Course Name: Industrial Wastewater Treatment

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Week – 10

Lecture 47: Treatment of wastewater produced from Refineries and Iron & Steel (Coke Ovens)

Welcome you all. Today I am going to deliver my lecture 2 of module 10 which is on treatment of wastewater produced from refineries and iron and steel industry. So, under this we are going to cover basically the coal washeries which are used for washing of coal and to produce good quality of coal which is to be used for power plant and other applications and then we will be following with the various process which are involved in the coal washery industries which are used in the washing of coal. Then we will be also talking about the various techniques which are involved in the washing of coal, then the treatment of coal washery effluents, the characteristics of the wastewater produced and its effluent discharge standards.

So basically, the coal washery, the basic purpose of the washery is to wash out the coal in order to remove out the impurities present in the coal. So, if we see the ash content of the coal which is produced in our country that is varying from 15 to 45 %, so it means that lot of coal that is converted into ash and that generates huge amount of ash after the burning. So, this on an average if we see most of the coal which is there in our country that have average percentage of fires that is 35 to 45 % and if we compare this coal with the coal which we import from other countries that has having a low ash content that is 10 to 20 % ash only, so they are bit cleaner coal compared to the coal which exists in our country and the another important properties of the coal that is the sulfur content which is basically very high in the imported coal as compared to the coal which is produced in our country. So, but in terms of ash content this percentage in our Indian coal that is very high as a result it generates huge amount of fly ash and that is a big problem for its disposal and management. And basically, this ash that is produced because of the presence of various types of impurities, so if we see the impurities basically there are two types of impurities which is one is the fixed impurities, which is the part of the coal component composition whereas the another type of impurities which we say that is a free impurity which are basically the attached inorganic and organic impurities which are associated along with the coal during its excavation. So, that all foreign materials which are attached with the mineral that is the coal basically they form the free impurities and out of these impurities if we see the fixed type of impurities basically, they cannot be removed simply by washing process they require more advanced process like thermos-chemical process thermal process for removal of those fixed impurities while in case of free impurities they can easily be removed through the washing of the coal. So, this is basically the basic purpose of the washing of the coal to remove out all inorganic impurities which are associated with the coal and are attached during its mining.

So overall after the coal is washed basically it has improved in terms of its quality in terms of its ash content in terms of its calorific value. So, these are basic purposes of like it can reduce the ash content up to 17.5% and also it enhances its heating value that is the calorific value of the coal and in addition to this also increases the fusion point of the ash because this removes out whatever the alkali chloride which is present during the washing, so this increases basically the fusion point of ash which is an important property of the ash and then it also reduces the clinking tendency and in addition to this the overall sulfur and phosphorus content that is also bit is removed through the washing process. So, there are one objective having various advantages of washing of this coal.

So let us look into the various process which are involved in the washing of coal in the coal wash array. So, first process that is runoff mine which is basically the excavated coal delivered from the mine which is having a size of around 450 mm and this basically runoff mine that reaches to the coal preparation plant and is used as a raw material for further beneficiation and upgradation in the quality of the coal mined out coal. This is basically the objective of the beneficiation of the coal and then in the second process, what we do basically crushing operation has to be done where this 450 mm size of this coal blocks which are mined out from the open cost and underground mines they have to reduced in smaller size to less than 75 mm size. So, this is done by crushing using advanced crushers designed for the size reduction of ROM that is the runoff mine and then the next process, we see that is the screening process this process basically removes the unwanted inorganic and impurities which are attached in the form of free impurities from the coal. So, this is basically used for purification of the mined-out coal and then basically the next process that is the desliming process. Desliming process is basically carried out by a screen which is used for removal of horse line from the larger particles usually with the aid of water space.

Then the next process that is the washing of the coal that is basically the removal of the impurities using the heavy media cyclones. So, here this cyclone is used where this fine coal that is mixed with the water and passes through the cyclones which removes the impurities which are associated with the fine coals. So, this is basically used for finer particle size of the coal and during this cyclonic action finer size of the particle they moves towards the center where the vertex is basically created and this vertex force, this smaller size of the particles to the top and from there it is separated. So, this is basically a process of separation of the fine coal particles from rest of the impurities. So, this is done using the heavy media cyclones in the coal washeries and then the next process that is again the same process that is used for removal of impurities from the coal so either we use this heavy media cyclones or then we can also use this flotation process that is also basically removal of the impurities, so in this basically we use this diesel oil and the fraction of tar oil both heavy and lighter liquids are used oils are used for separation of fine coals from rest of the impurities. So, it is treated in a flotation cells with the controlled aeration through which the finer size of the coal that gets separated that floats onto the surface from there it is removed and the coarser particles the impurities present in the coal that is that takes their weight to the towards the bottom and they are removed from the water and then after this upgradation of the coal beneficiation of the coal is done then the next process that is basically the dewatering of the coal that is done in the centrifuge. So, there are high speed centrifuge which are used for dewatering of coal so this is basically to produce the clean coal after the overall

washing process. So, these are basically the different unit process they are used in the coal washeries for washing of the coal and to produce a clean coal washed out coal which are used as a raw material in the thermal power plants and many other applications as a clean coal.

So, these are the process flow diagrams of coal washeries. So, here if we see that is basically the runoff mine which is comes from the mining operations, so from there basically crushing is done and after crushing the size range < 75 mm, they are basically taken to the screens so here in the screen if we see they are having the two size fractions. So, the size fraction having 20 to 75 mm size they are separated and lesser < 20 mm size they are separated from the bottom and the size which are > 20 mm they are further crushed into another crushing machines and then again they are broken and made it uniform size equal to less than 20 mm. And after this crushing operation is done then that is the de-slimming operations, so this is the next unit operations where again the very fine size of the coal and the coarser size of the coal they are separated so the size range < 0.5 mm they are basically called as the slims and these the process of removal of these finer size fraction of the coal from rest of the coal crust out coal so that is basically called as de-slimming and in this process we can see this > 0.5 mm size up to 20 mm size they are separated from the fraction or the size range < 0.5 mm, so this < 0.5 mm size particles they are further taken to the screens and washed out along with the water and thickened in a radial thickners and get excess water that is being removed and then this thickened slurry that goes for upgradation and beneficiation using this water only cyclones, so here it gets further removed of the water and another unwanted amputees which are still present in the coal. So, after this then it goes for dewatering and for dewatering of this finer section so here the size range > 0.5 mm, they comes here and then they are dewatered in a basket centrifuge which are basically a type of high speed centrifuge and from here this clean coal that is taken and this is kept here for clean coal storage and some of coarser size of the fraction that goes and it is kept in the storage for power grid coal. So, these two types of different grids of the coal they are generated and here if we see the size range which is > 0.5 mm that also goes for separation using this heavy media cyclone. So, here again this impurity is taken out from the rest of the coal and this again if we see that is the oversize 0.5 mm to 20 mm that basically goes towards this dewatering that is again using this basket centrifuge, so they are dewatered and they are kept in the storage for as a clean coal, whereas the larger size fraction that is > 20 mm, so that is taken again here for dewatering and is again after dewatering that is kept in the storage provided for the power grid coal. So, this is overall process that are used in the washeries and here if we see if this requires lot of water, so here there is a water reservoir so every washeries they have the pool of water stored in the reservoir and from here they use this water for different purposes like dust suppression purposes, potable purpose, like drinking purpose and rest of the water that is used as a process water and that is basically used in this desliming and other washing operations. So, this is basically the overall process diagrams which are used in the industry for cleaning and washing of the coal.

So, these are basically the various techniques which are used in the washing and cleaning of the coal that is dense medium separators, then there are jig separators, there are also the cyclone separators and then we will also look upon the froth floatation techniques for separation of coal from rest of the impurities. So, one by one we will be going to have little more insight into these types of techniques.

So, here if we see that is the first technique which is the dense medium separators, basically this uses dense media for separation purpose. So, here the characteristic of medium that has to be used to remove the coal from rest of the impurities to float the coal. So, the basic characteristic of the dense media which is required for this separation and floating of the coal from rest of the impurities. So, that is basically should have very low viscosity, should have very high density, should have specific gravity ≥ 2.0 and then it should be also very stable because this requires stability to get separation. So, effective uniform density that is very much required for efficient separation then for example if we see what type of media we use that is basically in coal washing purpose the mixture of sand and water sand if we see having the specific gravity varying from 2.6-2.7 so that is basically used and this is also an inert particle having very low viscosity and also the water that is used. So, this is like a mixture of sand and this water that is used in the washing purpose and then also we can use like the mixture of magnetite, finally divided magnetite along with the water for this as a dense media for separation of the coal fines and then this if we see these separators again there are having two configuration one is deep bath process another is shallow bath configuration. So, here in the deep bath process the mixture of sand and water is used which has having specific gravity greater than the clean coal and the ash and in this process the clean coal that is separated from rest of the impurities because coal has lesser density compared to the impurities. So, they are tended towards the bottom and this coal floats along with this media on to the top and that is removed out whereas the dirt which sinks towards the bottom they are removed from the bottom. So, if we see about this shallow bath process this is having the similar process but this requires basically much lesser volume as compared to the deep bath process. So, this is also advance configuration of the deep bath process. So, this is dense media separators which are basically used for washing up the coal.

And then let us talk about this is another technique called jig washers or jig separation technique which is used for separation of impurities from the fine coals. So, what happens here the coal bed that is maintained at the perforated plate here there is a screen that is perforated fitted at the top. So, this is called as the jig screens, so here all the coal that will be kept here and from here what will happen this water will flow from top to the bottom, so whatever the basically that fine impurities that comes down basically they will be induced with the pressure from the right-hand side and that induces this jigging action means this particle move upwards and then move downwards. So, during this upward and downward movement they come in closer with each other and by the way of abrasion the impurities which are attached with the coal particles they get detached and thus removed out from rest of the coal and this is basically a tailing overflow is provided at the top where the finer size of the tailings which are produced during this cleaning operation that is taken out and the impurities which are basically produced as a concentrate at the bottom that is taken out as a impurities from the washeries.

So, this is basically another process used for cleaning and then you see that is another technique which is basically called as the cyclone separators or cyclone washers. So, here if we see this is like coal plus dense medium, so this medium basically along with the coal that is inserted into this cyclone separators and here this coal along with this media that is rotated under a cyclonic action and this basically induces the differential forces wherein the this coal particles which are finer because of having lesser density they use they are floated up and these are basically the particles which are inert particles having higher space peak gravity they are basically moved towards the

bottom and from the bottom these impurities they are taken out as a refuse so and the clean coal which floats towards the top because of the buoyancy effects that is taken out from the top as a clean coal. So that is basically the process which are taken in the cyclone washers.

And then this is basically you see that is the another technique which is called as the flotation technique using the froth. So, froth is basically made in a flotation cell by bubbling the air through the water in presence of some frothing agents, so this frothing agent normally we use like cresol, pine oils or some other alcohols. So, what happens when this frothing agents come in contact with the water and the bubbling air, so they are basically makes the final core particles they are attached on the to the surface of the cold particles and they create buoyancy force and the coal becomes buoyant and they are they basically floats on to the top and they are removed. So, here this is a flow diagram of this the figure that shows the froth flotation techniques. So, here if we see that is basically fine coal and the waste, so from here the fine coal and the frothing agents they fed into this flotation cells where inside this flotation cells there is a rotating equipments which used to rotate this entire mass of fine coal containing the impurities and the frothing agents and here there is basically aeration system is also provided through this air feed system the air is bubbled into this all over this flotation cells. So, that basically makes the frothing agents to attach to the flotation frothing agents to attach the coal particles making it buoyants and because of buoyancy this coal particles they moves upwards and from the top they are taken out and collected separately. So, here from the outlet we will get this coal rich concentrates from where the coal is taken out and the dirt particle because of having higher densities, they will be moving towards the bottom and from the bottom that is the dirt particles outlets from there these particles there is impurities that will be taken out so this pictorial diagram also shows basically how the attachment of coal occurs with the bubbles and how these are basically the impurities because of higher space peak gravity they settle down and these are the bubbles through which so this is like the flotation techniques which are used for clarification of the impurities from the coal removal of impurities from the coal.

So, then let us see what are the characteristic of the wastewater that is generated from the coal washing operations. So, here if we see overall characteristics and the amount of the wastewater that is generated per unit ton of the coal that is basically around 180 liter per ton of the coal in terms of meter cube if we see that is 0.18 m^3/ton of coal and if we see the overall composition so what we see here that is having lot of solid content that varies from 1000 to 25,000 and if we see its average range so that varies from 5500 to 6000 mg/L. So, it contains lot of solids and if we go in more details of its type of solids. So, what we see that is like the suspended solids they are basically the maximum fraction present in the total solids that ranges from 800 to 24,700 and if we see rest of other than the suspended solids the dissolved solids that is basically very-very less so it does not contain lot of dissolved impurities other than the suspended solids. In terms of hardness also it is not very high alkalinity that is also less than 100 mg/L, chlorides are also to a normal range and in terms of pH if we see this type of the coal washery effluent pH the wastewater generated from the coal washery is slightly alkaline in nature. So if we overall analyze the characteristic of the coal washery effluent, so what we find that the major pollutant that is basically the suspended solids so that we have to remove out because in the effluent discharge which has to be disposed of the suspended solids concentration they should not be more than 100 ppm and here this is much-much higher than its discharge standard. So, this wastewater

need to be given lot of care for removal of the suspended solids present. So, from treatment point of view if we see this type of wastewater requires more of physical unit operations like clarifiers primary clarifiers and then clarifiers having high removal efficiency the coagulation and flocculation process for removal of the suspended solids. so in the next slide we will be seeing how this wastewater that is produced and how this what are the various techniques that are used.

So, if we talk about the various techniques so there are like bigger size of the plants if we see they have basically this Coagulation-Flocculation. Using the coagulation and flocculation process whereas the small and low-capacity coal washery units they are basically have the series of settling tanks which are designed for more than 95% removal of the suspended solids. So, they are constructed they are in practice for treatment of wastewater produced from the washery. So, here if we see basically what happens in the coagulation and flocculation process this is basically the wastewater which is stored in the equalization tank so here whatever the wastewater produced through the washing that is mixed here in the equalization tank and after this if we see the wastewater is taken to the next unit that is the coagulation tank. So, here what happens we used to add some coagulants because there are very fine size of the particles, they cannot they are not settleable in nature. So, we need to add some additional coagulants which can form the flocculates and helps in removal of very fine size suspended particles. So, here basically if we see in this process what happens the impurities mostly, they are present in the form of collides which possess normally the negative charges, so what we have to add is some coagulants which can produce the flocs having positive charges. So, these flocs when it comes in contact with these negative charges, so they are electrostatic attraction, they are combined, they are attached together and then they are basically taken for facilitating this attachment there is a process called flocculation. So, this is done in a flocculators or flocculation tanks where this entire coagulant mixed water that is rotated at a very slow speed here if we see in this coagulation tank the speed of mixing that the rotors they revolve the water the mixing is done at a rpm of around 100 to 120 rpm, whereas in flocculation tank this entire coagulant mixed water that is taken out from the coagulation tank that will be rotated at a very low speed around 2 to 3 rpm for around 20 to 30 minutes so that it provides sufficient times for the floc formation attachment and then consequently they are taken to the clarifier where this basically works like a sedimentation tank so all these flocs which are formed they are made to separated through the gravity separation process in the sedimentation tank and this the treated water clarified water then again recycled back in the plant. So, this basically provides you the chemical equations or the mechanism how this coagulation process helps into removal of very fine size colloidal particles, very fine size suspended particles present into the coal washery effluent. So, here if we see these are the impurities which are shown by this pinkish balls they are basically present in the form of collides and normally possess this negative charges on its surface. So, it is like a charged particles so that's because of similar charges they do not form an aggregate, so they are always present in the mixing conditions in a so this when this coagulant is added this generate the flocs or the particles having opposite charges, positive charges on its surface. So, it can have this H^+ ions and then in the process of flocculation basically flocs which are produced here they are made to attach with the particles. So that these particles in the later stage they are attached to this flocculant structure and then they are finally settled down in the bottom of the sedimentation tank.

Here, so this is basically the effluent discharge standard for the coal washery. So, this ministry of environment and forest government of India they have regulated all these washeries to adopt the zero discharge standards, so they are following this zero effluent discharge. So, this means like these washeries they can take the water for their cleaning process but they cannot discharge the water having effluent discharge equal to zero. So, what they have to do whatever the water they use for the washing purpose and again after the treatment the same treated water they have to use in the washing operations but there are the emergency when there is some problem some periodic cleaning and maintenance activities going on there is a heavy rainfall going on so in that condition they can discharge their wastewater their effluent into the river into the streams in into nearby water resources nearby water bodies. So, during this they have to follow certain set of water quality protocols. So that, they should maintain this pH that should be in the range of 5.5 to 9. And then this total suspended particle that is basically one of the important parameters so that has to be maintained < 100 ppm. And this is another type of major pollutant which is commonly found in the coal washery wastewater that is oil and grease, so they should also be treated to less than 10 mg/L. And it has its BOD and COD they should not be more than 30 and 250 mg/L. And some phenolic compounds they are also released in the coal washery effluent so we have to also check that their concentration should not be more than 1 mg/L.

So, these are the references you can refer for your further discussion and preparing the notes.

Thank you.