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ECOLOGY AND ENVIRONMENT

Wastewater Recycling: A sustainable option for water management.

Lecture 6

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WASTEWATER RECYCLING: A SUSTAINABLE OPTION FOR WATER MANAGEMENT

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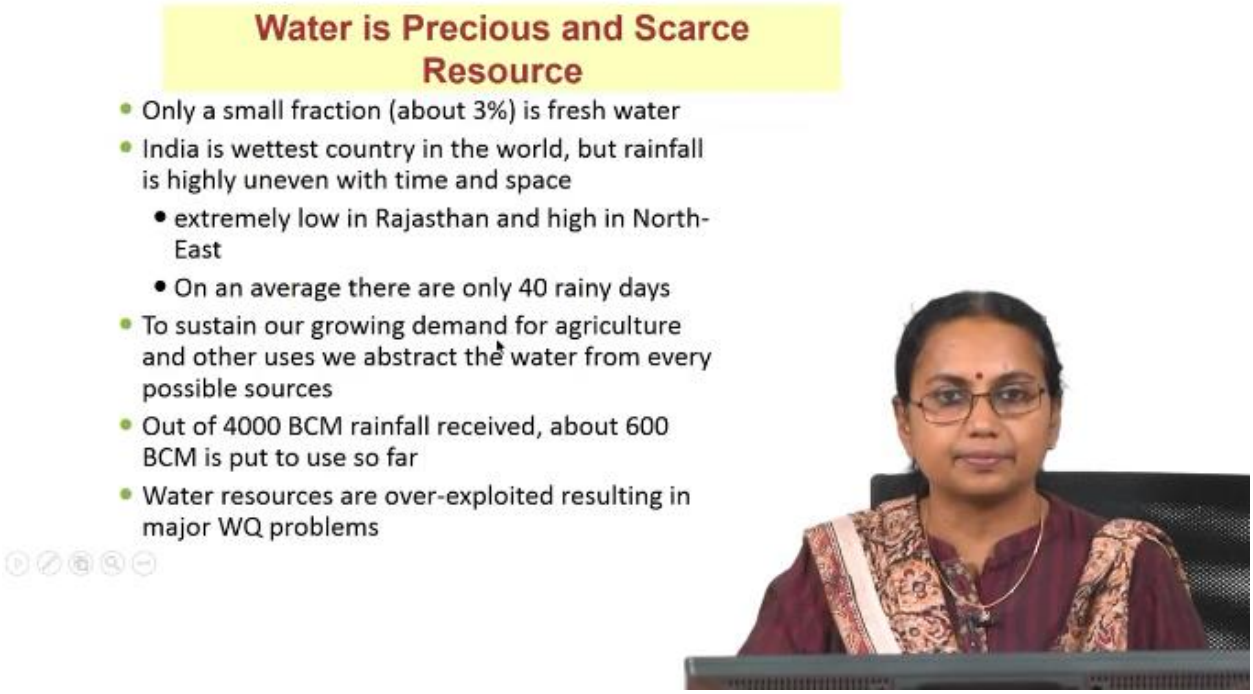
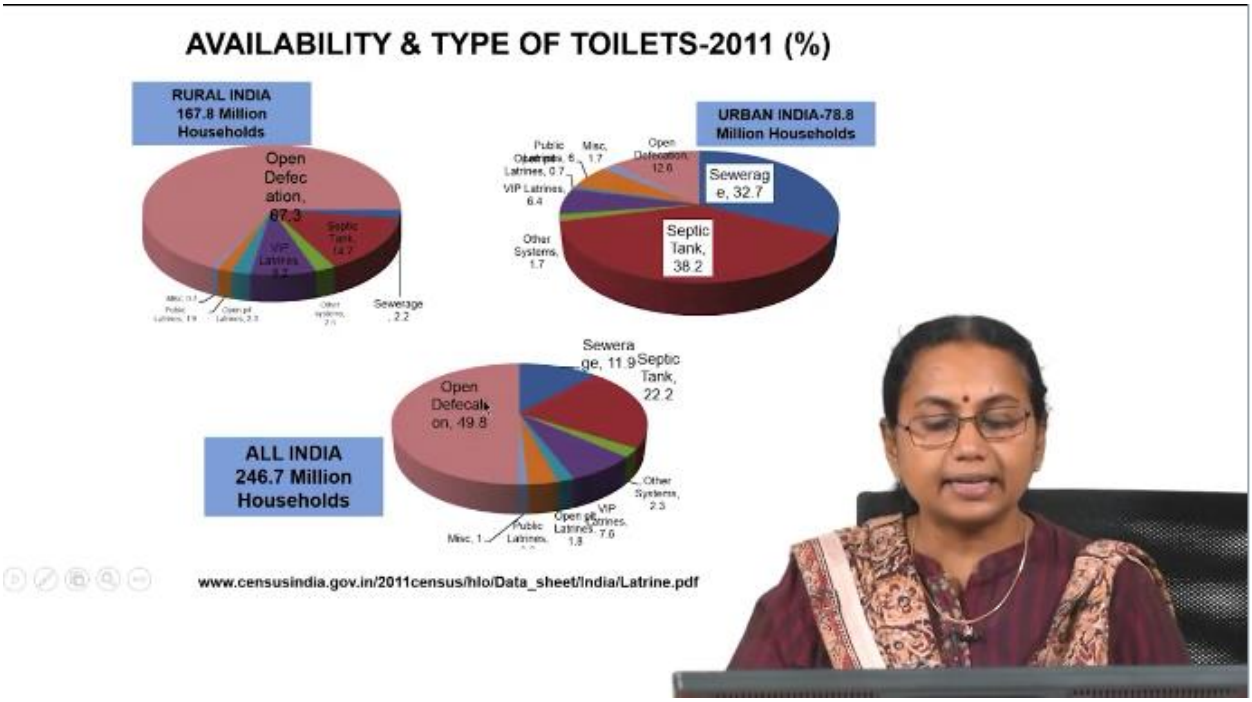
Okay, welcome back, the last lecture we discussed about wastewater management scenario in India, and what all are the treatment options. Today we will talk about wastewater recycling, a sustainable option for water management. We will see some case studies.

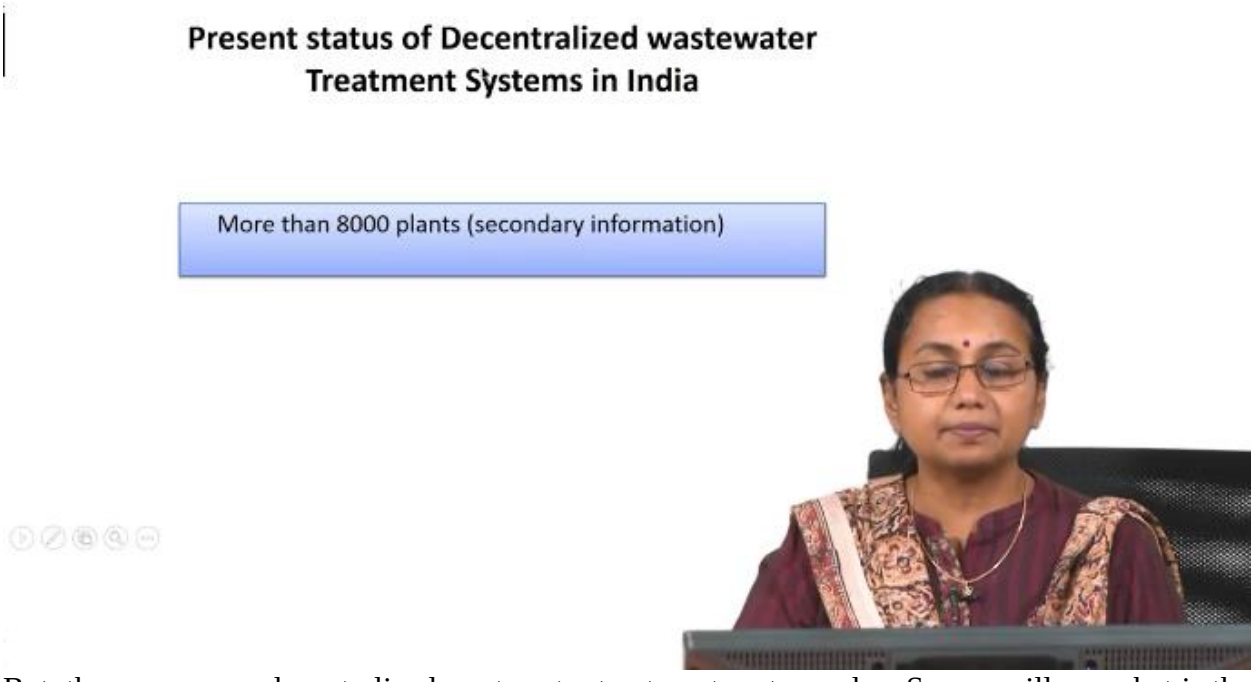


So, we all know that water is a precious and scarce resource, and in the previous lectures, we have seen that only a small fraction is fresh water less than three percentage. And India is the wettest country in the world, but rainfall is highly uneven with time and space, extremely low rainfall in Rajasthan and high in North-East, on an average there are only 40 rainy days.

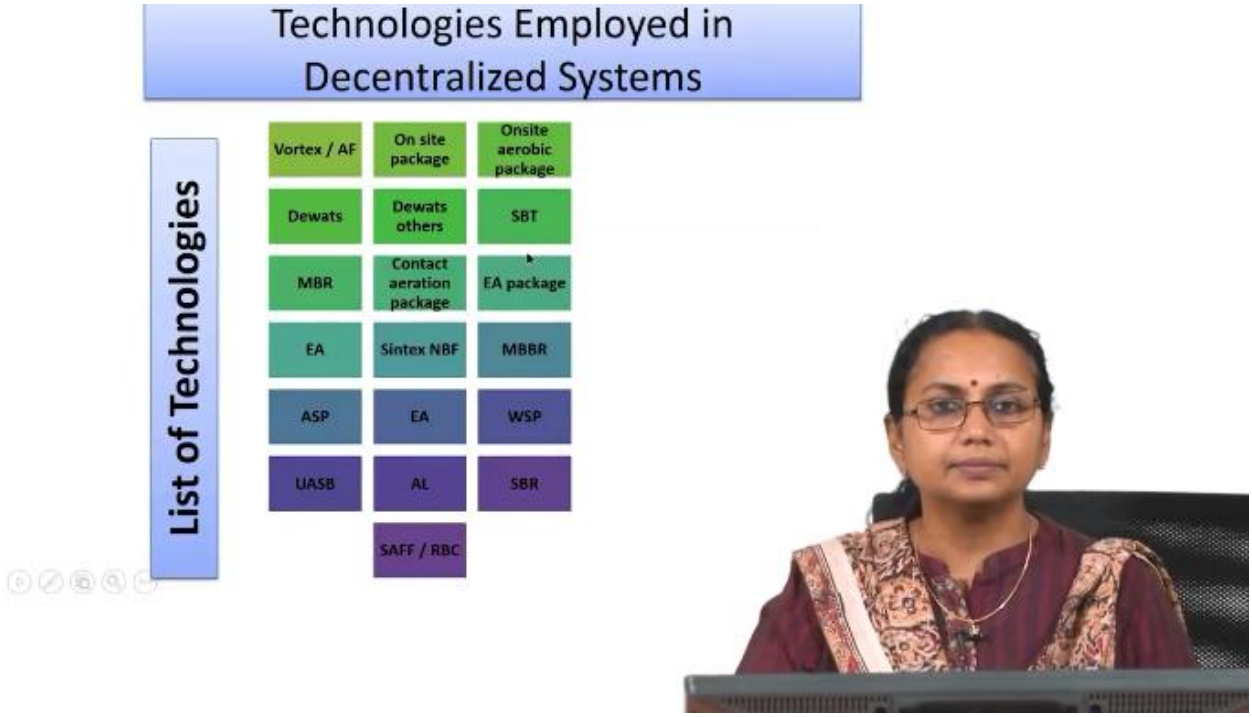
And to sustain our growing demand for agriculture and other uses we abstract the water from every possible sources, out of 4000 BCM rainfall received, about 600 BCM is put to use so far, remaining is just running off to the sea. Water resources are over-exploited, resulting in major water quality problems.



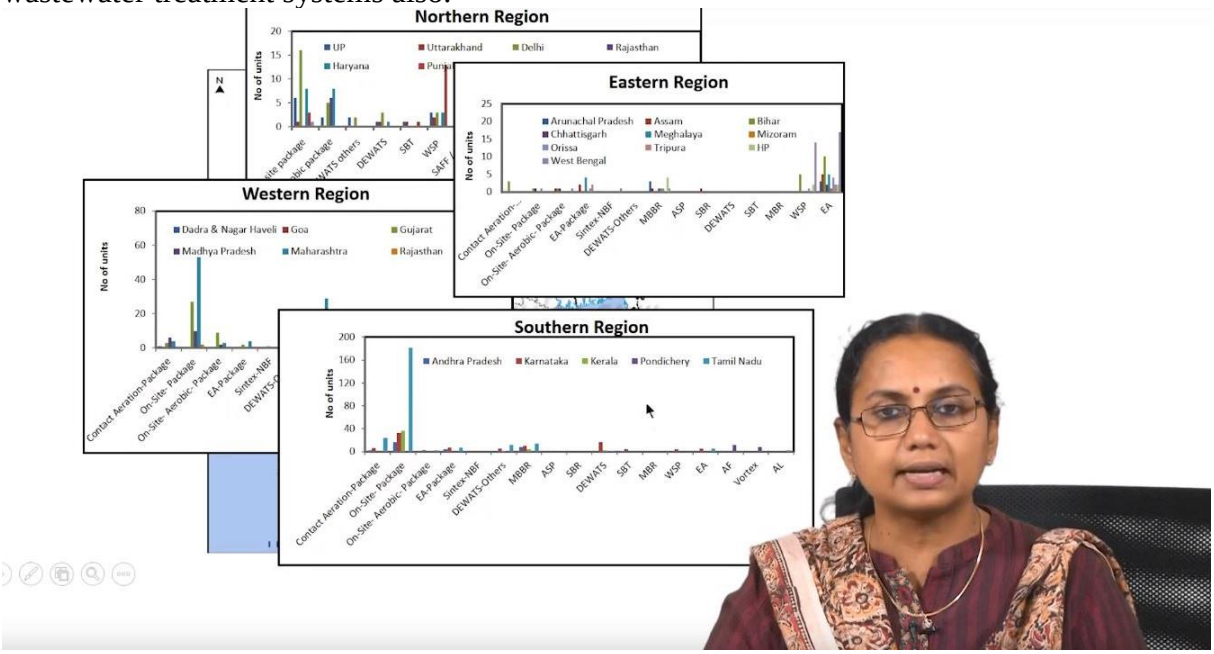
So, this slide I have already explained to you in the last lecture. Availability and type of toilets and we are, the majority of India is still depending upon septic tanks and or decentralized and onsite wastewater treatment systems, or mostly onsite wastewater management systems.



But, there are many decentralized wastewater treatment systems also. So, we will see what is the present status of decentralized wastewater treatment systems in India. I already explained to you what is a decentralized system. More than 8000 plants are existing, this is a secondary information we have collected.

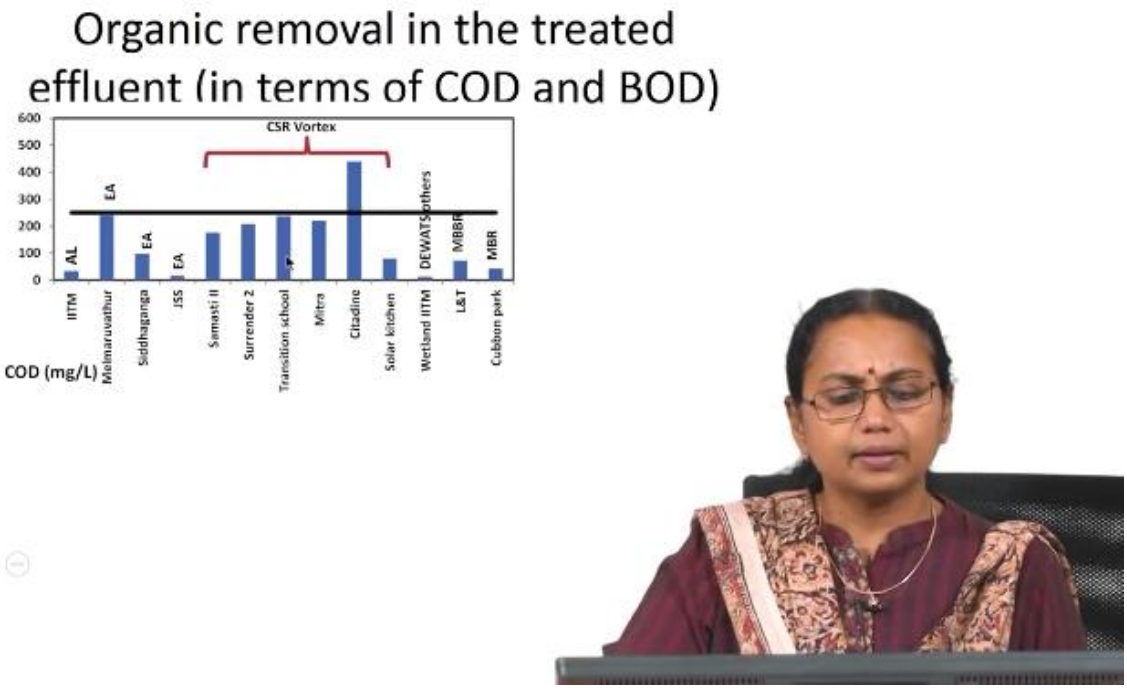


And technologies employed in the decentralized system, when we talk about centralized wastewater treatment system or decentralized wastewater treatment system, the technologies can be the same. Here we can see that India has all this type of wastewater treatment system, vortex and anaerobic filter, Dewats systems, decentralized wastewater treatment systems, membrane bioreactors, extended aeration, ASP, anaerobic up-flow sludge blanket reactor, onsite package systems, contact aeration, MBBR, EA package, soil biotechnology, waste stabilization, ponds, sequential batch reactors, RBC, all these technologies are being employed in decentralized wastewater treatment systems also.

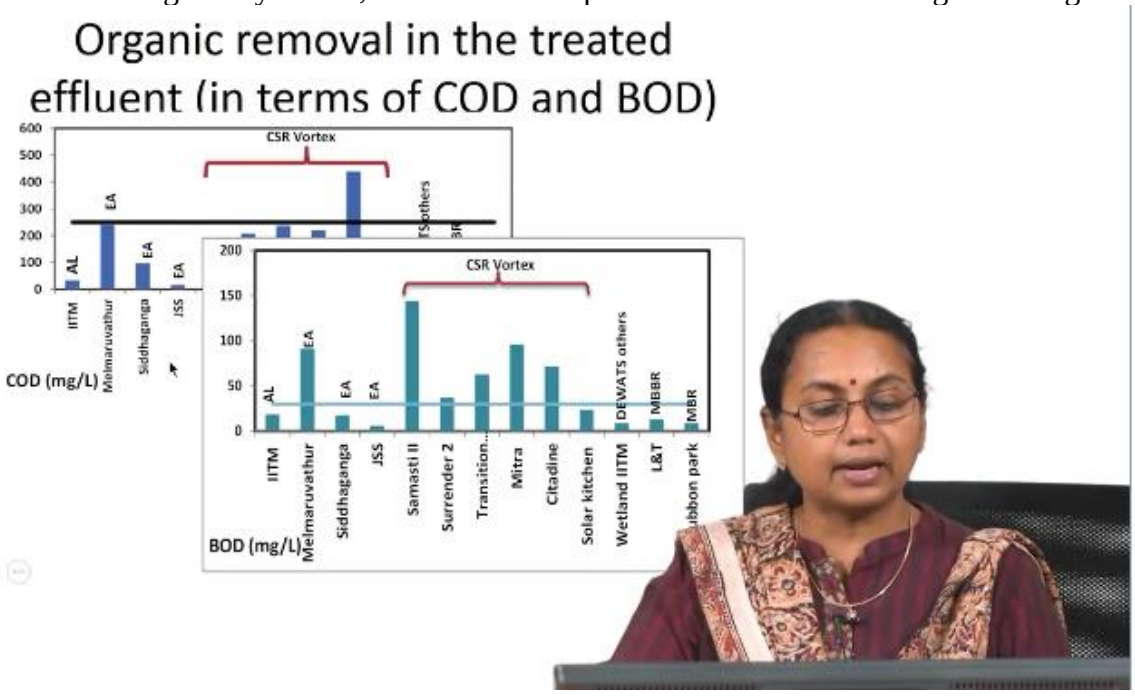


So, if we look into how it is distributed, this shows you, so this is North Eastern region. I have put all the technologies here and the number of plants. North Eastern states, yeah, we have

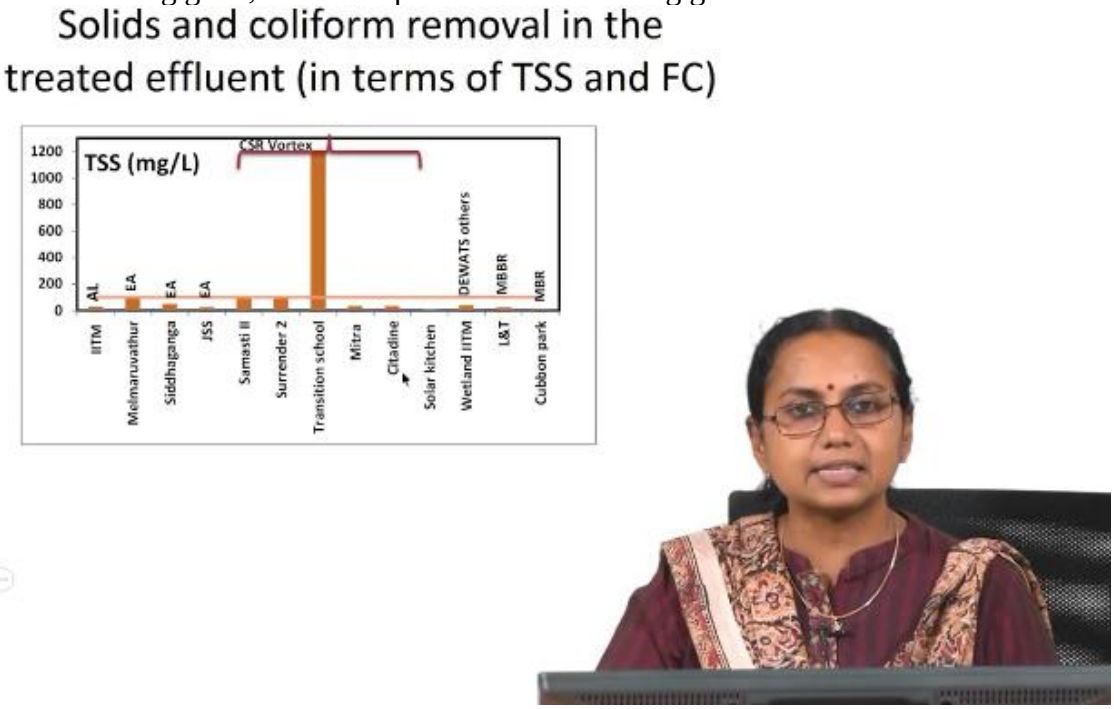
decentralized treatment systems, but the number is in the range of 10 to 15, different technologies, be around 10 to 15 plants in different places. The western region you can see that the Y-axis become 40 to 100, that means the number of treatment plants in the Western region is much more. And Eastern region again it is similar to the Northern region, the plants are relatively less, around 5 to 10 plants of each technology is existing. And if you see the Southern region it is very high, the number is going 40, 50 and some plants are going up to 160, 200 that means a lot of decentralized plants are available in India.



So, if you see the treatment efficiency, you can see that irrespective of the technology some plants are working very well, and some plants are not working that good.



This is for COD removal, this is BOD removal, and this is the COD removal, you can see that some plants are working good, and some plants are not working good.



Similarly, I have the TSS value and fecal coliform number. What I am trying to tell is different technologies are available. Most of the technologies are able to meet the requirement or wastewater quality discharge standards, most of these plants are able to meet if it is operated and maintained properly.

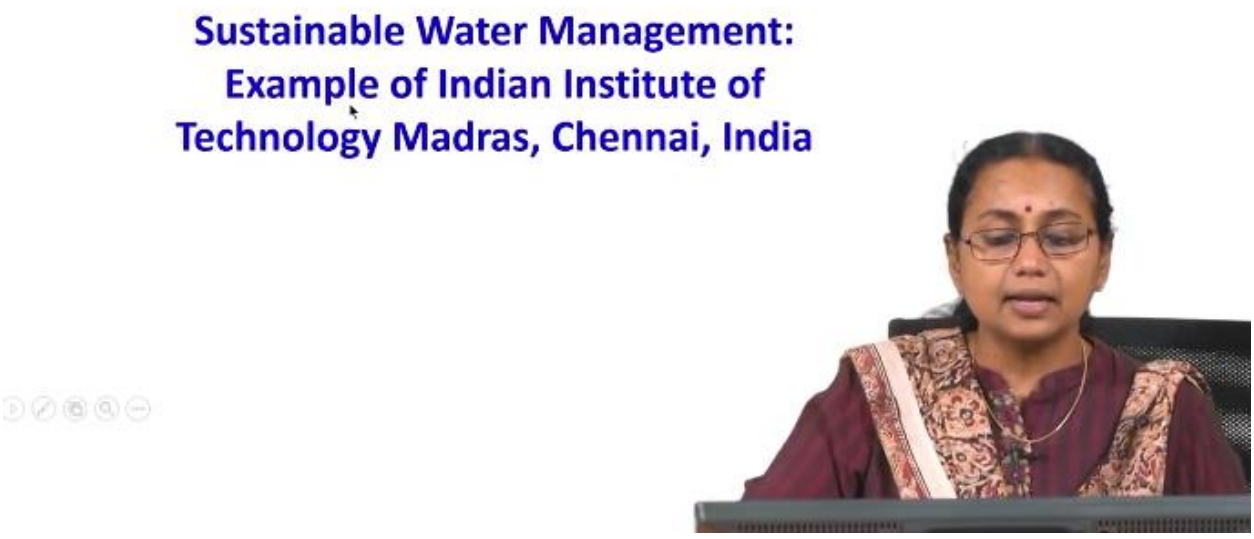
So, challenges to be tackled through policy. What extend one need to recycle? This we have to see because when we talk about the recycling, many people are having psychological inhibition,

how can I use my wastewater for other purposes? We are forgetting that we are doing that one unknowingly on day to day basis. I explained earlier, the river water, it is receiving a lot of untreated wastewater from other cities, and we are doing that one. So, this is one challenge. Quality and what quality we have to treat, it is based upon the beneficial use. Quantity is not affecting the functioning of existing infrastructure, because if you recycle too much of a wastewater the flow in the sewers will be getting affected that also we have to look into.

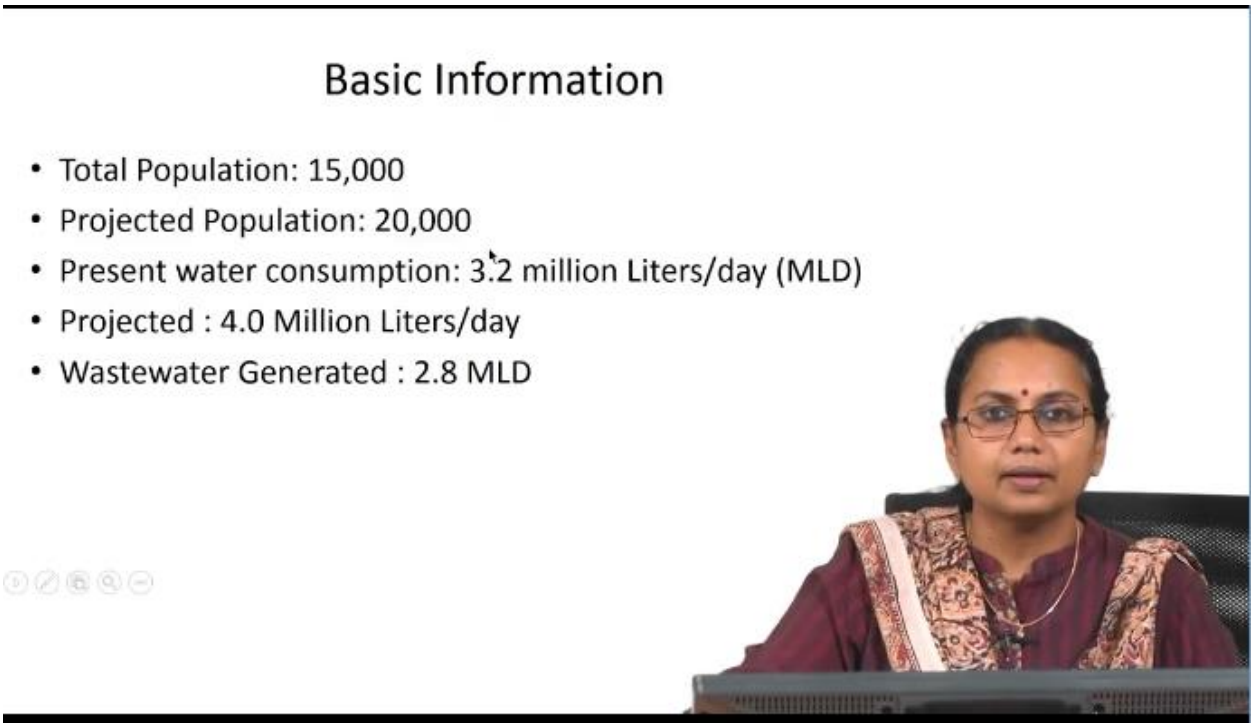
Land availability that is another problem; existing regulations regarding the distance of STP's from habitations, and infrastructural development rules all those things we have to look into. Then social acceptance that is another problem; awareness creation and social engineering is essential to tackle the waste management issues.

Then monitoring and enforcement, we have to have, because what is happening is people are putting large number of plants and if it is not monitoring, what will happen? All the untreated water will be getting into the ground, and ultimately it will be contaminating the groundwater and surface water. So, we have to have proper monitoring and enforcement that means, when you have a wastewater treatment plant, plan approval, third-party monitoring, consent renewal in frequent intervals, smart monitoring and appropriate actions, all those things can be thought about.

Then economics of the plants we have to look into, if the plant is very costly, nobody is going to construct the plants. So, we can we can look into prefabricated modules, economics of scales, pricing of virgin and treated water, because if you put a very high price for the pure or virgin water, then people will have a tendency to use the treated water, tax rebates, rating of buildings etcetera are other benefits one can give if people are going for the wastewater recycling.



So, I will talk about how a campus can be sustainable, can manage the wastewater in a sustainable way. So, I am giving the example of Indian Institute of Technology, Madras, Chennai.



So, this has some basic information. The total population is around 15,000, projected population is, for the next 5 years, 10 years around 20,000. Present water consumption is around 3.2 million liters per day, projected is around 4 million liters per day. Wastewater generated at this moment is around 2.8 million liters per day.

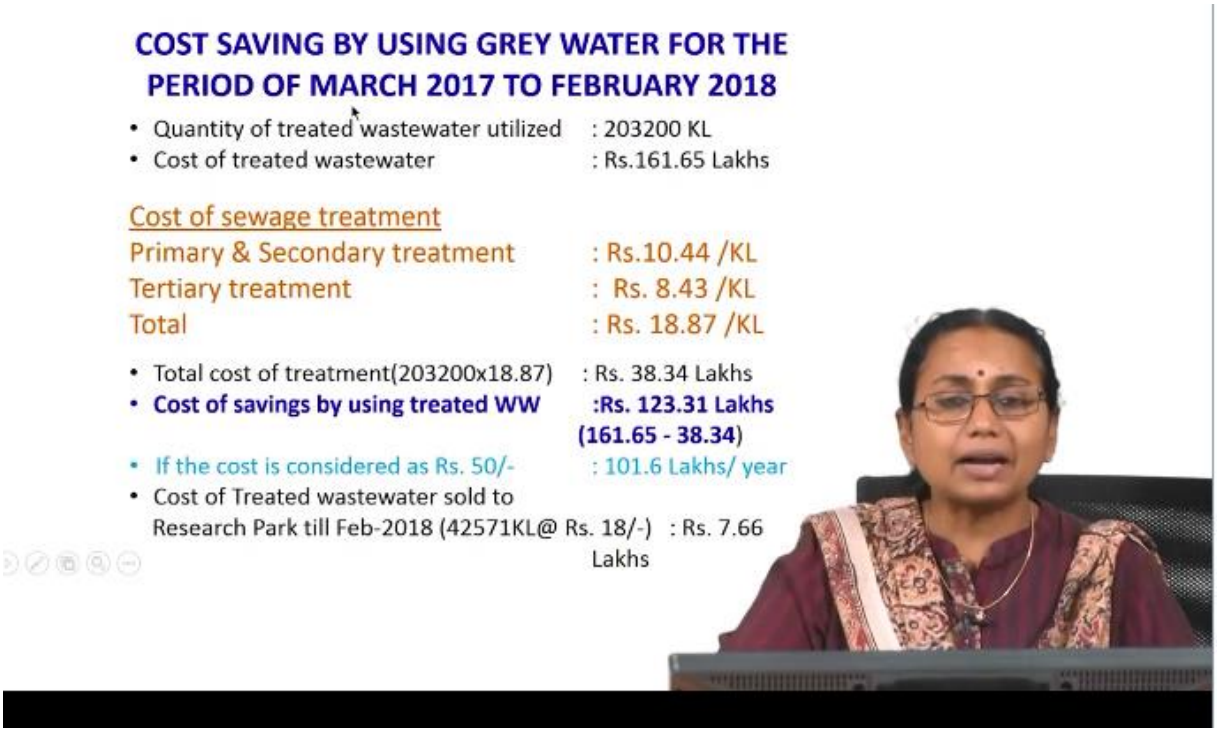
So, IIT Madras has constructed a 4 million liter wastewater treatment plant using the technology sequential batch reactor. And what the institute has done is after creating the wastewater treatment plant, they have put up a tertiary treatment unit of ultra-filtration and a disinfection unit with Ozone, Ozonation. So, the treated water quality is very good, and the sludge whatever is generated is centrifuged and dried to use it as manure.

So, this is the existing wastewater treatment plant, and you can see that this is the treated wastewater. So, here we have put different water samples, one is secondary treated water, tertiary treated water, tap water, RO water etcetera. So, it is very hard to find out which is the treated

wastewater, and which is the tap water. What I am trying to tell is, if you put a proper properly designed wastewater treatment plant and operate it properly, you can get very, very good quality water.

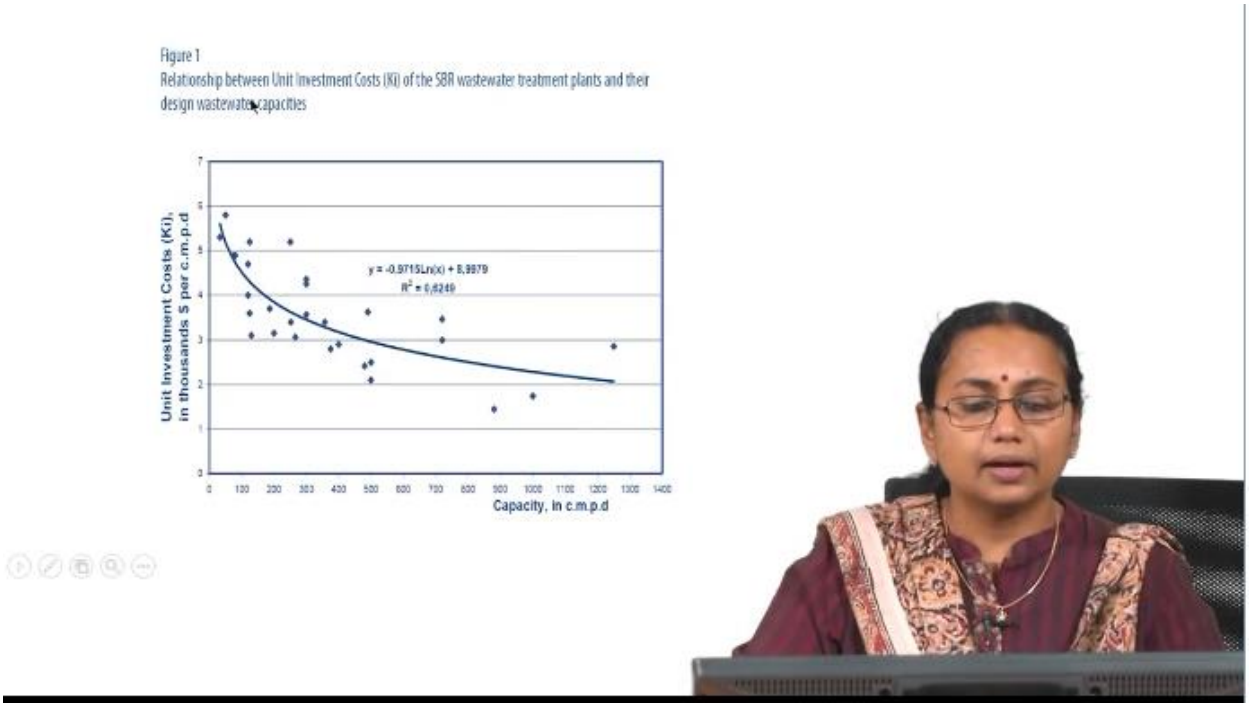
So, after that one what we are doing is, this water, the entire campus is having dual pipeline system, so this water is the treated wastewater is being pumped across the campus and is being used for all the toilet flushing, gardening, and as a cooling water for all the centralized air-conditioning unit. And whatever the excess water is coming, we are using it to augment the water in this lake. And you can see that we are getting a lot of birds and fishes and all the things in this lake. Not only that one because of this one, the groundwater to some extent the groundwater recharging is taking place.

So, we are not only doing that one. So, we have a lake; this lake is our rainwater storage, rainwater harvesting system. So, all that rainwater drains, drainage system are directed to this lake so whatever the rain comes in the campus or rainwater comes in the campus, everything is collected in this lake, and we have a small treatment unit, and this treatment unit is augmenting the water supply, whatever we are getting from the Chennai metropolitan, CMWSSB. So, here what treatment we are doing? We are having coagulation, flocculation, filtration, and chlorination. The conventional treatment we are doing, and we are constantly monitoring the quality and all the things.



So, what I am trying to tell is by doing this type of a system, so within one year we could, the institute could save around more than one crore rupees on water bill itself. Not only that one, we are supplying water to our neighboring campus, and from there also we are getting around 7 in one year we are getting around 8 lakh rupees, we are selling the water for around 18 rupees per meter cube.

Now what I am trying to tell is, if we have the will, we will be able to reduce our water consumption by 50 percentage, by properly treating the wastewater and recycling it. By doing this one we are reducing the pollution problem, and we are reducing the virgin water extraction from the sources.



And if you want to look in to which one will be economical because if you talk about a very sophisticated wastewater treatment system, if it is a very small plant the unit cost may be very, very high.

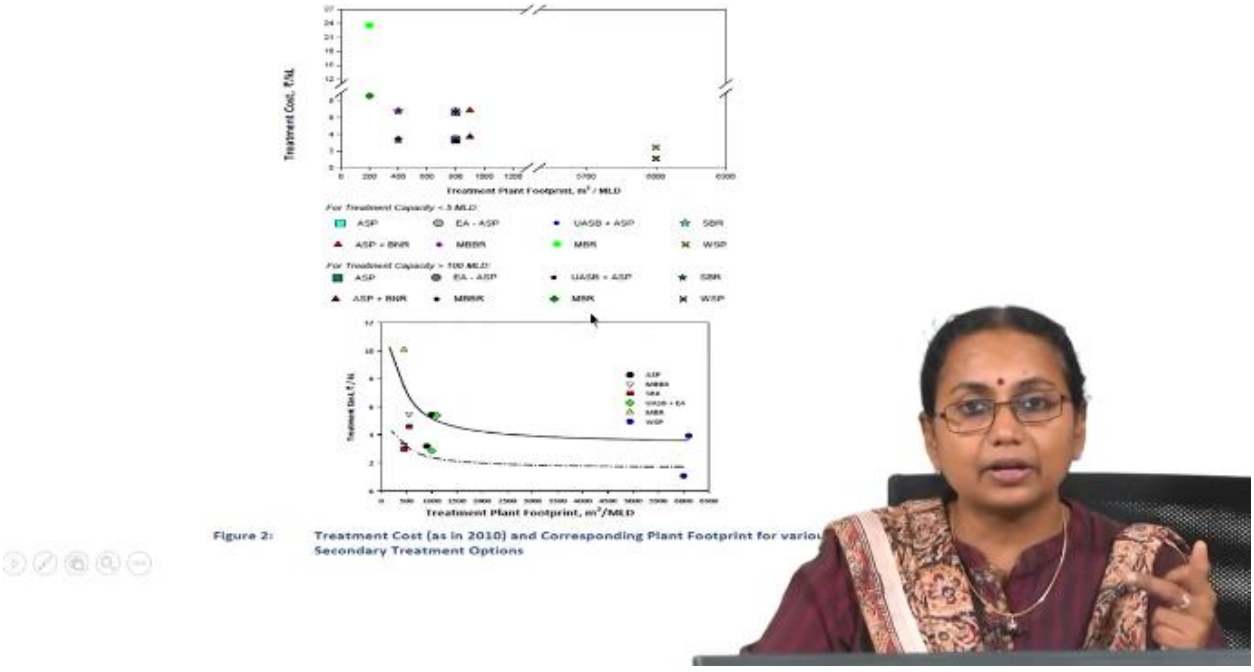
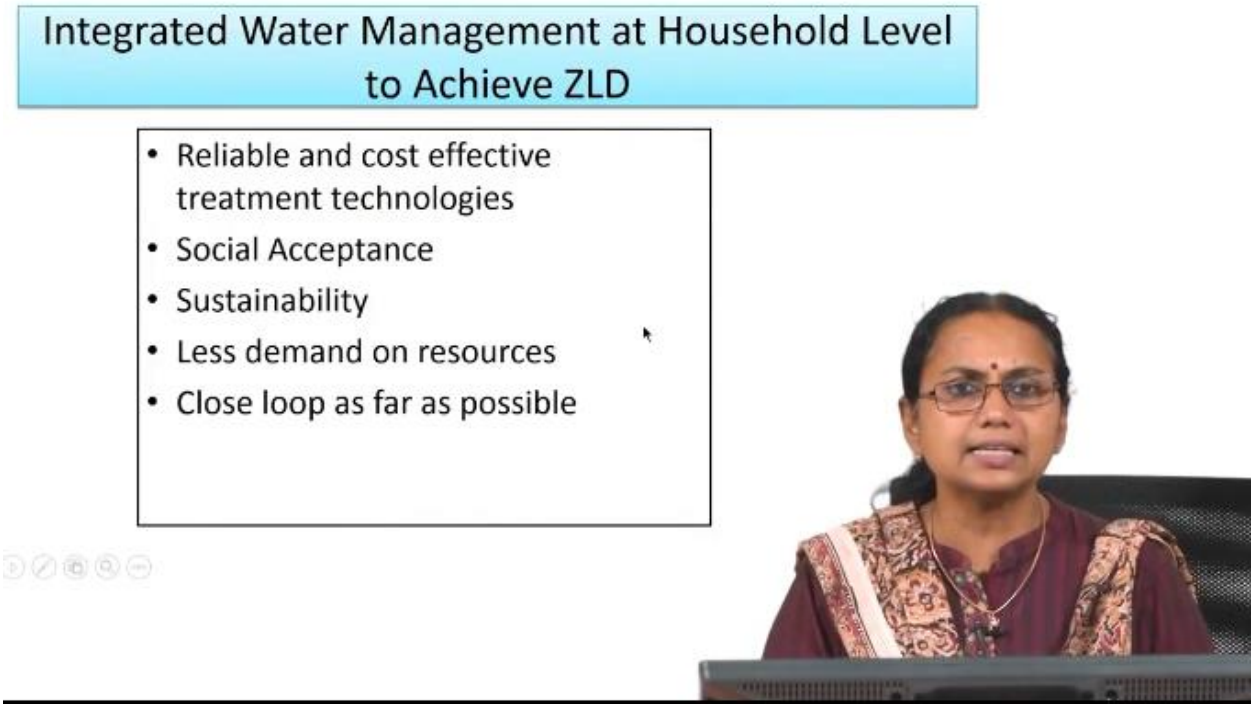
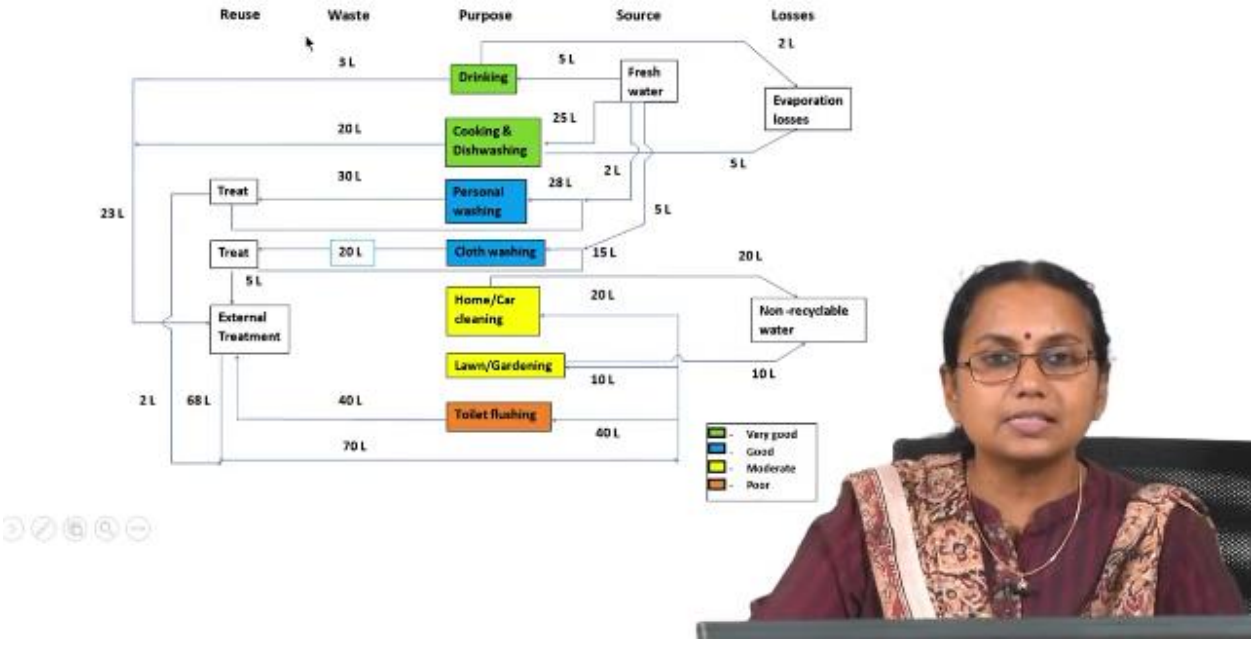


Figure 2: Treatment Cost (as in 2010) and Corresponding Plant Footprint for variou
Secondary Treatment Options

So, this is the unit cost for SBR wastewater treatment system, and here I have given the comparison of different treatment technologies and their cost and all the things. Whenever you have time you can look into that one, so that is one approach.



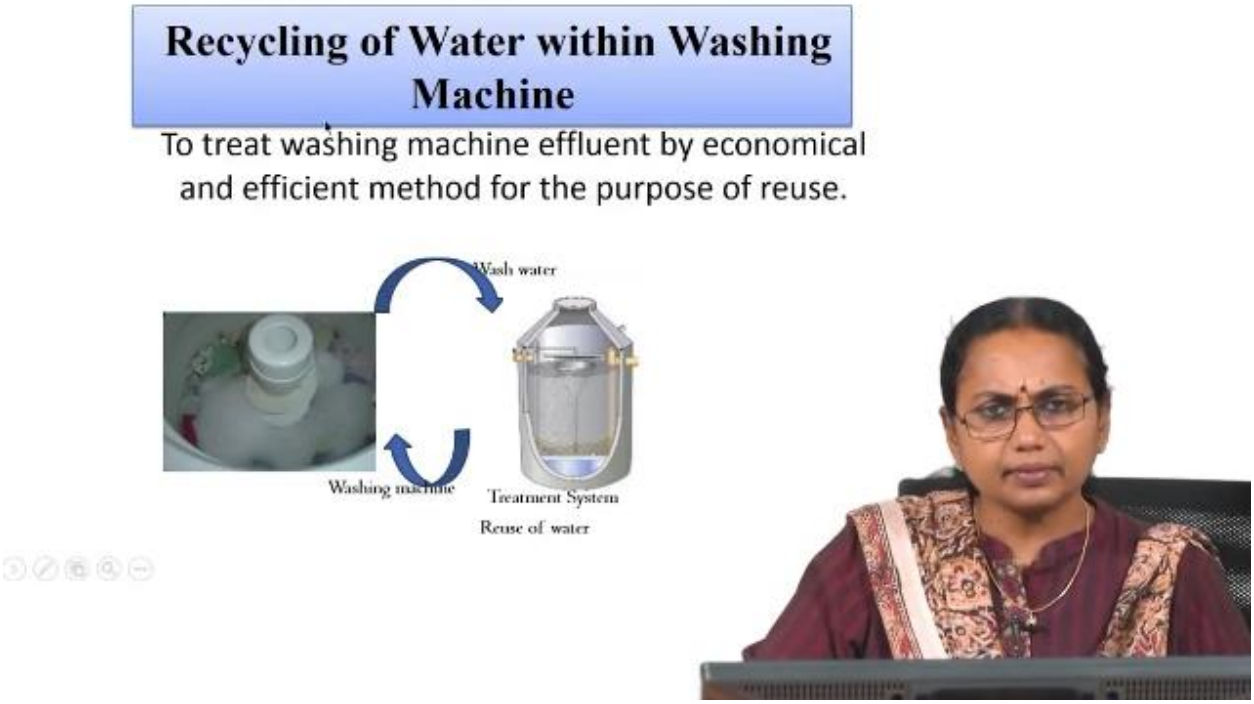
Another thing is whether we will be able to achieve zero liquid discharge in a household? Yes, it can be, but the system should be reliable and cost-effective. And whatever we are providing there should be social acceptance. It should be sustainable, less demand on resources, and as far as possible a closed loop should be maintained. So, we have done, our students have done many projects in this area, I am going to discuss a few of them.



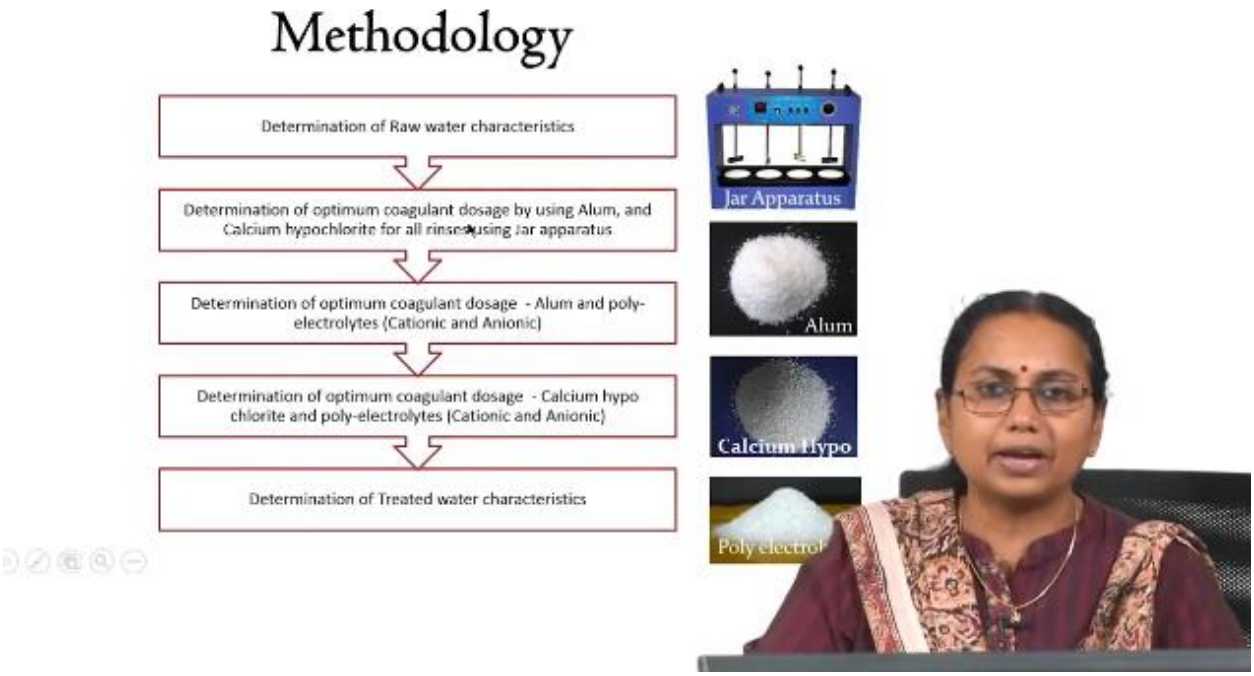
So, this is what we are trying to tell you, a person will be consuming around 135 liters per day water for various purposes like drinking, cooking, personal washing, cloth washing, homework, car cleaning, lawn, gardening, toilet flushing. So, when we talk about this one, we need very

good quality water for drinking and cooking and dishwashing. When it comes to bathing and cloth washing, yeah good quality water should be there. But home, car cleaning, and lawn, and gardening moderate quality, and when it comes to toilet flushing, we can use any quality water because we are just pushing the material outside the toilet, that is what we are using this flushing water.

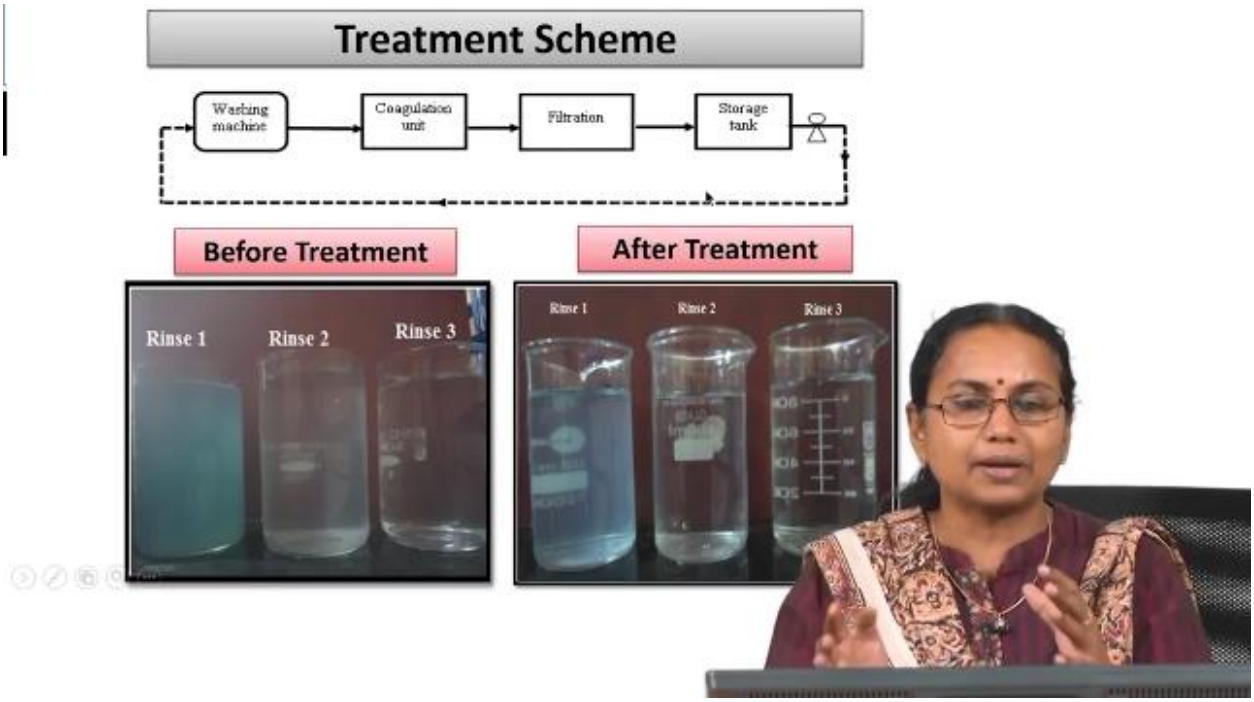
So, if you look into this one, so what we can do is use only fresh water for drinking and cooking purpose. This personal washing or bathing water and cloth washing water we can recycle it there itself. And whatever the cooking and drinking water waste coming, we can use it for home and car cleaning or lawn and gardening. And kitchen waste and whatever the other left out waste coming you treat and use it for toilet flushing. So, by doing this one, we will be able to reduce the freshwater requirements significantly.



So, this is some work studies we have conducted, recycling of water within the washing machine. Because you know that each time when we wash the cloth around 45 liters of water, for a household, a small household, around 45 liters of water is being used for a 6 kg washing machine. And we will be using it for 3 cycles, so 45, around 135 liters of water is being used. So, if you can clean it and recycle it we can save a lot of water, so that is what we were looking into.



So, we looked into various treatment technologies and all the things. And we have come up with a very simple process, some coagulation, flocculation, and filtration, and the important thing is between the washes we will be getting only 12 minutes time, within that time you have to treat the water.



So, we have developed the system, and you can see that this is the treated water, the treated water is almost equivalent to the tough water, and you can see the quality here.

Raw and Treated Water Characteristics

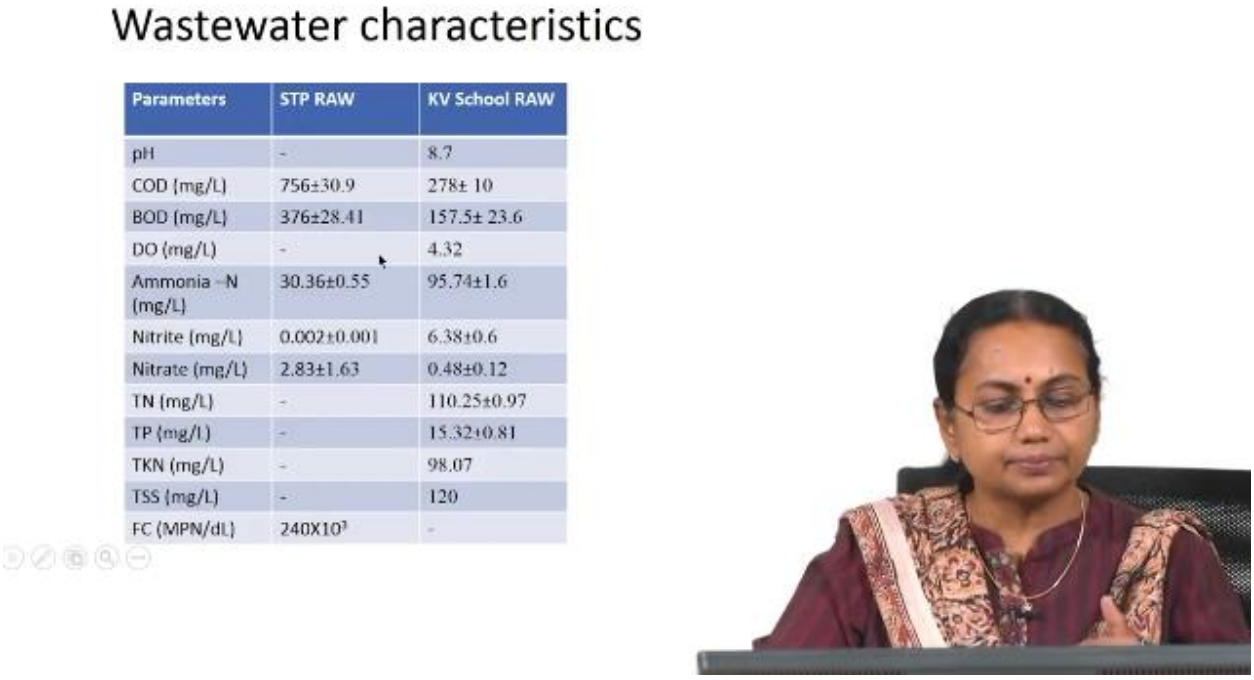
PARAMETERS	UNIT	RINSE 1		RINSE 2		RINSE 3	
		Raw	Treated	Raw	Treated	Raw	Treated
pH		8.92	8.56	7.34	7.32	7.18	6.33
Electrical conductivity (EC)	mS	1.974	1.23	0.715	0.603	0.638	0.43
Turbidity	NTU	136	35.3	17.47	3.44	9.68	1.62
Total Dissolved Solids (TDS)	mg/L	2157	1010	1320	656	1015	318
Total Organic Carbon (TOC)	mg/L	333.4	68.9	42.94	20.2	23.87	12.4
Total Coliform (TC)	CFU/100 mL	340	50	60	BDL	20	BDL
Faecal Coliform (FC)	CFU/100 mL	200	42	40	BDL	10	BDL

The treated water is meeting, you can see the organic carbon very little, total coliforms came down to the BDL, and your turbidities around 1.62, that means you are getting very good treated quality using this method.

Photograph of Laboratory scale Water Recycling Apparatus (WRA)

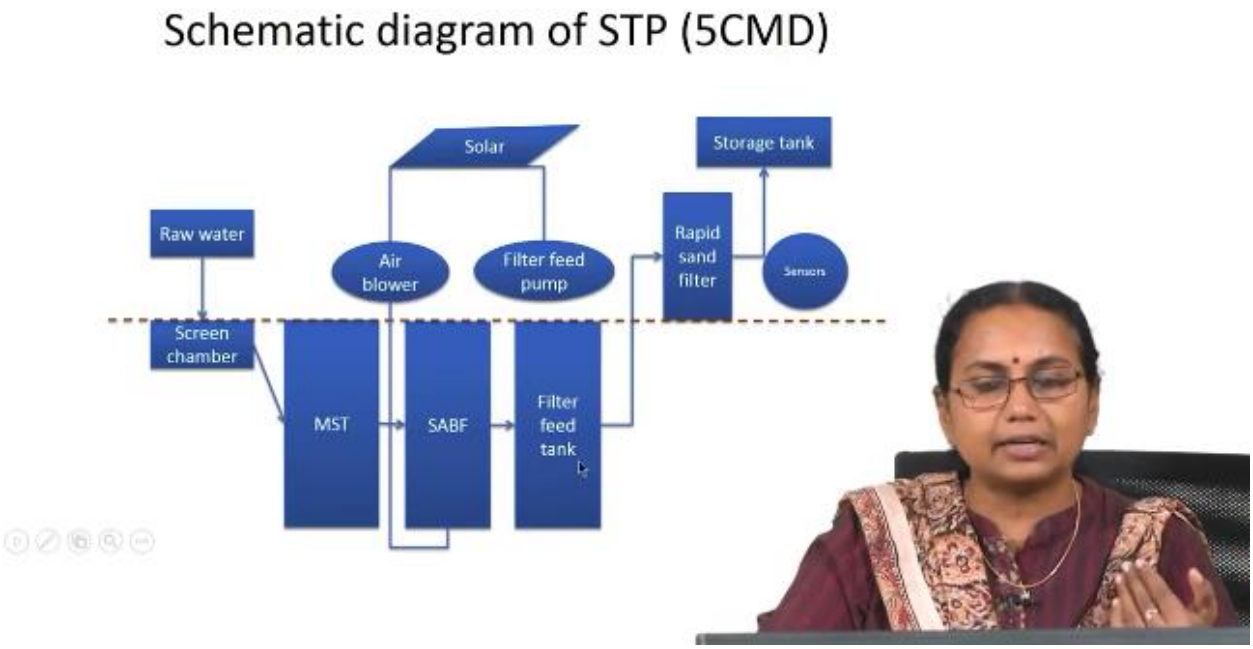
And you can develop better instrumentation systems and all so that this water can be pumped back to the washing machine and thus water can be saved. So, we we have already filed patent for this technology.

And another thing is solar power water recycling toilets, ensuring hygiene and safety.



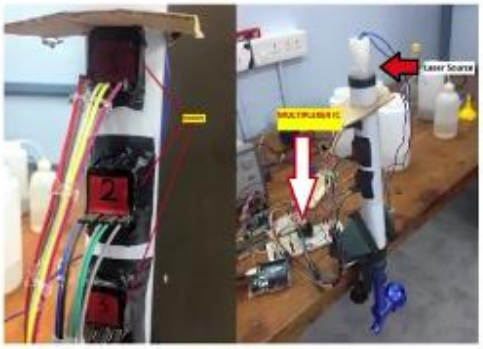
So, here what are doing is, for the schools and all, for example in water-stressed areas many schools will not be having enough water to flush the toilets and all, so it is creating a major problem for the girl students and, the students in general. So, we were looking into a system whether we can develop a wastewater treatment system which does not need any electricity from the grid, and which does not need any, which does not need much operation and maintenance and the quality have to be assured, or quality has to be checked on daily basis. So, that is what we have done, and you know that the school wastewater is very difficult to treat compared to domestic wastewater, because the organic or carbon content is very less, and your nitrogen

content is very high. So, what we have done is, we developed a treatment system, this is a modified septic tank. Then we have a small aerobic system, then you have a filter, it can be an ultra-filter unit or a sand filter depending upon what quality you need.



And the entire thing is powered by solar, solar system, but you know that sunlight is available only during the daytime, so, we have designed our aerobic system in such a way that whenever the solar power is there, the system will be working, and it will be meeting the required standard. So, that is the importance here. And what we have done is, we have also developed some sensor, which can, cheap, or inexpensive sensor which can be fixed online to the treated water line and we can check the quality, if the quality is meeting, the water will be going to the storage tank, overhead tank. If the water is, water quality is not meeting, we have a drainage field, it will be flushed to the drainage field. So, what is happening here, the maintenance is very very minimal, and power cuts are not going to affect the treatment system and the quality, quality is assured. So that the students are not under risk. So, this type of a system definitely will be helpful for schools. What is happening, all the wastewater, we can treat it, and recycle for flushing, purpose of flushing and gardening purpose so that the water scarcity will not be affecting the toilet usage.

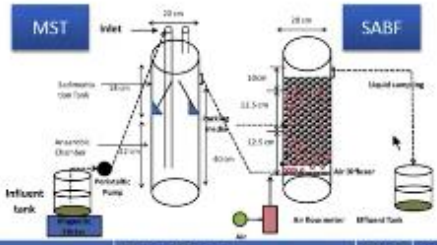
Sensors for online monitoring



Three sensors in parallel Multiplexer IC and the Laser Source

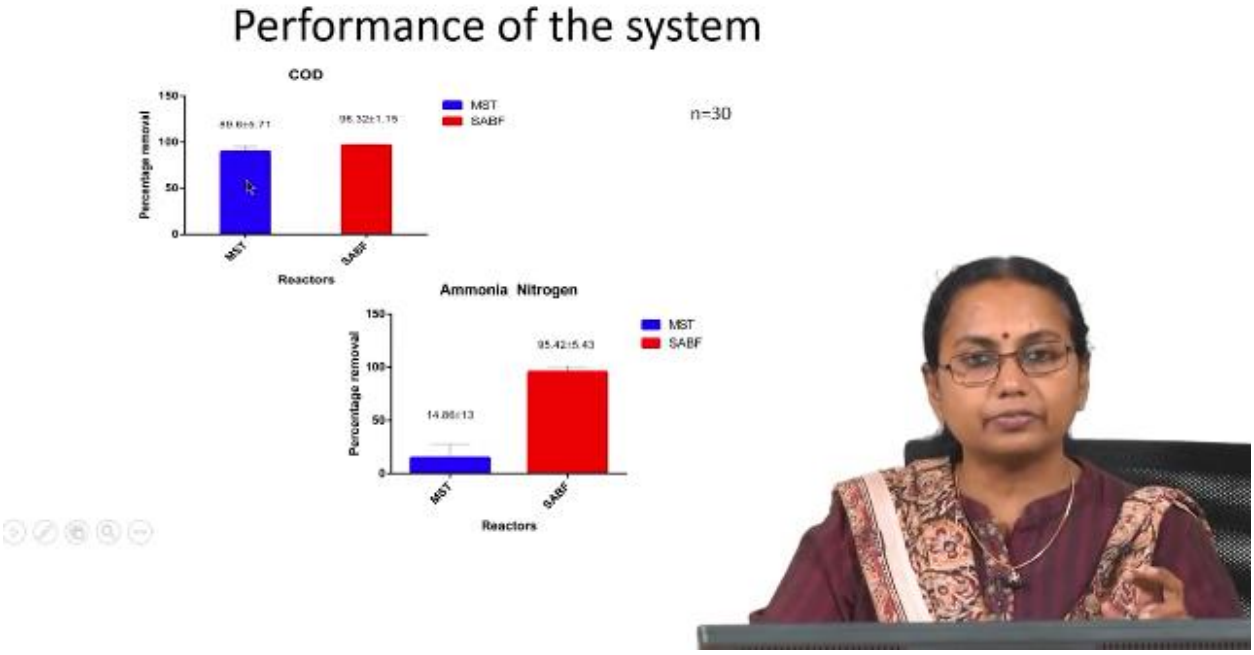
So, this is the sensor, the sensor we have developed is based upon color, turbidity, and oxidation-reduction potential, so that those parameter indirectly tell you whether your treatment system is working effectively and whether it is meeting the required standard. So, this is the sensor we have developed.

Lab scale reactor and running conditions

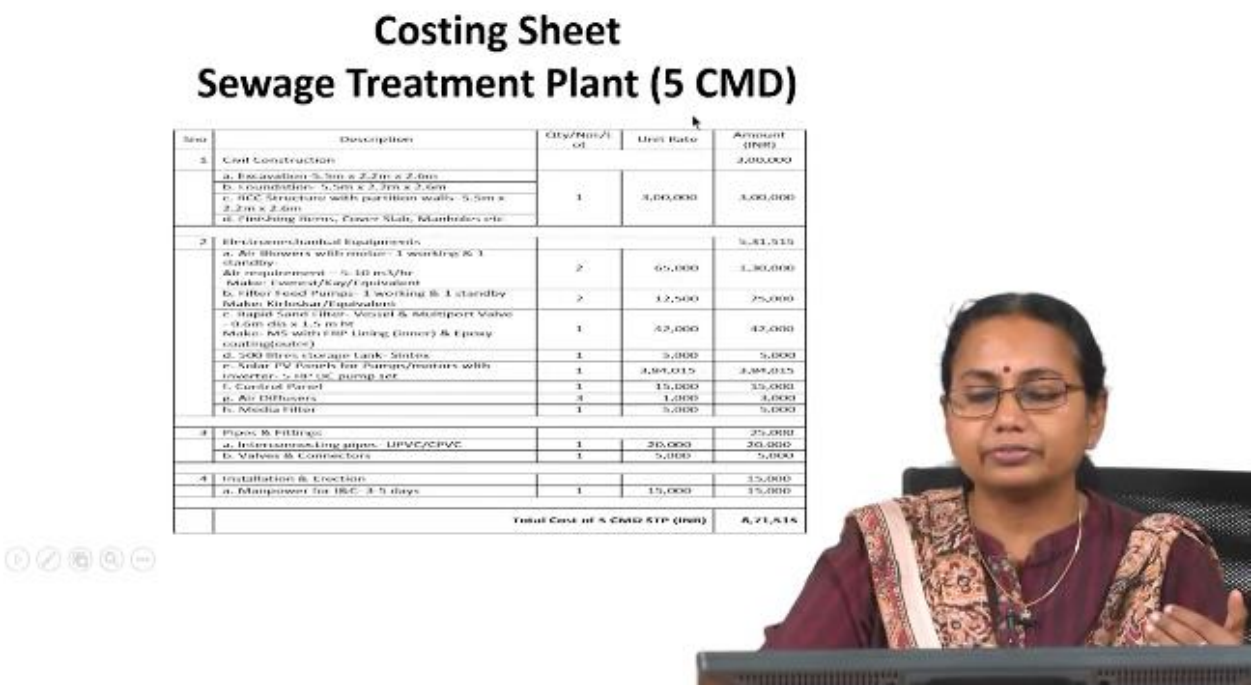


Phases	Influent COD (mg/L)	HRT (h)	Aeration time (h) SABF
Phase I (0-50th day)	500	24	24
Phase II (50-100th day)	500	24	20
Phase III (100- 120th day)	500	24	12
Phase IV (120-184th day)	500 (90:20% division)	24	12
Phase V (185th- 225th day)	400 (60:40% division)	24	12
Phase VI (226th- 238th day)	COD – 600 mg/L	24	8
Phase VII (239th – Current day)	COD – 400 mg/L Ammonia concentration – 75 mg/L	24	8

And so, we have done extensive lab studies. And you can see that a combination of this modified septic tank and the submerged and aerobic biofilm.

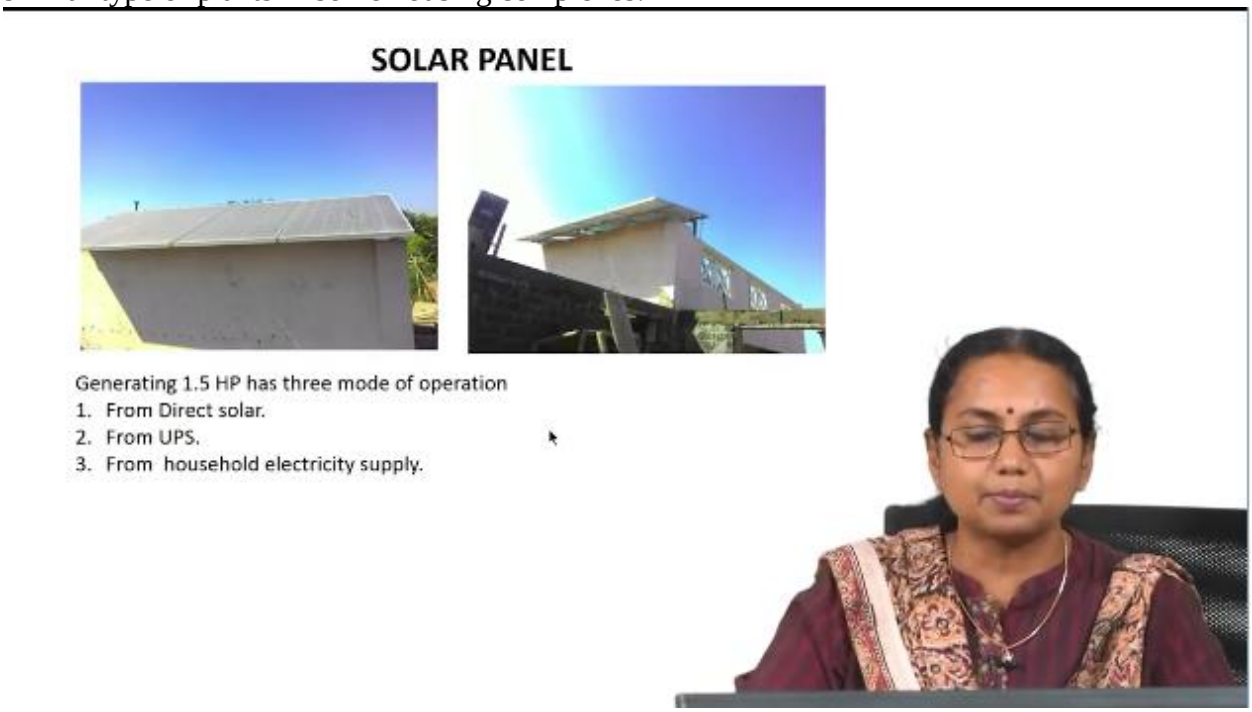


Altogether we are getting around 96.32 percentage of COD removal, and more than 95 percentage of ammonia, nitrogen and total nitrogen removal. So, this system is performing very well, and we have we have already installed this system in two schools. And the cost for 5 meter cube wastewater treatment is coming around 8 lakh rupees.



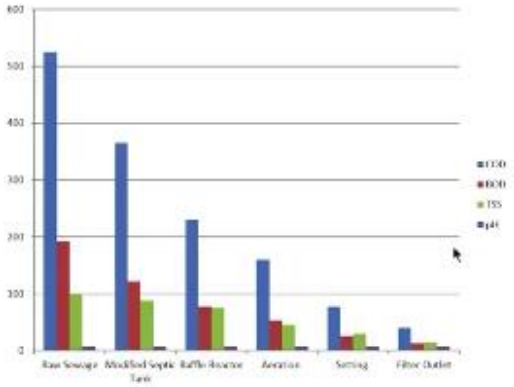
But this cost can be reduced significantly if you go for multiple units at a time. So, what I am trying to tell is there are very simple technologies which can do wonders, and the wastewater can be treated effectively, and you can reuse the treated water.

So, and the same system can be used for residential zones or residential complexes, there the treatment is much easier because you have enough carbon and nitrogen. So, we have also put up similar type of plants in some housing complexes.

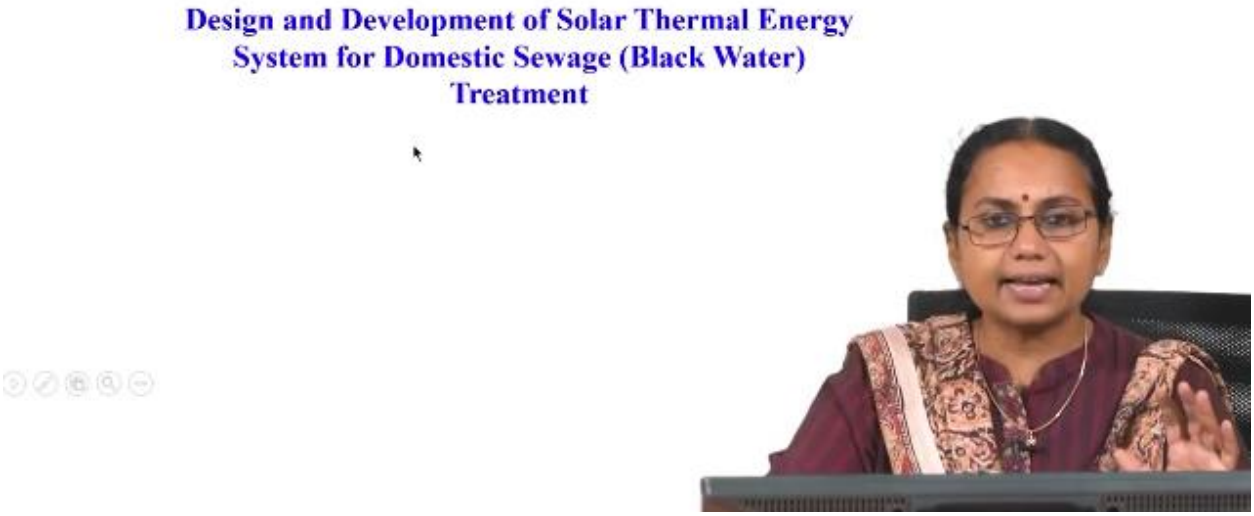


So, this is the treatment system, and you can see that the wastewater quality is improving very well and this is the raw water and the treated wastewater, it is very good quality.

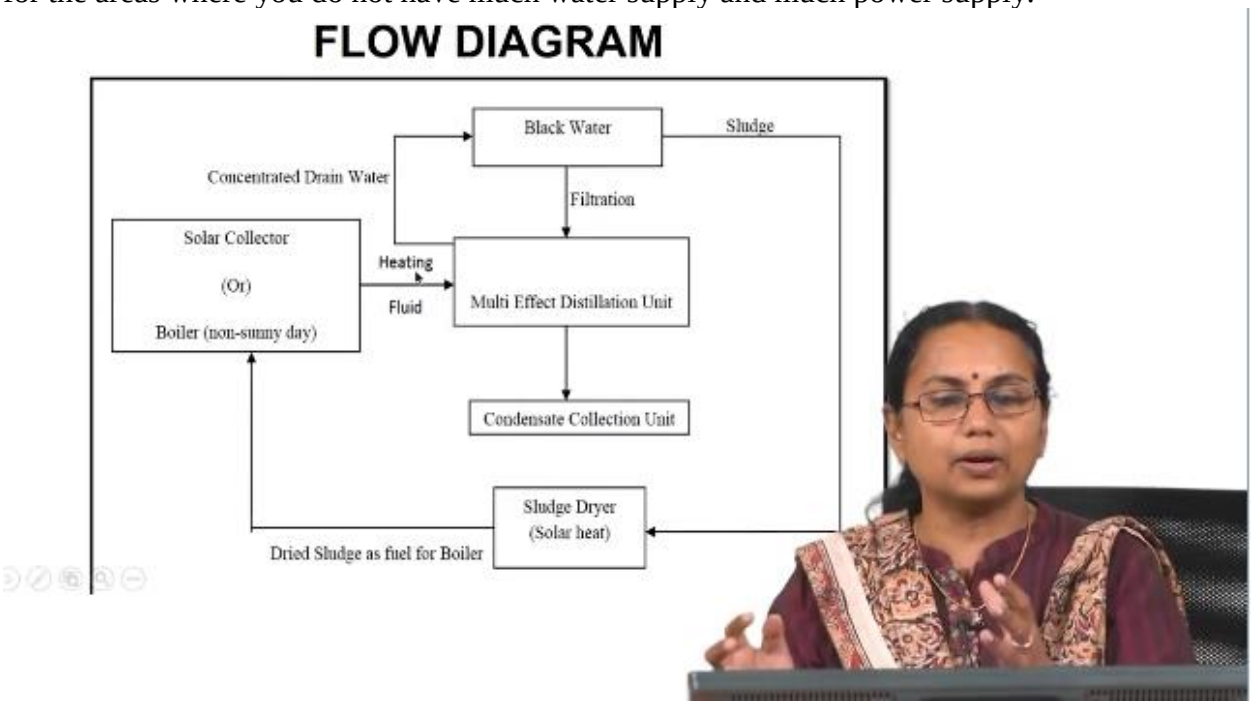
Graphs for analysis on 03.11.2015



Water Quality Photos



And another example I am going to explain is the design and development of solar thermal energy system for domestic sewage treatment, especially black water. These systems are suitable for the areas where you do not have much water supply and much power supply.



Especially for remote areas or tourist places where you do not have access to such places. So, here the system is very simple, what we are doing is from the toilet whatever is coming you separate the solid and liquid. And solid you dry using a solar dryer and the liquid what you do, you go for vacuum distillation using solar power. So, you will be getting very good quality water, distilled water. And you will be getting solids-free of all the pathogens, which is very rich in nutrients and organics, which can be used as a fertilizer. So, initially we have done the laboratory studies and all the things, and we could see that all the pathogens are getting killed in the liquid as well as the solid.

Elemental analysis

TESTS	C%	H%	N%	S%
Synthetic faeces with E.Coli	39.62	5.944	4.49	0.305
Synthetic faeces without E.Coli	41.70	6.336	4.24	0.284

Plate count test

	Before drying(CFU/100 mL)	After drying(CFU/100 mL)
Synthetic faeces with E.Coli	4*10^5	0
Synthetic faeces without E.Coli	-	

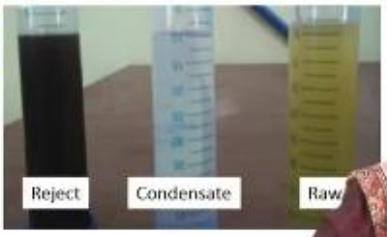
So, this is the thing, and when you do the distillation, you can see that this is the raw water, you can see the color, and this is a condensate, it is as pure as distilled water.

Synthetic Faeces made artificially in lab

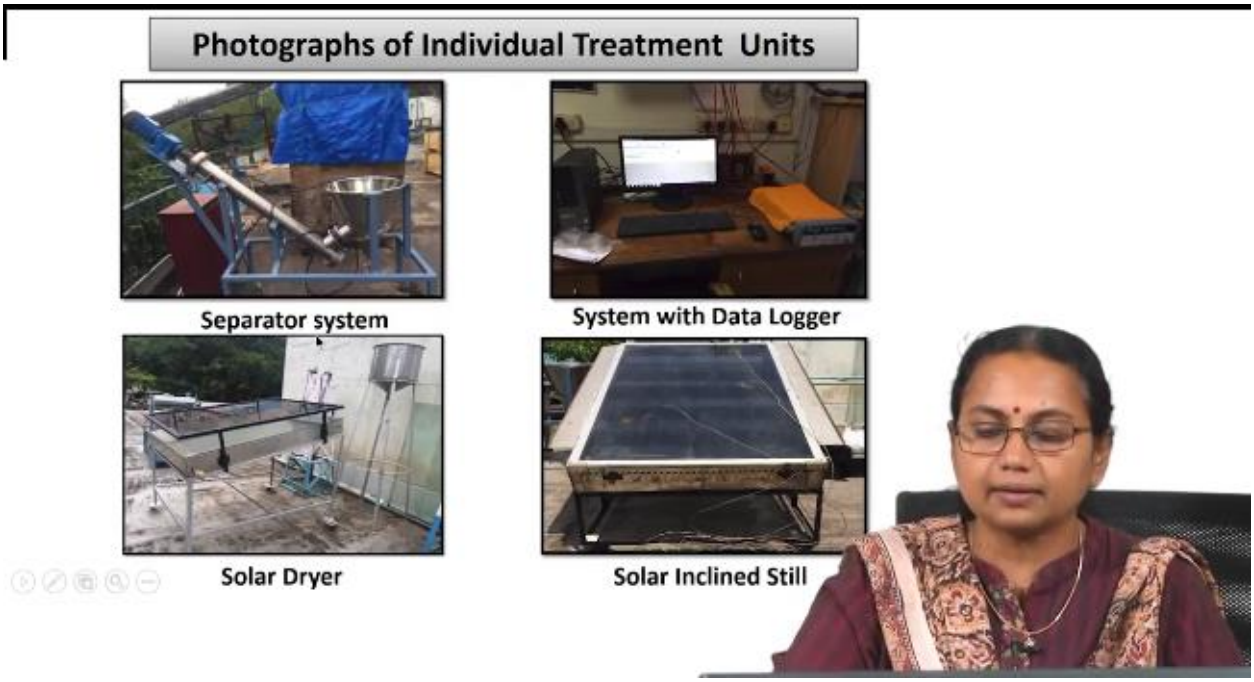
Synthetic Faeces After Drying

Synthetic Urine made artificially in lab

Synthetic Urine After Distillation



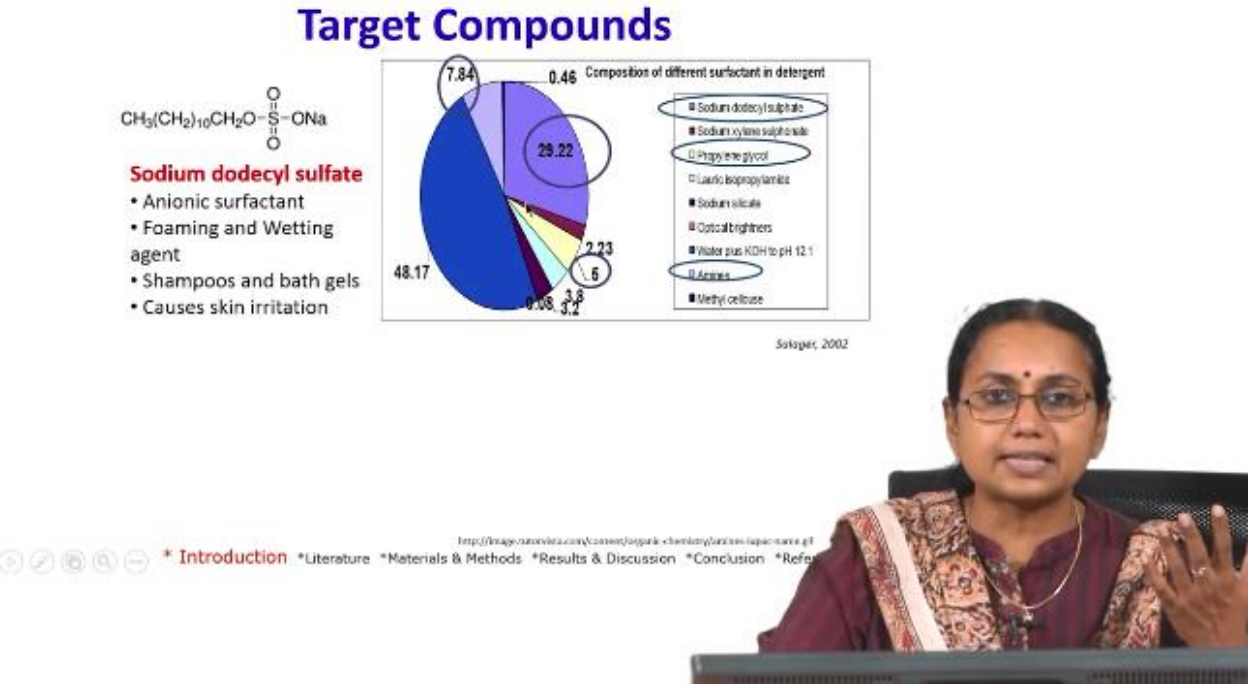
And you get around 10 to 15 percentage reject. What we do is this reject, you mix with the solid and dry it so that the nutrient content of the solid will be very, very high and the solid is free from all the pathogens and other things. So, these are our pilot-scale systems.



We could get very good efficiency. And this is the dried solid which can be used as the manure, and we have already installed a unit, toilet unit with the drier and other things, it is working very well.

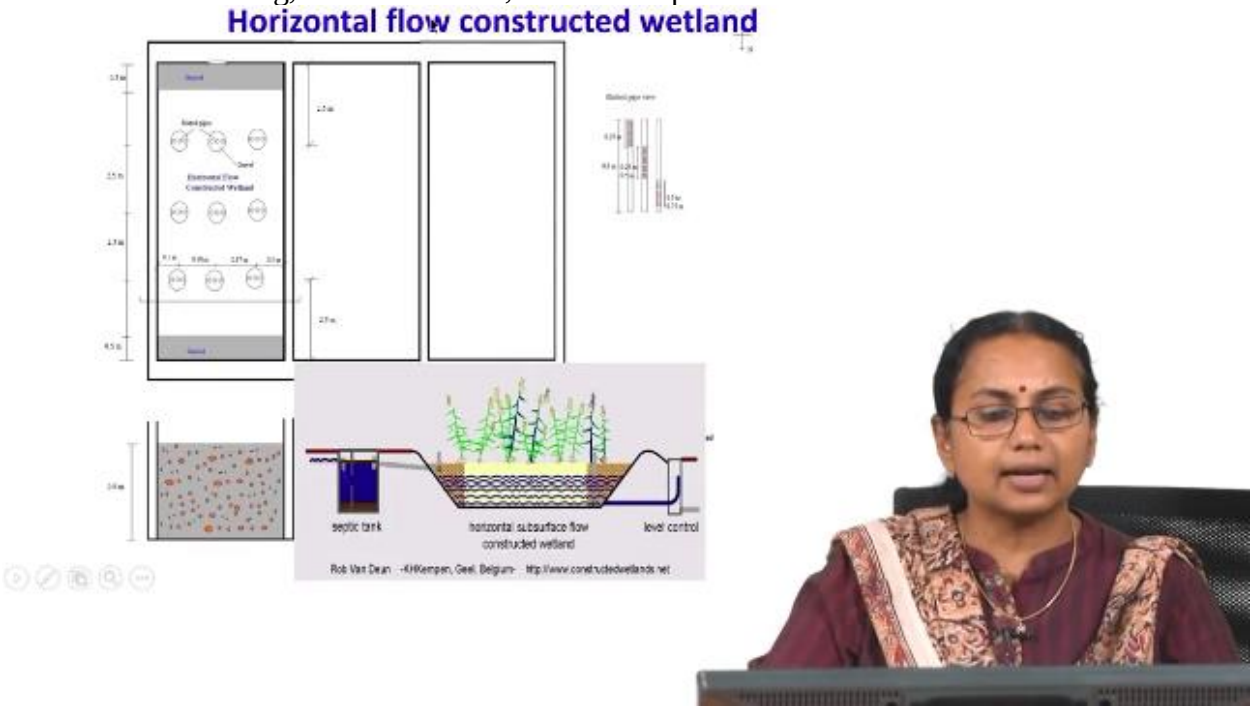
So, what I am trying to tell is, we can think of different options, which will be recovering all the resources present in the wastewater. Here we have two advantages; one is we are protecting the environment from the pollution, that means no residual pollution is getting into the environment. And we are recovering all the resources, and we are reusing, so these are the sustainable ways of managing wastewater.

I will also show another very simple method of treating the grey water; we can use constructed wetland. And constructed wetlands are different types available, horizontal flow, vertical flow, hybrid, or the GROW system that means which can be kept in the rooftop or even in your front yard or backyard. Different types of wastewater and we also looked into how the surfactant and all are getting removed.

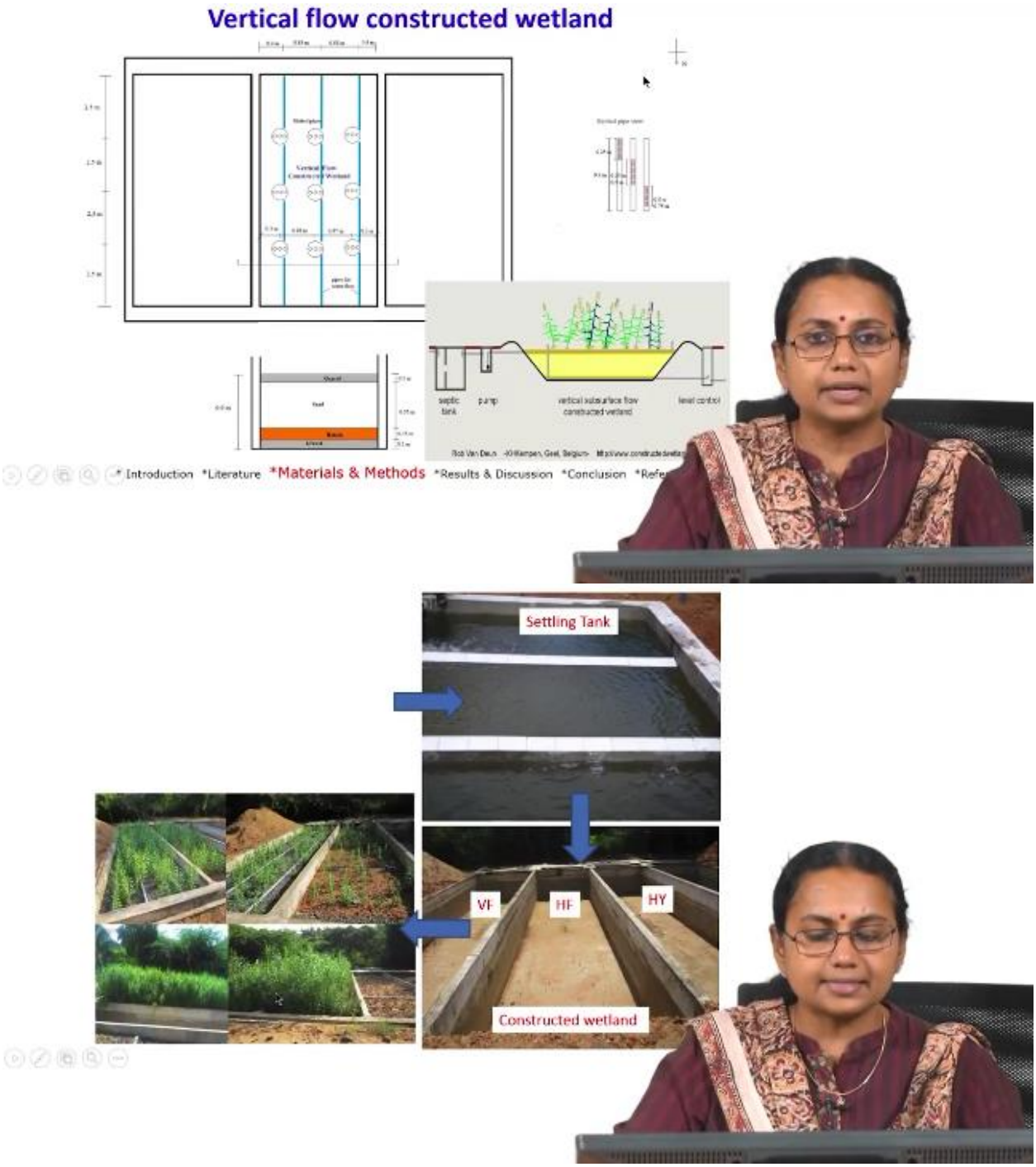


Because when we talk about the grey water, grey water is nothing but the water coming from bathrooms, washing machines, and washbasins. So, it will be having a lot of surfactant contents and all, so we were looking into the fate of this compounds etcetera in the constructed wetland.

Whether the water is safe for reuse that was the purpose. So, this is the constructed wetland, around 10 meters long, 2.5 meters each, so we have put it in a hostel.



And you can see that the plants are growing very well. So, what you have to do is have a settling tank, so that if you have any settleable solids, it will be settling.



Then allow the water to pass through the constructed wetland. So, all the pollutants will be getting removed by the combined action of physical processes, chemical processes, and biological processes and you will be getting clear water, this water can be used for flushing purposes, gardening purposes and all. So, this is an example of the GROW system.

This looks like a garden, and the water is subsurface flow, so you will not be having any mosquito menace or anything. So, the water enters here, and it flows like this in a plug flow manner, and you will be getting the treated water.

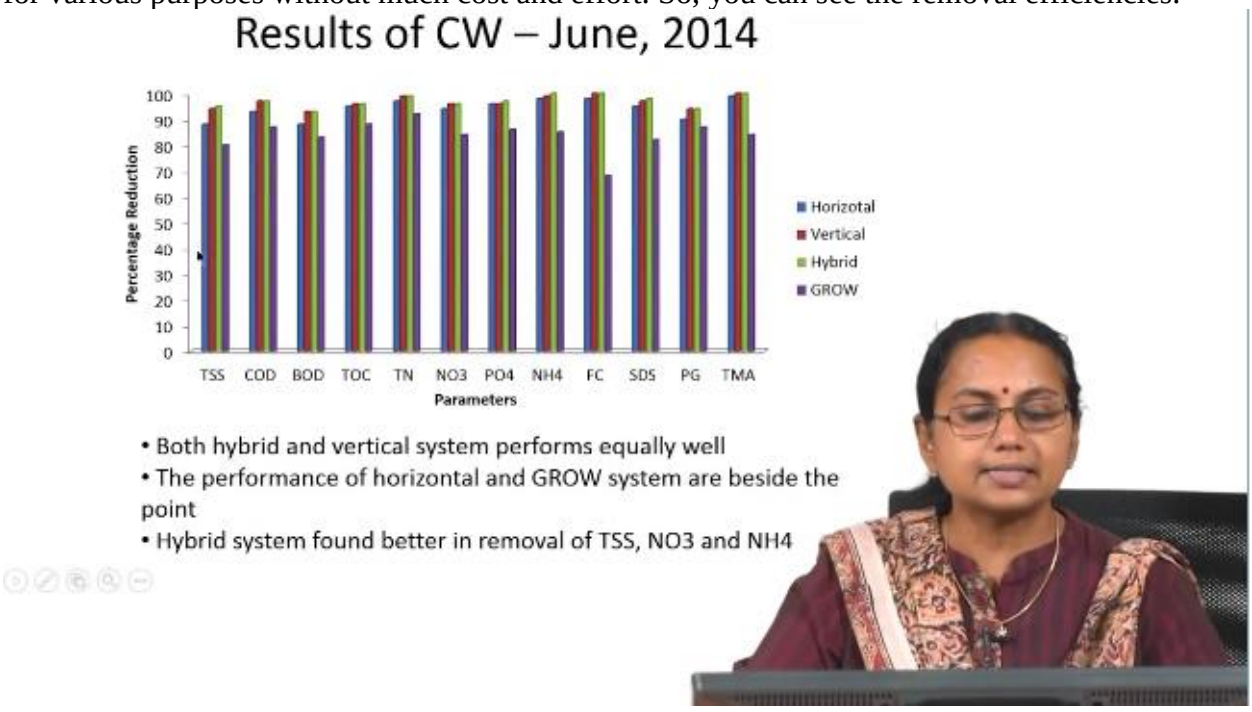
Greywater characteristic – IIT Madras

Parameters	Raw Sample	Settling tank outlet	HF Final outlet	VF final outlet	HY final outlet	GROW final outlet	Standard limits for reuse
pH	8.34	7.82	7.14	7.10	7.11	7.28	5.5 to 9.0
COD (mg/L)	240	160	16	8	8	32	10
BOD (mg/L)	80	64	10	5.6	6	14	< 5
TSS (mg/L)	280	140	28	16	14	56	10
TOC (mg/L)	36.482	22.397	1.82	1.46	1.40	4.28	NA
TN (mg/L)	28.82	18.10	0.82	0.22	0.28	2.28	NA
NO_3 – N (mg/L)	17.842	15.126	1.028	0.73	0.68	2.88	10
TP (mg/L)	2.934	2.472	0.128	0.118	0.102	0.482	5
NH_4 – N (mg/L)	14.56	7.87	0.24	0.12	0.12	2.14	50
MPN – FC (mg/L)	50	30	2	2	1	16	Not detectable / 100 m L
SDS (mg/L)	14.99	12.36	0.72	0.48	0.32	2.74	1
PG (mg/L)	46.59	45.31	4.58	2.84	2.72	6.22	NA
TMA (mg/L)	15.54	11.93	0.17	0.08	0.14	2.40	N

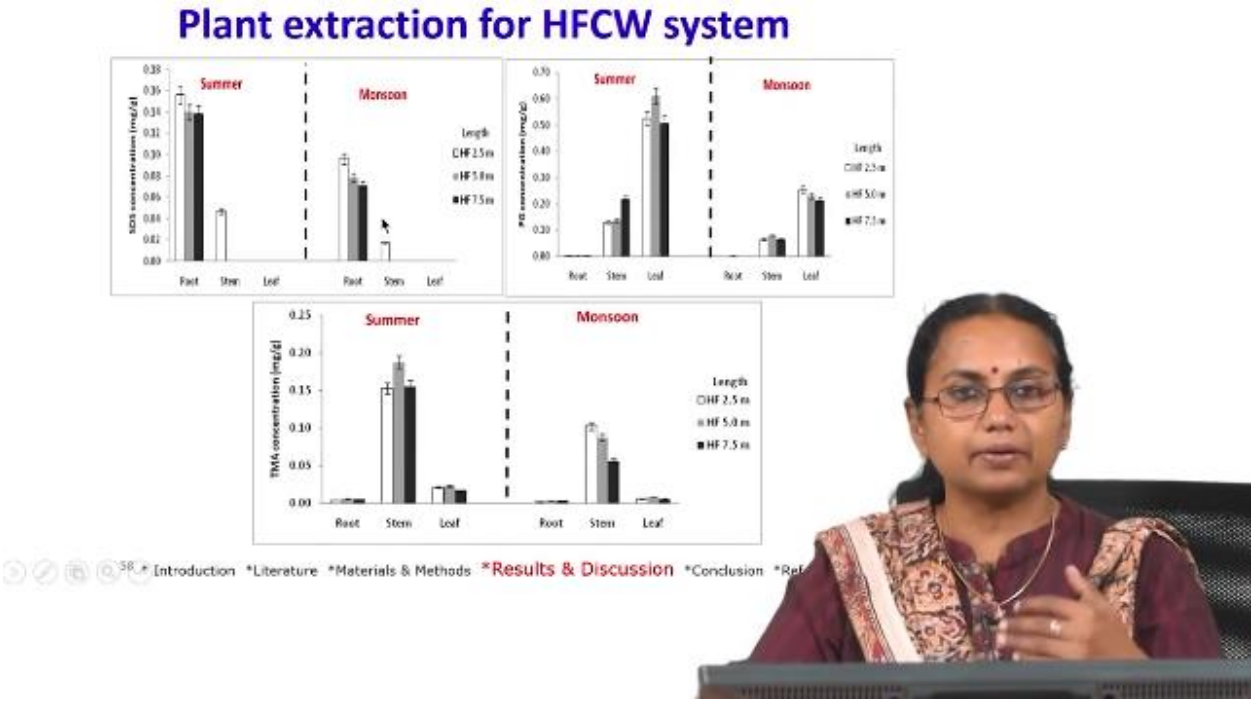
So, you can put any type of plants, flowering plants so it will be looking as a, looking like a garden, so you can put it in the front yard or in the roof, and you will be getting all your grey water treated properly. So, I am showing some example, you have a raw grey water, and we are treating it using the horizontal flow system, vertical flow system, and hybrid flow system, you can see that how the concentrations are getting reduce. This is the chemical oxygen demand, it is

getting reduced to very less 8 milligrams, and this is the BOD, TOC, and even the surfactants are getting reduced to very, very low level.

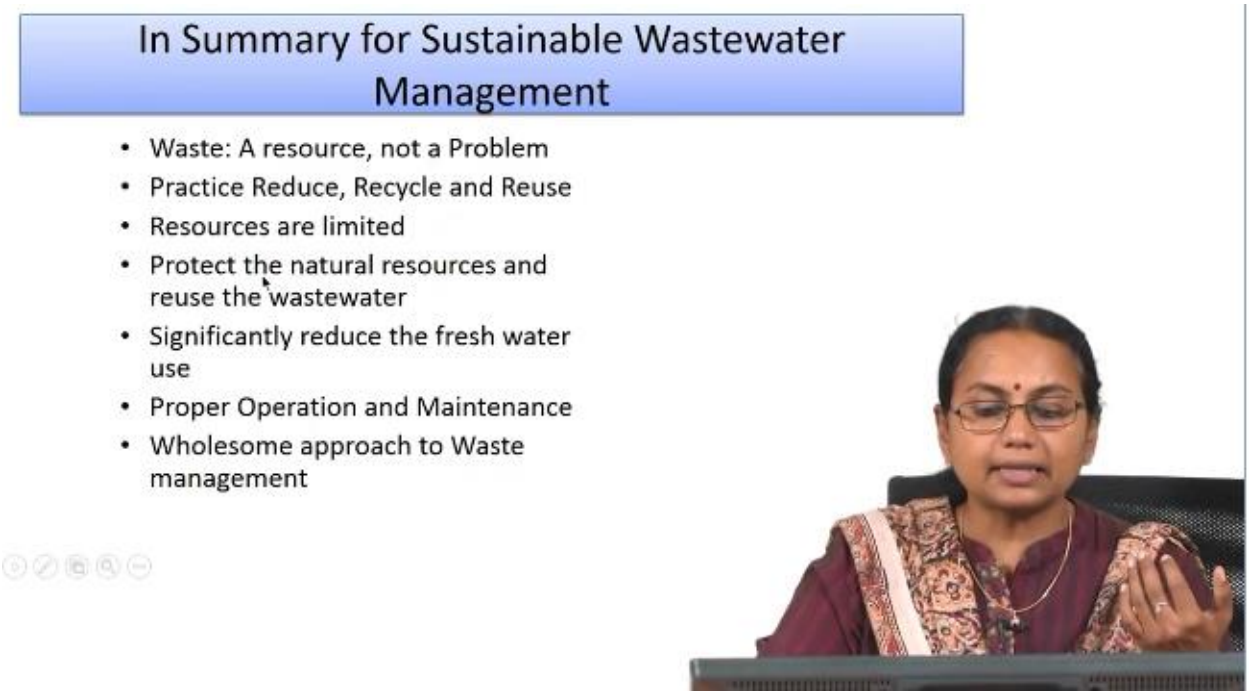
What I am trying to tell is, there are many, many technologies some are very sustainable and inexpensive for the management of wastewater. We can treat them properly; we can reuse them for various purposes without much cost and effort. So, you can see the removal efficiencies.



All the wastewater quality parameters I have put it here, and we are getting the efficiency more than 90 percentage. 90, 95 percentage in most of the cases.



And we also looked into the whether the plants whatever we are putting there, for example, I am putting some fodder grass there, whether this fodder grass can be used as a fodder. Whether it is having any health impact on the cows or cattle. So, we have looked into how much is the surfactants and all getting accumulated in the plant, and we could see that some amount is getting accumulated, but it is not up to that toxic level, so most of the time it will not be a problem.



So, in summary for the sustainable wastewater management, the first thing we have to do is, waste is not a problem, it is a resource. So, once we realize that one, half of our problem is, or majority of our problem is solved because the moment people realize that the wastewater is a reliable source of water supply, people will be interested to collect the wastewater and treat it. So, that is the first thing.

Second important point is practice reduce, recycle and reuse option. Wherever you get lot of water, do not try to use it as much, use as much as possible, try to reduce the use, recycle and reuse the water because the resources are highly limited. Protect the natural resources and reuse the wastewater, because unless we manage our wastewater properly, it is very difficult to protect our surface and groundwater sources. So, manage your wastewater properly so that the natural resources are protected.

And if you reuse the wastewater, you can significantly reduce the freshwater use, it can be reduced to 40 percentage of something like that because majority of our use can be met by the treated wastewater. Then proper operation and maintenance of the plants are essential because many times what happens people will be putting up the wastewater treatment plant with all the enthusiasm but when it comes to operation and maintenance, they will not be doing it. If you are not operating and maintaining the plant properly, the plant will not work, and it will lead to much more problem. So, if you want to have a proper wastewater management, we have to go for a wholesome approach to waste management. That means if you are talking about a city, you may

think about centralized, decentralized and onsite systems as a whole and city sanitation plan etcetera are very, very important in this aspect.

Thank you very much.