Water and Waste Water Treatment
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Lecture -12
Waste Water Treatment Plant: Basic Principles

Hello everyone welcome back to the latest lecture session. We were just stepping into wastewater treatment and relevant aspects rather we started discussing wastewater treatment and relevant aspects. In that context we looked at the general variables of importance or relevance to our particular UG course. We looked at organics in the context of BOD, COD suspended solids nitrogen and phosphorus nutrients and pathogens.

More or less, these are what we say parameters we want to decrease or are concerned with in the context of wastewater treatment. Obviously we also want to understand how much is coming in, only then can I design or look at the volume or you know estimate how much time the water can or will stay in my particular tank, and see if that particular time is good enough or not, for the relevant treatment so let us move on.

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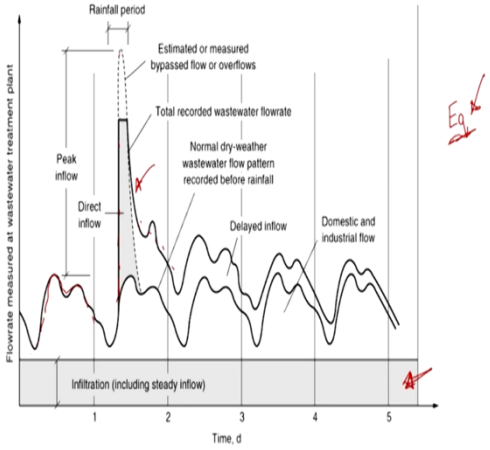

We started discussing this aspect and we saw that you know within the day there will be variation and depending on external events like rainfall you will have variation that is typically seasonal variation. You can have steady state flow but typically in Indian conditions you will not have that.

But within the day certainly you will have variation and within the season 2 you are going to look at variation.

To take care of this people build equalization tanks you are letting the flow come in and let us say I am building an equalization tank with retention time of 10 hours let us say. What will that help me or such or how will that help me? It will sit with that if I am having continuous mixing. If I am having it, the concentration is more or less the same within that equalization tank before it goes to my particular unit process.

Please note that these unit processes at least in wastewater treatment plant typically include a biological process where the bacteria are going to degrade or oxidize your particular or help in or catalyze oxidation of your waste which is the substrate or food for these microbes now. Similar to us let us say bacteria do not like shock loads. The term is shock loads or to eat a lot within a shorter period of time.

Typically, we are healthy when we sleep well, we maintain our, fitness and eat limited amount and more or less the same amount every day. If you eat a lot within a short period of time or do not eat, for a longer period of time obviously you are going to be affected. Similarly let us say I would like to use Layman's terms and use that analogy or apply that analogy to the microbes.

You want to avoid shock loads. Equalization tank will help in that other than that let us say you are dosing a chemical and typically let us say if you do not have accurate flow measurement devices or let us say the concentration of your particular compound that you are going to target is varying you are going to unnecessarily underdose your particular compound.

To rule out these aspects let us say and have a better functioning or more effective treatment plant equalization tank can be built. But again, in India at least sewage treatment plants people do not go for equalization tanks but that is another story.

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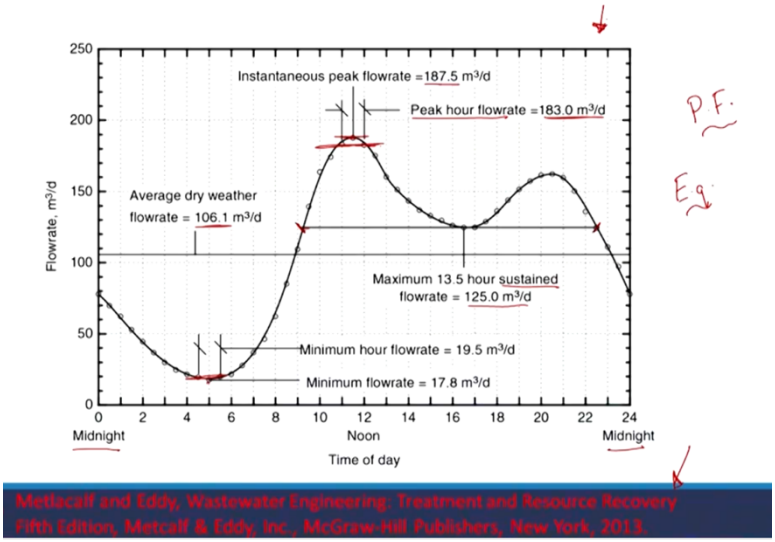

Here is data from dry weather day. What do we have here we been starting at midnight to midnight 24 hour period as we see it is peaking around 10 am or such this is from relatively recent data and again the reference is given out here Metcalf and Eddy this is the fifth edition. What do we have out here? We have an increase in the morning, when people go through their daily ablutions.

Then it decreases during noon and then again another peak during the evening and obviously a constable decrease during the night. That is what you see out here and the average dry weather flow is somewhere out here it is 106 meter cube per day. That is something to keep in mind. In the previous session before we ended the session we were talking about peak factor that will give us an idea about the peak.

But the peak is not an instantaneous peak the absolute peak for this day is this particular point instantaneous peak flow rate is 187. But I am not really concerned with this. Instantaneous peak flow rates I am concerned about sustained peak flow rates. What is the maximum flow that was maintained for an hour or two hour period? Let us say the peak hour flow rate as we can see is out here.

We see is, people mention that as 183 meter cube per day. This peak factor typically people use or at least in the developed countries people look at the 2 hour maximum. Here we have the peak hour flow rate, 2 hour peak flow rate let us say. That is what we are looking at for a sustained

period what is the flow rate that was held the maximum flow rate that was sustained for a given period of time.

Here the time is for 1 hour and for example here for a 13 and half hour period the flow sustained flow rate was 125 meter cube per day for 13 hour or 13 and half hour period let us say. Peak flow rate will be lesser when the time frame that we are considering is greater because it is going to or we are going to look at the sustained flow rate. We will also look at the minimum.

The absolute minimum flow rate and the minimum hourly flow rate let us say. How do you take this variation into consideration when you are designing the treatment plant is of general concern let us say. As I mentioned typically we would like to go for equalization tanks but in India people do not but again there are quite a lot of industrial wastewater treatment plants would certainly go for that and some sewage treatment plants too.

In general it is always better to get the data if you can but in India data availability is always an issue. People go for the average let us say. That is something to keep in mind.

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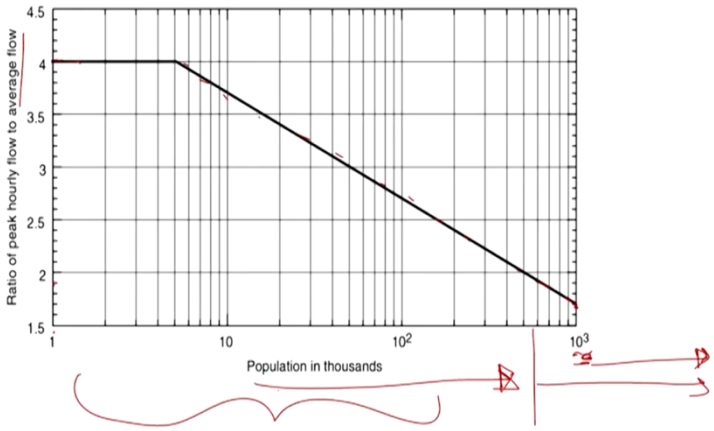

One other aspect is if we look at the ratio of peak hourly flow to average flow which will give us an idea about the variation. If I look at what this, this is 106 and this is 183. It is around 1.8 times higher the peak hourly flow rate, is 1.8 times higher than my average flow rate. But as you can see

in for smaller communities this ratio will be pretty high and for larger communities as you see increasing population, population in thousands.

Please note that, population in thousands here and also again logarithmic scale. Out here we see that for 1 million or 10 power 6 population you see that the peak flow rate or the variation is much less because you have a lot of people lot of activities. The flows average out in general that is one way to put it. That is something to keep in mind. India at least as of now we are not really capturing this level of population.

We are at least certainly out here or relatively or we are building STPs only for this level of population starting from somewhere around here as we develop as a country and you know greater what we say capital available for infrastructure development say we are going to, look at capturing the sewage from these particular communities too. That is one thing to keep in mind.

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CPHEEO Manual 2013

Table 3.2 Peak factor for Contributory Population

Contributory Population	Peak Factor
up to 20,000	3.00
Above 20,001 to 50,000	2.50
Above 50,001 to 7,50,000	2.25
above 7,50,001	2.00

This is the CPHEEO manual or I am just referring to it for the first time. I think it was last updated in 2013 if I am not wrong. It is relatively detailed at least for the Indian context and it will give you an idea about the design, the maintenance, the financial aspects and such with respect to the Indian context. That something that you can always look at. In this particular table what do we see we have the peak factor for contributory population.

As you see for population between 50000 to 7 and a half lakh from where we typically are the range above which we typically start building sea waste treatment plants in India. We see that you know the peak factor is relatively less compared to the case when the population is low. But again, India they are not really looking at peak hourly flow rate or 2 hour peak flow rates as they do in the relatively developed countries.

Because again we are some way off out here again if we are looking at the bigger populations you see that the flow averages out and that is what we see out here.

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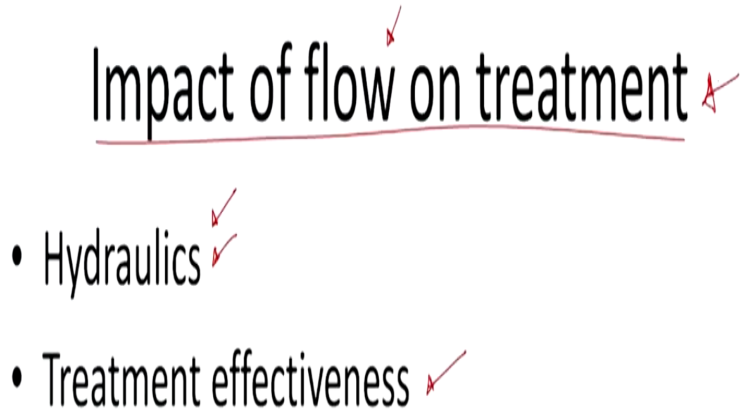

Let us just discuss why I need to be concerned about this variation in flow with time. One is obviously the impact on hydraulics. If you have uniform flows your particular hydraulics and the relevant machinery are going to last for not hydraulics. The machinery is going to last for longer or you will really need to be varying your pump capacity not capacity, usage and such depending on the flow rate inside.

Hydraulics plays a role with respect to the machinery. Other aspect is let us say right now I have a tank of this size and that is designed for the average flow but let us say if I have peak flow and my particular design did not take that into account let us say, what is going to happen I am going to have to increase the discharge and if I increase the discharge, that means my wastewater is not spending enough time in my reactor.

The discharge standards or the concentration of the organics in my particular effluent or the discharge are not going to be at the level that I decide because they are spending lesser time in the reactor. These are the aspects that obviously we need to be concerned about and another aspect is treatment effectiveness; we have typically two major classifications preliminary treatment and secondary treatment.

Preliminary treatment we are talking about sedimentation or coagulation and flocculation if used or such let us say they depend on gravity and so they are not very sensitive to changes in flow because gravity ever present, or you can easily know change the dose. Their effectiveness is not very much affected or adversely affected by flow or time varied flow.

But then you have your biological process in the secondary treatment we talk about secondary treatment where we are looking at removal of the dissolved organics by biological process or by the microorganisms. Obviously as I mentioned they are living things if I may say so living what we say life their life. They obviously do not want to experience shocks either with respect to temperature or their food which is are waste.

Obviously you want to look at or minimize shock loading and the other aspect though is that even without an equalization tank if you design your particular biological process in such a way that you know we capture the relevant peaks because HRT let us say we capture the relevant peaks such that we have for a given outflow or constant outflow or semi constant outflow more or less you are going to be able to handle the flow for that particular in flow even though the peak factor is around two.

That way you can reject the design without any equalization tank. One aspect is that the flow can affect your treatment effectiveness.

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Country/ constituent	BOD, g/capita·d	TSS, g/capita·d	TKN, g/capita·d	NH_3-N, g/capita·d	Total P, g/capita·d
Brazil	55–68	55–68	8–14	ND	0.6–1
Denmark	55–68	82–96	14–19	ND	1.5–2
Egypt	27–41	41–68	8–14	ND	0.4–0.6
Germany	55–68	82–96	11–16	ND	1.2–1.6
Greece	55–60	ND	ND	8–10	1.2–1.5
India	27–41	ND	ND	ND	ND
Italy	49–60	55–82	8–14	ND	0.6–1
Japan	40–45	ND	1–3	ND	0.15–0.4
Palestine[b]	32–68	52–72	4–7	3–5	0.4–0.7
Sweden	68–82	82–96	11–16	ND	0.8–1.2
Turkey	27–50	41–68	8–14	9–11	0.4–2
Uganda	55–68	41–55	8–14	ND	0.4–0.6
United States[c]	50–120	60–150	9–18	5–12	1.5–4.5

[a] Adapted from Tchobanoglous et al. (2003).
[b] West Bank and Gaza Strip.
[c] From Table 3–13.

Metlacalf and Eddy, Wastewater Engineering: Treatment and Resource Recovery
Fifth Edition, Metcalf & Eddy, Inc., McGraw-Hill Publishers, New York, 2013.

Let us look at the concentration of the relevant compounds that we are concerned with. Here we have the organics which we are measuring by BOD and suspended solids and then nitrogen content and then phosphorus. We have different countries and India is out here. We obviously do not have at least these people did not have the data for suspended solids nitrogen and ammonia.

But at least with respect to BOD you see that we are relatively lesser compared to most of the what we say or we are at the lower end let us say, only Egypt is along with us at least in these countries. We see that it depends upon what we say the level of development let us say. Is it relatively more developed country or developing country and the kind of food habits obviously will play a role relatively more vegetarian or non-vegetarian food intake.

Obviously class or purchasing power obviously is going to affect your particular quantity of waste you are going to give out. Here we have BOD in grams per person per capita meaning per person per day. As you see in India we are Indians, are relatively contributing less waste to nature. That is something to keep in mind but obviously with increasing industrialization and increasing purchasing power even our contribution of waste to nature is increasing now.

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Contribution of human wastes in grams per capita per day

CPHEEO

Parameters	Range
BOD	45-54
COD	1.6-1.9 times BOD
TOC	0.6-1.0 times BOD
Total solids	170-220
Suspended solids	70-145
Grit(inorganic, 0.2mm and above)	5-15
Grease	10-30
Alkalinity as $CaCO_3$	20-30
Chlorides	4-8
Total Nitrogen	6-12
Organic Nitrogen	~0.4 total N
Free Ammonia	~0.6 total N

Another aspect is contribution of human waste in grams per capita per day. But now the information is from that CPHEEO manual that I mentioned earlier I would suggest that you look that up. Per day but again this is relatively more recent now. BOD we are now at 45 to 54 COD around 2 times higher organic carbon and such let skip that suspended solids 70 to 145 grams per day and ammonia too total nitrogen, not ammonia total nitrogen 6 to 12 grams per day. You can understand the relevant range or masses that we are giving out per person per day.

(Refer Slide Time: 15:08)

Contribution of human wastes in grams per capita per day

Parameters	Range
Nitrate	~0-0.5 total N
Total Phosphorous	~0.6-4.5
Organic Phosphorous	~0.3 Total P
Inorganic (Ortho and Poly Phosphates)	~0.7 total P
Potassium as Pottasium Oxide	2.0-6.0

Microorganisms in 100 ml of Sewage

Total Bacteria	10^5-10^{10}	Protozoan cysts	Up to 10^3
Coliforms (F. Col)	10^8-10^{10}	Helminth eggs	Up to 10^3
Faecal streptococci	10^5-10^{16}	Virus(Plaque forming units)	10^2-10^4
Salmonella Typhosa	10^1-10^4		

Then what else are we typically concerned with. I am concerned with total phosphorus and you see out of that inorganic is around what we say 70% again we are talking about Ortho and Poly but please note that typically only Ortho is relatively more easily used up by the relevant microbes.

And then again, we have some information about the amount of microorganisms that are present in sewage.

What do we have? We have total bacteria remarkably high coliforms fecal streptococci salmonella and so on and so forth. In this context I should mention one aspect which I seem to have missed earlier when we were talking about pathogens when I was talking about pathogens. I mentioned what is prokaryotes, eukaryotes and the major differences between them. But you know what is it or how am I going to measure them.

I cannot measure each of these kinds of bacteria or the pathogens. There are a lot of pathogens out there. How can I measure everything now that is not going to be economically feasible. What do I do? I am going to look at an indicator organism and what is it that? This indicator organism should be able to indicate obviously it needs to indicate the presence of pathogens.

This indicator organism should always be present when the pathogen is present, that is one aspect and the ratio of the concentration of this indicator organism to the concentration of this pathogen should always be relatively constant. That I get an idea about the actual pathogen based on this indicator organism. Also this indicator organism should be tough and sturdy it should persist in the natural environment it should not be too fragile to say so.

Then it should be easily measurable. For that we look at coliforms as an indicator. Total coliforms for wastewater that is the way we measure it with respect to pathogens. Fecal coliform we use when we are talking about, drinking water or I think it is the other way around. We are going to typically look at total coliform and what is it now fecal coliform again these are indicator organisms we have different ways to measure them let us say.

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Per capita water consumption in India

Conditions	Consumption (liter per head per day)
For communities with populations up to 20k (water supply through house service connection)	70 – 100
For communities with population 20k to 100k with full flushing system	100 – 135
For communities with population above 100k together with full flushing system	150 - 200

Estimation of water requirement for drinking and domestic use (Source: NBC 2016, BIS)
http://cgwa-noc.gov.in/LandingPage/Guidlines/NBC2016WatRequirement.pdf

The amount of wastewater obviously depends on how much water the family or the person is consuming. Obviously depends again on the location, the purchasing power of the relevant community and such. Relatively smaller communities but those with house service connection 7 to 100 liters per day and typically 85% of the waste is I mean water consumption is what we presume to be the wastewater that is going to be discharged from that particular house.

Relatively higher population with full flushing. We see that, it is relatively higher again flushing as we saw in one of the earlier slides you know takes up I think almost 40% at least 40% of the wastewater generated or contributes to 40% of the generated wastewater in developed countries and that is where we will also lead to or end up. If we do not take different conservation measures or end up adopting relatively more what we say efficient flushing systems.

Communities with population above 100k with flushing system, so again this is the range and from here you can get an idea about the amount of wastewater per person per day. Then we have the masses that we are generating per day and from that you can get the relevant concentration.

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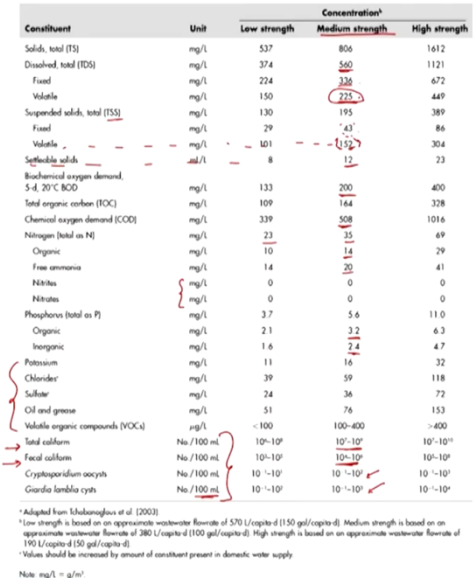

Constituent	Unit	Concentration[a] Low strength	Medium strength	High strength
Solids, total (TS)	mg/L	537	806	1612
Dissolved, total (TDS)	mg/L	374	560	1121
Fixed	mg/L	224	336	672
Volatile	mg/L	150	225	449
Suspended solids, total (TSS)	mg/L	130	195	389
Fixed	mg/L	29	43	86
Volatile	mg/L	101	152	304
Settleable solids	mL/L	8	12	23
Biochemical oxygen demand, 5-d, 20°C BOD	mg/L	133	200	400
Total organic carbon (TOC)	mg/L	109	164	328
Chemical oxygen demand (COD)	mg/L	339	508	1016
Nitrogen (total as N)	mg/L	23	35	69
Organic	mg/L	10	14	29
Free ammonia	mg/L	14	20	41
Nitrites	mg/L	0	0	0
Nitrates	mg/L	0	0	0
Phosphorus (total as P)	mg/L	3.7	5.6	11.0
Organic	mg/L	2.1	3.2	6.3
Inorganic	mg/L	1.6	2.4	4.7
Potassium	mg/L	11	16	32
Chlorides[c]	mg/L	39	59	118
Sulfate[c]	mg/L	24	36	72
Oil and grease	mg/L	51	76	153
Volatile organic compounds (VOCs)	µg/L	<100	100–400	>400
Total coliform	No./100 mL	10^6–10^8	10^7–10^9	10^7–10^{10}
Fecal coliform	No./100 mL	10^3–10^5	10^4–10^6	10^5–10^8
Cryptosporidium oocysts	No./100 mL	10^{-1}–10^2	10^{-1}–10^2	10^{-1}–10^3
Giardia lamblia cysts	No./100 mL	10^{-1}–10^2	10^{-1}–10^3	10^{-1}–10^4

[a] Adapted from Tchobanoglous et al. (2003).
[b] Low strength is based on an approximate wastewater flowrate of 570 L/capita-d (150 gal/capita-d). Medium strength is based on an approximate wastewater flowrate of 380 L/capita-d (100 gal/capita-d). High strength is based on an approximate wastewater flowrate of 190 L/capita-d (50 gal/capita-d).
[c] Values should be increased by amount of constituent present in domestic water supply.

Note: mg/L = g/m³.

150 mg/L BOD

Just for comparison, we have this we have low strength medium strength and high strength wastewater, this is sewage not sewage treatment. Total dissolved solids I am just going to look at medium strength for now 560 fixed and volatile that gives you an idea about the relatively inert and more and the organic content this is within the dissolved solids. Even within suspended solids you will have some organic content that is obviously seen from here.

Fixed is 43 and here we have what are those organic content that suspended and here is the organic content that is dissolved and settleable solids which is seems to be relatively less again units are milli liter per liter, and all the other units are mostly milligram per liter. And BOD we see it is around 200 typically in India 150 or such. Then COD is 500 again relatively higher for Indian scenario 300 or so in India.

Nitrogen ranges from 20 to 30 and of that typically nitrates relatively lesser because you know you need oxygen for them to be formed and obviously as you can see organic content or organically bound nitrogen and free ammonia are neck to neck more or less the same. Phosphorus you see organic which is relatively difficult to degrade and inorganic, this differs from the data that was given out by CPHEEO for Indian conditions anyway.

There they mentioned that the inorganic phosphorus was relatively higher, almost 70% if you remember. And then relevant other parameters of interest and then here we have the total coliform

and fecal coliform. We have considerable concentrations of this coliforms and different cysts. Considerable numbers per 100 ml sample. More or less in India at least it is 150 again this is the not 150, 150 milligram per liter BOD and COD typically twice or two and half times.

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Characteristics of Raw sewage at inlet of STP at IIT Roorkee

S. No.	Inlet Parameters of Raw Sewage	IITR (after sewerage network, 2019)	Typical	Effluent quality (CPHEEO guidelines)
1	pH	7.35	6.5 - 8	6.5–8.5
2	Biochemical Oxygen Demand (BOD5) at 20°C, mg/L	270	50-130	≤ 10
3	Chemical Oxygen Demand (COD) , mg/L	535	100-350	≤ 50
4	Total Suspended Solids (TSS) , mg/L	250	100-400	≤ 10
5	Total dissolved solids(TDS), mg/l	753	36	
6	Nitrogen, mg/l	29	40	≤ 10
7	NH_4-N,mg/l	12	12 to 25	
8	NO3-, mg/L	6.8		
9	Phosphorous-P, mg/L	12	2 to 4	≤ 2
10	Total Coliform, MPN/100 ml	<10^7	<10^7	
11	Fecal Coliform, MPN/100 ml	<10^5	<10^5	< 100
12	Free/Residual Chlorine (at treated outlet)			0.3-0.5

But for IIT Roorkee which I have this for IIT Roorkee let us say given and taken in 2019 after the sewerage network was more or less built, what do you have? Let us look at the typical value. Ph fine BOD obviously on the higher side COD too on the higher side again depends on the type of usage too. It is not just residential community you have considerable numbers of what is the amount of research going on.

The relevant compounds that probably should not be dumped into the sewage are being dumped. But again, that something we are taking care of this year let us see. Suspended solids dissolved solids but at that time there was a rainfall event that is why this there was considerable not rainfall event there was another issue for this dissolved solids and then nitrogen relatively lesser may be because of the vegetarian community.

Nitrates are relatively higher for some reason could be due to compounds being discharged directly and then phosphorus and then fecal and such coliform. And these are the guidelines as an after treatment to what level should that be brought down these are the latest guidelines and as you can

see BOD has to come to less than 10 and that is a considerable ask and COD also has to come to less than 50 milligram per liter BOD and COD.

Fecal too or coliform too as you can see from 10 power 5, 3 order magnitude decrease to less than 10 power 2. That something to keep in mind, considerable decrease and though they do not specify about they are now also talking about biological or nutrient removal which was not specified earlier. Nitrogen and phosphorous two you have to remove. We are concerned about organic content removal we are concerned about nutrient removal.

We are also concerned about the pathogens and while we take care of this obviously the TDS and TSS will be taken care of let us see while we take care of these aspects let us move on.

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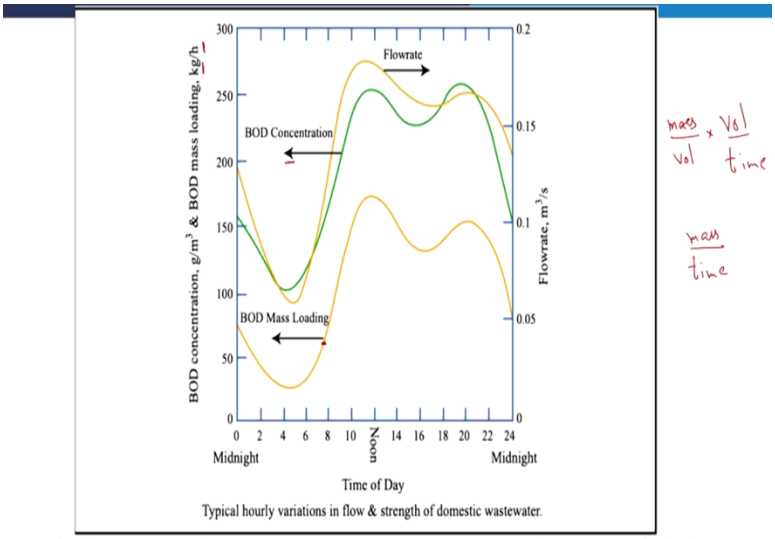

One aspect is concentration but obviously we are concerned with masses it is not just concentration, concentration is mass per volume. I need to look at the mass not just mass per volume so I need to look at the flow rate flow is how much water is coming in per time. With that I will get mass per time rates. That is this BOD mass loading mass per time. That is the graph we are typically more concerned with.

But for general sewage you see that the trends are relatively similar with respect to flow rate concentration and the BOD mass loading. That is something to keep in mind.

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General standards for Discharge of Environmental Pollutants, Part A: Effluents as per Schedule VI of the Environmental (Protection) Rules 1986 and National River Conservation Directorate Guidelines for Faecal Coliforms, (Values in mg/l unless stated)

Characteristics	Standards			
	Inland surface water	Public sewers	Land for Irrigation	Marine coastal areas
Colour and odour	Remove as far as possible			
SS	100	600	200	100
Particle size of SS	850 micron passing	-	-	Floatable max 3mm Settleable 850 micron max
pH value	5.5 to 9.0			
Temperature	Not exceed 5 degree C	-	-	Not exceed 5 degree C
Oil and grease	10	20	10	10
Total Chlorine residue	1	-	-	1
Ammonical Nitrogen as N	50	50	-	50
Total Kjeldahl Nitrogen as N	100	-	-	100
Free Ammonia as NH3	5	-	-	5

The general standards for discharge again the relevant schedule and the environmental protection rules first came about in 1986. Here we have national river conservation directorate guidelines but we will look at that later. Earlier as I was mentioning where do you have BOD, suspended solids and such obviously when they are talking about suspended solids that is why they are as I mentioned you need to give the relevant filter size.

That is why they mention the filter size. Ph is and such is fine. Nitrogen remarkably higher value but that is considering the total Kjeldahl nitrogen let us say.

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Characteristics	Standards			
	Inland surface water	Public sewers	Land for Irrigation	Marine coastal areas
BOD	30 10	350	100	100
COD	250 50	-	-	250
Arsenic		0.2		
Mercury	0.01	0.01	-	0.01
Lead	0.1	1.0	-	2.0
Cadmium	2.0	1.0	-	2.0
Hexavalent Chromium	0.1	2.0	-	2.0
Total Chromium	2.0	2.0	-	2.0
Copper	3.0	3.0	-	3.0
Zinc	5.0	15.0	-	15.0
Selenium	0.05	0.05	-	0.05
Nickel	3.0	3.0	-	5.0
Cyanide	0.2	2.0	0.2	0.2
Flouride	2.0	15.0	-	15.0

Here earlier BOD was 30 now as I mentioned the discharge standard is 30 not 30, 10 and COD is 50 milligram per liter not 250 but earlier as you see it was relatively higher. And then you have concentrations of different heavy metals but in general in sewage or domestic sewage if there are no industrial sources typically you will not get heavy metals. But in India you have commercial enterprises and houses in close proximity and we do not have separate networks.

Depending on the community and type of work they are engaged in sometimes heavy metals might be high. You will have to look at it because heavy metals at high concentrations are not just toxic to humans they are also toxic to microbes but obviously their threshold is relatively higher if especially you can design the relevant primary treatment process. That is something to keep in mind. BOD, COD and then.

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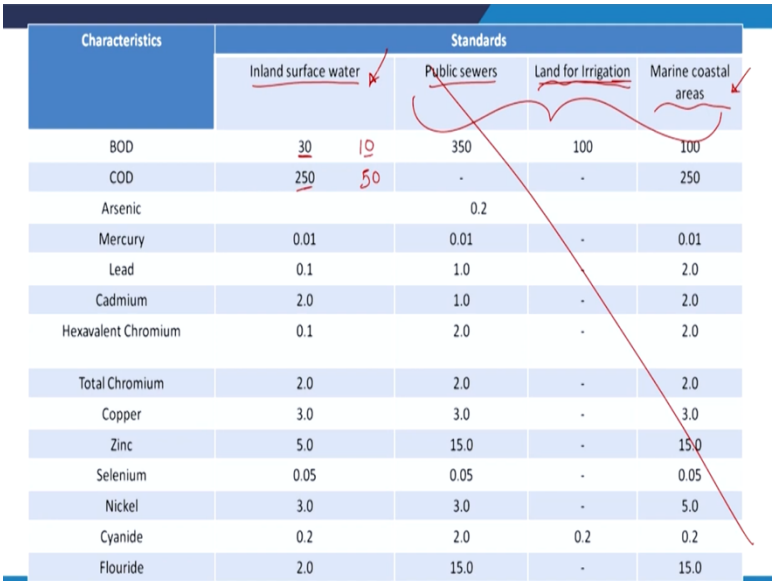

Characteristics	Standards			
	Inland surface water	Public sewers	Land for Irrigation	Marine coastal areas
BOD	30 10	350	100	100
COD	250 50	-	-	250
Arsenic		0.2		
Mercury	0.01	0.01	-	0.01
Lead	0.1	1.0	-	2.0
Cadmium	2.0	1.0	-	2.0
Hexavalent Chromium	0.1	2.0	-	2.0
Total Chromium	2.0	2.0	-	2.0
Copper	3.0	3.0	-	3.0
Zinc	5.0	15.0	-	15.0
Selenium	0.05	0.05	-	0.05
Nickel	3.0	3.0	-	5.0
Cyanide	0.2	2.0	0.2	0.2
Flouride	2.0	15.0	-	15.0

Characteristics	Standards			
	Inland surface water	Public sewers	Land for Irrigation	Marine coastal areas
Flouride(as F)	2	15	-	15
Dissolved Phosphates(as P)	5	-	-	-
Sulphide (as S)	2	-	-	5
Phenolic Compounds(as $C_6H_5O_6$)	1	5	-	5
Radioactive materials				
Alpha Emmitters Micro curie/ L	10^{-7}	10^{-7}	10^{-8}	10^{-7}
Beta Emitters Micro Curie/L	10^{-6}	10^{-6}	10^{-7}	10^{-6}
Manganese(as Mn)	2	2	-	2
Iron (as Fe)	3	3	-	3
Faecal coliforms MPN/100mL for discharge	Onto Land		Into water	
	1,000	10,000	1,000	10,000

We have different standards for fecal coliform and such and one co aspect, I should have mentioned earlier too is that there are different standards for discharging into inland surface water like river or lake and for discharging into public sewers discharging into land for irrigation or into coastal areas but in general this is not practiced and I know that people say that you can use it for irrigation.

But the issue is even with a BOD of 10 milligram per liter COD of 50 milligram per liter you have what we call as or referred to as these emerging contaminants which are remarkably persistent in nature. What happens they come from our waste and if we use that for our irrigation, they enter the food chain now even at levels of BOD of 10 and such and that is why I certainly would not recommend it.

Sometimes people did try this using land for irrigation and the concentration of this persistent organics or even heavy metals in your food grains or your pulses increase considerably. Again, that something that should be looked at in totality discharging to public sewers does not really work in India. In some areas marine coastal area discharge, we do have that but as you see the concentrations allowable for discharging into these three particular outlets, is higher.

Typically we are always concerned with discharging to inland surface water bodies. That something to keep in mind.

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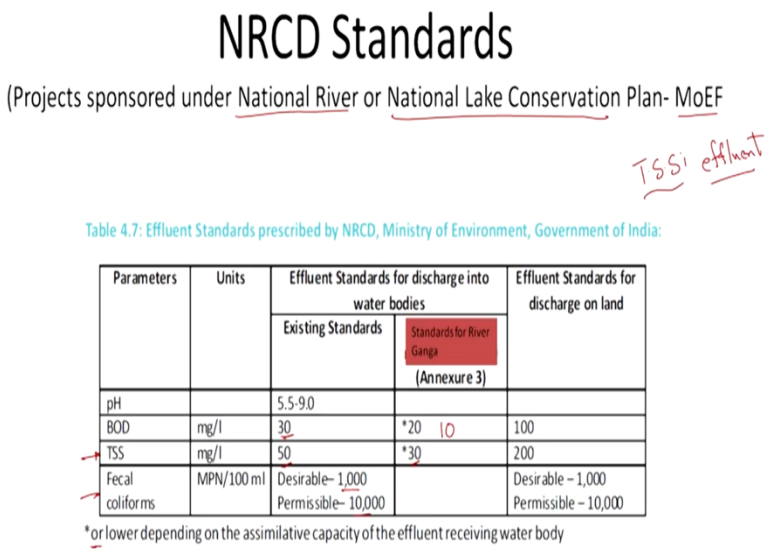

But as I mentioned recently people have been obviously looking at our resources not as limitless but as something that has a finite limit and something that we should pay attention to earlier. With the relatively low levels of population and industrialization that was not an issue but now we are understanding the importance of our resources primarily let us say water and air.

Obviously as you see we have the national river conservation aspects that we discussed about earlier discharge guidelines again by ministry of environment and forests. We will just look at the primary aspects instead of BOD of 30 though I mentioned it 20. It is now people are pushing for 10 and suspended solids instead of what is this 50 we are looking at 30.

One aspect with respect to suspended solids is that at least in the effluent, effluent when you measure the suspended solids you see that it is enclosed proximity or you know rather not close proximity correlates very well with the BOD. That is why if you measure the suspended solids in your waste water that is typically not wastewater, the treated effluent wastewater from a sewage treatment plant that typically gives you some idea about your BOD.

That is one reason obviously why you can look at suspended solids in the treated effluent. But one other disadvantage in just looking at suspended solids is that suspended solids can be inert that have no effect on marine or coastal life or your river. Obviously, you can it is a balancing game

out there. That is one aspect to keep in mind. Fecal coliforms earlier, and now they were asking for much lower value we will look at that.

But obviously there is always a rider or it could be lower depending upon the capacity of the effluent receiving water body. Different states it is a Jammu and Kashmir, Punjab or such have different standards or relatively more stringent standards.

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CPHEEO Guidelines

Table 5.20 Recommended Guidelines for Treated Sewage if Discharged into Surface Water to be used as source of Drinking Water

Parameter	MOEF Standards (A)	Recommended Values
BOD, mg/L	30	Less than 10
SS, mg/L	100	Less than 10
TN, mg/L	100	Less than 10
Dissolved P, mg/L	5	Less than 2
Faecal Coliforms, MPN/100 mL	Not specified	Less than 230

(A) General Standards, Environmental Protection Rule, 1986 & as authorized by PCB

But the issue is about enforcement, how do you enforce? CPHEEO guidelines as I mentioned MOEF standards and then we have the recommended values which are what people are pushing for right now let us say. Recommended guidelines for treated sewage if it is being discharged into surface water being used as a source of drinking water. But India more or less every surface water body is used as a source of drinking water. I have the more what we say recent guidelines.

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CPHEEO Reuse Guidelines

	Parameter	Toilet flushing	Fire protection	Vehicle Exterior washing	Non-contact impoundments	Landscaping, Horticulture & Agriculture			
						Horticulture, Golf course	crops		
							Non edible crops	Crops which are eaten	
								raw	cooked
1	Turbidity (NTU)	<2	<2	<2	<2	< 2	AA	< 2	AA
2	SS	AA	AA	AA	AA	AA	30	AA	30
3	TDS	2100							
4	pH	6.5 to 8.3							
5	Temperature °C	Ambient							
6	Oil & Grease	10	nil	nil	nil	10	10	nil	Nil
7	Minimum Residual Chlorine	1	1	1	0.5	1	nil	nil	nil
8	Total Kjeldahl Nitrogen as N	10	10	10	10	10	10	10	10
9	BOD	10	10	10	10	10	20	10	20
10	COD	AA	AA	AA	AA	AA	30	AA	30
11	Dissolved Phosphorous as P	1	1	1	1	2	5	2	5
12	Nitrate Nitrogen as N	10	10	10	5	10	10	10	10
13	Faecal Coliform in 100 ml	Nil	Nil	Nil	Nil	Nil	230	Nil	230
14	Helminthic Eggs / litre	AA	AA	AA	AA	AA	<1	<1	<1
15	Colour	Colourless	Colourless	Colourless	Colourless	Colourless	AA	Colourless	Colourless
16	Odour	Aseptic which means not septic and no foul odour							

All units in mg/l unless specified; AA-as arising when other parameters are satisfied;

But before we go further as I mentioned we have Delhi out here Madhura, Agra, Ettawah. Huge levels of population and Yamuna flowing. This person sewage after replenishment is going to be this person's drinking water or you know water for different purposes. Soon though we will not have enough water so that we are going to end up at the case at least maybe 100 years down the line.

They are already doing it in some developed countries at least in South Africa where they had no water you are treating it to a great extent such that it can be more or less used as drinking water. Wastewater you treated it to such an extent that it can be used as drinking water people have a mental block but you know it is just about compounds a b c and d and parameters x y z. And if you are able to bring them down or remove them, they are as good as or better than most of the drinking water that is available out there.

People in India are nowhere near being acceptable to or being ready to accept recycled wastewater for drinking. But here we have it for different reuse for toilet flushing. You do not need remarkably treated water for fire protection vehicle washing and so on and so forth. Crops which are eaten raw and cooked but I mentioned the issues out here.

At least in India we can go for toilet flushing because that takes up a lot of volume of water and the issue here is that though you have to have a separate plumbing network which is what we do

not have as of now. Again, different standards are given for this. This is the next step I would say and trying to minimize our footprint and see to it that the water resources which are finite can be reused by us. Let us move on. This is what I wanted to mention

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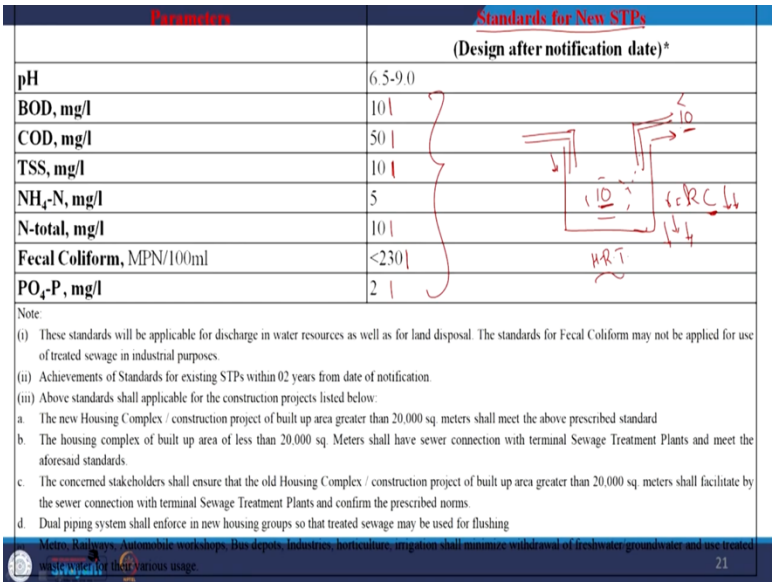

Parameters	Standards for New STPs (Design after notification date)*
pH	6.5-9.0
BOD, mg/l	10
COD, mg/l	50
TSS, mg/l	10
NH_4-N, mg/l	5
N-total, mg/l	10
Fecal Coliform, MPN/100ml	<230
PO_4-P, mg/l	2

Note:

(i) These standards will be applicable for discharge in water resources as well as for land disposal. The standards for Fecal Coliform may not be applied for use of treated sewage in industrial purposes.

(ii) Achievements of Standards for existing STPs within 02 years from date of notification.

(iii) Above standards shall applicable for the construction projects listed below:

a. The new Housing Complex / construction project of built up area greater than 20,000 sq. meters shall meet the above prescribed standard

b. The housing complex of built up area of less than 20,000 sq. Meters shall have sewer connection with terminal Sewage Treatment Plants and meet the aforesaid standards.

c. The concerned stakeholders shall ensure that the old Housing Complex / construction project of built up area greater than 20,000 sq. meters shall facilitate by the sewer connection with terminal Sewage Treatment Plants and confirm the prescribed norms.

d. Dual piping system shall enforce in new housing groups so that treated sewage may be used for flushing

Metro, Railways, Automobile workshops, Bus depots, Industries, horticulture, irrigation shall minimize withdrawal of freshwater/groundwater and use treated wastewater for their various usage.

These are the standards for the new sewage treatment plants that are designed after the relevant notification date as we see BOD standards are 10 COD is 50 suspended solids 10 fecal coliform less than 230 and nitrogen and phosphorus 10 and 2. Slowly but surely, we are pressing for relatively low values but the issue here is that let me see if I have space out here you know that it is a CSTR typically mostly CSTR or even if it is a SBR it is a batch reactor.

What do we know whatever is coming in I should not have mentioned SBR in the same breadth. But if it is a CSTR flow is continuous and flow is continuously going out and if you want to have 10 or less than 10 this has to be operated such that the most of it is less than 10 milligram per liter why is that CSTR whatever is in the tank or the reactor is what will go out. For that you have to have higher HRTs or hydraulic retention times.

As we discussed earlier the CSTR is not really an ideal CSTR you do not have instantaneous dilution but obviously if you are trying to build a reactor going for a plug flow reactor is certainly better. As the kinetics are going to be relatively higher r net for the particular volume as you can see r = k c And the lower I want to achieve the rate here is going to be very less.

This concentration if it is low rate is also the rate of removal. That is an issue that you have out here with the continuous flow systems but obviously with SBR which is a batch reactor or more or less variation of plug flow if you want to think of it that way or with well designed what we say reactors that are more or less or you know are similar to plug flow reactors you can achieve good removal rates but with conventional process which are already built or conventional sewage treatment plants getting to 10 is going to be remarkably difficult.

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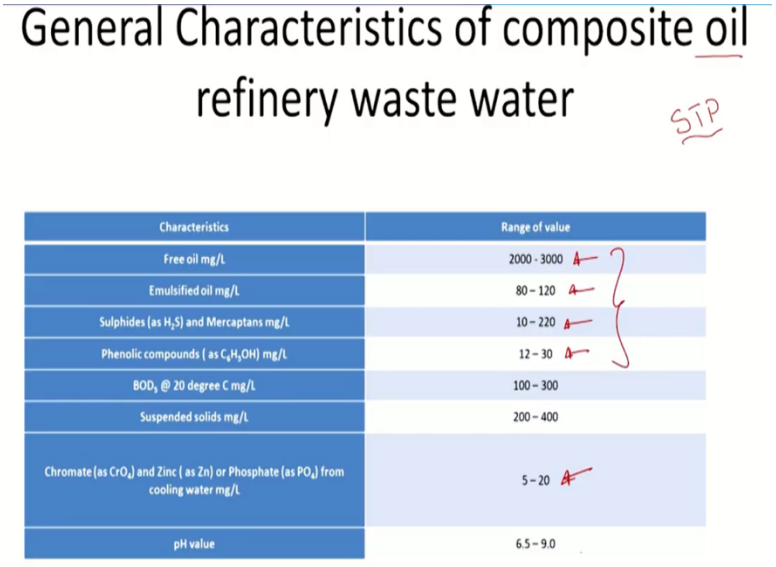

One aspect to keep in mind is that in this course we are looking at sewage treatment plants or treatment plants for domestic sewage, sewage from houses and such but obviously you have industrial wastewaters. I just wanted to give an example about this general characteristics of oil refinery wastewater. What is it oil obviously is remarkably high emulsified oil hydrogen sulfide is high.

We are trying to mention here is that there is no one size fits all but in India again lack of knowledge, but that is what we are trying to address out here by disseminating the relevant knowledge hopefully. We use one size fits all approach. That is not going to work out as you can see you have different challenges out here. You have to modify your sewage treatment plant accordingly again chromate and such or chromium.

For coal mines and etc. you have different discharge standards and such. One aspect is it is not just the industries you have, the different mining activities that lead to considerable pollution. Again, that is a gray area now we are still yet to put in more efforts into those polluting sources but again we do have the relevant laws but enforcement and will is the issue out here. In this course we are looking at domestic sewage.

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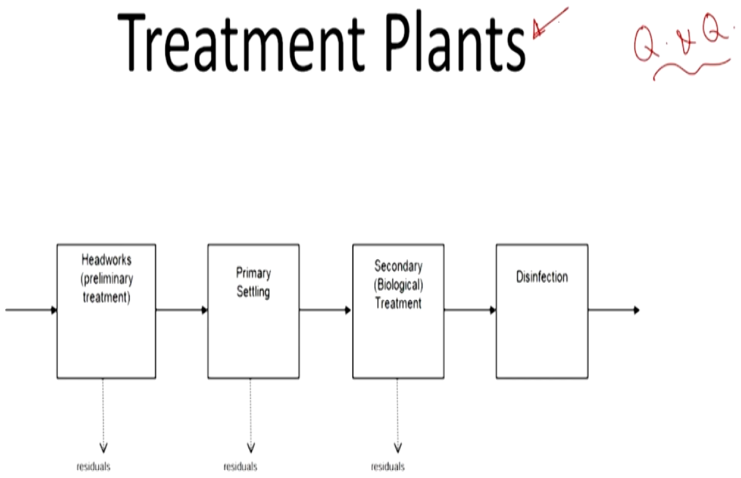

I am done with discussing quantity and quality we are now going to start looking at the crux of the issue. The treatment plants let us say but looks like I am out of time. Thanking you for your patience I will end today's session.