Course Name: Industrial Wastewater Treatment

Professor: Sunil Kumar Gupta

Department of Civil Engineering, IIT(ISM), Dhanbad

Week – 07

Lecture 31: Treatment of wastewater produced from Distillery and Dairy Industries

So, welcome you all today I am going to deliver lecture 1 of module 7 which is basically dealing with the treatment of wastewater produced from distillery and dairy industries. So, under this we have covered two industries, one is distillery and the dairy industries. So, first of all we will go for distillery industries. So, under this what we have included is basic introduction on the distillery industries, their production process, their raw materials what are using their growth pattern and what are the requirements. So, all this information we will be covering on the basic details of this distillery industry, their development in our countries and then we will be looking upon the distillation process which are the major process used in this industry for fermentation of molasses, for production of alcohol. So, under this we will be covering the two different process, one is like batch process and another is Biostil process which are used for fermentation of molasses. So, these two process we will be describing in detail along with their flow diagrams. So apart from this we will be also taking into consideration the various types of organisms, yeast and bacterial consortium which are used for fermentation process and then as the raw material molasses is used and what are the different types of molasses which are available and that can be used for production of alcohol and then finally we will be also looking on the sources and characteristics of the wastewater which are generated from different unit operations from this distillery industry and its characteristics.

So, let us first discuss about the basic introduction of the distillery industry. If we see that the distilleries are mainly used for production of alcoholic drinks, like wines, whiskey and beers which also includes 100% pure alcohol which is called as the rectified spirit which is sometimes used as a raw material for other industries like pharmaceutical and other associated industries. So, this is like the products which are generated from this distillery industries. So, if we see their growth pattern so what we find that at present there is around 295 distilleries in India which are producing about 13.8 billion liters of alcohol per year. Out of this if we see more than 63.4% of alcohol that is produced from the fermentation of molasses where rest 5.05 billion liter which is produced by the fermentation of grain-based molasses and it contributes to around 36.6%. So if we see during last eight years this industry has made a lot of progress and witnessed about 2.5 times of its growth in terms of its annual alcohol production capacity during the last eight years and if we see it has future prospects for its rapid growth looking into the Indian government target of ethanol blending of 20% and more to fight against the climate change so this is to reduce the CO_2 emission so this is getting lot of momentum and in future it is expected that these industries will show lot of potential and have future prospects of its exponential growth.

And if we see the growth pattern of the distilleries in our country so what we can see here in this diagram like this is like 157 industries distilleries were there initially in our country which in especially during 2013 to 2014 and this has increased to around 262 number of distilleries so this is showing around 66% of growth in terms of total number of distilleries but in terms of its production capacity if we see it has a marked like 2.5 times like from 215 to 619 billion liter per annum capacity has been enhanced in our country so this is like the growth that has been witnessed by this industries.

So before going into the basic details of this let's have some discussion on the distillation process so basically the process where this molasses or the sugar content which is present in different feed materials that is fermented and distilled in the form of alcohol. So this complete process this is represented in this flow diagram if we see there are different stages of this distillation process if we see the number one stage that is like if we can see this is the feed preparation, so this feed preparation involves like making the raw materials ready for fermentation process so this is one of the unit in the distillery industry where this raw material is basically what happens this the raw material what we use that is like sugarcane molasses which contains around 40 to 60 % of this sugar but for this process for fermentation the sugar content should not be more than 10 to 15 % so for this we need to dilute the sugarcane molasses with the water so as to bring down its concentration of sugar to less than 10 to 15 %. So in this section what is done is molasses is stored in the molasses storage tanks from there and this water is mixed here in this dilution tank so this will bring the sugar content less than 10 to 15 % and then you see that is the second stage of distillation that is fermentation process so this is usually performed in the fermenter, so if we see this is after dilution of this molasses this comes to the fermenter and here basically what happens here we have to inoculate the particular yeast culture which will ferment this cane sugar into alcohol and this process is done at a higher temperature so we need a cooling water as well for this process and here what happens when this yeast culture is mixed with this diluted molasses so whatever the sugar content that gets converted into alcohol and water vapors and then whatever the CO_2 that will be produced in the process that will be taken out from this process and this cooling water that after cooling the system it will come out as a end product here and then fermentation is carried out then all the sugar content that has converted into alcohol so then this is settled or filtered because there is it will contain a lot of yeast culture, yeast inoculum so it has to be filtered out or settled out and this yeast biomass that has to be removed and should be disposed into the environment. And after this filtration settling operation basically is performed for removal of this yeast from rest of the liquor so rest of the liquor then it goes to the another stage that is called distillation. So here there is an analyzer column where it is whatever the liquor comes that contains unfermented sugar and alcohol which is being fermented and this is basically in the dissolved phase so what happens here in this analyzer column we try to heat it so that its temperature is increased and they are the alcohol that is in the dissolved phase gets converted into vapor paste and from here and whatever the rest of the sugar content which is also not fermented will get fermented and will produce CO_2 from here also and after this whatever the alcohol vapor comes out that goes to the another column but which we say that is rectification column so here whatever the alcohol comes that may also contain some of the water vapor so here rectification of that alcohol is done so as to produce 100% alcohol which is also called as the rectified spirit. In this process if we see after this analyzer column there is a waste water is produced so this

wastewater is the main waste water what we call that is the spent wash and is one of the most caramelized type of waste water which is produced from this distillation process and needs thorough treatment before it is discharged into the environment and the second type of the waste water that is spent lease so this type of waste water also that is generated after the rectification column so this may also contain the some fractions of this alcohol which is not being evaporated and then also some part of the BOD and COD so this is comparatively lesser strength as compared to the spent wash so these two types of waste water they are mainly generated from this process and they should be collected and after that they should be treated and for treatment if we see these two waste water they has to be basically treated using the anaerobic treatment system because that is the system which can handle very high BOD and COD present in the wastewater so this anaerobic treatment system is here then used for treatment of this waste water generated from this process and then finally they are disposed into the environment or as per their existing practices. So, this is basically the entire distillation process which is carried out in a distillery industry for converting the sugar into alcohol and its rectification so as to produce 100% alcohol and then using this alcohol various products like wine, whiskey, beers depending upon the %age of alcohol they are manufactured and sold in the market.

So this is like before going into the more detail of the process let's see what type of molasses they are used. The first type of molasses which we use that is beet or cane molasses which basically contains 50 to 50% of the sugar and this has also got the maximum yield of alcohol that is around 70 to 80 gallons of alcohol per ton of this molasses and overall this molasses as it contains 50 to 55% of this sugar content and this fermentation process that needs to bring down this sugar content around 10 to 15%. So, this also need dilution so this is like dilution is required if we are using this cane molasses or beet molasses as a raw material for fermentation of alcohol and then if we see that is another raw material which we can use also that is cane sorghum and this if contains around 14% of fermentable sugar content so this if we see does not need any dilution so it's exactly as per the requirement of sugar content in for the fermentation process and similar is the case for this sugar beet here also the sugar content in this type of molasses that is around 15% and does not need any kind of dilution but in terms of its yield if we see the cane sorghum molasses that has a yield comparatively lower yield of alcohol that is around 13 to 15 gallon of alcohol per ton of this molasses whereas in case of sugar beet that is around 20 to 25 gallon of alcohol per ton of molasses. But because this is exactly meeting the requirement having higher yield so this is mostly preferred in most of the distillery industries in India as a raw material for producing alcohol. And then another type of sugar corn based nowadays this is the kind of green initiatives where sugar corn based they are which contains around 7 to 15 % of the sugar content and having comparatively significant alcohol yield around 8 to 18 gallons of alcohol per ton so this can be used but this type of molasses is slightly alkaline in nature so this requires acidification process so these are like various types of molasses which we can use for fermentation in order to produce the alcohol.

So let's see how they looks like if we see that is the beat or cane molasses this kind of thick soup you will see in the tank and they are stored in a molasses storage tanks and if we see the another type of this cane sorghum raw material which is used to derive the sugar content so that is this and this is basically the photographs for sugar beet which is grown up and having a very good

content of sugar and this is like sugar corn waste which contains a lot of sugar and it can also be used as one of the raw material for fermentation of alcohol.

So then let's talk about the various organisms which are used for carrying out this fermentation process so there are basically bacteria also can be used and the type of these cultures they are also used so they are basically having different types of species like if we see under bacteria if we see that is the Clostridium species, Spirochaeta species, Sarcina species and then Streptococcus type of species these are the different group of the bacteria which are active in fermentation of sugar into alcohol so they can also be used but in most of the distillery industry we use a type of yeast culture which is Saccharomyces species, so this species is a type of yeast culture which is used for fermentation of alcohol and selection of the particular bacteria or the yeast culture which we should use that basically depends upon its growth and fermentation rate and also in terms of ethanol yield we found that this yeast culture have better ethanol yield compared to the bacterial culture and also if they require like low pH and high temperature. So these are the different process parameters that we have to look into in order to decide the type of the culture we have to use for fermentation process and then also because our molasses contains a lot of sugar contains so our bacteria should having a lot of tolerance against this ethanol and glucose.

Then let's see but what are the various biochemical reactions that happens when this sugar is converted into alcohol through this fermentation process. So, here if we see this if we write this cane sugar as its chemical formula $C_{12}H_{22}O_{11}(cane\ sugar) + H_2O \xrightarrow{Fermented\ by\ yeast} 2C_6H_{12}O_6(Glucose)$. So this is like cane sugar which in presence of water it will be fermented by the yeast culture and the yeast culture what we use that is Saccharomyces cerevisiae so this is the type of the yeast culture which will first convert this cane sugar into glucose so this is the first stage of glucose conversion and then finally this glucose is taken as a substrate by this yeast culture and they will ferment it into this alcohol and carbon dioxide ($2C_6H_{12}O_6 \xrightarrow{Saccharomyces/cerevisiae} 2C_2H_5OH + 2CO_2$). so both basically initially this carbon dioxide that will be taken out and this ethanol will be separated for its rectification and final production of alcohol.

Let's go into the various processes which are used for production of alcohol in the Indian distillery industries. So this if we see there are two processes mainly used one is like batch process and another is like biostil process so as the name indicates these are the process which runs in batches there are number of batches and they produce intermittently the batches of alcohol and whereas this biostil process that is basically the continuous process, where the alcohol is continuously generated so these are the two process mainly used in our industry so if we see out of these two process most of the old industries when the technology were not updated they were using this batch process but nowadays all those new distilleries and also they have modified the process the old industries also and they started using this biostil process.

So let's see what are these two process how this they are differ from each other how this fermentation is carried out so that is shown by a flow chart here. So here if we see that is first of all this molasses which is coming from the sugar industry this is also one of the by-product of this sugar industry so this is first is stored into the molasses storage tanks so there you can see in the industry there are number of circular shape rectangular shape of this molasses storage tanks

where the raw material will be stored and then before going into the fermentation process it is weighed by using this weighing machine and then it comes to a dilution tank where water will be added here and this will be mixed in order to reduce its sugar content because if we see in the raw molasses there the sugar content is around 40 to 45 % and for this fermentation process the sugar content should not be more than 10 to 15 % so here in this dilution tank what we do is to add the water in order to reduce this sugar content to less than 10 to 15 % and then it is thoroughly mixed and after mixing if we see that is the entire liquid that is sent to the pre-fermenters. So, there are pre-fermentation process which is carried out at a pH of this 4 to 4.5 because this acidification is required for fermentation of this molasses so we have to adjust this pH of the entire liquid to 4 and 4 to 4.5 and we have seen like some of the molasses are slightly alkaline in nature so for that we have to add here this H_2SO_4 or lactic acid in this pre-fermentation tank in order to bring down the pH in this range. Then another condition that is to maintain that is temperature so this has to be heated in order to get a temperature of around 35 to 37 °C and in at this pH and this temperature this entire liquid is fermented using the yeast cultures and in this basically the entire pre-fermentation process like conversion of this cane sugar into glucose that is completed within 4 to 5 hours so this is the first stage of fermentation of cane sugar into glucose and then this liquor containing a lot of glucose will be taken to the next unit that is called as the main fermenter so from here entire liquor is coming to this main fermenter and this is where the second stage of fermentation will be carried out that is like conversion of glucose into alcohol so this is done by a particular yeast culture in this what will be there this yeast culture plus this diluted molasses so this diluted pre-fermenter was here will be kept in the main fermenter for an around 36 hours so this required complete conversion of glucose in the form of alcohol and this process if we see that is carried out at 35 °C and then after this if we see that entire fermented liquor which contains a lot of alcohol so that comes to this another unit which is called as the boiling column here what we do we use to heat this entire liquor at a temperature of 75 to 80 °C because in this fermenter that alcohol is in the dissolved phase and if we heat the entire liquor whatever the alcohol that will be vaporized and along with this there will be some water vapors that will also get included into this alcohol and from the top if we see that is alcohol and water vapors that will come out from the top and whatever this wastewater that will be coming out from the bottom that is termed as the spent wash so this entire water vapor and this along with this alcohol vapors that comes to the next unit that is called as the rectification column. What happens in the boiling column because there is a both alcohol vapor and water vapors are so are there so they need to be separated and basically we use here density separation technique where because this water vapor has higher density so it will remain at a bottom whereas this alcohol vapor having lower density compared to the water vapor that will go from the top and will come out here in the rectification column and here again this further heating will be done so as to further remove the rest of the water vapor from this alcohol and we have 100 % alcohol vapor that is taken into this condensation column then where this is cooled down because here when it comes out it has a temperature of around 75 to 80 °C then here in condensation column it is cooled down when it is cooled down temperature is reduced then it is again converted into rectified spirit form, liquid form and which is collected and having different % age of alcohol and it's further used in the pharmaceutical and other associated industries and if we see from the bottom because from the bottom this water vapor will be collected so this goes to the exhaust column where from this

water vapors are condensed and generated as a spent lease so this is another source of wastewater which is generated.

So this is spent was one and this is spent lease two so two units they generate two different types of wastewater having entirely different characteristic because here this is spent was it will be very highly strength wastewater and whereas this spent lease is comparatively of lower strength compared to this spent wash another type of process which is called as the biostil process which are used for production of alcohol. So this is as I said this is continuous process so here what happens this molasses what comes from the sugar industry that is having again this 40 to 55 % of the sugar so here this goes directly to fermenter unit which contains basically a mix of this molasses plus yeast culture and there will be also addition of this recirculated fermented wash so this is by the some of the fermenter wash which will be generated after this fermentation that is recycled here so recycling of this is done basically to control this %age sugar content because here if we see that is sugar content 40 to 45. So approximately 50 to 60 % of this weak wash which is generated in this fermenter wash feed tank that is recycled here so as to reduce its sugar content to less than 10 to 15 % and in this tank if we see we require only three hours of detention time because here the type of culture we use having fast fermentation process and entire fermentation of sugar into alcohol that can be carried out in maximum of three hours and for this also if we see the temperature the same temperature is required approximately 35 to 37 °C. So this is like the main fermentation process and here if we see in this what these are the control parameters we have to adopt. So this recycling of basically this week was how much it has to be recycled so as this here after recycling there will be some ethanol concentration also so that should not be more than 5 to 7 % and after recirculation this sugar content in this entire this fermentation tank that should not be more than 0.2 % so this are the control parameter for carrying out efficiently this fermentation process and then you can see after this fermentation the entire liquid entire liquid that is taken to the yeast separator unit where yeast culture that will be separated from rest of the liquor and this yeast culture that will be taken out from this unit and will be disposed separately but whatever the rest of the liquor that is generated out of this filtration process that is collected into this fermented wash feed tank which are used for further separation of alcohol from rest of the liquor. So, this is the wash feed tank, fermented wash feed tank which will store all the fermented wash here. So, from here the recirculation will be also maintained and then the next step in fermentation process that is vaporizer column like rectification and separation of this alcohol vapor from the carbon dioxide and rest of the gases present in this so here that is vaporization is done, so here again we used to increase the temperature so here what will happen whatever this alcohol vapor that will come out from the top and this water vapor that will be down so here from this and rest of the liquid that will be basically generated as a spent wash and after heating when this alcohol gets vaporized so there will be some also water vapors so they will be taken out along with this alcohol vapors to the another column that is called as the stripping column and here what happens here further rectification of the alcohol is done because it still contains 10 to 15 % of the water vapor. So this has to be again removed by excessive heating through the boiler here so in this column it is further heated then whatever the moisture that is vaporized and rest of the vapors that is then taken to the another column that is basically the condensation column and here this is condensed the temperature is reduced. So this is converted into the liquid form and that is called as the

rectified spread which is having 100 % of alcohol so these are the two processes which are used in industries for production of alcohol.

So let's see what are the comparative advantages and disadvantages of the two process. So, here if we see the two process batch process and biostil process, so these are the parameters of its comparison like if we see the type of fermentation so if we see this biostil process that is very quick because here quick fermentation takes with maximum four hour is required so no unnecessarily increasing the size of the reactors, fermenters that will be saved here in the biostil process. So, this is if we see is a quick fermentation process compared to the batch process and because of this delayed fermentation in this process if we see that is carried out around 36 plus 4 hours so around 40 hours, so because of this there is a production of lot of higher alcohols fused oils, glycerins which basically affects the fermentation process and overall reduces the quality of the alcohol which is being produced so compared to this batch process in terms of quality also the biostil process is better than this batch process and then biostil process does not require any pre-fermentation stage so it requires number of pre-fermenter in case of batch process and then if we see another parameter like in terms of alcohol yields so always this is having around 25 % more yield compared to the batch process so for example if we take a 30 KLD distillery industry so it can produce around 7.5 kl/d extra alcohol compared to the batch process so here in this process the alcohol yield is comparatively less than the biostil process then in terms of spent wash generation if we see kind of wastewater it is generated so here if we see come in terms of volume it is highly reduced around 5-7 liters of spent wash per liter of alcohol but in case of this around two times that is 15 to 16 liter of spent wash per liter of alcohol is produced and similarly if we see the characteristics so here that is reverse so this is highly strength wastewater compared to the BOD and COD concentration here in the batch process the concentration of this BOD and COD in the biostil process that is around two times then the concentration of the spent was generated from the batch process. And similarly if we see the kind of steam consumption because this is one of the requirement of the process we need to have steam generation and its steam will be used for heating systems so here it requires around 7.5 % less steam in the biostil process compared to the batch process and similarly if we see pH adjustment is also not required in biostil process compared to the batch process here we have to add acid in order to bring down pH 4 to 4.5 and then again if we see in terms of dilution here it is not required in case of biostil process whereas this is extremely required in case of batch process because until unless you reduce the concentration the fermentation will be not efficient.

So these are the references you can refer.

Thank you