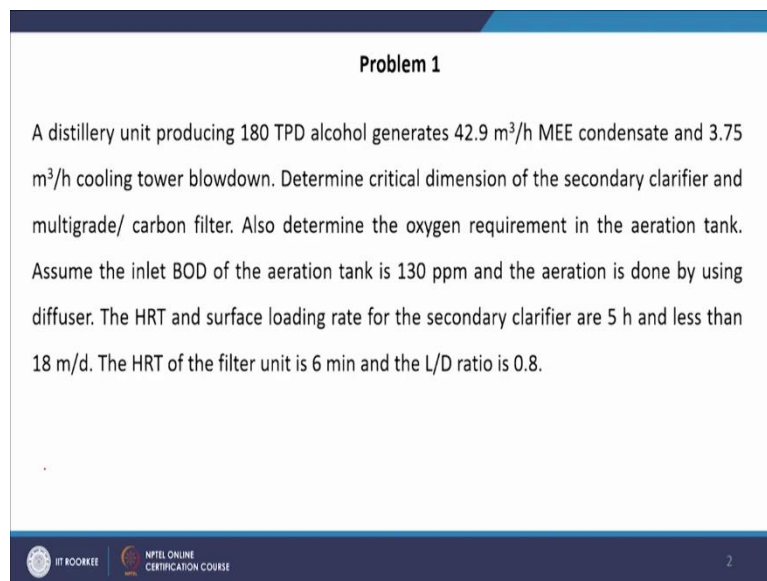


**Basic Environment Engineering and Pollution Abatement**  
**Professor Prasenjit Mondal**  
**Department of Chemical Engineering**  
**Indian Institute of Technology, Roorkee**  
**Lecture: 50**  
**Tutorial 10**

Hello everyone. Now, we will have a tutorial session and we will solve some numerical problems on the basis of discussion we have made in last 4 classes.

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**Problem 1**

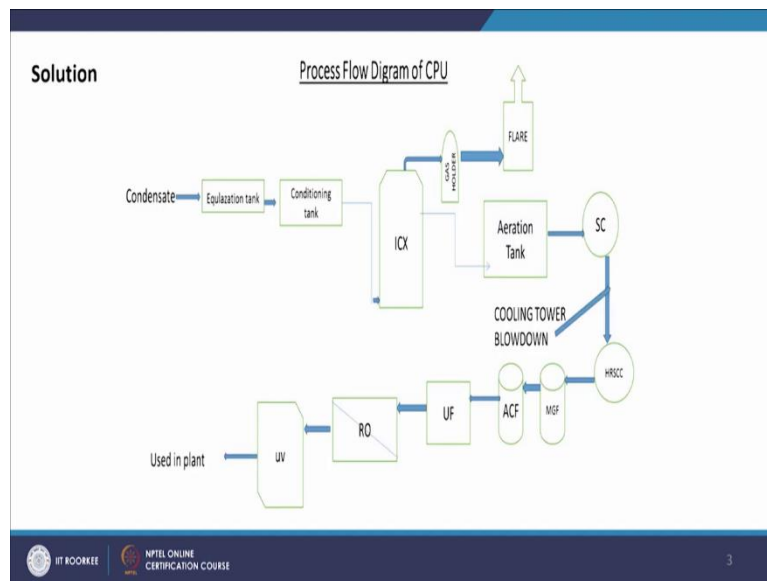
A distillery unit producing 180 TPD alcohol generates 42.9 m<sup>3</sup>/h MEE condensate and 3.75 m<sup>3</sup>/h cooling tower blowdown. Determine critical dimension of the secondary clarifier and multigrade/ carbon filter. Also determine the oxygen requirement in the aeration tank. Assume the inlet BOD of the aeration tank is 130 ppm and the aeration is done by using diffuser. The HRT and surface loading rate for the secondary clarifier are 5 h and less than 18 m/d. The HRT of the filter unit is 6 min and the L/D ratio is 0.8.

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Our first problem, statement is a distillery unit producing 180 TPD alcohol generates 42.9 m<sup>3</sup>/h MEE condensate that is multi-effect evaporator condensate and 3.75 m<sup>3</sup>/h cooling tower blowdown. Determine critical dimension of the secondary clarifier and multi-grade or carbon filter. Also determine the oxygen requirement in the aeration tank. Assume the inlet BOD of the aeration tank is 130 ppm and the aeration is done by using diffuser. The HRT and surface loading rate for the secondary clarifier are 5 hour and less than 18 m/d that is m<sup>3</sup>/m<sup>2</sup>day. The HRT of the filter unit is 6 minute and the L by D ratio is 0.8.

So, now, we have to solve this problem. And we know that this problem is basically based on the treatment of wastewater in a distillery unit and in this case, as MEE condensate is there that means thermal process is used for the condensation of spent wash.

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And you see the flow sheet for the water treatment. So, we have MEE condensate. So, this condensate is coming into the equalization tank and then equalization tank to conditioning tank. So, here pH adjustment takes place and then it is going to ICX that is biological tower. So, here anaerobic condition prevails and biogas is produced and the gas is lost, it is flared. Through the flaring the gas is burnt and the water which is coming out from ICX goes to aeration tank and in aeration tank oxygen is supplied microbial seeds are provided and remaining organic compound present in the water is degraded here.

So, we have to calculate the oxygen requirement in this tank and after this the treated water goes to secondary clarifier and the water enters into the HRSCC and the sludge goes for dewatering into a decanter. And another water stream that is provided in the problem statement that is cooling tower blowdown. So, that directly does not enter into the equalization tank. It enters here with the treated water after secondary clarifier and then in the HRSCC both streams are added.

So, here HRSCC we are getting another settling, so the clarified liquid is passed through the tertiary treatment unit. So, this is our MGF and ACF, multi grade filter and activated carbon filter then it goes to UF, RO, UV and then used in the plant. So, we have to find out the dimension of this ACF and MGF. We have to find out the dimension of this SC, secondary clarifier and we also have to calculate the oxygen requirement in this aeration tank. So, these are the task we need to complete.


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In distillery ETP the MEE condensate is treated through the condensate polishing unit (CPU) through equalization tank, anaerobic digester, aerobic tank followed by tertiary treatment. However, the cooling tower blowdown is treated only through tertiary unit. Thus, if we assume that there is no loss of water during the process and ignore the sludge volume (which may give conservative design), only condensate water will be processed in secondary clarifier. However, both condensate and blowdown water will be used in multigrade /carbon filter.

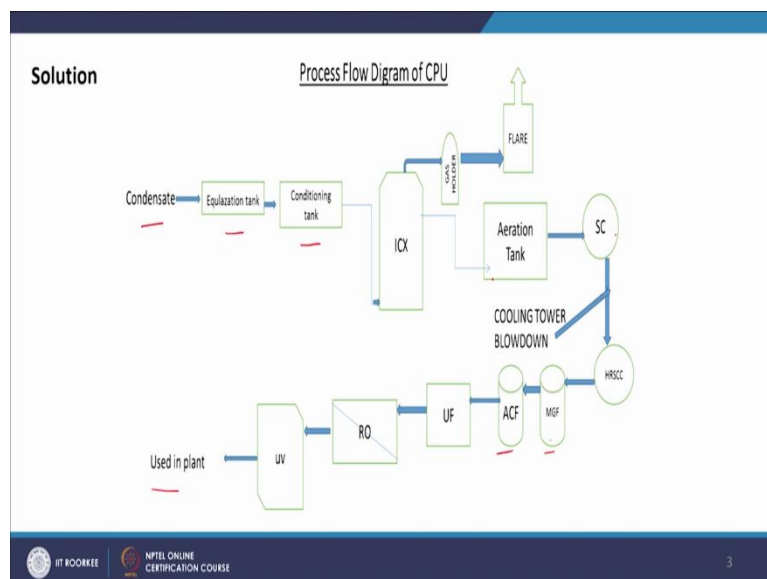
Since, the HRT of secondary clarifier is 5 h the working volume of secondary clarifier will be  $5 \times 42.9 = 214.5$  KL

Since the surface loading rate is  $18 \text{ m}^3 / \text{m}^2 \text{d} = 0.75 \text{ m}^3 / \text{m}^2 \text{h} = 0.75 \text{ m/h}$

Thus, the cross section area of the tank will be  $= 42.9 / 0.75 = 57.2 \text{ m}^2$


  
 $A = \frac{\pi}{4} D^2$

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Now you see, in distiller ETP, the MEE condensate is treated through the condensate polishing unit through equalization tank, anaerobic digester, aerobic tank followed by tertiary treatment. However, the cooling tower blowdown is treated only through tertiary unit. Thus, if we assume that there is no loss of water during the process and ignored the sludge volume only condensate water will be processed in secondary clarifier. However, both condensate and blowdown water will be used in multi grade and carbon filter.

Now, we have taken one assumption that we are assuming that the sludge volume is negligible. So, although there will be some sludge production, but by this assumption the design will be more conservative, so, there will be no harm.

Now, since that HRT of the secondary clarifier is 5 hour. The working volume of the secondary clarifier will be  $5 \times 42.9 = 214.5$  KL.

Since the surface loading rate is  $18 \text{ m}^3/\text{m}^2\text{day} = 0.75 \text{ m}^3/\text{m}^2\text{-h} = 0.75 \text{ m/h}$ .

Thus, the cross-section area of the tank will be  $A = Q/V = 42.9/0.75 = 57.2 \text{ m}^2$

So, if we get the value of area then we can get the diameter.

(Refer Slide Time: 07:43)

Thus, height of the secondary clarifier =  $214.5/57.2 = 3.75 \text{ m}$

However, at least  $0.3 \text{ m}$  free board is necessary, thus the actual height of the secondary clarifier will be  $= 3.75 + 0.3 = 4.05 \text{ m}$

Thus, actual volume of the secondary clarifier will be  $= 4.05 * 57.2 = 231.7 \text{ m}^3$

The radius of the secondary clarifier will be  $= \sqrt{57.2/3.14} = 4.27 \text{ m}$   $A = \pi r^2$   
 $r = \sqrt{A/\pi}$

And the diameter will be  $8.54 \text{ m}$

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In distillery ETP the MEE condensate is treated through the condensate polishing unit (CPU) through equalization tank, anerobic digester, aerobic tank followed by tertiary treatment.

However, the cooling tower blowdown is treated only through tertiary unit. Thus, if we assume that there is no loss of water during the process and ignore the sludge volume (which may give conservative design), only condensate water will be processed in secondary clarifier. However, both condensate and blowdown water will be used in multigrade /carbon filter.

Since, the HRT of secondary clarifier is 5 h the working volume of secondary clarifier will be  $5 * 42.9 = 214.5 \text{ KL}$

Since the surface loading rate is  $18 \text{ m}^3/\text{m}^2\text{d} = 0.75 \text{ m}^3/\text{m}^2\text{h} = 0.75 \text{ m/h}$   $AV = Q$   
 $A = \frac{Q}{V}$

Thus, the cross section area of the tank will be  $= 42.9/0.75 = 57.2 \text{ m}^2$

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Thus, height of the secondary clarifier =  $214.5/57.2 = 3.75 \text{ m}$

However, at least  $0.3 \text{ m}$  freeboard is necessary, thus the actual height of the secondary clarifier will be  $= 3.75 + 0.3 = 4.05 \text{ m}$

Thus, the actual volume of the secondary clarifier will be  $= 4.05 * 57.2 = 231.7 \text{ m}^3$


The radius of the secondary clarifier will be  $= \sqrt{57.2/3.14} = 4.27$  m

And the diameter will be 8.54 m

So, one problem is solved.

(Refer Slide Time: 09:41)

Volume of water to be processed through the multigrade/ carbon filter per hour =  $42.9 + 3.75 \text{ m}^3 = 46.65 \text{ m}^3/\text{h}$   
Thus, volume of water processed in 6 minute =  $46.65 * 6/60 = 4.67 \text{ m}^3$

Assuming diameter =  $x$  ✓  $\frac{L}{D} = 0.8$    
length =  $0.8x$  ✓  
Volume =  $3.14 * (x^2/4) * 0.8x = 4.67$   
Or  $0.628x^3 = 4.67$   
Or  $x^3 = 4.67/0.628 = 7.44$   
Or  $x = 1.95 \text{ m}$   
Thus diameter =  $1.95 \text{ m}$

And length =  $1.95 * 0.8 = 1.56 \text{ m}$

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Now, in the second case, we have to find out the dimension of the filter units. So, in this case it is a unit of tertiary treatment. So, both condensate and the blowdown water will be passing through it.

The volume of water to be processed through the multigrade/ carbon filter per hour =  $42.9 + 3.75 \text{ m}^3 = 46.65 \text{ m}^3$

Thus, the volume of water processed in 6 minutes =  $46.65 * 6/60 = 4.67 \text{ m}^3$

Assuming diameter =  $x$

length =  $0.8x$

Volume =  $3.14 * (x^2/4) * 0.8x = 4.67$

Or  $0.628x^3 = 4.67$

Or  $x^3 = 4.67/0.628 = 7.44$

Or  $x = 1.95 \text{ m}$

Thus diameter =  $1.95 \text{ m}$

And length =  $1.95 * 0.8 = 1.56 \text{ m}$

So, now, we are able to find out the dimension of each filter unit.

(Refer Slide Time: 12:20)

The inlet BOD of the aeration tank is 130 ppm

Assuming permissible of BOD in the treated water after secondary treatment = 30 ppm

Thus, BOD removal in the aeration unit =  $130 - 30 = 100$  ppm

Since, aeration is done by using diffuser, the air requirement may be considered as  $36 \text{ m}^3/\text{kg}$  of BOD removed

For the present case, BOD removed per hour =  $42.9 * 0.1 = 4.3$  kg

Air requirement =  $36 * 4.3 = 155 \text{ m}^3/\text{h}$

*Handwritten notes: 130-30, 0.1812 = 0.1 kg/KL*

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Next part, we have to find out the air requirement in the aeration chamber. So, in the aeration chamber, we have seen that the wastewater after treatment in the bio tower it enters into the aeration chamber.

The inlet BOD of the aeration tank is 130 ppm

Assuming permissible of BOD in the treated water after secondary treatment = 30 ppm

Thus, BOD removal in the aeration unit =  $130 - 30 = 100$  ppm

Since, aeration is done by using diffuser, the air requirement may be considered as  $36 \text{ m}^3/\text{kg}$  of BOD removed

For the present case, BOD removed per hour =  $42.9 * 0.1 = 4.3$  kg

Air requirement =  $36 * 4.3 = 155 \text{ m}^3/\text{h}$

Now, we are able to solve the problem completely.

(Refer Slide Time: 14:16)

**Problem 2**



In an industrial biogas plant food waste is anaerobically digested to produce biogas. The slurry contains 10 % of solid food grains. The elemental composition of the waste food grains on dry basis is C: 52%, H:9%, O:29%, N:10% (mass %). Around 85 % of the waste food grains are converted to biogas and all the converted hydrogen forms methane. If the flow rate of the slurry is 4000 litre per day, calculate the rate of biogas ( $\text{CO}_2 + \text{CH}_4$ ) production.

**Solution :**

Flow rate of the slurry = 4000 L ✓

Dry solid of waste food grains used =  $4000 \times 0.10 = 400 \text{ L} = 400 \text{ kg}$

Assuming density of slurry = 1 kg/L ✓

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Now, we will see the problem number 2. Statement is in an industrial biogas plant food waste is anaerobically digested to produce biogas. The slurry contains 10 % of solid food grains, the elemental composition of the waste food grains on dry basis is carbon 52 %, hydrogen 9 %, oxygen 29 %, nitrogen 10 % on mass bases. Around 85 % of the waste food grains are converted to biogas and all the converted hydrogen forms methane. If the flow rate of the slurry is 4000 L/day. Calculate the rate of biogas that is ( $\text{CO}_2 + \text{CH}_4$ ) production.

So, this is one another problem related to anaerobic digestion and we have to calculate the rate of biogas production. The composition is given and the C, H, N, S for elemental analysis is also given.

Flow rate of the slurry = 4000 L

Dry solid of waste food grains used =  $4000 \times 0.10 = 400 \text{ L} = 400 \text{ kg}$

Assuming density of slurry = 1 kg/L



(Refer Slide Time: 15:52)

C present in 400 kg dry food grains =  $400 \times 0.52 = 208$  kg ✓  
H present in 400 kg dry food grains =  $400 \times 0.09 = 36$  kg ✓  
O present in 400 kg dry food grains =  $400 \times 0.29 = 116$  kg ✓  
N present in 400 kg dry food grains =  $400 \times 0.10 = 40$  kg ✓

Since 85 % food grains are converted to biogas

C converted to biogas =  $0.85 \times 208$  kg = 176.8 kg  
H converted to biogas =  $0.85 \times 36$  kg = 30.6 kg

Since all the H is converted to  $\text{CH}_4$ ,  
The methane production =  $(16/4) \times 30.6$  kg = 122.4 kg = 7.65 k mole

C used for methane production =  $122.4 (12/16)$  kg = 91.8 kg

C used for  $\text{CO}_2$  production =  $176.8 - 91.8$  kg = 85 kg ✓

$\text{CO}_2$  produced =  $85 \text{ kg} \times (44/12)$  kg = 311.66 kg = 7.08 k mole ✓

$\text{CH}_4 + \text{CO}_2 = 122.4$  kg +  $311.66$  kg = 434.06 kg Or  $7.65 + 7.08 = 14.73$  K mole

*Handwritten notes:*  
 $\text{CH}_4 \rightarrow 12+4=16$   
 $12+4=16$   
 $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$   
 $16 \quad 12+32=44$

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C present in 400 kg dry food grains =  $400 \times 0.52 = 208$  kg

H present in 400 kg dry food grains =  $400 \times 0.09 = 36$  kg

O present in 400 kg dry food grains =  $400 \times 0.29 = 116$  kg

N present in 400 kg dry food grains =  $400 \times 0.10 = 40$  kg

Since 85 % of food grains are converted to biogas

C converted to biogas =  $0.85 \times 208$  kg = 176.8 kg

H converted to biogas =  $0.85 \times 36$  kg = 30.6 kg

Since all the H is converted to  $\text{CH}_4$ ,

The methane production =  $(16/4) \times 30.6$  kg = 122.4 kg = 7.65 k mole

C used for methane production =  $122.4 (12/16)$  kg = 91.8 kg

C used for  $\text{CO}_2$  production =  $176.8 - 91.8$  kg = 85 kg

$\text{CO}_2$  produced =  $85 \text{ kg} \times (44/12)$  kg = 311.66 kg = 7.08 k mole

$\text{CH}_4 + \text{CO}_2 = 122.4$  kg +  $311.66$  kg = 434.06 kg or  $7.65 + 7.08 = 14.73$  K mole

So, 14.73-kilo mole gases will be present in the produced biogas.

(Refer Slide Time: 20:00)

### Problem 3

If the average heat rate of a co-gen power plant is 2611 KCal/kWh, calculate the average efficiency of the plant.

**Solution**

$$\text{Thermal Efficiency } \eta = \frac{\text{energy generated} * \text{time}}{MC * CV} * 100$$

Where: MC – quantity of fuel / feed consumed; CV- calorific value of feed

$$\begin{aligned} \text{Thermal efficiency} &= 100 / [(MC * CV) / \text{energy generated} * \text{time}] \\ &= 100 / [\text{heat energy input supplied by fuel to the power plant for a} \\ &\quad \text{period (Kcal)} / \text{energy generated for the period (KWh)}] \\ &= 100 / \text{HR (KCal/kWh)} \quad \text{As 1 KWh} = 859.8456 \text{ Kcal} \\ &= [100 * 859.8456 / \text{Heat rate (HR in KCal/kWh)}] \% \\ &= 100 * 859.8456 / 2611 = 33 \% \end{aligned}$$

Now, problem number 3. Statement is the average heat rate of a co-gen power plant is 2611 kCal/KWh. Calculate the average efficiency of the plant.

So, we have discussed in our previous class also that thermal efficiency

$$\text{Thermal Efficiency } \eta = (\text{energy generated} * \text{time}) / (MC * CV) * 100$$

Where: MC – quantity of fuel / feed consumed; CV- calorific value of feed

$$\text{Thermal efficiency} = 100 / [(MC * CV) / \text{energy generated} * \text{time}]$$

$$= 100 / [\text{heat energy input supplied by fuel to the power plant for a period (Kcal)} / \text{energy generated for the period (KWh)}]$$

$$= 100 / \text{HR (KCal/kWh)} \quad \text{As 1 KWh} = 859.8456 \text{ Kcal}$$

$$= [100 * 859.8456 / \text{Heat rate (HR in KCal/kWh)}] \%$$

$$= 100 * 859.8456 / 2611 = 33 \%$$

(Refer Slide Time: 21:50)

#### Problem 4

The flow rate of chrome bearing wastewater from a tannery unit is 2kL/day contains chromium concentration( $\text{Cr}^{+3}$ ) of 20 mg/L. The efficiency of chromium recovery unit is 95 %. Then, calculate the amount of fresh chromium sulphate required per day.

#### Solution :

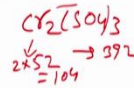
Chromium concentration in wastewater: 20 mg/L

Since efficiency of chromium removal is 95 %

Amount of chromium recovered=  $0.95 \times 20 \times 2000 \text{ mg/day} = 38000 \text{ mg/day} = 38 \text{ g/day}$

Amount of chromium lost =  $(1-0.95) \times 20 \times 2000 \text{ mg/day} = 2000 \text{ mg/day} = 2 \text{ g/day}$

Since 392 g chromium sulphate contains 104 gram chromium ( $\text{Cr}^{+3}$ )



So amount of fresh chromium sulphate required =  $(392/104) \times 2 \text{ g/day} = 7.5 \text{ g/day}$



Next problem number 4. The statement is the flow rate of chrome bearing wastewater from a tannery unit is 2 kL/day contains chromium concentration or  $\text{Cr}^{3+}$  of 20 mg/L. The efficiency of chromium recovery unit is 95 %. Then calculate the amount of fresh chromium sulphate required per day.

So, this is a problem related to chromium recovery in a tannery unit

Chromium concentration in wastewater: 20 mg/L

Since the efficiency of chromium removal is 95 %

Amount of chromium recovered=  $0.95 \times 20 \times 2000 \text{ mg/day} = 38000 \text{ mg/day} = 38 \text{ g/day}$

Amount of chromium lost =  $(1-0.95) \times 20 \times 2000 \text{ mg/day} = 2000 \text{ mg/day} = 2 \text{ g/day}$

Since 392 g chromium sulphate  $\text{Cr}_2(\text{SO}_4)_3$  contains 104-gram chromium ( $\text{Cr}^{+3}$ )

So amount of fresh chromium sulphate required =  $(392/104) \times 2 \text{ g/day} = 7.5 \text{ g/day}$

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### Problem 5

The flow rate of wastewater from a tannery industry is 2 kL/day and it has chromium content of 15 mg/L. As per CPCB standard, the effluent should not contain total chromium as more than 2 mg/L. Find the rate of chromium removal in g/day required in ETP. If 90 % of this chromium is recovered, how much MgO will be required for this recovery of the chromium if stoichiometric conversion takes place.

#### Solution :

Influent chromium concentration: 15 mg/L ✓

Effluent chromium concentration: 2 mg/L ✓

Flow rate of influent wastewater: 2 kL/day ✓

$$\begin{aligned}\text{So rate of chromium removal} &= (15-2)*2*1000 \text{ mg/day} \\ &= 13*2000 \text{ mg/day} \\ &= 26 \text{ g/day} \quad \checkmark\end{aligned}$$



And next, we are coming to volume number 5. And the statement is the flow rate of wastewater from a tannery industry is 2 kL/day, and it has chromium content of 15 mg/L. As per CPCB standard the effluent should not contain total chromium has more than 2 mg/L. Find the rate of chromium removal in gram per day required in ETP. If 90 % of this chromium is recovered, how much MgO will be required for this recovery of the chromium if stoichiometric conversion takes place.

So, here we will see that how much chromium is removed. So, that chromium removal may be taking place at the chromium recovery unit or in the effluent treatment plant.

We are assuming this that some part is recovered and some part is being removed in a treatment unit.

Influent chromium concentration: 15 mg/L

Effluent chromium concentration: 2 mg/L

The flow rate of influent wastewater: 2 kL/day

$$\begin{aligned}\text{So rate of chromium removal} &= (15-2)*2*1000 \text{ mg/day} \\ &= 13*2000 \text{ mg/day} \\ &= 26 \text{ g/day}\end{aligned}$$

(Refer Slide Time: 25:09)

Chromium recovered =  $26 * 0.9 = 23.4$  g/d

Thus,  $\text{Cr}_2(\text{SO}_4)_3 = 23.4 * 392 / 104 = 88.2$  g/d

Now the stoichiometric reactions are

$$\begin{array}{ccccccc}
 3\text{MgO} + \text{Cr}_2(\text{SO}_4)_3 + 3\text{H}_2\text{O} & = & 3\text{MgSO}_4 & + & 2\text{Cr}(\text{OH})_3 & \downarrow & \text{H} - \text{H} \\
 \underline{3*40} & \quad \underline{392} & \quad \underline{3*18} & \quad \underline{3*120} & \quad \underline{2*103} & & 
 \end{array}$$

Thus, MgO required =  $3 * 40 * 88.2 / 392 = 27$  g/d

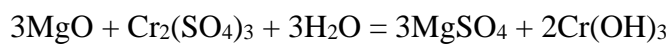
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Now, we are considering the 90 % is recovered out of it,

$$\text{Chromium recovered} = 26 * 0.9 = 23.4 \text{ g/d}$$

$$\text{Thus, } \text{Cr}_2(\text{SO}_4)_3 = 23.4 * 392 / 104 = 88.2 \text{ g/d}$$

Now the stoichiometric reactions are



$$3*40 \quad 392 \quad 3*18 \quad 3*120 \quad 2*103$$

$$\text{Thus, MgO required} = 3 * 40 * 88.2 / 392 = 27 \text{ g/d}$$

So, now we are able to solve this problem also. So, we have solved all the problems in this tutorial class and we have seen that different industries produces different types of pollutants in the wastewater streams.

Now, we will show you one video that will give the working of a sugar industry and I hope you will enjoy it and it will give you more clarification. The video is self-explanatory. Please watch the video.


(Refer Slide Time: 27:45)



**INFLUENT FROM SUGAR INDUSTRY**

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This slide shows a wide-angle view of a rectangular concrete channel in a wastewater treatment plant. The channel is filled with a dark, turbid liquid. In the background, there are various pieces of industrial equipment, including a large white tank and some piping.



**INFLUENT FROM SUGAR INDUSTRY**

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This slide provides another view of the same concrete channel, showing the flow of the dark, turbid liquid. The background features more industrial structures, including a large metal framework and a white tank.



**SCREEN CHAMBER**


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This slide shows a close-up view of a screen chamber. A large, white, corrugated pipe is connected to the chamber. The chamber contains a screen that is filtering the liquid. The liquid is dark and turbid, and there is some debris visible on the screen.




**OIL AND GREASE REMOVAL**

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**OIL AND GREASE REMOVAL**

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**LIME DOSING**

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**AEROBIC TREATMENT**

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This slide shows a large, rectangular concrete tank used for aerobic wastewater treatment. The water surface is turbulent and brownish, indicating the presence of microorganisms. The tank is situated outdoors with trees in the background.



**SEDIMENTATION OF SLUDGE**

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This slide shows a large, circular concrete tank used for the sedimentation of sludge. The water is dark and still, with a metal walkway and railings around the perimeter. The tank is located in an open area with a clear sky.



**SLUDGE DEWATERING**

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This slide shows a sludge dewatering machine, which is a large, rectangular metal structure with multiple horizontal bars. It is used to separate water from sludge. The machine is located outdoors, and a pile of dark, wet sludge is visible in the foreground.





**TERTIARY TREATMENT**

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**TREATED WATER**

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**THANK YOU**

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Now, I think the video has made many clarity on your thoughts and up to this in this class.  
Thank you very much for your patience.