Water and Waste Water Treatment
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Lecture -11
Water Quality: Total Suspended Solids and Pathogens

Hello everyone. Welcome back to the latest lecture session. Let us look at what we were discussing in the previous session. We were discussing about the quality of wastewater and the relevant parameters that we are typically concerned with. Let us have a quick recap.

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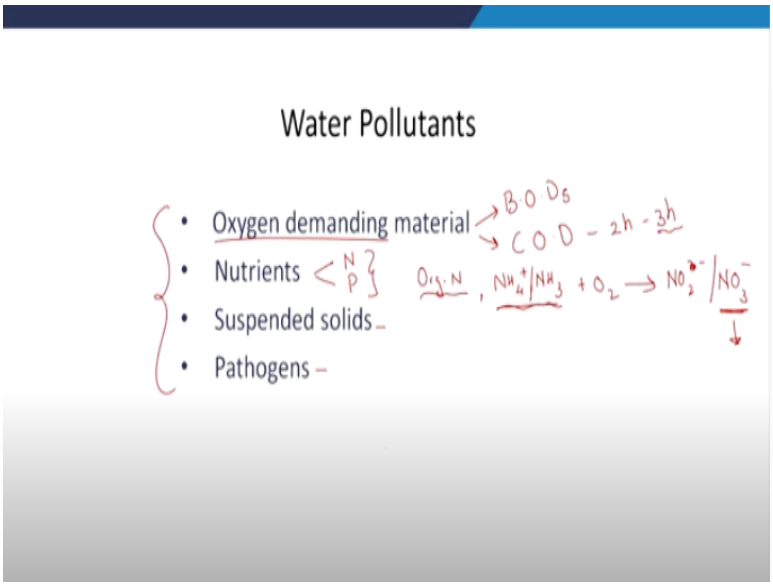

We were primarily concerned with four major parameters. In the context of organics we say or we try to understand them or measure them in terms of oxygen demanding materials. Biochemical oxygen demand typically over a five day period and the chemical test COD chemical oxygen demand typically takes 2 hours to 3 hours including setup time it takes 3 hours. Nutrients we were concerned with nitrogen and phosphorus. Why is this? Why were we concerned with nitrogen and phosphorus?

We were talking about issues with respect to algal bloom and we looked at that in relatively greater detail. As I mentioned or as we discussed in inland surface waters, phosphorous is typically the limiting nutrient in oceans it is typically nitrogen. And in that context, we saw how nitrogen can

be bound to organic compounds amines proteins and so forth are the sources. We also have the forms in terms of ammonia that is something that we have.

After oxidization or oxidation, pardon me what can they be transformed into NO_2^- or nitrite or nitrates. One aspect to note is that nitrates are regulated compounds and drinking water as in; if I take nitrates at a concentration greater than the threshold that is mentioned in the relevant standard for a given period of time, I will observe adverse effects in my body or in my health. Typically, methemoglobinemia; where you have the blue baby syndrome that is an issue with respect to nitrate.

You do not want to have a lot of nitrates in your particular solution and thus we are going to look at removal of nitrogen. Suspended solids and pathogens we will discuss that in detail today.

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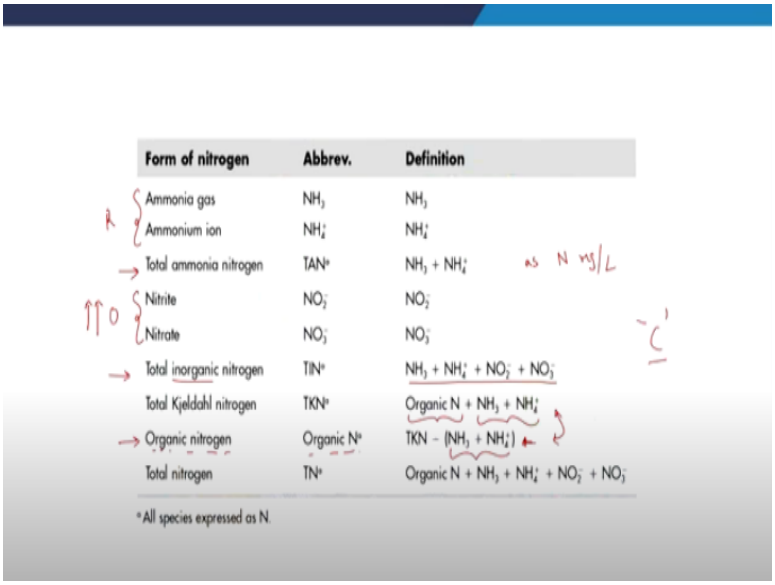

Before we go further what we will be talking about in the context of nitrogen we talk about ammonia or total ammonical nitrogen typically expressed as N units or typically as N milligrams per liter typically. Then the oxidized forms nitrite and nitrate depending on the source and more importantly depending upon the time available, you might have a combination or typically will have a combination of both these reduced forms and oxidized forms of nitrogen.

If oxidized forms of nitrogen are predominating that can mean that the waste what we say has been around for quite some time. The degradation or oxidation has been taken place or has been occurring. We have the total inorganic nitrogen as the name indicates it is inorganic that is why you do not have any organic content as no C let us say no carbon.

We have the relevant inorganic nitrogen and then total Kjeldahl nitrogen which is going to measure the organic N and then the reduced forms of nitrogen and then organic nitrogen too. But how do you differentiate between total Kjeldahl nitrogen and organic nitrogen? Both depend on the Kjeldahl method but in the measurement of organic nitrogen we try to remove the ammonia from the relevant solution typically by boiling let say. And allowing for change in phase you need to look at the pH too.

Another aspect to note is that to convert or not to look at is that when we are trying to look at organic nitrogen, we then digest this particular organic N. It is bound to the organic compounds. You want to break these particular bonds and you typically look at digestion by applying acids and maybe some heat supplied. That something to keep in mind typically we are concerned with TKN. And then we were looking at phosphorus.

In the context of phosphorus, we looked at the three aspects. Typically, we looked at ortho phosphates as being of primary interest to us as in $H_2PO^-_4$, HPO_4^{2-} , PO_4^{3-} and such. Why is that? Because they are easily soluble or very soluble and easily relatively more reactive as in the relevant bacteria can make use of these relatively soluble compounds relatively easily.

We have polyphosphates where we have what we say more than one phosphorus and then the organically bound phosphates. But these are relatively less soluble and also relatively slow to hydrolyze and thus be degraded or be used by the microorganisms. That is something to keep in mind Nitrogen and phosphorus. We are going to look at suspended solids now.

But why do I care about suspended solids? If I am having bigger particles which are suspended that by itself can create issues in my system or even aquatic system. They can aquatic ecosystem they can interfere and or be deposited on the gills of the fish you will have such issues and digestive

tract issues. Another aspect is that these suspended matter the matter or particles suspended in the water. They are going to act as possible carriers or sites for microbial growth or even virus.

You do not want to have what we see surfaces where the microbes can grow on. But if you have; lot of suspended solids that is one particular aspect to be concerned about growth of microbes.

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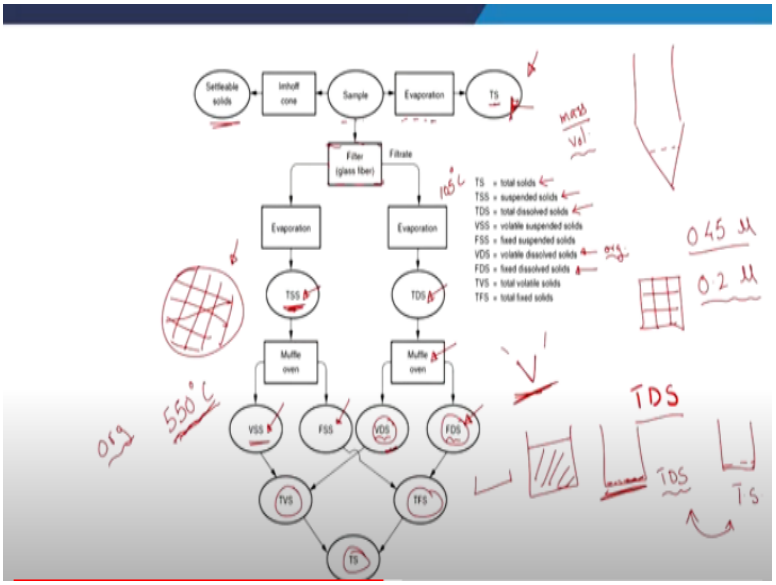

Let us look at how it is that we are going to measure this suspended solids or different solids. Why just talk about suspended solids? Though I am talking about suspended solids here we are going to look at solids and then suspended solids. Let us move on. Here we have the sample. One aspect is the settleable solids. We have an Imhoff cone something like this and after a particular time you will see up to a particular depth how much has settled.

Settleable solids as in within a reasonable period of time how many solids can be or how much of the solids can be removed from your water by gravity itself. That is settleable solids and if I am not just concerned about settleable soils and I want to look at the total solids. What do I do? I am going to evaporate it, put it in an incubator or oven at around 100 or 105 degree centigrade.

Then I am going to evaporate it and I will get the total solids in that particular beaker. I will weigh the beaker before and after and I will get the relevant mass and then the volume of water you use.

You will get mass per volume and you will be able to get your relevant total solids. TS is for total solids. And then if I want to dig deeper which is what we are always concerned about at least in this course or in wastewater treatment. I want to look at suspended solids and dissolved solids. Why is that?

Well, it is because different unit process tackles different kinds of solids. Total suspended solids are typically going to be removed during primary treatment. Dissolved solids typically during your biological process where the bacteria are going to try to degrade your dissolved solids. We need to be able to understand the relevant variables to be able to design for our wastewater treatment plant.

Suspended solids let us see how you will get it. We are talking about suspended. You need to filter it through a particular glass fiber filter. And in this context whenever you are reporting the suspended solids or the dissolved solids you are typically going to have to mention the size of your filtrate or filter size. It is 0.45 microns 0.2 microns or such. Because if the size is smaller most of it might not pass through or lesser fraction will pass through.

But if the size of my filter is larger more of it will pass through and I will classify that as suspended. That is one thing to keep in mind. Total dissolved solids in that context. If I did not spell it out wrong this is my filter. This is not how the filter is going to look like we are talking about remarkably low sized filters glass fiber filters. If I take a smaller one so as we just discussed the size of the relevant glass fiber filter has to be mentioned when we are mentioning the total dissolved solids or such.

That is something to keep in mind. Let us move on and understand this in somewhat greater detail. I have a known volume of sample. I am calling that V and then I am going to pass that through this particular filter 0.45, 0.2 or different particular filter. It is going to pass through that particular filter as in particles of size less than the filter size or the pore size will pass through that particular filter.

I am going to collect that in a particular beaker. I am going to collect the water in a particular beaker. This I will put in an oven and at a temperature of around 105 degree centigrade or 100 degree centigrade and I let the water evaporate out. At the end of day or so or the relevant period I will just be left with the total dissolved solids. If I did not filter it, I would have just gotten total solids.

This way I will get the total dissolved solids. And typically, sometimes people take the difference to measure the total suspended solids or you can look at what was collected on your filter. You can look at what is collected on your filter and measure the difference before and after filtration. When I say difference the difference in weight of your filter. Then you will get your total suspended solids.

Yes, so that is one way but if you want to rule out the error this is a better way. But in general, you always need to take a greater volume if not you will run into issues with respect to accuracy. Because we are talking about 200 milligram per liter or in case of ground water the TDS or TSS pardon me will be much lower. You need to be really careful when you are trying to measure it based on the kind of water or sample you are measuring. Let us move on now.

I am done with dissolved solids and suspended solids now. We are going to look at the organic content in my particular sample which I am going to say is going to be measured by putting the sample in a muffle furnace at around 550 degree centigrade for a given period of time. That is what I have a muffle furnace or muffle oven. Whatever is left in here this is the total dissolved solids. But I want to look at it further.

I want to classify it further as volatile dissolved solids and fixed dissolved solids. Where do I have that volatile dissolved solids fixed dissolved solid? Volatile dissolved solids they more or less mean the organic content. That is what we are trying to measure when we say it is volatile dissolved solids. When I increase; the temperature and maintain it at 550 degree centigrade.

Most of it is going to what we say I should not use the term burn but you understand what I am trying to say out here. The organic content is not going to be out there and that difference will be

the volatile dissolved solids. But what is left inside your particular beaker or petri dish? After you maintain the temperature at 550 degree centigrade will be the fixed dissolved solids typically relatively inert or inorganics and satchels.

Similarly for the suspended solids also you can measure the volatile and the fixed suspended solids. We are trying to get an idea about organic content that is suspended, organic content that is dissolved. That is one aspect to look at, and total volatile solids. We have that and total fixed solids , just general summation out here with respect to both the suspended and dissolved and you can even probably look at it directly from this sample.

This total should be equal to the total solid which we would have or we get from out here. Why are we looking at suspended solids, dissolved solids and volatile solids and fixed solids and such? Because each unit process is going to look at removal of certain kind of material or such. For example, primary treatment we are looking at removal of suspended solids or settleable solids. If not, we will add a coagulant and then let them flocculate and then settle down by gravity.

We are going to look at suspended solids in that context. In the context of biological treatment my major focus is going to be on the dissolved organics. I am going to try to remove the dissolved organic content. Thus, I need to be able to measure the different variables that we just listed out here.

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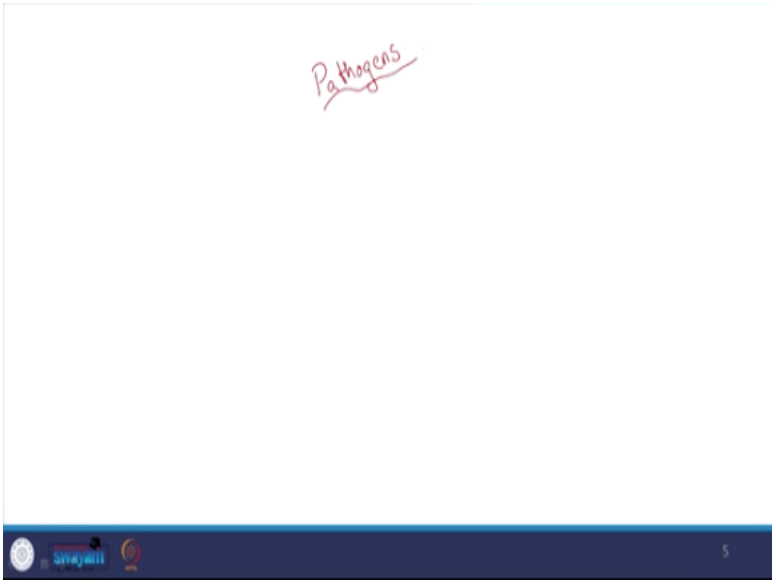

Now we are going to look at pathogens. We discussed this at the start of the course but let us just try to refresh our memory. Pathogen's are microorganisms capable of causing disease that is what we have.

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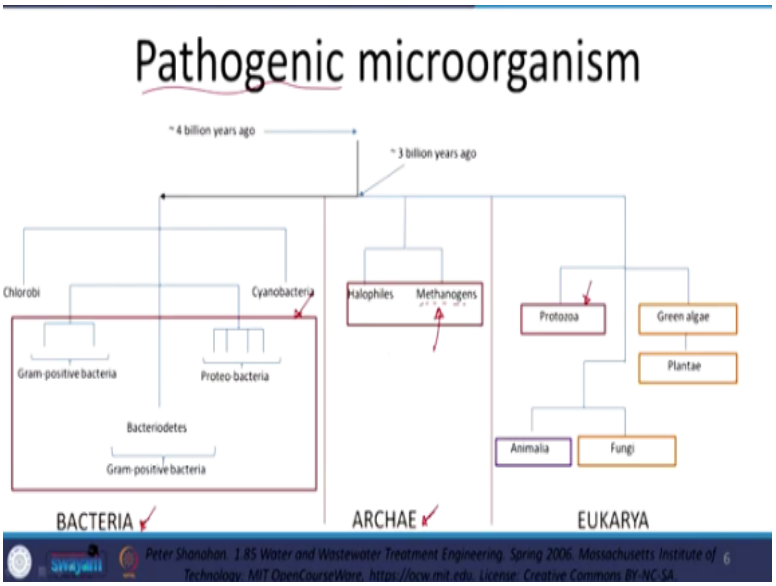

General aspect pathogenic I should not have used the term pathogenic microorganisms. Microorganisms we see the evolution three billion years ago. Bacteria and archaea please do not or how do I say this? Use me as a reference for pronunciation and we call the bacteria and archaea together as prokaryotes and the bigger and more complex forms as eukaryotes.

What is the difference between bacteria archaea on one hand and this eukaryote on the other hand. Well, in these particular prokaryotes which encompass bacteria and archaea we have or they are relatively simpler life forms unlike the eukaryotes. We have a picture out here but we will go through that or we will look at that. Here the chromosome in bacteria and archaea is not within a nucleus and in eukarya it is going to be within the nucleus.

That is one particular difference pattern and here what are the typical pathogens protozoa and gram positive bacteria protobacteria are these bacteria that we already mentioned out here. Typically, in archaea there are no known pathogens. But archaea or microorganisms of interest include methanogens. As the name indicates it is the final product is going to be methane and that is typically used in anaerobic treatment.

Anaerobic as a process occurring in the absence of oxygen anaerobic and in that process, it is the methanogens that play a considerable role or the major role. That is why we highlighted that. No known pathogens among archaea and yes, we do have a lot of known pathogens within bacteria and eukaryotes.

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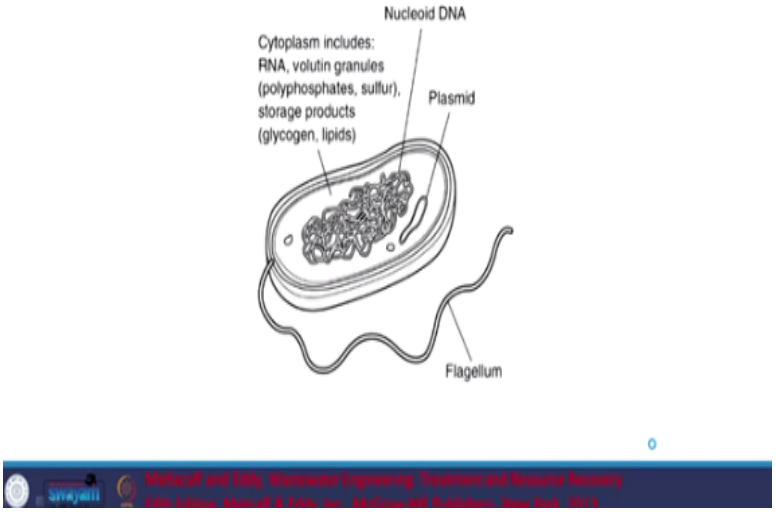

Here prokaryotes we see the relatively simple structure as I mentioned chromosome not with a nucleus or no nucleus.

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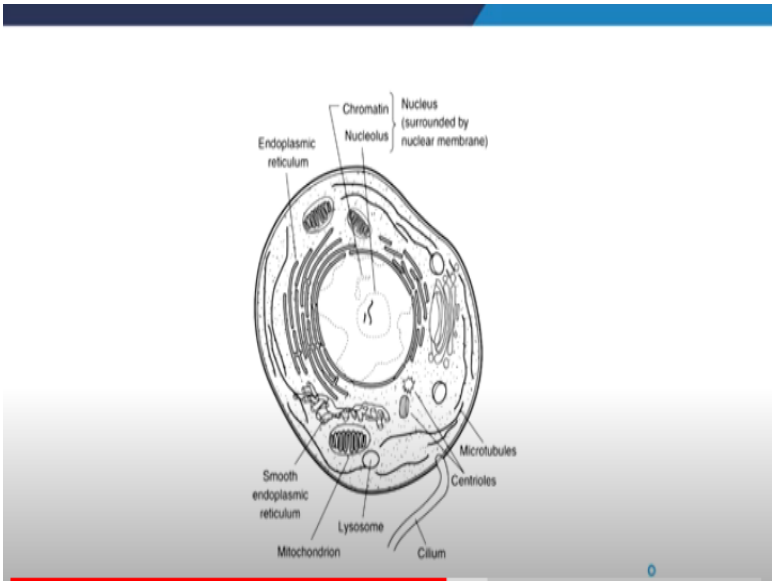

Here you can see the eukaryotes or one particular example out here and you see the nucleus, you need to see the membrane, the cell wall and so forth but relatively simpler forms and relatively complex forms of life.

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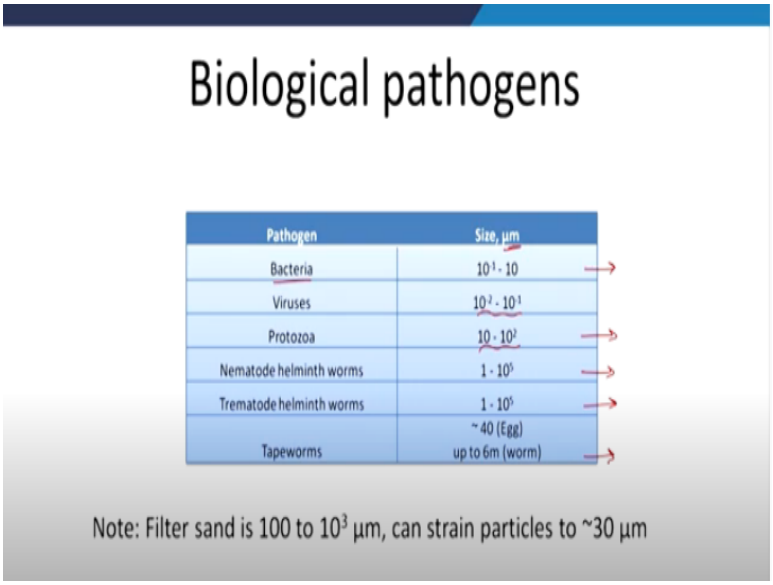

Why do I need to understand this because we when we are treating wastewater we are looking at removal of organic content as we discussed we are looking at removal of suspended matter. We are looking at removal of pathogens too, pathogens and if you are looking at tertiary treatment then nitrogen and phosphorus the nutrients. Pathogens to be able to choose a good disinfection process.

Or to be able to understand the cause for an outbreak of disease we need to be able to understand at least what are the major pathogens and such. Here we have a classification with size. We looked at this earlier. Bacteria this is microns micrometers 0.1 to 10. Viruses much smaller one orders of magnitude smaller. Protozoa are relatively much bigger. Eukaryotes and prokaryotes.

Then the worms you can see the big size and tapeworms with respect to sanitation if you have issues tapeworms. In that context we looked at this particular piece of information. Filtered sand can strain particles up to 30 micrometers. We saw that one of the greatest advancements in health was not due to a medical advancement.

But due to an engineering innovation wherein people started using filtered sand or sand to filter water. That itself removed a lot of or considerable sections of pathogens and then disinfection.

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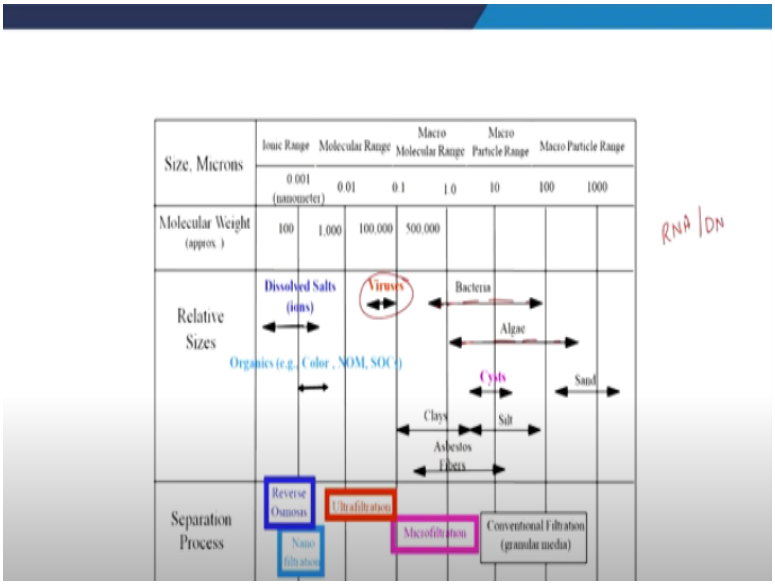

We have this size out here bacteria and algae but what about these viruses? Remarkably small viruses they just have RNA or DNA and with the corona crisis in vogue most people are certainly aware of viruses. But for the sake of providing general information or knowledge if I may say so in the form of RNA or DNA, but they need a host.

Humans can be hosts you have different other hosts. Once they get into a host they more or less use the host's metabolic process to replicate. These are Layman's terms, but we have different

viruses. Typically, with conventional filtration as you see we can look at removal of most of the bacteria or considerable section of bacteria and eukaryotes but not the viruses.

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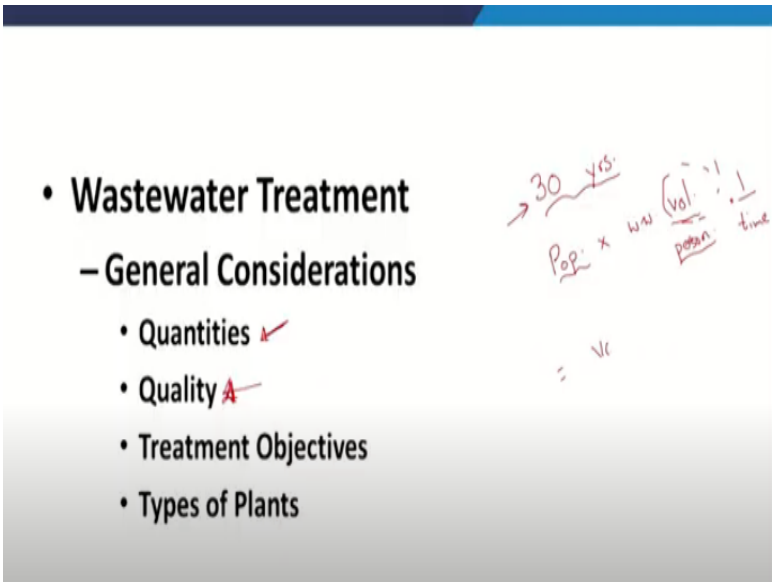

Until now we discussed or looked at quality, and then for example I need to choose what kind of process I am going to look at quality. But when I am going to look at what we say just quality I cannot really understand the size or come up with designing the size of my particular unit, the size of my tank and then the hydraulic retention time or so on and so forth. How do I get that information?

I cannot get that information. For that I need to understand the quantity of wastewater that is coming in and the variation of this particular quantity with what we say time either, day, hour or year. That is something to keep in mind. In general, I came to know that or I know rather that for wastewater pardon me sewage treatment plants in general we look at a design period for 30 years.

You are going to look at what we say forecasting the population for that relevant area and then you will get the design flow rate or such. But how do we get this design flow rate? I know the population for which I am designing this. I said it is going to be relevant to a 30 year period. I need to know the waste water or volume generated per person. Then I will be able to calculate what we say the volume for the relevant period or such is it per time per day or such.

Per time is a factor out here, then I will more or less get volume per time. But the issue is this particular wastewater that I leave or let out from my home is not going to be the same throughout the day or throughout the year. It depends on the relevant season. People with the garden you will have much more water usage. People without it relatively lesser people with water closets large volume of flushing people with Indian style restrooms or bathrooms relatively lesser volume or usage.

Then depending on class you are going to have different levels of water usage. It is going to be dependent upon or the wastewater generation is going to be depend upon the population, the kind of population and the population.

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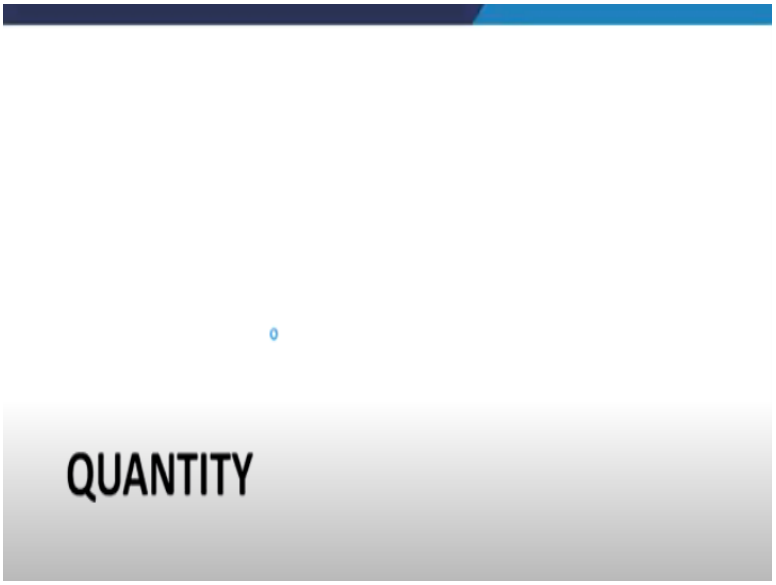

We are going to look at quantity.

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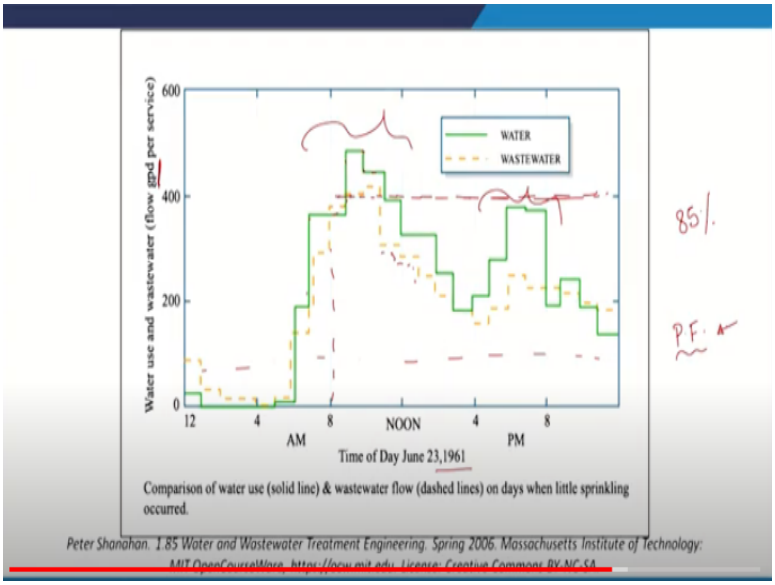

In that context where you believe we already looked at this graph . Please note that this is from the US but long ago. But it is pretty reflective, at that time people were waking up way early. But I am assuming that in India it is going to shift to the right. You see that the wastewater generated which is this dotted line more or less is in line with the water that is being consumed.

Typically, in India we assume that its wastewater generated is around 85% of the water that is being consumed at least in India. But here with habits we see that in the morning the flow rate is higher. We have here it is units of gallons per day. One gallon is 3.7 liters and then during work day relatively less and in the evenings, it picks up a bit. In late night relatively nil and then it increases remarkably.

These are the aspects you need to take into account or understand when designing your wastewater treatment plant. For example, I cannot just design for this particular flow rate. It is going to be uneconomical and also even difficult to operate. But if I choose a remarkably low value during this high flow time periods, I am going to face an issue. You are going to typically look at the average while also looking at the peak factor.

But in India people really do not look at peak factor. They look at average annual flow rates or such or expected flow rates. But we see that the data indicates that there is considerable variation.

If you want to build a wastewater treatment plant that is relatively more functional and relatively more effective it is always better to gather the local data if possible and then design your wastewater treatment plant. I have some more data out here.

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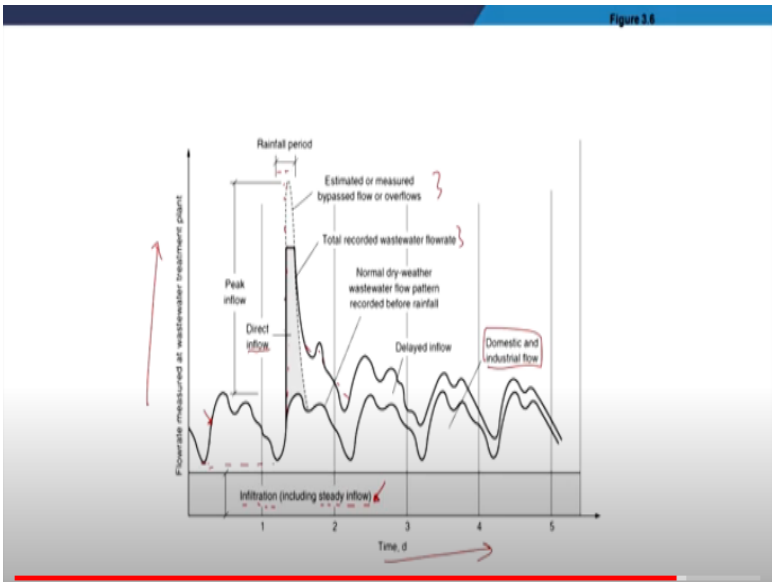

Here we have time in days out here and flow rate measured at wastewater treatment plant on the y axis flow rate. Different days so here we have our particular domestic and industrial flow. That is what you see out here. We see that the minimum is always greater than 0. That is because of infiltration as a study in inflow. But if the groundwater table is less or at least in a developing country like India chances of infiltration can be relatively less at least in Indian context.

That is something to keep in mind, and then what do we have? Let say we have a rainfall period out here. Or mostly in India you have open sewers. Only now are we going for underground sewers and such. In India we have combined sewer networks both for the storm water and for your sewage, domestic sewage. A lot of the runoff from the rainfall or rainfall events typically ends up in your wastewater treatment plants.

That is why you see that just after this rainfall period you see a considerable spike in your flow into the wastewater treatment plant. Typically, all this waste is relatively diluted. People just let it flow out if the concentrations are within the thresholds. What do we have these we classify as direct flow coming into the relevant drains.

Total recorded wastewater estimated or measured bypass flow or overflow. That is a different aspect and then normal dry weather pattern recorded before rainfall. But that is not reached immediately even after the rainfall event. Why? You have delayed inflows. But in the context of India with respect to your high, what we say built up area we would not have a lot of delayed inflow.

But yes, you will have some delayed inflow. After some days or such the flow rate is going to come back to normal. But in India unlike in other countries, we have considerable rainfall during a short period of the year. You are going to have repetitive events like this. That is what we see out here. The issue is, do you just design for this particular flow rate or which flow rate ?

In this context people look at peak flow. At least in the US the design flow rate is the average annual flow rate. But with the rider that the equalization tank will be based on considering the peak factor. We have a figure that will explain this in greater detail. Q peak flow rate at the peak by q average. Peak it can be hourly peak or the maximum one hour flow rate that you saw within that one year or such or it depends, it can be a month maximum what we say monthly flow or such.

You will look at that peak factor and then depending upon your sewage treatment plant's capacity you will think of adding an equalization tank or not.

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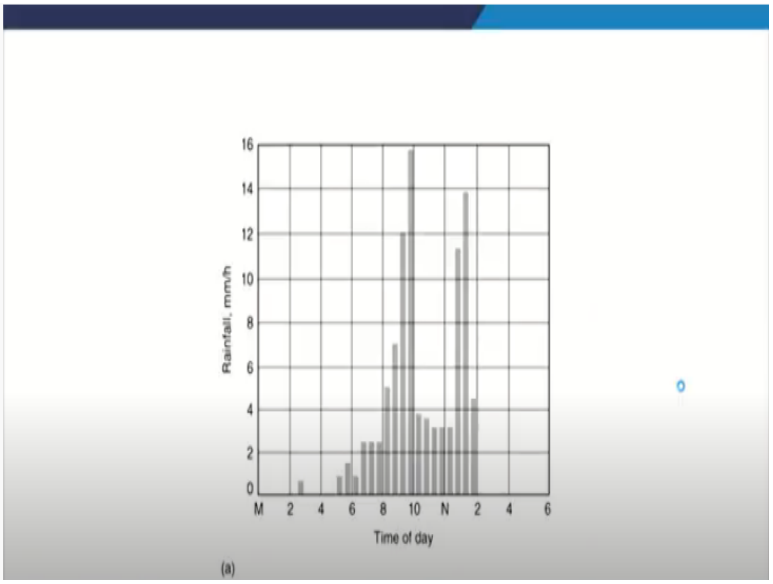

Let us move on with respect to rainfall. Here we have a hyetograph now, rainfall and time of day, how much rainfall in millimeters per hour so, that is what we have out here. Considerable rainfall around 10 am and then noon.

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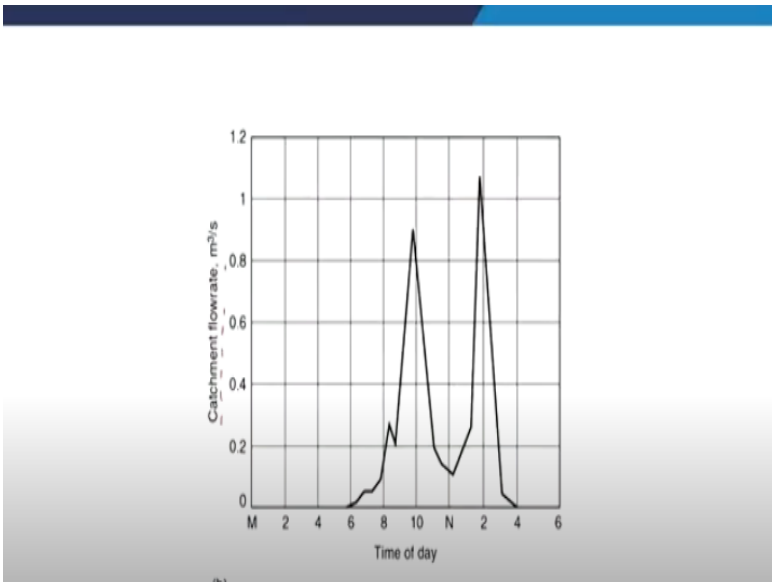

If you look at the hydrograph where we have the catchment flow rate, we see almost a similar profile being captured. You can see the relevant profile. The time scale is the same please note that. More or less similar profile means that the time for flow is relatively less. That is one thing to keep in mind. In other cases, the time will be can typically higher.

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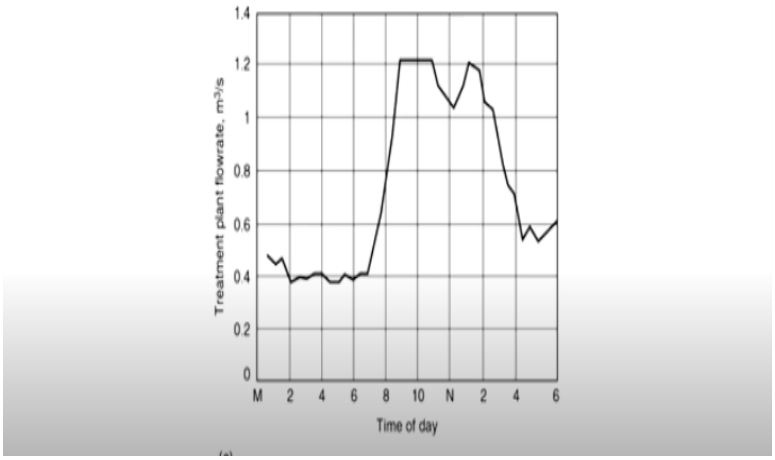

But for the same catchment area the wastewater treatment plant you see that the peaks are averaged outlets. That depends upon the flow coming in throughout the day and also the kind of sewerage network that you have and the kind of storm water control or diversion networks that you have. With that I will end today's session because I am almost out of time. But in the context of wastewater treatment, we understand two aspects or need to understand two aspects.

Quantity as in how much water is coming in and then quality as in the concentration why is that? When I look at the quantity and then the quality as in the concentration of the relevant variables of concern, I will be able to get the mass. Once I get the mass, I will apply the mass balance. As we generally say everything is about mass balance now. With that thanking you for your patience. I will end today's session.