Course Name: Industrial Wastewater Treatment

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Week – 12

Lecture 58: Mine Wastewater including Acid Mine Drainage and Industrial Complexing for Zero Pollution Attainment

Welcome you all. Today I am going to deliver lecture 3 of Module 12, which is on Mine Wastewater including acid mine drainage and industrial complexing for zero pollution attainment.

So under this what we are going to cover is how this acid mine drainage that is generated from underground mines and then we will be looking about various treatment technologies, various methods which are used for treatment of acid mine drainage. Here we will be including conventional neutralization and precipitation method, high-rate algal pond system for treatment of acid mine drainage. Then we will be also looking about the controlled biological treatment system of acid mine drainage which is basically used for recovery of metals and Sulphur from the acid mine drainage and then we will be looking about the in-situ treatment technology for the prevention of acid mine drainage and then finally we will look upon the phytoremediation process which are used for the treatment of acid mine drainage.

So let us start with the formation of acid mine drainage, how this is produced basically in the underground mines. So here if we see like in the surface if we see there are various waste rock piles which are generated through this underground mines whatever the OB dump that is generated through this underground mine that is separated from the ores and rest of the OB material like impurities present in the ore that is stacked in the form of dump and that we say that is the waste rock pile and from this waste rock piles there is a lot of heavy metals and other contaminants present into this waste piles and when there is a rain happens especially during the rainy season when precipitation occurs, so this water basically infiltrates through this gaps through this waste piles and during its seepage through this waste pile slightly acidic because of rain water so when it seeps through the waste piles it basically dissolves various metals, various minerals present into this waste piles and after this this seeps below the earth surface and like the streams containing various mineral contains like magnesium, sulphate, lead, manganese, iron then again this lead, arsenic, sulphate these all they are generated from different bodies situated on the surface like these are again if we talk about the this tailing dams, so here also the same thing happens the tailings are separated from the water and the water clarified water that is pumped out for the treatment and when this rain water precipitate because of its acidic nature it dissolves these minerals and the metals which are present into these tailings and this flows and this is basically the aquifer if we see so in this aquifer it meets with the water bodies and makes the water highly contaminated with metals and sulphate and other contaminants present into these waste pile. similarly, there are the smelting operations also happens. So, through the smelting

operations also whatever the tailings and waste piles they are generated and basically during smelting operation lot of flue gases are generated which also contains various particulate matters of metals and that basically gets precipitated along with the rain and they reaches onto the surface water bodies. So, through surface water bodies also the seepage process takes place and this basically contaminates the aquifer below the earth surface. So, this is the aquifer and then if we see there are confined aquifer which are underlined between the two impermeable barriers so these are treated as a water barrier so here also because of the seepage through this because this is slightly impermeable. So, whatever the fractures and faults present in this impermeable barrier so this water may leak out and this contaminated metals and minerals that may flow into this water bodies and that flow through this fracture and ultimately meets this acid mine drainage which are generated at the mining phase. So, this if we see this is basically this is the mining site which are constructed for underground mines and these are basically the layers of the mining where the mine has to be carried out so here when this is excavated and it is exposed with the water. So, water dissolves all these metals and along with these metals and sieves whatever the metal contains that comes through this seepage that flows through this and finally this acidic water that is generated here that contains lot of copper, sulphate, sodium, fluoride and iron, sulphate, sodium like various metal contains and the mineral contain that is found during seepage and at the mining phase also the lot of acid ions that are generated, so it will dissolve all these metals and finally this acid mine that is produced from the underground mines and that is basically pumped out through this onto the surface and then it is sent for the treatment. So, this is basically the schematic layout of the various sources where from this acid mine drainage is generated from the waste piles, from the tailing ponds, at the mining phase through the surface water body through this melting operations. So, this is like the ways where this acid mine drainage that is being generated from the mine operations.

So then let us talk about the various treatment techniques which are used for the treatment of this acid mine drainage. Mostly all the coal mines which are located in the tertiary coal fields. They use this technique which is called as the conventional treatment technique which implies basically the neutralization and precipitation process. So, this combined neutralization and precipitation helps in precipitation and removal of various heavy metals present into the wastewater at the same time the water gets neutralized. So, this basically is a reliable and very effective technique that is used presently in most of the mines situated in India and facing this acid mine drainage problem, but basically this technology has a drawback that this becomes basically impracticable in case there is an abandoned mine and it contains a lot of pyrite minerals. So, this conventional technology for neutralization and precipitation because it involves addition of chemicals. So, this basically require a lot of fund and because of limited fund availability the management of acid mine drainage in the abandoned mine using this conventional treatment practice that is not being very suitable. So, this is mostly practiced in the active coal mines where this the problem of acid mine drainage occurs.

So, this is basically the flow diagram of neutralization-cum-precipitation process for the treatment of acid mine drainage. So, here basically this is the wastewater which contains a lot of metals and sulphate content that is taken into the equalization tank first and here the entire water generated from different portion of the mines from OB dumps, from waste piles and that is equalized here and then this equalized flow that is sent to rapid mixing tank where this water is

mixed with the various reagents, the coagulants which are used for neutralization of the acid mine drainage. So, mostly this lime is used and in case there is also very fine colloidal impurities present. So, we can use other coagulants like alum, like ferrous sulphate. So, they are used as per the requirement and here in the rapid mix tank there are the mixers provided with thoroughly and uniformly mix these coagulant solutions with the entire wastewater. So, after mixing of this coagulants when this entire water is taken into the flocculation tank, where flocculation process is carried out in the flocculation tank basically because of neutralization. When the pH increases whatever the metals they are present in the dissolved form they will be precipitated in the form of their hydroxide, in the form of their carbonates and then this flocculation tanks helps in making the more heavier flocs by adding certain polymer, so that the these metal precipitates which are formed they can be separated from rest of the water in next unit operation that we call is clarifier this basically gravity separation technique, where this heavier precipitate that gets settled on to the bottom and from the bottom we take it out and for this sludge is then taken to the sludge thickener where this water is removed from the sludge and the thickened sludge that is taken out to the for the next unit operation which we call filter press, where the water is further squeezed out from the rest of the solid mass and recirculated again to the equalization tank for its treatment and whatever the solids they are produced they will be taken out and then finally they will be disposed of as a hazardous sludge. And then after removal of these solids from the clarifier rest of the water that goes to the pH neutralization tank because for precipitation process sometimes the pH has to be increased to a level of 10 to 11 and because of this high pH, it is not suitable for the discharge as per the effluent discharge standard so again this acid is added in order to bring down the pH and a neutralized range and then this treated effluent is finally disposed or put for its industrial use, for its sprinkling into the mines. So, various types of uses or maybe further we can convert this water in the form of drinking water for its use as a drinking purpose, domestic purpose and many other beneficial purpose even treated water that can be put for irrigation purpose. So, these are the various unit operations which are involved in a combined neutralization and precipitation process which are used for the treatment of acid mine drainage.

So, let us take another treatment technique this is basically the natural process where this algae is produced and during production of algae there is a lot of alkalinity generation occurs. So, this alkalinity which is produced through the yield of algae that is used here as a neutralizing agent for the treatment of acid mine drainage. So, here this basically gives the complete chart for high-rate algal pond system which are used for the removal of metals and sulfate from acid mine drainage. So, here basically if we see this is basically the high-rate algal pond where the algae is grown so nutrients are added here from this nutrient solution tank. So, this feed tank is basically contains the solution containing nitrogen, phosphorus and other nutrients required for the growth of this algae and this pond generates a lot of algae. So, when algae is produced this basically generates a lot of alkalinity and the alkaline water along with this algae is then taken to the biomass harvesting system where this is basically a kind of filter which removes out biomass or the algae from rest of the alkaline water and this alkaline water then is used as a neutralizing agent here in the neutralization process. So, this is added in a precipitation reaction vessel where this alkaline water is mixed with this metal rich wastewater. So, this is basically the acid mine drainage that we can take and here when this both the water alkaline water and this metal rich wastewater that is mixed here, so because of having high pH of alkaline water and low pH of acid mine drainage

both this water when they are mixed they will be neutralizing each other and then the finally we neutralize the ratio of addition of this the two best stream is set in such a way that we get at least neutralized range of pH and for precipitation whatever the pH that is required. So, accordingly we add this alkaline water so as the pH can be raised to a particular level where these metals they are precipitated in the form of precipitates or sludge and then they are taken out for its further treatment and disposal and rest of the water after precipitation that goes to the anaerobic treatment system which acts as a policing treatment system because this contains some of the organic matter also. So, this organic matter they will be removed here in the anaerobic digesters or the policing treatment system and then finally this water that will be after the treatment of anaerobic treatment system this will be discharged and this treated water a part of this treated water that will be also used for preparing the nutrient solution. So, this is basically the entire cycle of and the flow diagram of the various unit operations, which are used in the high-rate algal pond system for the removal of metal and sulfate content from the acid-mine drainage.

Then let us talk about the another treatment system which we say that is the controlled biological treatment of acid-mine drainage. So, basically it consists of three main sub process, so in the first process basically what happens this sulfate reducing bacteria they anaerobically convert the sulfate content which is present in the acid-mine drainage to the sulfide using organic compounds such as acetate, lactate, propionate, butyrate ethanol or glucose. So, these are like energy sources or maybe carbon dioxide and hydrogen both together can be used as an energy source, so in presence of these substrate this sulfate reducing bacteria, they used to reduce the sulfate into sulfide anaerobically under anaerobic conditions and in the second phase basically whatever the sulfide that is being generated that is being produced during the reaction that basically reacts with the metal ion content and they will be precipitated in the form of their sulfides and if in case if the metal contents are not there so in absence of the sufficient metal content a further step is required for the treatment of excess sulfide and that is basically the process of recovering of sulfur from this sulfide and that is basically achieved by sulfide oxidizing bacteria which utilize this oxygen or nitrogen as an electron acceptor for oxidation of this sulfide to elemental sulfur and finally we are able to recover this elemental sulfur.

This is basically the flow diagram of this controlled biological treatment system which are used for recovery and removal of sulfate from the acid-mine drainage. So, this is basically the acid-mine drainage that is the first stage, in the first stage that is the anaerobic system where this sulfate reducing bacteria they are active and this acetate or the combination of hydrogen and carbon dioxide or glucose, any of the substrate that can be used as a energy source for this anaerobic bacteria for converting this sulfate into sulfide and this process basically converts all the sulfate present in the acid-mine drainage in the form of sulfide and this sulfide then reacts with the metals present into the acid-mine drainage and they form their precipitates in the form of metal sulfide or material carbonates and they are finally settled on to the bottom of the clarifier which is provided next to the anaerobic reactor so this clarifier basically separates the precipitates of the sulfides metal sulfides and rest of the clarified water that basically comes out from this clarifier and then it is treated aerobically in an aerobic reactor, where whatever the remaining sulfide which could not be precipitated in the previous process that basically will be converted in the form of elemental sulfur using sulfide oxidizing bacteria these sulfide oxidizing bacteria they use this oxygen or nitrate as an electron acceptor and oxidize this sulfide in the form of elemental

sulfur and finally we are able to convert this entire sulfate in the form of sulfur or in the form of this metal sulfide and which are basically separated from the acid-mine drainage and the treated acid-mine drainage then can be used for different beneficial purposes, industrial uses. So this is about the process which are used like the biological treatment system which are used for the treatment of acid-mine drainage.

And then let us talk about the alkaline injection technology which is basically Institute technology which are mostly used for underground mines which is flooded with the acid-mine drainage. So, this implies basically the injection of alkaline material in the form of self-slurry directly into the underground mines through the downhole grouting equipment which contains the acid-mine drainage and this alkaline coal combustion residues in the form of slurry were made with the mine water and injected at a very high pressure. So, there are number of injection wells through which this coal combustion residue basically they are alkaline in nature when they are mixed with the water. So, they form slurry and in the form of slurry we used to pump inside the underground mine where this the problem of acid-mine drainage occurs and this basically the treatment involves the creation of highly alkaline buffering zone inside the mines which slowly neutralize the acid-mine drainage water prior to its discharge into the surface and these injection well results increase into the pH and impart the alkalinity at this elevated pH basically what happens whatever the metals of species which are present in the acid-mine drainage they gets precipitated inside the mines in the form of their hydroxide and carbonate compounds and they are removed and rest of the water that is pumped out. So, this is basically the AIT technology and this is in situ technology used in the situation where other perceived treatment system cannot be applied because of mine chemistry constant.

So, this is the diagram of in situ treatment alkaline injection technologies. So, here this basically shows the injection points and this is the rubber sheet control points, through which the discharge of this alkaline slurry through this injection point that can be controlled over. So, here we can say these are all like the control point and the injection points, so through this the coal combustion is reduced that in the form of slurry that is injected under very high pressure inside the underground mines where the acid-mine drainage problem occurs which ultimately creates a buffering zone which increases the pH of that zone and finally neutralize the water which is in contact with this zone. So, that is like in situ treatment techniques which are adopted for the treatment of acid-mine drainage.

And then let us talk about the another treatment system, which are most commonly used like the phytoremediation process for the treatment of acid-mine drainage. So, this is basically the schematic of the phytoremediation techniques. So, here if we see that shows the influent which contains the acidic pH having lot of sulfate, iron, aluminum and then there are manganese also, zinc, nickel, various metal contains which are present into this acid-mine drainage and basically in the phytoremediation process is based on the use of photochemical absorption of heavy metals present into acid mines wastewater. So, this acid-mine drainage basically in the first stage they are basically present in their different oxidation state and they are basically oxidized some of them like iron they get oxidized to this ferric iron and then this aluminum that gets precipitated in the form of aluminum oxide or aluminum hydroxide using oxic metal hydrolysis. Then there are oxidation process which basically oxidize the metals and then there are another phenomena which

we call that is the chelation adsorption through which this aluminum and cobalt these metals they get basically absorbed and then this is like anaerobic reductive dissolution of manganese which takes place and whatever the energy source that is present in the acid-mine drainage like this lactate if we see that is microbiologically degraded through this fermentation process and then finally this fermentation products, they will reduce this sulfate and this carbon dioxide and this bicarbonate that will be produced in the process. And then this is like finally these metals what they are coming from this will be precipitated here in the form of their sulfides and zinc sulfide and this is another pathway if we see that is like the plant uptake, where this the plant directly uptake the heavy metals present into this like this if we see that is the iron plates that is accumulated in the root zone of this plant and this is Phyto-stabilization process where this whatever this iron and other metals like zinc, nickel, chromium that basically using this microbial biofilm they are forming the plates and they get absorbed with the plants. So, these are like different processes which are involved in the phytoremediation of these metals and sulfate content present into the wastewater especially in the acid-mine drainage. So, this is mostly used for remediation of this acid-mine drainage.

So, these are the references we can use for preparing assignments.

And thank you.