Course Name: Industrial Wastewater Treatment

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Week - 01

Lecture 01: Sources and characteristics of industrial wastewater

Hello everyone, myself Professor S.K. Gupta. Today we are going to learn about industrial wastewater treatment, the basics, the sources and its characteristics, various tools and techniques involved in the management of wastewater will be dealt in this course. Before going into the main aspects of various tools and techniques involved in the wastewater engineering, wastewater management, we need to know about the wastewater. So first let us see what are the concepts that is covered in this slide.

That is, we will deal with the brief introduction of wastewater and we will also deal with the types of wastewaters, different sources, their characteristics of wastewater, physical, chemical and biological characteristics. Before going into the main content, let us talk about the concept behind the wastewater. So, wastewater is basically the water which is being used by various industrial purposes and result as a effluent which may contain various forms of impurities in a concentration that may impair the quality of water for its various uses. So basically this is the complex matrix which may contain various types of solids, particulate matters, microorganisms, nutrients, various types of heavy metals and micropollutants.

If we see the total composition of wastewater, we will see that of total wastewater 99.9 percent is water and remaining only 0.1 percent is the impurities which are present in the wastewater. The concept on the wastewater nowadays you see that has changed from waste to its resource. Rather than treating the wastewater as a burden, now the scientific community and researchers, industrial managers, they are treating the wastewater rather than a waste it is treated as a resource because using various reduce, recovery, recycling and treatment techniques, we can reuse that wastewater which is otherwise being discharged as a wastewater.

Before going into more detail, let us talk about various types of wastewater which are generated from the society. So first of all, the wastewater we can broadly classify as industrial wastewater, domestic wastewater and storm runoff. Storm runoff basically if we see that is the amount of precipitation which does not infiltrate below the ground and

directly reaches to the surface water body as a runoff which may contain various types of inorganic materials like sand and silt particles which laden the waste material into the receiving water bodies. If we talk about the industrial wastewater, so industrial wastewater is the wastewater which is generated from the industries like we have different types of industries, they have different types of water demands and when these water is used in different process, it may contain various types of solids, materials, liquid materials, acids, alkalis and different types of organic and inorganic impurities. So when it is generated as a industrial effluent, it may contains various forms of impurities in the form of suspended impurities, dissolved impurities, floating impurities and other types of impurities and it impairs the quality of water for its beneficial uses.

So broadly it can be classified as a grey water and the black water. Grey water basically is the water which is generated from your bathroom, laundry and kitchens which does not contain any fecal contaminants like urine and feces other than this whatever the water is being generated from these forces that comes under grey water while the water which is generated from your urinals, your WCs that comes which contains various coliforms, various fecal and pathogenic bacteria is termed as black water. So depending upon the water generated from different sources like from runoff, from industries, from domestic applications, we have different strategy for its management. First of all, we talked about the different sources from where the wastewater is generated from the industries like we have different types of industries starting from textile, metal industries, refineries, leather industries and pulp and paper, then we have dairy industries, then we have paint industries, metal industries. So these industries they use various types of raw materials, acid, minerals and ultimately when the process goes on lot of impurities get involved into the water and as a result the effluent generated from these industries may contain various types of inorganic impurities, organic impurities, colouring compounds, dyes, heavy metals.

So water generated from industry that basically depends upon the type of raw material we are using, the type of acids we are using, the amount of alkali we are using and accordingly the effluent characteristic is generated from different industry. That's why the water which is generated from industry cannot be categorized, cannot be given as comprehensive characteristic rather than the characteristic of this wastewater generated from industry to industry will vary depending upon its process and operation. Let us talk about the storm runoff. As I defined the storm runoff is the part of precipitation which has not infiltrated below the earth surface, below the ground and directly meets to the surface water body that may contains various types of sediments and then silted particles which have lot of potential to erode of erosion and can get lot of sediment load into the receiving water bodies. When the surface runoff flows onto the earth surface it may also dissolve into human made, man made contaminants to the wastewater that may contain pesticides, fertilizers and many other impurities which we use into agricultural and other operations.

So agricultural runoff mostly we are looking upon because it has lot of potential to cause nutrient pollution and these nutrients rich stream then may turn into eutrophied streams having involved into various stages of eutrophication. Then this slide will indicate you the various types of pollutants, the common pollutants which are normally found in the wastewater like suspended impurities, iron and silt particles, iron and grease like if we have listed 13 impurities starting from 1 to 13. so 1, 2, 3, 4, 5, 6 up to these 6 like pathogens, nutrients, biodegradable organics, iron and silt particles, suspended impurities they are very common in the domestic wastewater while the impurities listed from 7 to 13 like inorganics, salts, mineral acids, metals, metal compounds, non-biodegradable organics like nitric pollutants, refractory organics, calcitant organics, various types of heavy metals, toxic metals, pesticides which are mostly generated from the agricultural runoff, synthetic detergent and many other variety pollutants that may be present into the industrial wastewater. That is why the characteristics of the still wastewater if we see from place to place little bit it varies it remains more or less uniform whereas in case of industrial wastewater the characteristic of wastewater varies from industry to industry and will depend upon the type of industrial activities, the raw material processes and the technology being adopted by particular industry. This slide basically deals with major characteristics of the wastewater like if we broadly classify the characteristic of wastewater they may be classified as physical characteristic, chemical characteristics and then biological characteristics. So physical characteristics are those parameters which may be determined by using physical methods whereas the chemical characteristics or the parameter or the chemical constant strength which may be determined by using various analytical techniques which uses various chemicals and reagents and involve a set of analytical procedures like DO, BOD, COD, POC, total nitrogen, phosphorus, chloride, sulfate, alkalinity, various types of chemicals that are present into the wastewater.

And then we deal with biological characteristics which may contain like various types of bacteria, algae, fungi, viruses, protozoa for this there is a detailed procedure for analysis of identification of bacteria, analysis of bacteria, algae, fungi. So this type of impurities normally comes under biological characteristics. And then we talk about start with the physical characteristics which may like the color, color is in basically indicates the stage of the wastewater from its generation like the age when the wastewater is generated like the wastewater if you see as far as municipal wastewater is concerned it is having light brownies to gray color which may become gray, dark gray and black depending upon the stage of its decomposition as soon as the wastewater is generated there are the bacteria they undergo anaerobic decomposition and get stabilized in the due course of time. The color of the wastewater also changes depending upon its degree of degradation and accordingly by seeing the color of the wastewater we can identify whether the sewage is fresh sewage or it is stabilized or it is of under septic conditions. So different forms of the

wastewater, different conditions of the wastewater we can determine by analyzing the color of the wastewater.

As far as the color is concerned in the industrial wastewater that may be also due to the presence of various types of metals like iron and manganese, humus and peat material, plankton and beets they have different peculiar color and may give rise to the color of the wastewater. Color may be also attributed due to the presence of various types of dyes and coloring pigments present into used into the various process during industrial operation. Analysis of the color indicates many more objective driven aspects in the industrial wastewater management and the unit we for its measurement is hazard that is true color unit. In another aspects that is odor, odor in the industrial wastewater is very common and that may be because of release of various odorous compounds and gases which are produced during degradation of organic compounds in the industrial wastewater. A major odor causing compounds if we see that is hydrogen sulfide, ammonia, sulfur dioxide, skatoles, mercaptans, amines and indoles.

Odor is basically measured by its threshold odor and that is the unit we have ppm, part per million. Then we have another list of the compounds which may have different types of odor like if we see presence of a mine will give fissile odor. This is the chemical formula for amines and then we have ammonia this is like inorganic gases which are produced will give a ammoniacal odor whereas diamines if it is present it will give decayed base odor whereas hydrogen sulfide if it is present it will give rotten egg color and presence of mercaptans basically it gives us the decayed cabbage. Cabbage like when it is decayed the kind of smell the kind of water we receive that may be because of presence of methyl or ethyl mercaptans. So, there are butyl and crotyl also mercaptans and they have skunk type of odor whereas the organic sulfides if they are present, they will also have the odor like rotten, cabbage.

Similarly skatoles they will also provide like the odor of fecal metals. So, these are the peculiar odors are being generated from different odorous compounds present into the wastewater. Then the next parameter the physical parameter what we talked about is the temperature. So as you know temperature is one of the very important parameter which determines the degree of the reaction of the bacteria, the rate of reaction of the various chemical reactions and as per the effluent discharge standard like any wastewater which is having temperature which is heated cannot be directly discharged into the neighboring downstream water bodies as if it increase because it may increase the temperature of the receiving water bodies that may initiate dissolution of DO content into the water and the DO level into the water will be decreased. It may also increase the rate of biological

degradation of the organic matter which will consume lot of organic dissolved oxygen and may reduce the DO content into the wastewater.

Bacterial action also increases at higher temperature which may result into accelerated depletion of DO levels into the water bodies. This is the major effects of the temperature like it will increase the rate of reaction, it can also increase the rate of dissolution of the solids, it will also have the impact on the viscosity of the water which gets reduced because of increase of the temperature which may have various impacts on the industrial based water. Then the major physical impurities that comes under characterization that is total solids that is the total solid content of the industrial wastewater basically defines the strength of inorganic and organic solids present into the wastewater which can be analyzed which can be defined as the total residue that is obtained after heating the water sample, wastewater sample at a temperature of 103 to 105 ˚C till it attains a constant temperature. So these solids they may be basically present in the different form that may be floating solids which may float onto the surface of the water. Second type of solids which have a specific gravity more than one mostly inorganic in nature they will settle down they have the nature to settle down so they are classified as a set level solids and then we have also some colloidal solids are the solids which are of very fine size like less than micron size and are present in colloidal stage.

Whereas the dissolved solids they are present in the dissolved form like various organics and inorganic impurities which are dissolved into the water which have a size range $< 10^{-10}\ to\ 10^{-9}$ like in angstrom size range those size solids they come under this category. So little bit more details about the types of solid their size and the types of impurities like if we see this on the x-axis we have plotted the size particle size as on the x-axis we have different types of solids like suspended solids, collides and dissolved solids. So here dissolved solids if we see that is the size range $< 10^{-9}$ whereas if we see of colloidal solids so they are like the particle size having $< 1\mu$ and they lies within nano size like 10^{-9}. Whereas suspended solids will have size $> 1\mu$ nearly 10 to 100 μ this sand and silt present that comes under this suspended solid while the very fine silt size and the clay that comes under the colloidal impurities whereas algae which are present in the water which is which comes under suspended and colloidal solids size range whereas bacteria also if we see they are present both in suspended and colloidal stage whereas the virus if we see they are mostly in colloidal stage. So removal of these very fine and coarser impurities like sand and silt particles becomes a big problem for wastewater to be managed to be reused to be recycled.

So determination of these type of impurities they are different form present into the

wastewater that is very very important. So here we see the test procedures like what are the various types of solids how we can determine these solids what are their methodology normally we follow methodology standard methods as published in APHA manual that is American Public Health Association. So this is like if we see that is total solids. So total solids are like all the solids which are present if we evaporate our wastewater sample at a temperature of 103 to 105 ˚C till it attains the constant weight. So whatever the solids are residue that will be remained after evaporation at this particular temperature if we weigh down so whatever the amount will come that comes under total solids and they are mostly measured in terms of milligram per liter.

Then we have total volatile solids these are the solids which are volatile in nature. So if the solids what are obtained after heating 103 to 105 ˚C if we further heat this residue at a temperature at a little higher temperature that is 500±50 ˚C then the volatile compounds present into this residue that will be volatilized and burned off when the temperature is enhanced to 500 ˚C and whatever is being left out that is basically the fixed solid whereas whichever is being evaporated that will be counted as total volatile solids. So there is different test procedures classified the volatile solids, fixed solids and the total solids. Similarly now if we try to find out different forms of solids like the solids which are present in suspended form the solids which are present in the dissolved form. So we have again different procedures so for this suppose we have to obtain the total suspended solids so we have to again use a filter paper filter the entire wastewater samples at temperature of 105 ˚C and then evaporate the residue remained on the filter paper at a temperature of 105 ˚C then whatever will be remain that will be termed as the total suspended solids whereas whatever the filtrate now again in the total suspended solids if we need to find out the volatile fraction of these total suspended solids then we can again is heat the samples at 500 ±50 ˚C and whatever is being evaporated or volatilized or burned off during this temperature high that amount of solids are mostly they are volatile in nature and whatever is being remain as a residue after this temperature that comes under fixed suspended solids.

So that residue which is remain that is fixed and the amount of suspended solids which got evaporated which got burned off at a temperature of 500 ˚C that will be treated as the total volatile suspended solids and then we talk about the TDS. TDS is one of the important parameters which we obtain after filtrating the sample whatever the filtrate is remain so that filtrate if we again heated it at 180 ˚C till it attains the constant weight the amount of solid that will remain as a residue that will be treated as a total dissolved solids and they are basically present in a size range of 0.001 to 1 µ and then similarly in this total solids again if we need to have the volatile fraction of dissolved solids so again the sample has to be heated at a temperature of 500 ˚C and then whatever the residue remain that will indicate the fixed dissolved solids whereas which is being burned off which is being

volatilized that portion of the solid that will say about the volatile suspended solids and then we are having more interest on the removal of these solids basically suspended solids so for that we again classify the suspended solids in two forms that is settleable solids and non- settleable solids. So for this we have a special type of cone known as Imhoff cone and Imhoff cone we fill with the one liter of wastewater sample and try to let the sample get settled the amount of settleable solids which have the specific gravity more than one they will be settled faster as compared to the other impurities at settleable solids which are settled after a period of one hour at solids they are termed as the settleable solids and these were the major physical characteristic of the wastewater similarly we have the more detailed characterization of the chemicals or the chemical impurities which are present in the wastewater they comes under chemical characterization and that includes various types of acids various types of metals acidity, alkalinity, hardness many more parameters so one by one we will deal with the chemical characteristics of the wastewater so the very first chemical characteristic that comes in our mind that is the pH. pH basically is the very important parameter in when we look upon the industrial wastewater management so this is basically defined as the $-log_{10}[H^+]$, so this is basically the potential hydrogen ion present into the wastewater.

pH basically defines whether the water is acidic whether the water is alkaline in nature and how much content of the hydrogen or hydroxyl ions that are present into the wastewater so this typically chemically we write this H_2O if ionized they will be present in the form of H^+ ions and OH^- ions and if we write K, K will be equal to its ionization constant and that is H^+ ions into OH^- ions divided by molar concentration of H_2O that is equal to 10^{-14}. So, if we see that our water is pure then this molar concentration of water that will become 1 and thus the dissociation constant that is K_W which is obtained from this chemical reaction molar concentration of H ion into molar concentration of OH^- ion and that will give equal to 10^{-14}. So now if we measure H^+ ions or OH^- ions we can get the pH value of the water or pOH value of the water which will define the acidic or alkaline nature of the wastewater. So if pH < 7 the wastewater is termed as acidic wastewater if the pH>7, it is termed as alkaline wastewater and if the pH=7 then it means the water is neither acidic neither alkaline if we see upon the domestic wastewater typically it has slightly alkaline nature and it varies from 7 to 7.5 whereas in case of industrial wastewater is maybe acidic maybe alkaline depending upon the process type of inorganic acids and bases that are used in the operation and will entirely depend from industry to industry.

So this is the way how we can measure the pH so that is we use pH electrode so this electrode is dipped into the water samples and whatever the reading we get here that is like currently this is 7.89 so it gives little alkaline nature of the wastewater. So this is a simple technique we have to dip the electrode into the wastewater sample directly it will

analyze the H^+ ions and accordingly the reading for your pH will be displayed over this pH meter. Then many other important characteristics we will go through the first one that we go through that is the inorganic salts so inorganic salts that may cause scaling problem to the pipelines that may cause nutrient problem into the wastewater that may cause hardness of water so that may make the water acidic that may make the water alkaline. So there are different types of inorganic salts and that depends upon the type of raw material and the process operation the industries they are using and they can have different impact depending upon the type of inorganic salts if they are present in the wastewater.

So like if there is a lot of nitrogen and phosphorus they will induce the growth of microbes, microscopic plants like algae and that may cause the eutrophication process and then we have different types of acids and alkali as I told there are this acid addition of acid will increase the acidity in the water because of use of various types of bases and alkali material during the process that will result alkaline nature of wastewater. So this depends upon the type and amount of acid and alkalis we used into the process. Then we have organic matter basically organic matter of prime concern in the industrial based water more the organics present it will exhaust the oxygen resources of the river body during its decomposition because organic matter most of the organic matters they are biodegradable they are not there are also the organic matters which cannot be degraded but the organic matters which are biodegradable in nature immediately that undergoes its decomposition and that will take consume the oxygen present into the water bodies and will cause depletion of DO level in the receiving waste streams and critically for survival of any fish or aquatic life the DO level in the stream body that should never decrease by 4 mg/L as it may affect the survival of these microorganisms, aquatic lives present into the water bodies. Then we have various types of toxic chemicals industries use they may be organic they may be inorganic in nature and many of these compounds are not removed mostly in our conventional treatment process and have a cumulative impact onto the biological system. Then we have microorganisms like there are industries like canaries, slaughterhouses they discharge the wastewater containing various types of bacteria that may be harmful to the human health and the environment so these bacteria which assist in degradation of organic matter aid in as a seeding material also a steam and accelerating occurrence of oxygen sag curve in the water because during its decomposition DO level will keep on decreasing and it will try to deplete the DO oxygen level into the water body and then we have pathogenic bacteria which have direct impact onto the human health and will cause various types of waterborne diseases along with the various other impacts onto the aquatic lives and the quality of the water.

Then we have many types of radioactive materials which are present and they have the cumulative damaging effects onto the living cells and then in the industrial wastewater there are also the foam producing matters they are of time importance as far as treatment

of wastewater is concerned and these foam producing matters they are mostly discharged by various industries like textile industries, pulp and paper mills and other chemical plants. So, these also have a potential to deplete out the oxygen from the receiving water body. So, these are the few chemical characteristic of the wastewater that we have discussed there are many more and that we are going to discuss in the forthcoming lectures my next lecture.

Thank You.