus in batch process this is very less 200 to 300 mg/L whereas in case of biostil process this goes to 1600 to 2000 mg/L. So, this is like if we see overall compare the characteristic of the spent wash which is generated from the batch process and also which is generated from the biostil process. we will see the biostil process though the quantity of wastewater that is spent wash which is relatively 50 % than it is generated in the batch process but in terms of concentration if we see that is around 2 times of the concentration normally which is observed in case of batch process.

So here let us see another waste stream which is generated from rectification column where this alcohol vapors they are separated from rest of the water vapors. So, here if we see the BH range varying from 3.6 to 4.5 but it is BOD and COD that is not very high COD that is around 5000 to 6000 mg/L and this BOD concentration goes around 200 to 300 mg/L. Similarly, if we see that is in terms of dissolved solids so here the dissolved solids that is around 5000 to 6000 mg/L but suspended solids concentration that is very less around 500 to 1000 mg/L. So mostly the solids which are present they are in the dissolved form compared to the suspended form and similarly chloride also if we see in this type of waste steam like spent lees the concentration is very-very less like 100 times than the chloride concentration found in the spent wash. So this is one of the like weak stream compared to the spent wash which is generated from the distillery industry.

And after going through the details about the waste water characterization we come to know that the spent wash that is very high strength waste water and contains various types of suspended and dissolved impurities so a single treatment system basically is not efficient for the treatment of the waste water which is basically the spent wash from this industry so a combination of the following process that is being used combining the physiochemical treatment process, aerobic treatment process, anaerobic treatment process somewhere in the older days this composting process were also used and this incineration process can also be used to totally reduce the totally dispose this entire spent wash to incinerate this spent wash and then finally this treated effluent can be used for land application because it contains lot of nutrients like phosphorus, potassium nitrogen. So, this have another alternative for its land application so these are the various alternatives or the techniques which are used in the several industries but out of these various techniques if we see more than 70 to 75 % of the distilleries which are operating in our country, they are implying the aerobic digestion system followed by aerobic treatment in the form of activated sludge process. So that is the most adopted technology and we will be going in more details of this technology which are used for disposal and treatment of the spent wash.

So, under physiochemical treatment techniques mostly if we see that is like physical separation of the yeast culture then cooling of the wastewater which is having a temperature around 70 to 80 °C through designing number of cooling ponds designing the equalization tank for equalizing the flow and the concentration of the waste water generated from the process because some of the process they use number of bad process which generates intermittent waste water so equalization tank is always used and then since the waste water is basically acidic in nature so in physiochemical treatment also involves its neutralization. So, these are the physiochemical treatment process which are essential for as a pretreatment process for the treatment of the spent wash then for reducing the organic strength from the waste water we can have aerobic system we can have anaerobic system, so out of the two systems if we see that the concentration of organic matter which are present in the spent wash that is very-very high compared to the aerobic system, anaerobic system becomes more promising so here the anaerobic systems are used so in anaerobic system again there are number of configuration that we will be discussing about and then it follows the aerobic treatment system where the rest of the BOD and COD which are not being degraded in anaerobic treatment system so that is being degraded in aerobic treatment system which follows the aerobic treatment anaerobic treatment system and then finally the waste water can be also used for composting and there are other alternatives like incineration and its land application. So, one by one we will be discussing about all these alternatives in the coming slide.

So, here if we see what kind of physiochemical treatment system that are used like the kind of pretreatment system which is required because first of all if we see the high temperature of spent wash is generated so it needs cooling down the temperature of the wastewater before it goes for main treatment process to the atmospheric temperature so which is basically tolerable by the anaerobic consortia so first of all the cooling number of cooling ponds are designed so that function is to bring down the temperature of the spent wash generated from the process to the atmospheric temperature and this is done by designing number of cooling ponds and then the second step what that is like mixing so this mixing of the intermittent waste water is to be done in a new equalization tank. So this equalization tank basically dampens the shock load which basically equalize the strong variation in the flow and the characteristics of the waste water generated from time to time from the industry so there is a equalization cum neutralization tank that has to be designed for mixing and dampening the shock loading to the biological treatment systems which are the major treatment system used for removal of organic matter present into the wastewater. And then if you see that is neutralization process as I said in the equalization tank this neutralization is a very important step because the waste water which contains having the pH range varying from 3 to 4.5 so this has to bring down to the slightly alkaline range most optimized pH which is required for anaerobic treatment system which is 7.7 in case of distillery spent wash so lot of alkali addition has to be done in the equalization tank for neutralization of the spent wash which is basically acidic in nature and then finally if we see the overall characteristics so we will see there is a lot of imbalance in the CNP ratio, so they are going out of range then the tolerance limit which is required CNP ratio like 300:10:1 for anaerobic treatment system. So, this adjustment has to be done so we have to have addition of additional nutrients which is required for treatment of the wastewater.

Then let us talk about the more details about this treatment processes which are used so first of all let us see the UASB reactor how it looks like so U indicates for upflow, A for anaerobic as for sludge and then B abbreviate for blanket. So this UASB reactor if we see the influent waste water that is fed into the reactor from bottom of the system this is a many fold system which equipped with number of outlets from where the waste water which enters into the system first strikes at the bottom and then the entire wastewater in the form of layer goes towards rise upwards inside the reactor and immediately after this waste water feeding system there is a sludge blanket which consist of high concentration of microorganism anaerobic consortia so here as soon as this waste water comes in contact with this anaerobic consortia so anaerobic digestion of the waste water or the organic matter takes place and as a result of carbon dioxide and methane that is generated. So, these gases they are they generates and they leap upwards and from the top of this the biogas is taken out and if we see in the middle of this system there is a deflector beams are provided which basically facilitate the removal of the biomass which gets bind along with the biogas so they strikes with this deflector beams here so this sludge mass is separated and the rest of the biogas that goes towards the top and gets out of the reactor through the outlet vent pipe which is given for collection of this biogas generated from the system and then if we see this is basically the gas liquid solid separator system when this treated waste water comes with this so it separates out the rest of the biomass so this biomass after getting separated they will settle back to the system and the biogas that will go towards the top and the treated effluent that comes out through this effluent weirs are provided at the top so treated waste water that will go out of the system and at the top if we see this is the floating domes that is provided so which facilitate the collection of biogas and that is taken out of the system through the vent pipe and inside this if we see this these are the small dots which basically shows the sludge blanket if we see this the bottom portion that is a concentrated sludge stream so this is called as the sludge bed whereas when the biogas is entrapped within this biomass they get dispersed into the inside the reactor in a larger area and form a sludge blanket zone here which helps in further degradation of the organic matter present into the waste water. So this is all about the UASB system. And then if we see the this anaerobic contact process the another type of system this is the old system where the spent wash is filled into the reactor where it undergoes anaerobic digestion system so it contains active zone where the mixing of the sludge with the incoming spent wash is carried out by the mixers and then the digestion process generates lot of biogas the biogas generated from this process that will be stored in this floating dome and from here through the vent pipe it is taken out in this process if we see from the bottom this whatever the sludge that will be taken out along with the waste water so this will go to the vacuum degasifier where this sludge along with the waste water that will be degasified then this entire content that goes to the settling tank where this sludge will be settled out at the bottom and this will be taken out a part of this that has to be recycled into the reactor so as to maintain the proper F/M ratio inside the system, so sludge recirculation and then the vacuum degasifier of the sludge makes the sludge more settleable in nature and then the treated effluent that comes the top layer in the settling tank that is taken out of the outlet pipe as a treated effluent so this is the reactor configuration which are used for anaerobic contact process so here both sludge degasifier are used recycling of sludge is used mixing is done whereas in the UASB system if we see the mixing is performed by the flow system and the bio gas generated that creates the turbulence within the system and carried out the entire mixing process. And then another type of the system which is used that is anaerobic filter media here if we see this is the filter media which is filled into a tank and the wastewater that the influent spent wash that is fed to the reactor from the bottom of the reactor when it goes towards the top it come in contact with the filter media which provides the surface for the growth of anaerobic consortia, so as soon as this spent wash comes in contact with this microorganism its anaerobic degradation takes place and it again forms lot of biogas and then the bio gas that will be collected through this vent pipe which is given at the top of the system so this from here the bio gas will be taken out and the treated water which goes at the top that will be connected through this effluent weir system and it will be taken out of the reactor so a part of again this waste water which is treated waste water that is again recycled into the system in order to maintain again this F/M ratio in anaerobic filter media. So, these are the basically various reactor configurations which are used in the treatment of distillery spent wash various alternatives.

Then let us see the another reactor configuration which is basically the diphasic anaerobic treatment system which is used for treatment of spent wash so this is the flow diagram if we see a rice spent wash basically first of all is given physiochemical treatment pretreatment like it has to be sent to the number of cooling ponds so the temperature of the spent wash which comes out of the fermentation column that is around having 70 to 90 °C, so in this cooling ponds they are basically shallow tanks which are used for cooling of the spent wash bringing down the temperature to its atmospheric temperature and then the cooled spent wash that is sent to this holding tank also called as the equalization cum neutralization tank so here all the waste water that will be again mixed together and the ph as we know this tank the pH of the spent wash that is around acidic range so here we have to add lime or alkali material in order to bring up the pH to slightly alkaline range and from number of studies it has been found that if we maintain the pH>7.7, so that is like the toxicity due to sulfide formation that takes place during the anaerobic digestion process can be greatly controlled and we can have more efficiency of anaerobic treatment system so here we try to maintain a pH of 7.7-7.8. So here that is to be done by adding lot of lime and alkaline material as per the requirement of the process then this if we see here we have two process like die phasing system if we see so this is like anaerobic digestion process if we see the pathways of anaerobic degradation of the organic matter so there is acidification and then the two major process acidification and then the methanogenesis so here the two process they are carried out in two different stages. So, first of all entire spent wash that is taken into the UASB reactor one which is called as the acidic reactor where first stage of the anaerobic treatment of the spent wash carried out and all the organic compounds which are present into the spent wash that will be converted into various forms of acid like propionic acid, valeric acid, organic acid, acidic acid and finally there are acetogenic bacteria which will convert all these acids into this acetic acid and then this waste water containing lot of acetic acids that will be sent to this two number of UASB reactors which are in the parallel so the wastewater coming from acidic reactor that will go to the methanogenic reactor so UASB-2 and UASB-3 they are basically the methanogenic reactors which carry out a conversion of this entire acetic acid into methane and carbon dioxide so this total biogas generated through these two reactors that will be taken out of the process and it will be further purified and the methane will be separated from rest of the component and then can be used as a source of energy generation and here if we see in these two process whatever the recycle different which contains lot of sludge so they has to be separated and then a part of this recycle different that has to be again recycled into the holding tank for helping into the neutralization of the spent wash which comes from the cooling pond and then you see after this treatment if we see about 60 to 70 % of organic matters they are removed on this diphasic anaerobic treatment of the spent wash but if we see the analyze the treated effluent is still there is around 25,000 to 30,000 mg/L of COD still remains after this entire anaerobic process so this is again then here since the aerobic process they cannot be used for very high concentration, so this is again diluted in a dilution tank so as to reduce its concentration to 5,000 to 10,000 mg/L. So here one is to one dilution is carried out with the water and then this diluted spent wash sent to the areas in tank one, aeration tank two which are there in the series so this aeration tanks they will further undergo aerobic decomposition of organic matters which are not anaerobically digested and will carry out the digestion process will convert into carbon dioxide and as this aeration tanks they are basically the activated sludge process so it is always combined with the secondary settling tank which is used for removal of the suspended microorganism which comes out of the reactor along with the treated wastewater so here secondary settling tank the amount of the biomass which is present in the treated effluent that will be separated and a part of this will be again recycled into this to maintain a proper F/M ratio so similar process here also in aeration tank two is also carried out a part of this treated effluent will be recycled here and then after this if we see the treated effluent comes to final treatment and finally treated wastewater will be taken out will be characterized and will be looked upon to meet with the effluent discharge standards. So here if we see there we are using the two number of settling tanks whatever the sludge which are separated that is further taken into the sludge digester which is one of the treatment system used for treatment and digestion of the sludge and then this digested sludge that will be taken out to the sludge drying bed which basically acts as filter to remove out the water from rest of the sludge and that is basically a kind of filter we design and then this digested sludge that can be then disposed of which contains lot of nutrient and can be used for agricultural application for enhancing the fertility of the sludge.

And if we see bioenergy potential of the distilled effluent so here if we see that is the data for different states starting from Andhra Pradesh, Assam, Bihar, Goa different states so this basically says how much capacity of the alcohol industry we have in different states the number of the units and then the how much wastewater, spent wash that is generated from different distilleries and this column gives about the biogas potential of the distillery industry into different states and this columns basically gives the total nitrogen and the nutrient value which is present and then finally this is giving the amount of biomass in terms of tons. So, this is the data that we can see there is a huge potential of this industry in terms of generation of bioenergy. So, if we see all the distilleries which are used to carry out this anaerobic process they used to generate the biogas then this biogas they used to remove the carbon dioxide and other impurities from the biogas and this methane is separated which is having a calorific value around 5000 to 6000 kilocalorie and that can be used for generation of electricity and many of the plants they have this energy generation facility out of this treatment process.

So now we will take some numerical which will describe about bioenergy potential of the distillery industry. So here if we see in this numerical what we see a distillery of 30 KLD means

30 kiloliter per day capacity that generates spent wash at rate of 15 liters per liter of alcohol and if we see its BOD concentration is given that is around 150000 mg/L and it is said that the spent wash treated in UASB reactor and generates lot of methane and the methane yield from the system if we see that is given 0.35 m^3 of methane that will be generated per kg of BOD removed and also given that assume this biogas contains 70% of the methane and rest is carbon dioxide and this methane has a calorific value of 900 kcal/m^3 and if we also see there is a biogas production rate that is given as 0.5 m^3/kg of BOD removed. So, these are the problem and then using this data how we can use this data for determination of the total biogas which will be produced and then the how much methane will be generated and then what will be the energy equivalent of the total methane which is generated from the treatment of spent wash.

So, if we see first of all we have to determine the quantity of spent wash that is generated so we have seen there is a ratio that is given 15 liter of spent wash that will be generated out of per liter of alcohol being produced. So, here our capacity of distillery that is given as 30 KLD it means 30000 liter per day so if 30 KLD is converted by multiplying with this 1000 and this ratio is multiplied in order to get the total quantity of spent wash that is generated which is around 4,50,000 L/day and then the second step we need to calculate how much BOD is removed so as to get the total amount of methane that will be generated. So here we know how much spent wash is generated and how much BOD that will be generated. $Amount\ of\ BOD\ generated \times quantity\ of\ spent\ wash\ generated \times BOD\ removal\ efficiency$ So here if we multiply this the concentration of BOD ($150000 \frac{mg}{L} \times \frac{10^{-6}\ kg}{mg} \times 450000\ L/day \times 0.85$) = 57375 kg/day. So these are the other data like plant capacity and this is BOD concentration this is methane yield what is given here that is the calorific value and then this is biogas production rate. So after calculating how much BOD that is being removed per day we can calculate by multiplying with the biogas production rate $Biogas\ production = Biogas\ production\ rate \times BOD\ removal\ rate$ that is 0.5 $m^3/kg\ of\ BOD\ removed \times 57375\ kg/day$ = 28687.5 m^3/day. So once we have got this biogas we can calculate how much methane that will be produced so this is like BOD removal rate and then this is methane generation rate so if we multiply with this so we will get this total amount of methane that can be produced because the theoretical methane yield that is 0.35 $CH_4/kg\ BOD\ removal$ and that gives us a value of 20,081.25 $m^3\ CH_4/day$ that will be generated from this treatment process and then finally we have been asked to calculate its energy equivalent, so we know the calorific value of methane if we multiply with its generation rate so we can calculate how much total energy we can generate out of this treatment that is obtained $180.73 \times 10^6\ kcal/day$.

So, these are the references that we can use for this topic.

So, thank you very much.