Course Name: Industrial Wastewater Treatment

Professor: Sunil Kumar Gupta

Department of Civil Engineering, IIT(ISM), Dhanbad

Week - 01

Lecture 02: Sources and characteristics of industrial wastewater

Hello everyone. If we recall to our previous lecture, we have dealt with wastewater, its concept behind the wastewater, then we have gone through classification of various types of water, their sources and then the characteristic of the wastewater wherein we have discussed about the physical, chemical and biological characteristics. So now, today in our, this lecture, we will deal with some of the chemical characteristic of the wastewater which we could not deal in the previous lecture. This is a biological oxygen demand, BOD. It is a very common parameter in industrial wastewater and is basically the amount of the oxygen required by the microorganism for decomposition of biodegradable organic matter which are present in the wastewater especially during the aerobic condition. So, this indirectly indicates the organic strength of the wastewater.

Generally, this BOD is made to measure the amount of organic pollution in the wastewater. More the BOD level, it indicates more the organic strength which may undergo fast anaerobic decomposition and can deplete our dissolved oxygen content. So, BOD test, this requires basically 5 days which is carried out at 20 °C. So, biological oxygen demand, this is one of the very common parameter in industrial wastewater which defines basically the amount of oxygen required by microorganism for decomposition of biodegradable organic matter present into the wastewater under aerobic condition.

So, this basically measures the oxygen required for oxidation of organic matter. It indirectly gives us the organic strength present in the wastewater. More the BOD, it indicates basically the more the organic strength present in the wastewater which may undergo rapid oxidation of using the bacteria and that may deplete the DO levels in the receiving water bodies. So, this test requires 5 days and which is carried out at a temperature of 20 ˚C But nowadays, because this takes a lot of time, so 3 days BOD at 30 ˚C is preferred for quick determination of biological oxygen demand.

Now, let us talk about another important parameter of industrial wastewater which we say that is chemical oxygen demand. As we have seen in the biological oxygen demand which is mediated through microorganism, but this test involves a strong chemical oxidizing agents that basically completes the oxidation of both organic, whether they are

biodegradable, they are non-biodegradable. So, both type of organic compounds they are measured under this test. So, this is basically referred to the total amount of oxygen which is required for complete oxidation of both biodegradable and non-biodegradable organic matter using a strong oxidizing agents. So, due to the use of this strong oxidizing agents, all the organic matter present in the wastewater is chemically digested and the test is completed within 2 to 3 hours.

So, this is basically the quick determination we can carry out within 2 to 3 hours and this is most commonly preferred chemical test that is conducted to measure the organic strength of industrial wastewater. Now, let us talk about the biodegradability of the wastewater BOD and COD. These two tests are conducted basically to measure also the ratio of BOD-COD ratio which basically depicts the biodegradability of the wastewater and helps in determining the visibility of a biological treatment system for the given wastewater. If the BOD-COD ratio is more than 0.5, it means more of the organic matters they are biodegradable in nature and they can be treated usually by using this biological treatment system.

If the BOD-COD ratio that is less than 0.1, 0.2, 0.3 up to like less than 0.5, we can use this wastewater. So, now BOD-COD ratio basically as I discussed this is basically measures the biodegradability of the total organic compounds they are present in the wastewater. So, this basically depicts the nature of the biological treatment system that can be adopted for its management or its treatment. Then we have another chemical characteristic that is the nitrogen content present in the wastewater. So, nitrogen content if we see that in the wastewater may occur in one of the following forms like free ammonia or we also say the ammoniacal nitrogen then it is like albumenide or organic nitrogen. The nitrogen in the wastewater may also be present in the form of NO_2^- and NO_3^- depending upon its oxidation state.

If we see free ammonia which is basically indicates the very first stage of the decomposition of organic matter, so it indirectly indicates the extent of organic degradation that has already been achieved in the given wastewater samples. And then nitrite basically this indicates the intermediate stage of conversion of organic nitrogen into NO_2^-. This is basically little bit more stable form compared to free ammonia, but still this NO_2^- very instable and it is very fast it gets further oxidized to nitrate form which indicates the purely fully oxidized organic matter which is present in the wastewater. This is complete oxidation state of the nitrogen which is present in the wastewater. Now, if we talk about the albumenide or organic nitrogen this indicates the total amount of nitrogen content present in the organic form and whereas this NO_2^- is mostly not observed in the wastewater sample because this is intermediate stage of oxidation of nitrogen that is organic nitrogen or free ammonia depending upon its oxidation process and that gets immediately converted into the NO_3^- form.

So, this nitrite normally it is not found in the wastewater. So, presence of various forms as we have seen various forms of nitrogen in the wastewater indicates basically the stage of wastewater generation and as it is linked with the probability of organic pollution. So, this a complete measurement of organic nitrogen and the ammoniacal form of nitrogen in the wastewater sample is measured by another parameter what we call is total Kjeldahl nitrogen which is basically the addition of organic nitrogen and NH_3-N. Again, we also measured the total nitrogen which is basically the sum of the TKN, NO_3^- and NO_2^- form. This nitrogen indicates the sum of the total Kjeldahl nitrogen I mean to say the organic nitrogen and NH_3-N along with the other forms of nitrogen which is NO_3^- and NO_2^-.

Determination of various forms of nitrogen is extremely essential to assess the extent of degradation and the sources and the kinds of treatment system that has to be adopted for the management of a given industrial wastewater. Now, let us talk about the various impacts of the nitrogen, their different forms like if free ammonia is present this is very inhibitory to the biological treatment process like we in our industrial wastewater treatment process we involve number of biological treatment process, aerobic treatment process, anaerobic treatment process, anoxic process. So, this if free ammonia is present in the wastewater that will inhibit their activities and that lead to the failure of that treatment process. High level of ammonia can also irritate and burn the skin, mouth, throat, lungs and our eyes. Very high levels of ammonia can damage to the lungs and cause death of industrial workers.

Similarly, if we see the nitrate form of nitrogen this is one of the major precursors responsible for formation of N-nitro compounds which have genotoxic effects and termed as carcinogenic compounds. Nitrogen can also cause nutrient pollution leading to the eutrophication of the receiving water bodies like streams and lakes. Determination and its management of various forms of nitrogen in industrial wastewater treatment and its management is very important. Before we go into another parameter let us talk about the three important processes that are carried out and are responsible to make the nitrogen present in different forms. So, if we see the NH_3-N if it is there it will immediately get oxidized to NO_2^- and this NO_2^- using the Nitrosomonas bacteria and then it converts to the NO_3^-.

So, this form of a conversion of ammonia into NO_2^- and then nitrate this process we say that is nitrification process and is used as one of the treatment process as an aerobic treatment process for removal of NH_3-N. Similarly, then we also carry out the denitrification process basically this whatever the NO_2^- that is converted into the nitrate that is again is being degraded into NO_2^- and then finally converted into the NH_3-N and this NH_3-N is finally converted into N_2 gas. So, this process of nitrification and denitrification is mostly used in removal of NH_3-N agent into the wastewater in sequence

so that ammonia nitrogen is first nitrified in the form of NO_3^- and then this NO_3^- becomes the substrate for denitrifying bacteria which are present in the wastewater and in anaerobic conditions they are finally converted into NO_2^-, NH_3-N and then finally to N_2 gas. So, this is basically the denitrification process. So, these two process nitrification and denitrification usually we carry out in usual nitrification denitrification process for nitrogen removal from the wastewater.

So, nowadays there is important research that has been carried out and that is direct conversion of ammoniacal nitrogen into guide nitrogen gas and that is done by this anammox process which is basically there is annamox bacteria which they feed directly upon the ammoniacal nitrogen and directly convert into dinitrogen form using inorganic nitrogen agent into a wastewater. So, this is the shortcut process in ammoniacal nitrogen removal in the industrial wastewater treatment system. Next, there are also various types of Sulphur compounds like sulphate and sulphides present in the municipal wastewater depending upon their sources and characteristics. They may be found in the form of sulphate, dissolved solids, hydrogen sulphides and organic Sulphur. So, these are different forms of Sulphur compounds which are normally found in the wastewater in the inorganic and organic form like if we see these are the organic forms of Sulphur whereas organically bounded Sulphurs that is also found in the wastewater.

So, these Sulphur compounds they are mainly generated from tanning industries, mining industries, petrochemical industries, salt fermentation process and food processing industries like number of fertilizers they we use and they have lot of Sulphur compounds, food products they have lot of Sulphur compounds, fermentation process they also use to generate number of Sulphur compounds into the wastewater. Determination of various forms of Sulphur in the wastewater becomes very important from treatment and disposal. So, let us talk about the presence of various forms of sulphate their impact on to the environment and the human health. So, sulphate in the wastewater is mostly present in the dissolved form and that is precipitated through rainwater in the form of acid rain and forbs which acidifies the water and the soil and which could damage our ecosystem forest and the plants. So, this sulphate whatever is being precipitated that may undergoes its decomposition using sulphate reducing bacteria there are they used to reduce this sulphate into hydrogen sulphide gas which is basically very toxic compounds, odorous compounds which may induce various types of odors and smell problem in the wastewater.

This is also very toxic to the methanogenic bacteria which are basically involved in anaerobic decomposition of the wastewater. So, this overall affects the anaerobic treatment of the wastewater. So, determination of the various forms of H_2S, SO_4, dissolved S^{2-} even if it is present in the wastewater have toxicity if it is present in more than 150 mg/L. Similarly, H_2S concentration if it is present in the more than 5 ppm it may become very toxic to various types of other microorganisms. So, H_2S mostly this is naturally converted

into the H_2SO_4 which is also corrosive in nature and can corrode our steel and concrete material.

Let us talk about the PO_4. PO_4 again if we see that is present in the different form in depends upon the pH condition of the wastewater. So, at very acidic pH like at pH 1 the phosphoric acid is practically is present in its undissociated form but as and when the pH increases but up to the 4.7. So, this dissociation of this H_3PO_4 takes place and this is basically converted into dihydrogen phosphate ions that is H_2PO_4 and is practically the only species present at this pH.

Around pH 9.8 this phosphate is present in the form of mono hydrogen phosphate ions is which is the only species present. At pH 13 the higher the are higher the acid is completely dissociated as phosphate ions and this phosphate in industrial wastewater that mostly comes from pulp and paper industries, fertilizer and laundry and detergents. Phosphates are essential to the aquatic plants but too much of phosphate can lead to the growth of algae and that can result to the algal boom. Then let us talk about the heavy metals. So, heavy metals you know that is naturally occurring elements basically if we define the heavy metals they are the metals which have the high atomic weight and a density at least 5 times greater than that of the water and is termed as heavy metals.

So, they have potential effect on to the human health and the environment like they may cause toxicity, genotoxicity and thus they are carcinogenic in nature. Because of their high degree of toxicity, we of major heavy metals like arsenic, cadmium, chromium, lead and mercury they rank among the variety metals that are known to induce multiple organ damage even at low levels of their exposure. Therefore, they are classified as a human carcinogen as well according to the US Environmental Protection Agency and the International Agency for Research on Cancer. Thus, the removal of heavy metals from industrial wastewater is very, very important and is mainly achieved by using various chemical precipitation process, ion exchange process, adsorption process. There are many more processes which we will deal in the subsequent lectures for removal of these heavy metals.

So, these heavy metals they have various types of effect on different organs like if we see them all as a whole, so these are the heavy metals like arsenic, cadmium, lead, copper and then mercury then we have chromium. So, every individual elements if we see they have their own impacts like mercury, like chromium. So, this if we talk about the arsenic, so it has lot of problem on to the skin, it may cause skin cancer, lung cancer, brain damage, kidney, liver, so number of things, number of organs they are associated to be get damaged because of high concentration of organic beyond their permissible limit. Similarly, for

cadmium if we see it can affects to our bone, liver, kidney, lungs and it can also damage to our brain and immunological system, cardiovascular problems and similarly lead, we have number of impacts of lead on to the bone, liver, kidney, brain. So, these are various types of impacts of presence of different types of heavy metals on to the industrial wastewater.

So, removal of these heavy metals from wastewater is very important for its recycle and reuse. Then we have the number of biological characteristics. So, biological characteristic includes basically determination of various types of microorganism, bacteria, protozoa, worms and various types of virus which are associated to cause various types of waterborne diseases like hepatitis, typhoid, then polio, cholera and dysentery like waterborne diseases. They may be basically transferred to the human being through a direct contract as well as indirect contacts like they directly like because of their bad personal hygiene and indirectly through the contaminated wastewater, contaminated water, contaminated food they are exposed to. So, these are various types of microbiological characteristics of the wastewater like bacteria, if we see virus, protozoa and helminthous.

So, they are most common in the wastewater. So, if we see this bacteria, they are cell types. So, bacteria they are unicellular organism whereas virus they are further more finer size, they are present in the form of intracellular parasites whereas again this protozoa that is unicellular while this helminthous that is of multicellular forms. So, they have different size range if we see that bacteria that is of size range 0.5 to 5 µm whereas this virus they are of size in nanometer, they are 20 to 200 nm very very fine size like in nano size they cannot be seen through our naked eyes and similarly these are the protozoa they have less than 50 µ size whereas helminthous they are generally till similar size of protozoa like 40 to 60 µm.

So, they are associated like various types of disease like typhoid, paratyphoid, dysentery and cholera. Similarly, if we talk about the virus they may cause respiratory problems, eye infections, they may cause stomach upsets, diarrhea this kind of problem because of virus. Similarly, if there is a presence of protozoa they may cause malaria, they may cause toxoplasmosis, cyst formation so number of types of health problem they are associated with. Similarly, if helminthous are present they may be as aqueous problems, then cyst problems etc. They are mostly formed helminthous they are mostly found in intestine.

Similarly, protozoa they abode onto the also onto the human intestine whereas these bacteria and virus they are capable of self-reproduction whereas they abode inside the living cells of an organism. They are different types of biological impurities; they are classified under biological impurities. So, these are the few photographs of E. coli bacteria which are basically the indicator of presence of pathogenic bacteria which may cause

various types of waterborne diseases. They are mainly rod shapes and then these are like virus, polio virus which may cause polio to the human being.

Similarly, there are number of cyst formations in the urinary bladder, there are cysts into the uterus, ovaries so number of cyst formation this type of bacteria can results and then similarly these are the intestinal worms. So, they are found in the human intestine and can produce number of stomach problems. So, now we have dealt with various types of physical, chemical and biological characteristics. So, determination of these different forms of impurities present, different types of physical and chemical parameters, biological parameters is very important because nowadays there is a regulatory requirement for any industrial wastewater that has to be exposed into the water bodies that should conform these parameters before they are discharged into the receiving water bodies or for different form of disposal. So, like if we see the industrial, industries are domestic wastewater they are generated and they are treated and after the treatment they should confirm the following standards.

Like these standards they are defined as per the Indian standard IS2490 that is being published in 1993. So, this is the effluent discharge standard here we can see that is the different mode of disposal like they are treated wastewater that can be disposed directly onto the surface water bodies or they may be discharged into the public sewers, they may be also reused for land irrigation whereas the wastewater is that can also be disposed into the marine or the oceans depending upon the proximity of the mode of disposal. So, here these are different parameters like color and odor and there are suspended solids, then we have pH, then we have temperature. So, these are the parameters and these are the different standards like there as far as possible there shouldn't be any color or odor present in the treated wastewater means color has to be completely removed from the wastewater and there shouldn't be any objectional smell or order that should come before it has to be disposed. So, then if we talk about the suspended solids that basically indicates the presence of inorganic impurities into the wastewater that need to be discharged with great care as it may cause lot of turbidity problem.

So, it's standard for different types of wastewaters are given for inland surface water body if see the standard is very less that is 100 ppm whereas if we are disposing on to the public sewers, so it can have little more content like up to 600 mg/L can be disposed as wastewater going through the public sewer again will have to be treated. So, again that treated wastewater should conform to this standard. Then wastewater which is to be used for land irrigation for agricultural purpose, agricultural reuse that should not have more than 200 mg/L of suspended solids when it is disposed on to the oceans or marine it should not have more than 100 mg/L. Similarly, for pH if we see the pH of the effluent being discharged into different mode of disposal like it should not have more than 5.5 to 9 and

for temperature is one of the very important parameters because it may have different impact as we have already seen.

So, this temperature of the wastewater if we discharge should not exceed the ±5 °C temperature of the receiving water body. So, that is basically the standard fix for temperature. Then we have oil and grease, we have total residual chlorine, ammoniacal nitrogen, total Kjeldahl nitrogen, pre-ammonia concentration, nitrate nitrogen, BOD, COD, fluoride, sulfide, dissolved phosphorus and then finally the bio-assay test. So, these are different parameters they have different standards for different mode of disposal and they must be confirmed before the wastewater is to be discharged finally to any mode of disposal. So, this is all about our industrial wastewater characteristics, its importance and the final effluent discharge standard which our industrial wastewater should be treated before they are disposed to the environment. These are the references.

Thank You.