Course Name: Industrial Wastewater Treatment

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Week – 12

Lecture 56: Mine Wastewater including Acid Mine Drainage and Industrial Complexing for Zero Pollution Attainment

Welcome you all. Today I am going to deliver lecture 1 of module 12 which is on mine wastewater including acid mine drainage and industrial complexing for zero pollution attainment.

So under this we are going to cover about the basic introduction on the coal mine industries in India. What type of coal industries are there? Different types of coal fields. Then we will be also talking about the types of coal deposits which are available in our country that is Gondwana coal field and tertiary coal field. Then we will be looking about the how this mine water is generated during mining operation. What are the major contaminants? A little bit overview about the coal mine water and then we will be looking about the classification and characteristics of various types of mine water that is generated like alkaline water and then acidic water. And then we will be looking about the more details about the acidic runoff or the acid mine drainage and its composition and then various impacts of the acid mine drainage which is generated from the coal mine industries which requires treatment of the acid mine drainage for its safe disposal and to minimize the ill effects of this acid mine drainage which are produced in the coal mines.

So let us start with the basic introduction about the coal mines in India. If we see the total coal reserve in our country that is about 293.5 billion ton and of this the proven reserve is about 118.15 billion ton which is approximately 10% of the total coal reserve which is found in the world and if we talk about this coal reserve so this coal reserve is mined out by two methods that is open cost mines and underground mines. So, if we compare the two types of mining methods so what we found that around 84 % of the coal that is mined out using open cost mines and about 15 to 16% of the coal that is mined out by underground mines and in terms of quality of the coal. If we see that the Indian coal that contains a low amount of sulfur and high ash content. Here the ash content in our coal is that is very-very high that is around 30 to 70% compared to sulfur and ash content that is obtained in the imported coal. So, sulfur content in the imported coal that is about 1.42 to 7.26% while the ash content is merely 15 to 20%. So, this is an important property of the coal where it after burning the coal generates a lot of fly ash. So in Indian coal let us lot of fly ash is generated whereas the imported coal which contains hardly 15 to 20% of the ash so comparatively a very less amount of fly ash that is being generated from the coal which is imported from the other country and then we see about the utilization of the coal so here what we get that around 75% of the coal what we mined out that is used mostly in the power sector and rest of the coal that is used as a fuel in other applications and if we compare about the production of the coal like state-wise production of the coal, so what we get in 2022-23 the Odisha registered

the highest coal production followed by Chhattisgarh and then Jharkhand followed by Madhya Pradesh that is around 146.028 million ton which constitute to around 16.35%. So, if we see the production from different states, so this Odisha basically that produces around 25% of the total coal that is mined out in our country so that is around 218.981 million ton. So, this is about the basic introduction about the coal miles in our country.

And then let us talk about the how much coal reserve are there in different forms like Gondwana coal field and then we have tertiary coal fields. So, Gondwana coal field if we see so there are different states we have coal deposits of Gondwana origin, like Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh. So, these are the different states where this Gondwana coal fields are available and if we see their geological reserve so this is proven category this is indicated category and this is inferred category. So proven means the coal reserve which is well explored and proven coal reserve whereas the indicated basically indicates the coal reserve with continued exploration where exploration is undergoing and under this inferred category the coal reserve which is indicated which is found and is yet to be explored. So, this category basically comes under inferred category so if we see the total coal reserve of different states, so what we find so this state like Jharkhand we have the maximum coal reserve and here there is a Jharia coal mine which is the largest coal field in the Asia having coal reserve of around 80,356.20 million tons and the second largest coal field in our country that is basically the Odisha, where this is having around 71,447.41 million ton of coal reserve then we have third number is basically the Chhattisgarh where there is approximately 50,846.15 million ton of coal reserve and then it follows like Madhya Pradesh is the fourth largest state having the Gondwana coal fields.

So, if we talk about the Tertiary coal field, so here also we have seen the Tertiary coal field that is available mostly in the eastern part of our country that is in the Arunachal Pradesh, Assam, Meghalaya, Nagaland and here also if we see in terms of total coal reserve Meghalaya is the largest coal field having the Tertiary coal field deposit of around 576.48 million ton followed by this Assam where there is a 510.52 million ton of coal reserve and then in third number Nagaland comes where there is approximately 315.41 million tons of coal reserve, here again we have different category proven category, indicated category and then inferred which is under exploration and then this is another category where mapping is done but exploration is to be carried out and if see overall the total coal reserve of the two types of coal reserve that is Gondwana coal field and then the Tertiary coal field so we find that very less amount of this type of Tertiary coal is available, which is approximately 0.5 % of the total Gondwana coal reserve available in our country. So, this type of coal basically that is containing lot of sulfur content and nitrogen content and basically having lot of generation of acid mine drainage problem. So, this coal fields basically are associated with the acidic mine generation whereas the Gondwana type of coal fields there the alkaline wastewater is generated. So, this alkaline mine water that is slightly less polluted compared to the acidic mine drainage that is produced from the Tertiary coal field so these are basically the major coal fields and the type of the coal reserve which are available in our country and in terms of Gondwana coal field results into mine water which is slightly less polluted compared to the mine water which is generated from the Tertiary coal field because it is acidic in nature and it dissolves lot of heavy metals present in the coal fields, so that basically makes the water much contaminated compared to the alkaline mine water. So, this is about the how this mine water is basically generated.

So, here what we see when we carry out this mining operation, so as I discuss you there are two types of mining method one is underground mine, another is open cost mines so open cost mines basically we carry it out till the depth of coal reserve above level up to the 200 m, 300 m whereas the underground mines are carried out when the coal reserves they are up they are found below the earth surface at a much larger distance like 500 m, 700 m, 1000 m, more than one kilometer. So, like depending upon the type of the coal reserve and its location below the earth surface we carry out the open cost mines or underground mines and when we carry out this mining operations basically coal reserve that is excavated from its deposits and during its excavation below the earth surface there are aquifers like unconfined aquifers, confined aquifers, Perched aquifers a number of aquifers are present and when this excavation is carried out. So, these aquifers they get punctured and during this process what happens whatever the water that is contained in the aquifer that comes out through the mining surfaces and then it flows over the benches of the mine and during its flow through the mine benches. It carries lot of inorganic and suspended impurities and the form of sand and silt particles and also lot of minerals are present onto the mining bed so that water also dissolves various types of metal which may be contaminated in the mine water and this mine water basically collected onto the mine pit which is the bottom most pit where from this mine water is pumped out and brought to the surface by pumping for continuation of the mining operation. So, this mine drainage basically refers to the any surface water or the groundwater that drains from the active or abundant mining operations and is collected in the mine pit from where it is brought to the surface for continuation of this mines. So, during this process the leaching contaminants from the waste piles and OB dumps that also introduce lot of sediments, acidity and other contaminants in the form of organic and inorganic impurities and thus the resulting mine water gets contaminated and may have lot of harmful impacts onto the humans, animals and the plants where it is disposed off and that's why this mine water after its generation is collected and then it is brought to the surface for it’s for the treatment because it requires extensive treatment for its utilization for different purposes like drinking, irrigation and industrial uses. So, this is a visualization of mine water generation as I explained. So, these are the different benches of the mines so when this is mined out whatever the water that flows over these benches and finally get collected here onto the lowest portion of the mine that is called as the mine pit and from here it is pumped out and then it is taken out to the surface and this is called as the mine pit water. Similarly, this is another mine these are number of benches and during this mining operation whatever the water that flows down over these benches and then this water is collected over here in the mine pit and from here this is pumped out using the submergible pumps and then it is brought to the surface for its further treatment and disposal. So, this is about the process how this mine water gets generated and the visualization of this mine water in the pit and from where it is pumped out and then treated for its final utilization.

So, as I told this mine water basically generates two types of wastewaters that is alkaline stream that is alkaline mine water and then there is an acidic stream that is acid mine drainage so both type of these streams are generated. So, one by one we will be going through the classification and characteristic of this acid mine water and then alkaline mine water and this table basically gives the different categories of alkaline mine water that is generated from the coal mines. So, here we have again categorized into A-1, A-2 and A-3 categories. So, these three categories of the alkaline mine water they are generated from the coal fields and in this column if we see these are

the water quality parameters like pH, alkalinity, hardness, TDS, suspended solids like all water quality parameters and then these are like calcium, magnesium, iron, sulfate, chloride and other microbial impurities they are present and these are the different categories of the alkaline mine water generated. So, here if we see that is A-1 category, A-2 category and A-3 category. So, these categories they are basically divided based on their hardness and TDS concentration. So, here if we see in A-1 category the hardness of the water is from 50 to 150 mg/L and whereas in A-2 category this hardness goes more than 150 and value lies in the range of 200 to 1500 mg/L whereas in A-3 category this hardness in the mine water that is around 1000 to 2000 mg/L. So, based on this hardness and similarly if we see the TDS concentration that is in the A-1 category water that is having 300 to 700 mg/L, whereas in A-2 category that is 500 to 1500 mg/L and then more than 1500 mg/L, up to 2500 mg/L, TDS that comes under this A-3 category. And then there are other parameters like pH, if we see so pH always for this is slightly alkaline water that is 7.5 to 8.5 in case of A-2 category that is 7 to 8.5. So, this is like different categories of mine water that is generated. Similarly, if we see the other parameters like magnesium, total iron, sulfate, chloride these are basically the major contaminants they are found in the alkaline mine water which is generated from mining operation.

So, let us talk about another waste stream that is acidic mine water that we also say that is acid mine drainage. So, this acid mine drainage basically is the acidic runoff or the seepage which is generated due to uncontrolled oxidation of sulfide minerals which are present in the waste mineral stockpiles or tailing or in the mine pits or in the coal reserves. So, that basically pyrite present in the coal reserve or the waste piles or the OB dumps, so that gets exposed to the atmosphere in presence of water there are ferro-oxidant thiobacillus bacteria which oxidize the iron present in the pyrite and as a result lot of acid ions that are generated which makes the water very acidic and because of this the pH of this acid mine drainage that is very-very low that ranges from 2 and varies up to 5. So, this pH range is 2 to 5 and if we see in the process of acid mine drainage lot of $Fe(OH)_3$ that is ferric hydroxide, which is also termed as the yellow boy that is produced, so that gives red muddy color to the acid mine drainage and because the acid mine drainage that is basically the acidic in nature, so it dissolves a lot of metals which are present in the coal reserve and the waste piles or the tailings are the deposits. So, that metal content that gets dissolved into the water and thus the acid mine drainage is highly rich in the metal and sulfate content. So, this is highly polluted waste streams which are generated mostly from the tertiary coal field where the sulfur content is high and there is a availability of plenty of pyrite found in the coal deposit so this type of the acid mine drainage that is mostly generated from the tertiary coal field.

Then this is like visualization of the acid mine drainage which is coming out from this open cast mines that you can see this is a color of the acid mine drainage, so that is red muddy color, slightly yellowish color and this is flowing through the surface drains over there. So, these are all like the visualization of the acid mine drainage flow and these are the land where this acid mine drainage is passing through. So, this also affects the entire land and makes the soil acidic and infertile wherever it goes.

Then let us talk about how this acid mine drainage that is generated so here the microbiology plays a very important role in generation of acid mine drainage as we know this pyrite is the

mineral which is present in the coal basically in the tertiary coal field. And this pyrite mineral in presence of thiobacillus ferro-oxidant bacteria. So, if it is exposed to the atmosphere where it gets oxidized and because of oxidation of iron present in the pyrite there is a lot of generation of H^+ ions and that causes basically acidity in the mine water. So, these are the photographs of this staining of bacteria.

So, let us talk about the chemistry of this acid mine drainage how the acid how the acid mine drainage that is generated. So, here if we see in the initial step basically this iron pyrite is present, this pyrite when it is exposed to the atmosphere gets plenty of oxygen and in presence of moisture it gets oxidized to ferrous ions during the process this H^+ ions are generated ($2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4 + 4H^+$) and once this ferrous ions are produced then it again further gets oxidized to ferric ions and this ferric ions ($4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$) again get hydrolyzed and after hydrolysis of this a lot of ferric hydroxide ($4Fe^{3+} + 12H_2O \rightarrow 4Fe(OH)_3 + 12H^+$) which we call that is the yellow boy that is basically generated, so this basically provides the red muddy color to the this mine water which is produced from tertiary cold field after that once this ferric ions are generated. So, this FeS_2 again gets reacted with these ferric ions to again produce this Fe^{2+} and this Fe^{2+} again starts this oxidation to produce Fe^{3+} ions. So this is like cyclic propagation of acid generation and in that if we see the rate limiting step is second reaction that is conversion of Fe^{2+} to Fe^{3+} because this Fe^{3+} again gets hydrolyzed to form this $Fe(OH)_3$ and again it reacts with the FeS_2 to produce this Fe^{2+}. So, again this starts the cyclic propagation of acid ions generation. So, this is the chemistry behind the acid mine drainage and this process does not stop until unless this entire this pyrite that is oxidized present in the coal reserve or the waste stockpiles.

Then let us talk about the characteristics of the acid mine drainage. Here if we see the pH is acidic compared to the alkaline pH that is in the alkaline mine water. So, here pH varies from 3 to 5.5 and there is a lot of magnesium, calcium, aluminum, iron, and manganese lot of metal contains that are present. So, here if we see aluminum that is 50 mg/L iron that is 50 to 300 mg/L manganese also that ranges from 20 to 300 mg/L and it also contains lot of sulfate ions that is up to 2000 mg/L. So, here if we see this acid mine drainage that is highly polluted waste stream that is generated from the tertiary coal field. Whereas this alkaline mine water as we have seen is not much polluted as in terms of metals in terms of Ph. So, this wastewater stream has to be carefully handled and requires extensive treatment before it has to be disposed off.

So, this is the characteristic of acid mine drainage their global variations. So, we have collected data for different countries where from this acid mine drainage problem is there like Ontario, British Columbia and then this is copper mine of British Columbia, this is active silver mines this is active uranium mines and these are the like parameters like pH, sulfate, acidity, iron, manganese, copper, aluminum almost all the heavy metals they are present in this type of waste streams and at a very high concentration. So, sulfate here if we see that is 7440 here, 7600 there here there is a 1500 mg/L the pH also here it is 2, 2.8, 3.5, so this is like lot of acidity there in this type of wastewater and in terms of acidity if we see acidity is around 14600 mg/L in this British Columbia mine, silver mine there is around 43000 mg/L of acidity and similarly there is a lot of fluctuations variation in the metal content found in the different mines basically the variation in the acid mine drainage produced from different countries different coal deposits entirely depends

upon the properties of the coal and the mineral composition of the coal deposits that is playing much role in acid mine drainage.

Then let us talk about the effects of acid mine drainage. So, this acid mine drainage as I told you is highly polluted the waste stream that is generated. So, it has a lot of impact on to the environment on to the living being and also on to the property. So, if we see it can cause groundwater contamination because when we do carry out mining, so lot of OB materials they are generated. So, these OB materials they are stacked in the form of dump on to the surface of the mines and there when the rain precipitates, so during infiltration through these waste piles are OB dumps whatever the minerals present into this OB dumps are waste piles basically they get dissolved into the water like various heavy metals they get dissolved into the water and then finally it infiltrates below the earth surface and then this causes groundwater contamination and if it is disposed into the surface water body because of acidic pH it will lower down the pH of the water and because acid mine drainage also contains lot of $Fe(OH)_3$, Yellow Boy, so that gets deposited on to the bed of the river or the surface water body and thus reduces its carrying capacity and then it also enrich the water body with the heavy metal concentration, so it causes lot of impacts on to the water bodies by enriching the heavy metal concentrates and makes it unfit for use as a drinking water and other beneficial purposes. And if we talk its impact on to the living being. So, this has harmful impact on to the living being also like if we see it is not fit for drinking because of having lot of heavy metals present into this having acidic pH, so that cannot be used as a drinking water and if it is disposed into the surface water body, so it will kill out all the aquatic lives flora and fauna present within the water, so this will destroy this all aquatic plants and lives surviving over the water bodies and then it will also disrupt the growth and reproduction of the plant on the surface or within the water body wherever it is disposed of and it can cause also the skin problems. And if we talk its effect on to the property so it's highly acidic so it is highly corrosive also so it will corrode out all the pipe materials, culverts, bridges, pipes, pumps, dams, boats wherever this acid mine drainage comes in contact so that will damage and will corrode out that material and thus overall reduces its life span.

So, these are the visualization of impacts on to the water body so this is the existing water body so when this acid mine drainage is disposed into the water so this entire water gets colored and the water also becomes acidic rich in the heavy metal concentration so this entirely pollutes this surface water body where this water cannot be used for drinking and other beneficial uses. And if it is disposed on to the land basically it makes the soil infertile because of adding a lot of acidity soil will become acidic and also it will reach in various heavy metals so it will loose its fertile nature and the land will become barren after continuous disposal of this acid mine drainage on to the land and if it is used for irrigation so it will cause loss of vegetation, plant’s life. So, this is having a lot of impact on air, on water, soil, vegetation everywhere it has a harmful impact.

And then looking on to the water crisis in our country now this mine water now become the resource rather than being the waste streams because in the mining operation huge amount of mine water that is being generated and that need to be used for its beneficial purposes. So looking into this the Ministry of Coal in 2023, instructed all the public sector units which are operating the coal and lignite mines to adopt the treatment and supply of this mine water for drinking and other domestic purposes and they are also instructed to prepare the coal JAL app. So, different

coal fields in our country the ministry has instructed them to prepare the coal gel app carry out the water audit of these individual mines so as to find out the water balance and this water has to be further treated for its beneficial utilization into industrial, drinking and other domestic purposes. Because of this initiative green initiatives taken by the coal ministry now the coal mine water benefiting around 18 lakhs people of 900 villages by adopting this green drive by coal and lignite companies in the country.

So, this is a case study of Jharia coal mines which shows that how much coal mine water that is generated how much water demand can be met with this mine water that is being disposed as a waste into the water bodies. So, this is like if we see there are underground mine pumping around 61 million gallon per day of water that is generated and the domestic water demand in that Jharia coal mine area that is around 49.5 million gallon per day. So, we can see most of our domestic water demand that can be entirely met by this underground mines and apart from this domestic water demand there is an industrial water demand of 34 million gallon per day in this area. So, together if we see the total demand that comes to around 83.5 million gallon per day of this 61 million gallon per day we can use from the mine water which is available from underground mining, so that can meet our most of the water demand and this can be treated as a strategy to meet the water crisis in the various coal mines the surrounding villages surrounding area where there is a lot of crisis of water.

So, these are the references you can use.

Thank you