**INDIAN INSTITUTE OF TECHNOLOGY MADRAS**

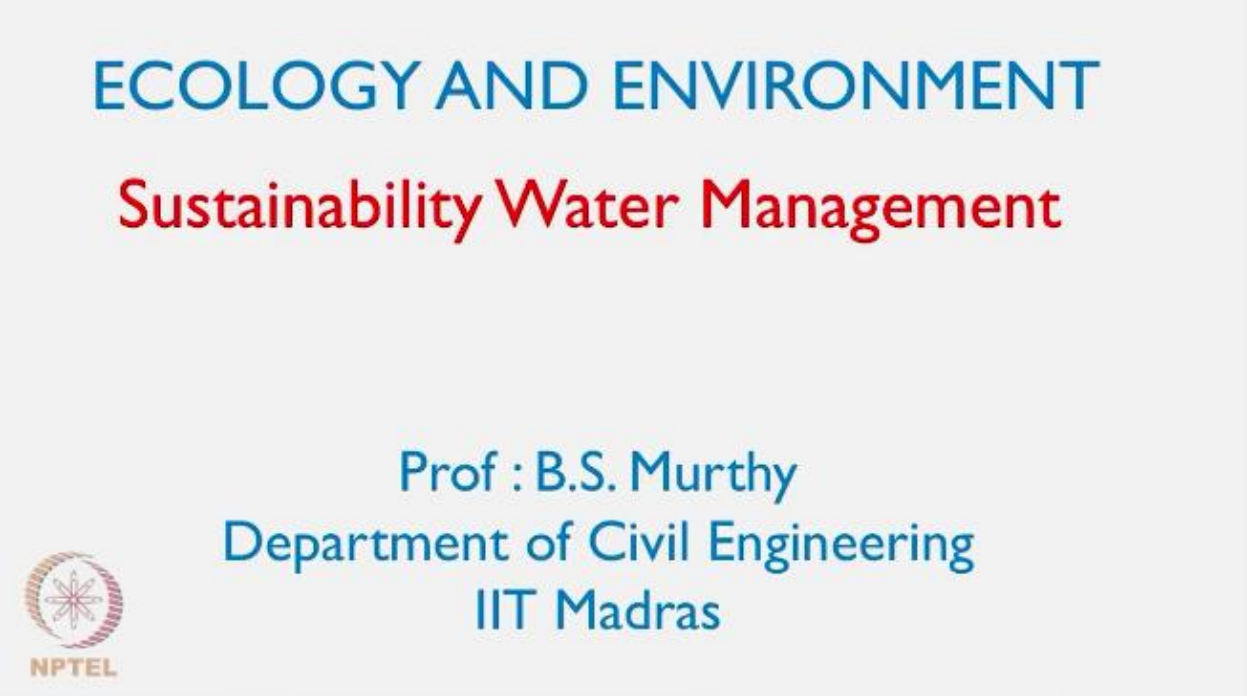
**NPTEL**
**NPTEL ONLINE CERTIFICATION COURSES**

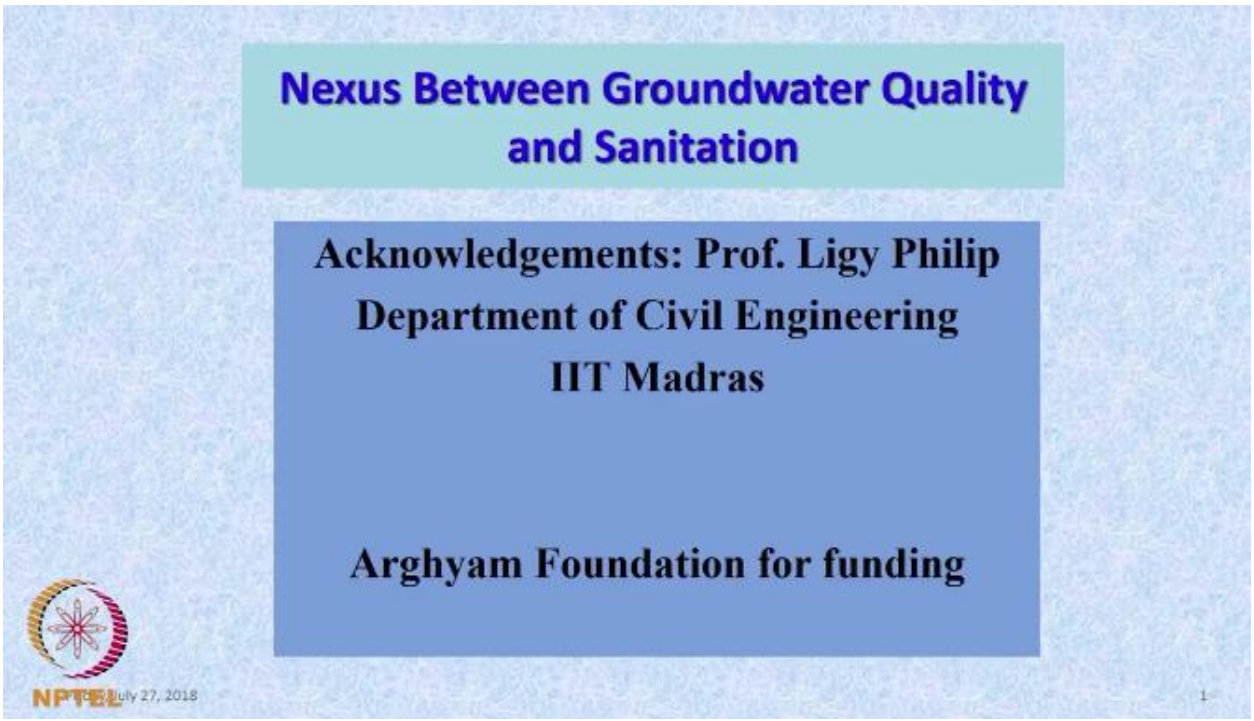
**ECOLOGY AND ENVIRONMENT**

**Sustainable Water Management**

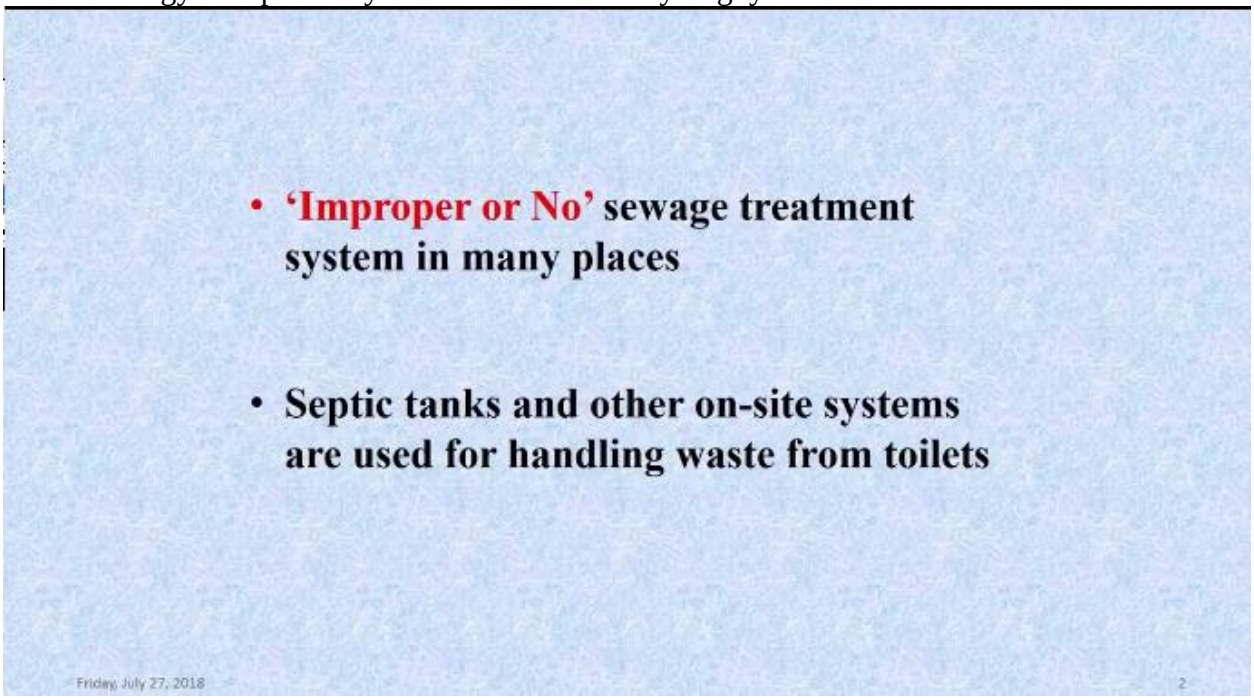
**Prof. B.S. Murthy**
**Department of Civil Engineering**
**IIT Madras**

**Nexus Between Groundwater Quality and Sanitation**



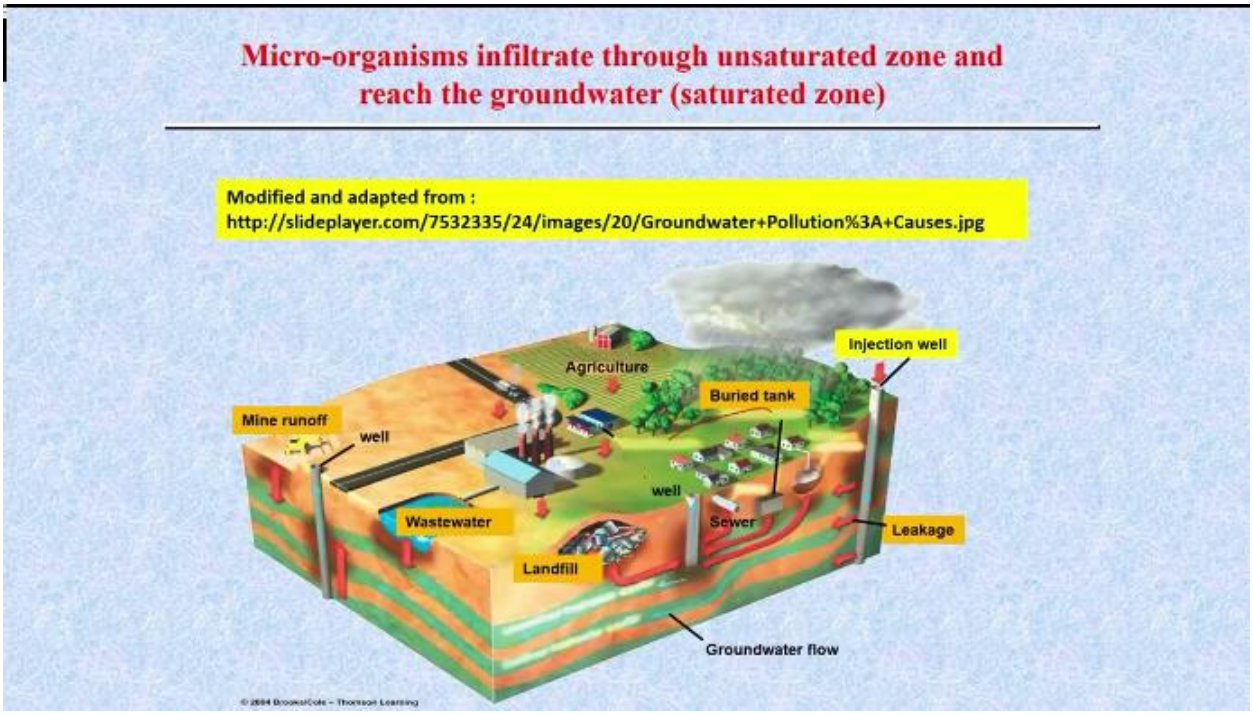



In this lecture, I would like to demonstrate the interconnectedness between several issues when it comes to sustainable development. This, I would like to demonstrate through discussions of a case study on nexus between groundwater quality and sanitation. This study was carried out by Professor Ligy Philip and myself and was funded by Arghyam Foundation.

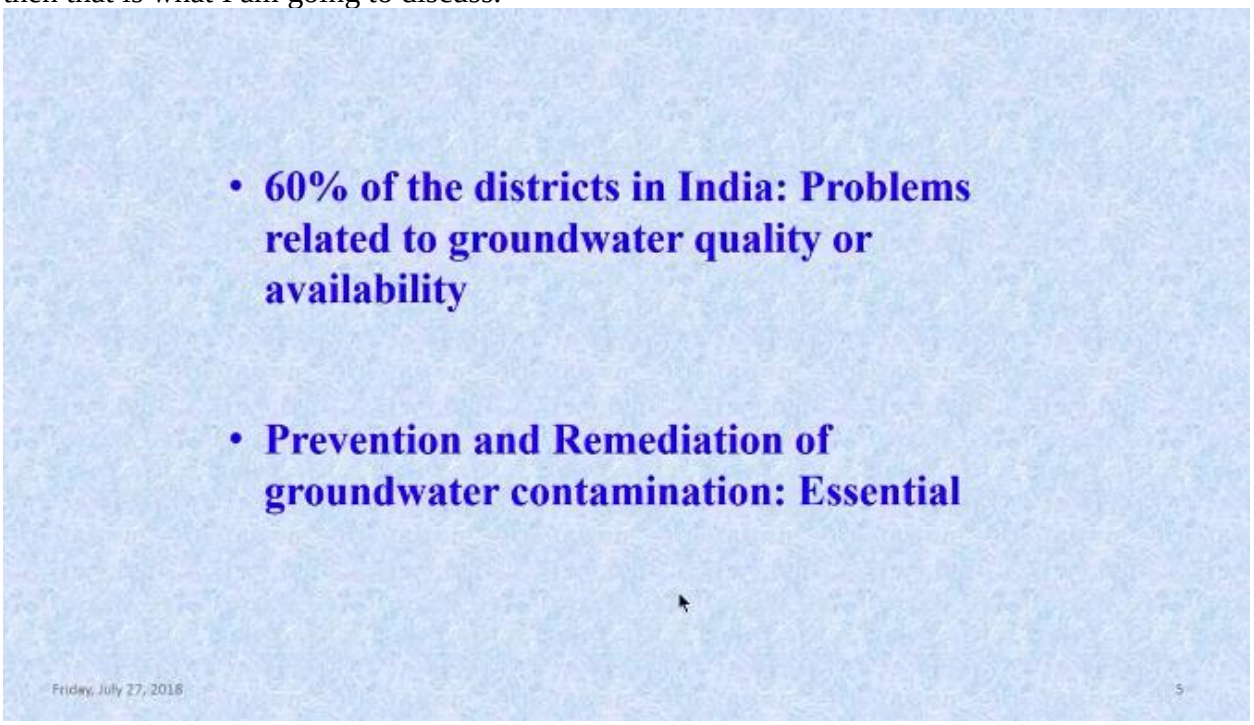



We do not have proper sewage treatment system in many places in India and elsewhere, in fact, improper or no sewage treatment systems in many places, not only in India but in many other countries too. And in such situations, septic tanks and other onsite systems are commonly used for handling the waste from toilets.

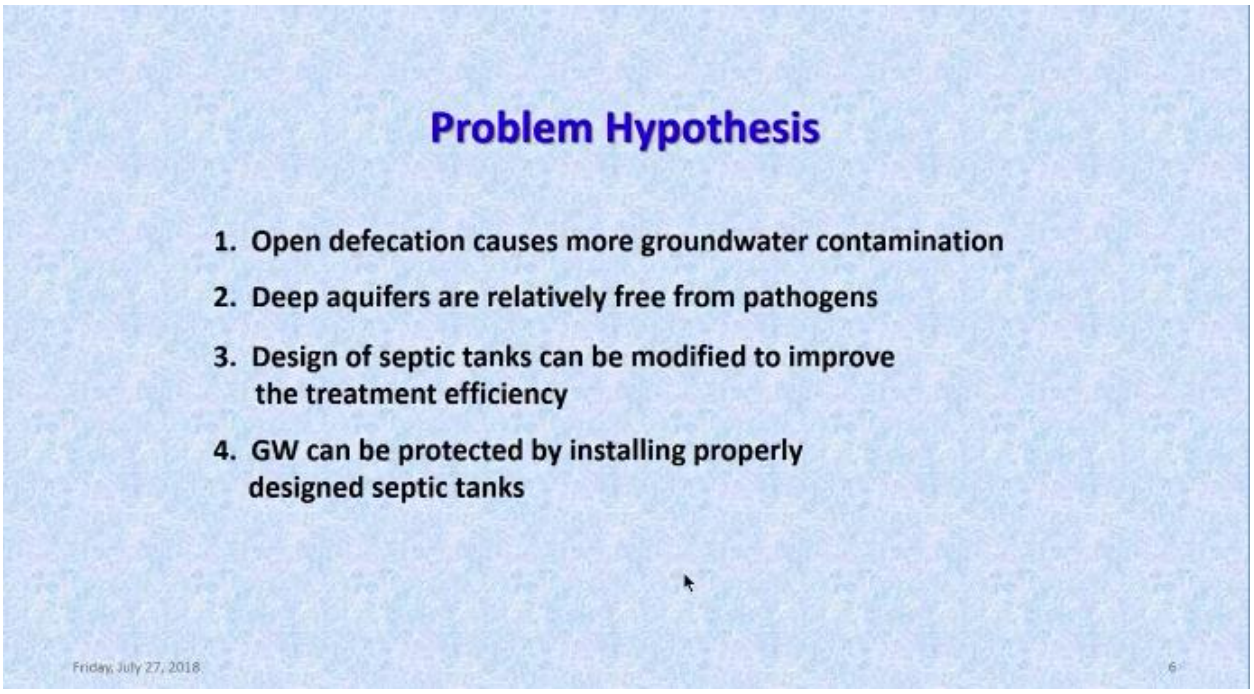

For example, here we show a septic tank that is the waste from the toilet comes into this septic tank and then it gets treated locally there, and this is showing that an actual septic tank here, and this picture shows the drawings of a septic tank. These septic tanks have to be constructed in such a way that there is no seepage of the wastewater from the septic tanks into the surrounding grounds. But many times they may not have been constructed properly or many times people do not provide this bottom, impervious bottom to the septic tanks and let the seepage or the wastewater that can, from the septic tanks can seep into the grounds like what we have shown here.



You have a cluster of houses, and all this waste from the toilets is taken to the septic tanks here. And if this septic tank is not constructed properly or it is not operated properly, then the leachate from the septic tank can go through what we call the vadose zone first and then it will go and then get mixed with groundwater and then contaminating the groundwater. So, your surface sanitation conditions are linked to you know sustainable maintenance of water quality in groundwater sources. This we want to demonstrate, and we have done this particular work, and then that is what I am going to discuss.

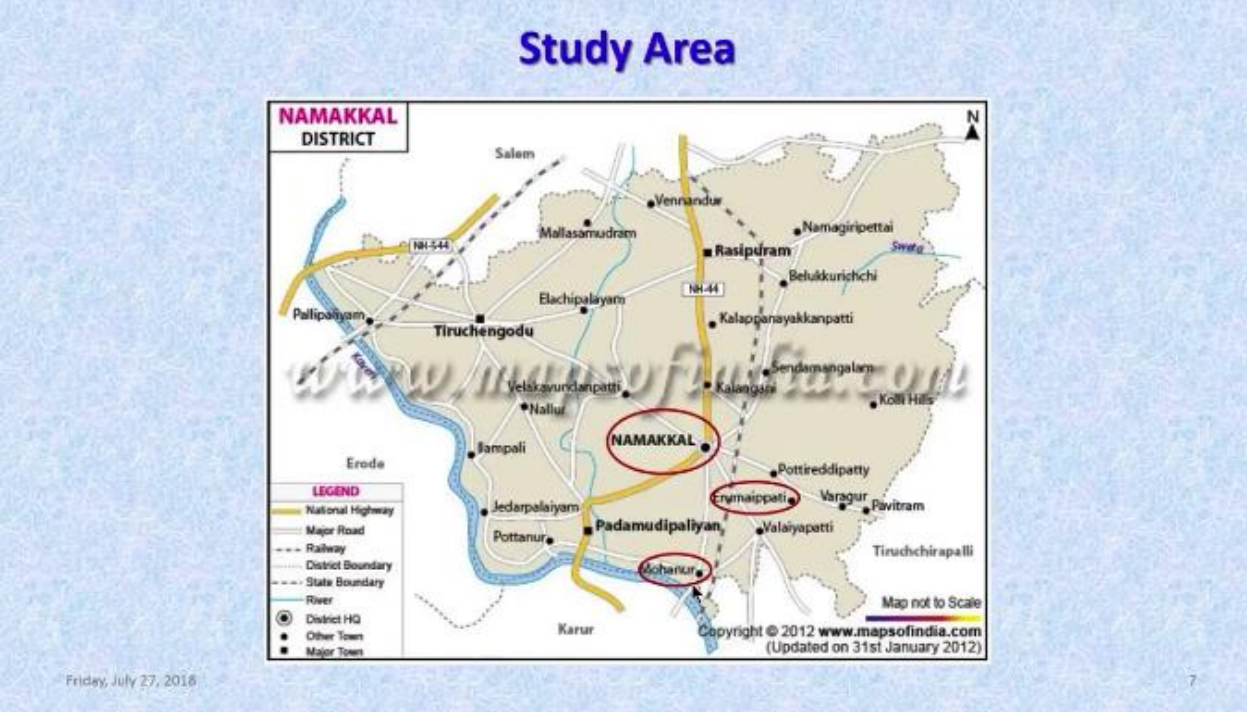



Like 60% of the districts in India, we have problems related to groundwater availability as well as groundwater quality. And we have to protect the quality of this groundwaters if you want to use them for any domestic purpose or any other purpose. And so the prevention and remediation of groundwater contamination is very essential because it is a major source of domestic water.




So, in this particular case study, before we started we had certain hypothesis that is open defecation which is quite common in many places in India causes more groundwater contamination. Deep aquifers that is if we have groundwater table very much below the ground level, those are the deep aquifers are relatively free from pathogens because even if there is a seepage of wastewater from the septic tanks and other onsite systems on the way, there is a filtration action of the soil might prevent pathogens entering into the groundwater bodies.

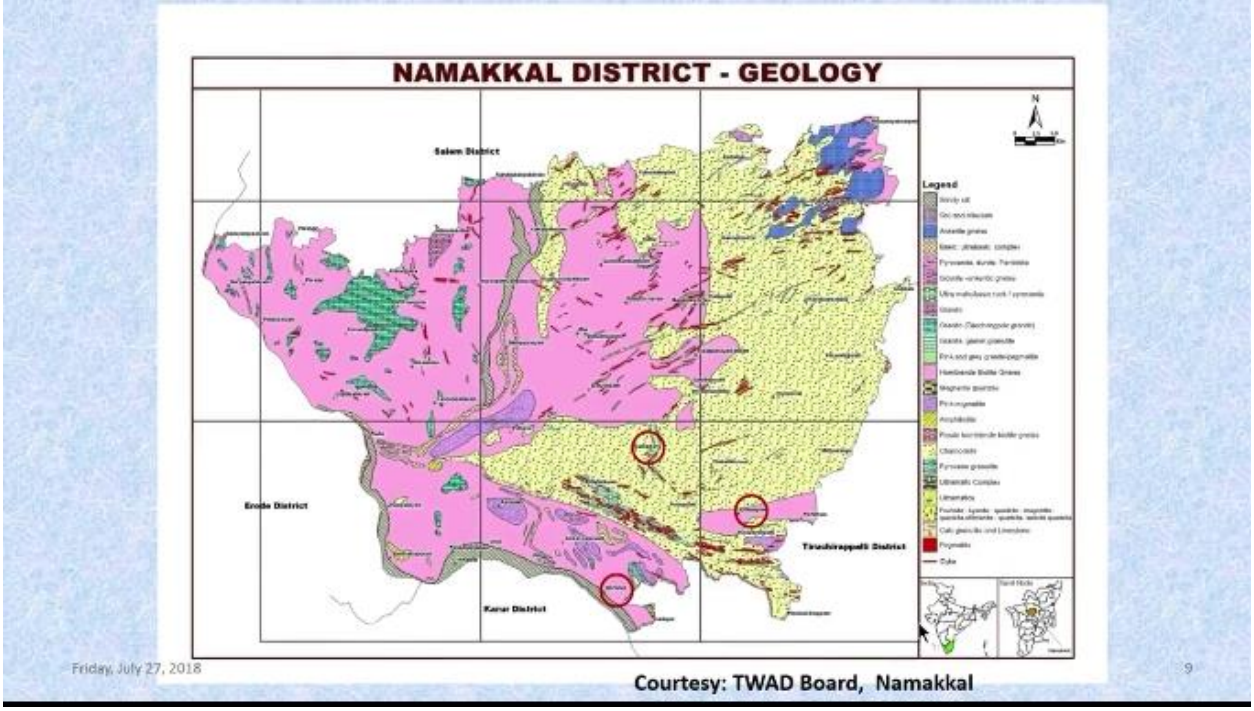
Design of septic tanks can be modified to improve the treatment efficiency. That is we can modify the design of whatever the conventional septic tanks and we can improve the treatment efficiency. And groundwater can be protected by installing a properly designed septic tank. These are the hypothesis we had, and then we will see what we have found out.



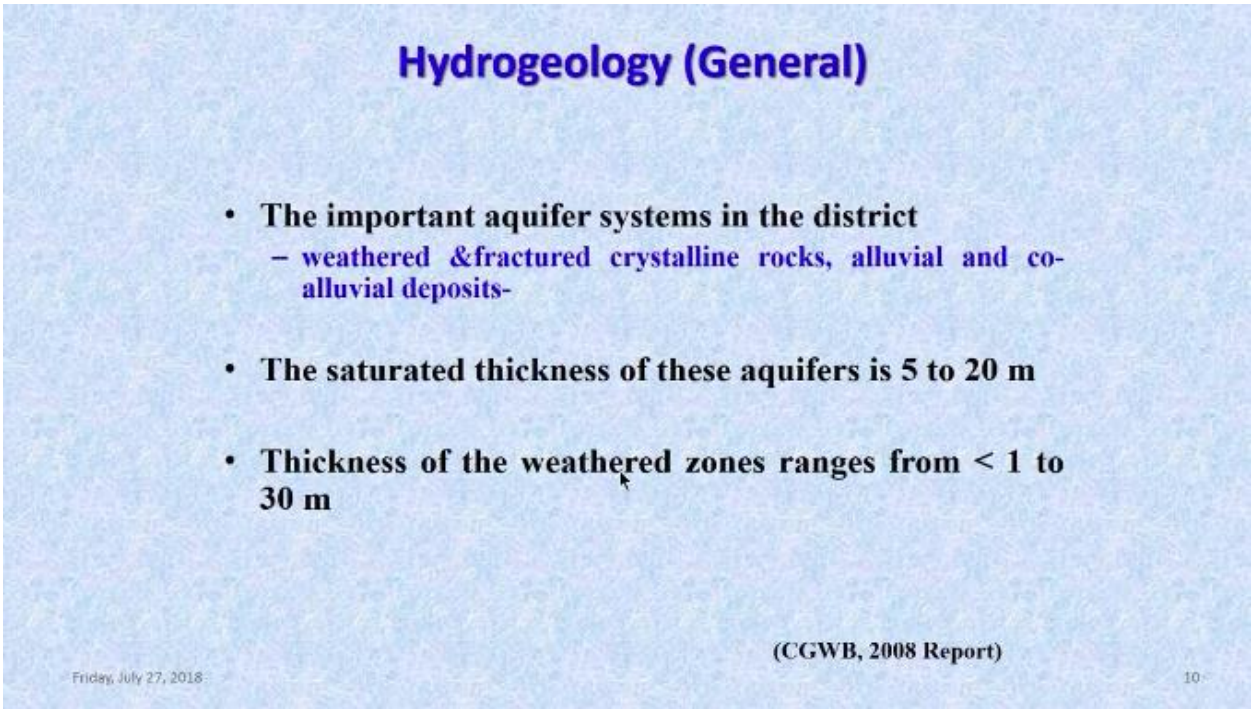

So, we had taken three towns in Namakkal district in Tamil Nadu, that is Namakkal town itself, and then there is another small panchayath town that is Erumaipatti and another small town Mohanur which is very close to actually the Cauvery river.


And the Namakkal town we had a population of 55,145 and as per the last census, and then Erumaipatti we had 12,085 persons. In Namakkal town, 100% of household surveyed had the toilets, but then 100% usage of these toilets is little doubtful because we also could find some open defecation areas. They do have septic tanks, but then the design of this septic tanks is also doubtful, in the sense whether this septic tanks had impervious sides and the bottom that we are

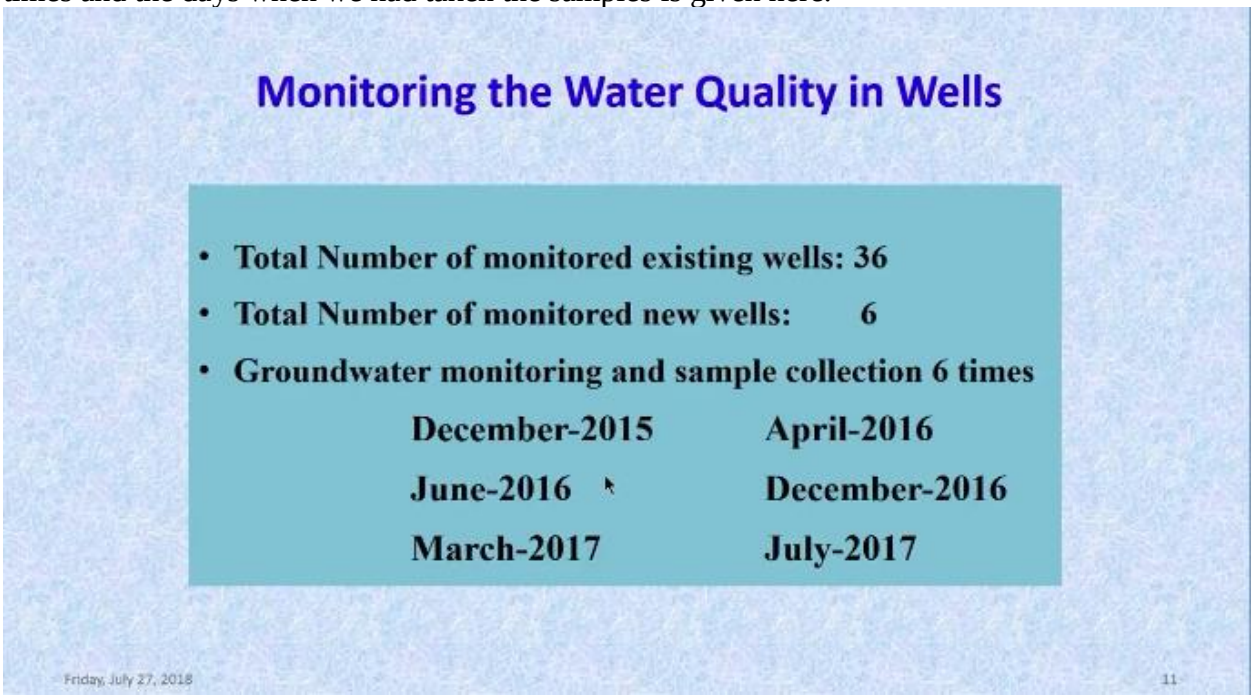
not sure. In fact, many of the septic tanks had pervious bottoms, and then allowed seepage of wastewater into the soil and eventually to the groundwater.



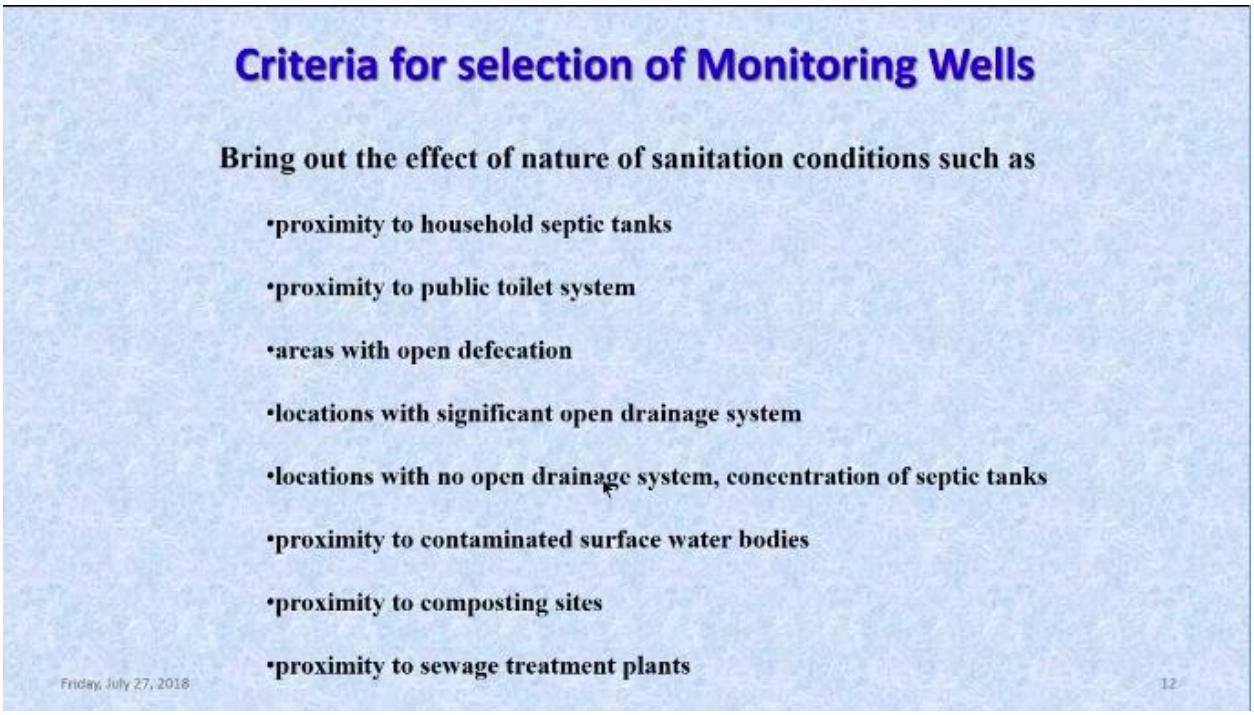

In Erumaipatti 64% of the households that we surveyed have septic tanks, again their design is little doubtful. So and the geology of the area is, it is a hard rock area and this both here, Namakkal as well as Erumaipatti. Erumaipatti had hornblende-biotite gneiss, and then Namakkal had Charnockite. And they had a weathered rock up to 30 meters. The top 1 to 5 meters is soil, then we had weathered rock, and then, of course, we had fractured aquifer. And groundwater level was almost you know 10 meters to even more than 100 meters. The groundwater level was higher in Namakkal town whereas groundwater level was very, very low in Erumaipatti. So, that is what I mentioned about I mean geology of the area which is very important for studying the nexus between the surface sanitation conditions and the groundwater quality.




So, we have chosen about 36 wells which are already existing for monitoring. We have also constructed 6 new wells, as part of our study, and we had carried out groundwater monitoring by collecting samples from these 36 + 6, 42 wells and we had done it over a period of 2 years and 6 times and the days when we had taken the samples is given here.




And we had taken the samples and then we have analyzed for the groundwater quality.




And the way we have chosen these wells which we have monitored is like we have to bring out the effect of nature of sanitation conditions such as weather, the valleys very close to a household which is having septic tanks, proximity to public toilet systems, whether the well is located in an area where open defecation is practiced or location with significant open drainage systems. And in these two towns we had found a lot of drainage system which is not completely impervious, and then the drainage system itself was carrying a lot of wastewater that is coming out of the toilets, and location with open drainage system, with no open drainage system but concentration of many septic tanks, and then proximity to contaminated surface water bodies, they were some few tanks and lakes which actually were receiving partially treated wastewater from a sewage treatment plant, and then proximity to composting sites or solid waste management sites, proximity to sewage treatment plants. And then we also made sure that we sampled both open wells and bore wells. And we were conscious about how much of aerial extent that we can cover through our sampling within each of these things.

## Criteria for selection of Monitoring Wells

- sample both open wells and bore wells
- as much areal extent as possible
- accessibility
- ease of collecting samples and measuring water table level

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And of course, when you chose this monitoring wells, you also have to worry about accessibility that means we can reach these wells easily, and then we can make the measurement, sampling you know in an easy way. Ease of collecting samples and measuring water table level.

## Criteria for selection of monitoring wells

Wells adjacent to toilets & improper septic tanks

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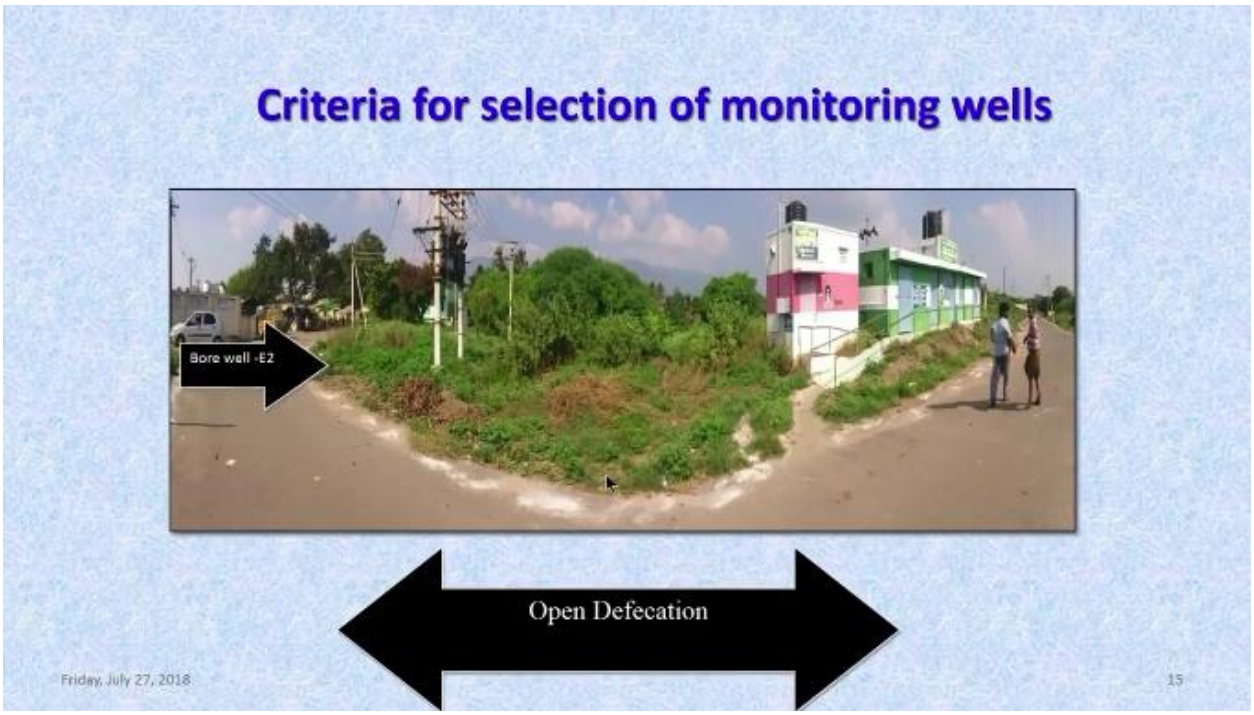
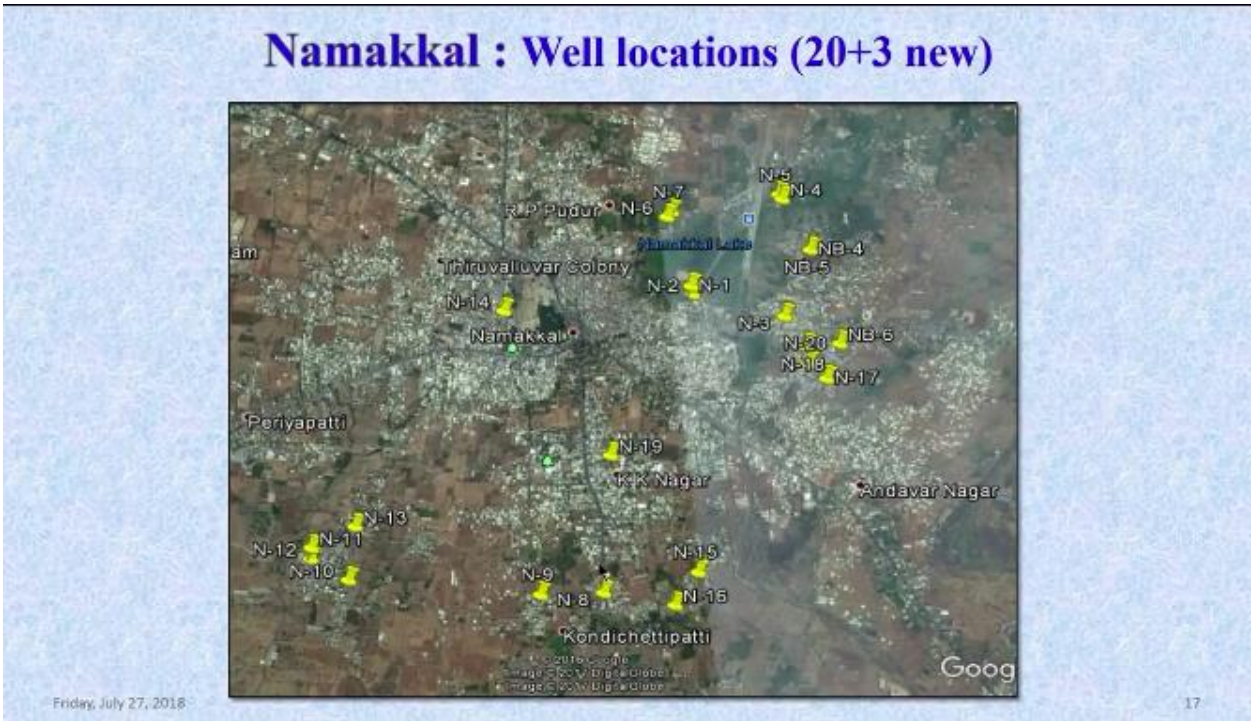
So, I was showing you some, few pictures of our sampling. There is one, I mean a borewell which was located very close to the toilets and improper septic tanks. And there is a borewell which is located to an area which is nearby an open defecation that is being practiced in this area.

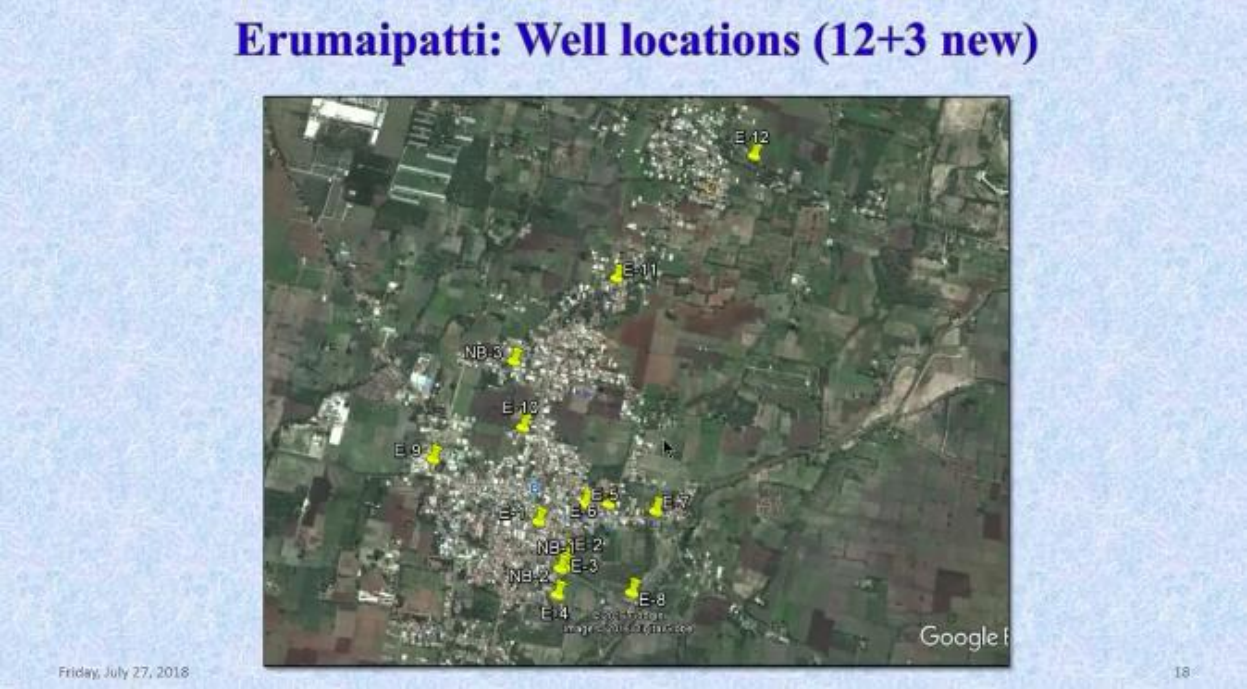



Although they had a community toilet for some reason because of availability of water and other problems, people were practicing open defecation here. So, we had a bore well located, and then we took samples of water from that and analyzed, and then we had an open well which is located very close to a solid waste dumping yard, or it is actually a compost yard not a dumping yard, compost yard.


And then there is an open well, like this we have chosen 36 wells, and then we had taken samples and then we have analyzed them for different water quality parameters.

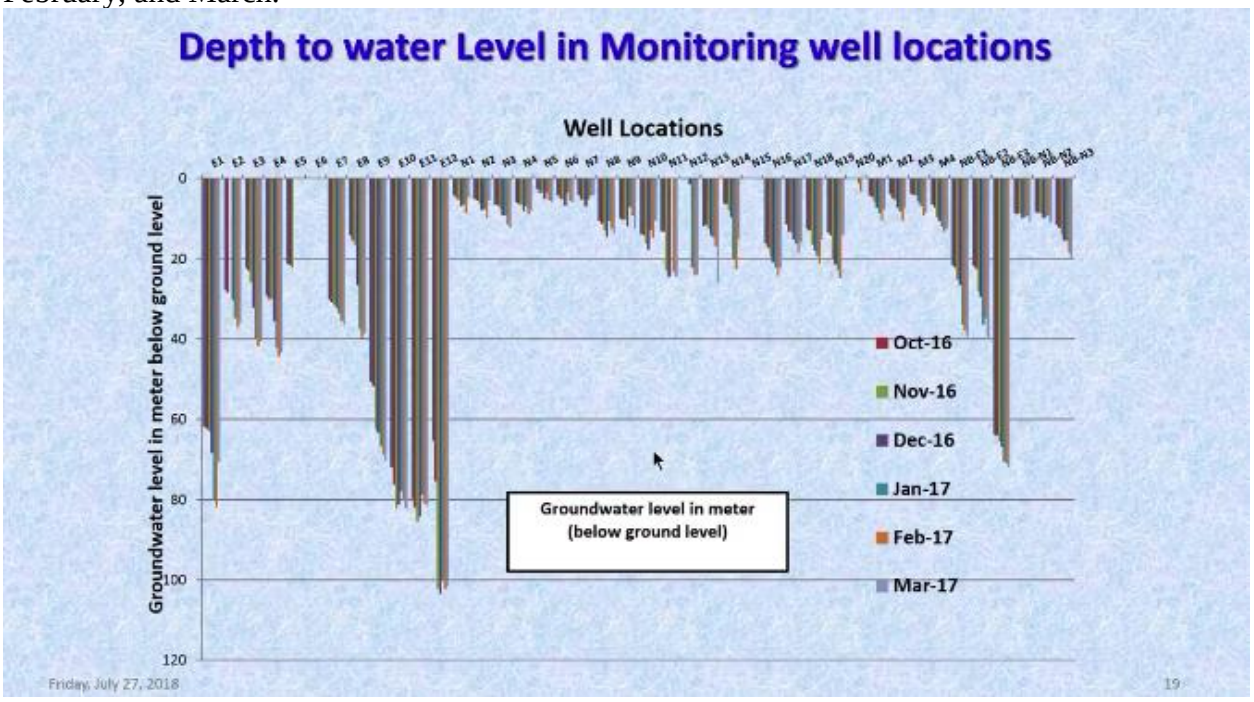



This picture shows that you know in Namakkal town where all we have you know our sampling wells. That I was telling about this is the lake, which is actually receiving, the treated or no the partially treated wastewater and then, and we had some wells around that, and then we also had another solid waste dumping yard, and then things like that and some wells were chosen close to that.

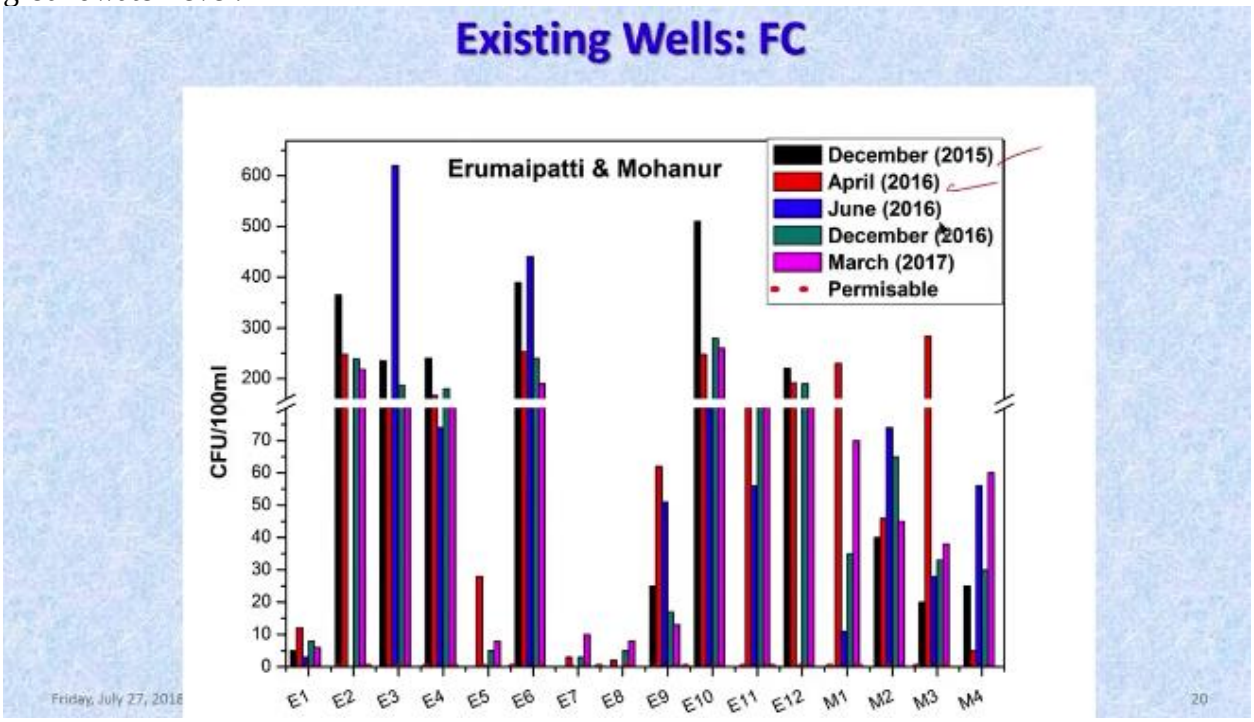



And in this is the Erumaipatti, here we had 12 existing wells and then we also installed 3 more wells for monitoring. And we also measured depth to the water level in these wells, and then we

had done this on 6 times in October 2016, November 2016, then December and then January, February, and March.

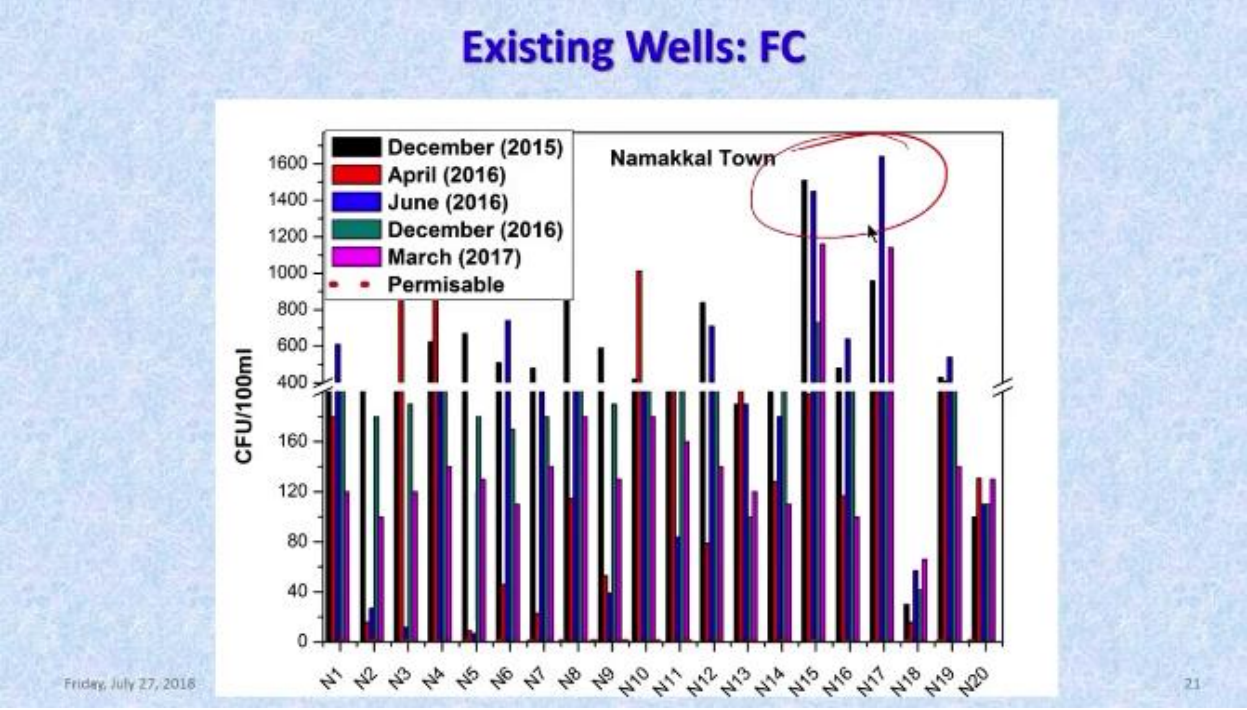



And then we can see that many of these wells in Erumaipatti that is this, this is the region, where the groundwater level is almost 100 meters below the ground level. Whereas in Namakkal town only in some wells it is going below 60 otherwise it is up to about 10 to, I mean 20 to 40 meters. Because this the groundwater level does affect the quality of the groundwater, I mean the quality of the groundwater as affected by the surface sanitation conditions does depend upon this groundwater level.



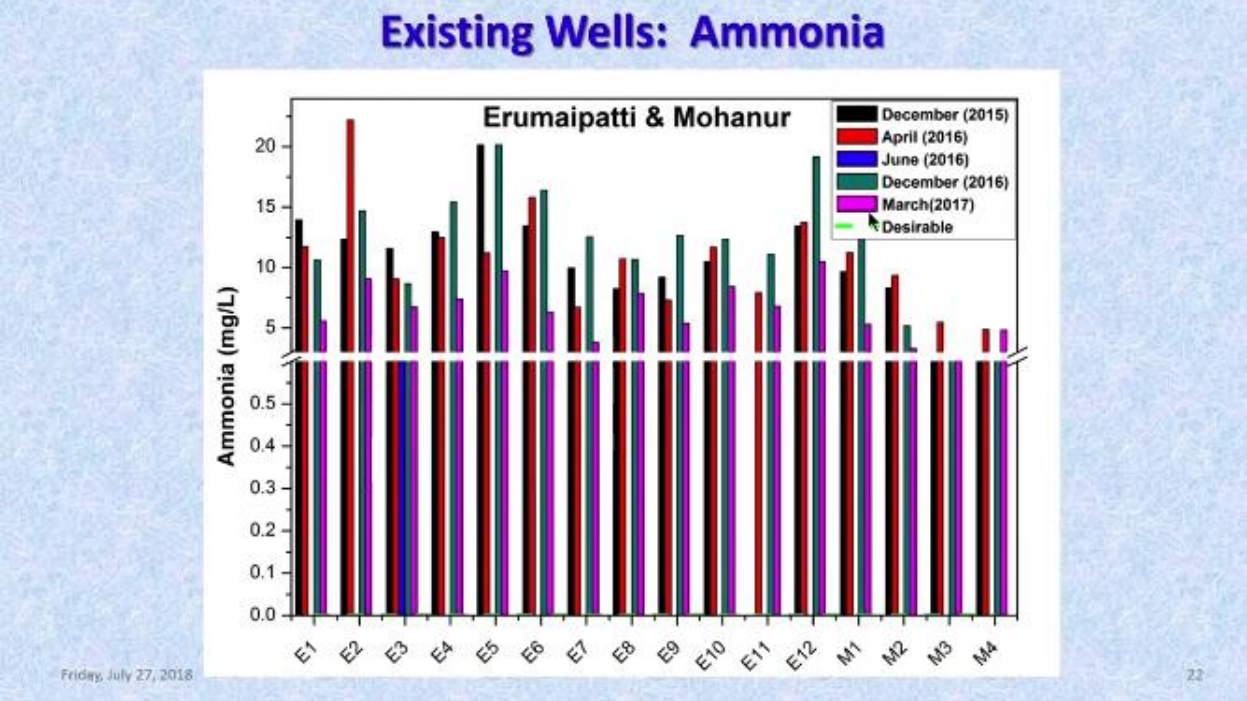
And what are the results we got? For existing wells, FC is the fecal coliform. And as I mentioned we have taken the samples on December 2015, April 2016, June 2016, December 2016 and March 2017, the permissible value for fecal coliform is absolute zero, but you can see that the concentration of the fecal coliform is as high as in some instances, 600 CFU per 100ML, when it should be actually zero. And another interesting thing is, all the wells in Erumaipatti, the 12 wells in Erumaipatti and then four wells in Mohanur, all the wells are contaminated by this fecal coliform.

Irrespective of where they are located, irrespective of what is the surface sanitation conditions close by that, close to that well, whether they are open wells, or whether they are deep wells or deep bore wells or what is the water level in the, you know, what is the water table level in these wells, irrespective of that all the wells are contaminated by fecal coliform. And this is in Erumaipatti and Mohanur. And similar results, we found for the existing wells in Namakkal town, here also in fact in Namakkal town in some of the wells the fecal coliform concentration goes as high as 1600 you know CFU per 100 ML and in fact these are the wells which were very close to the solid waste you know the compost yard.

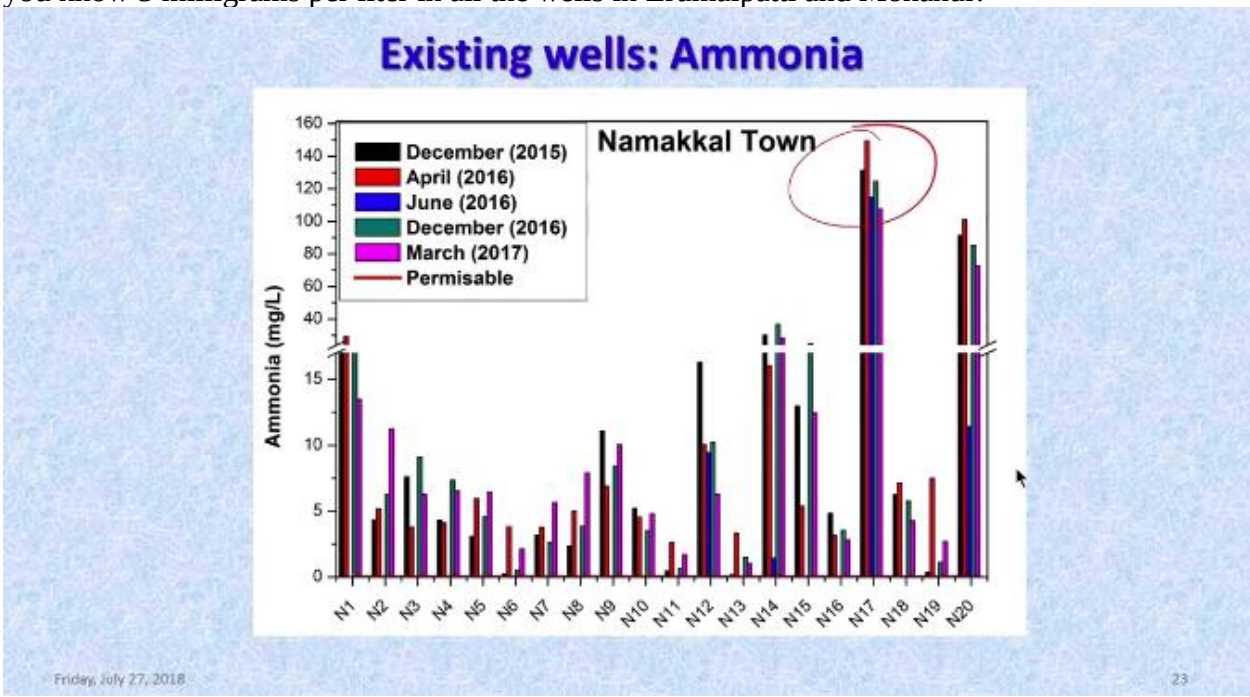


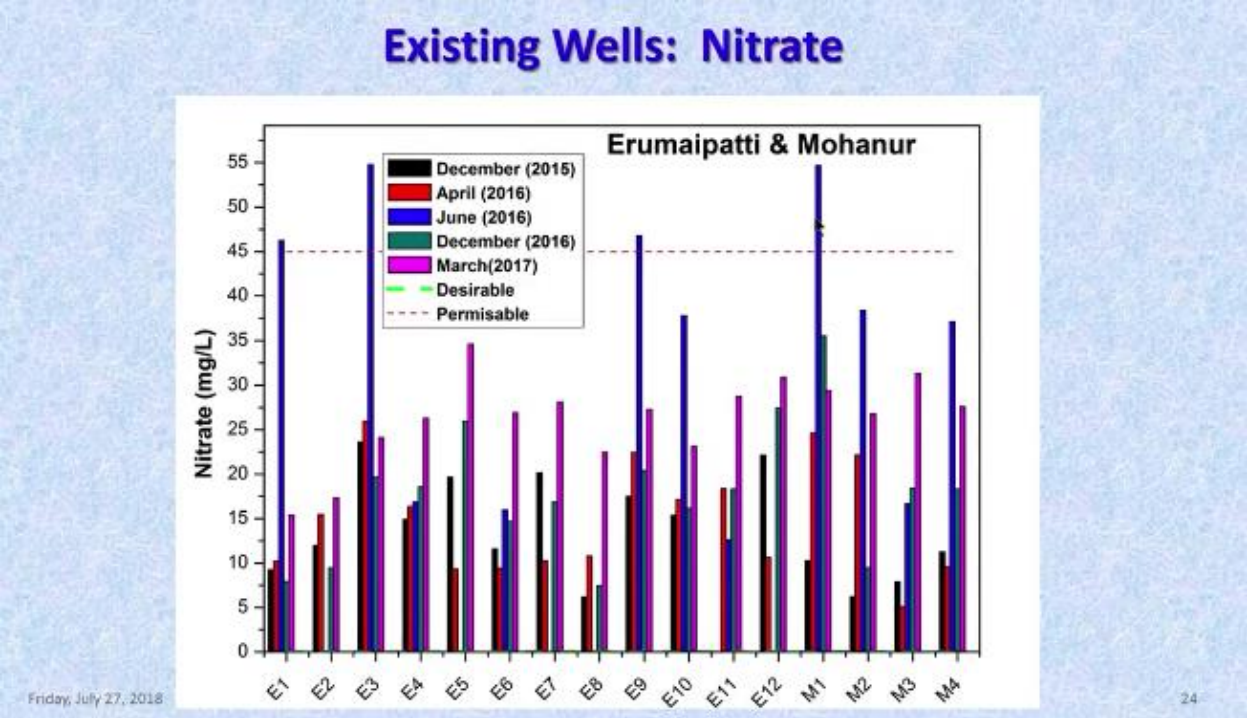

And again all the wells whether they are bore wells or the open wells or where they are located, all the wells have shown the, you know, the presence of fecal coliform in the groundwater.

And if you compare the concentrations of fecal coliform in Namakkal town with respect to the concentrations of fecal coliform in Erumaipatti, in general, the concentrations in Namakkal town or more than the concentrations in Erumaipatti.

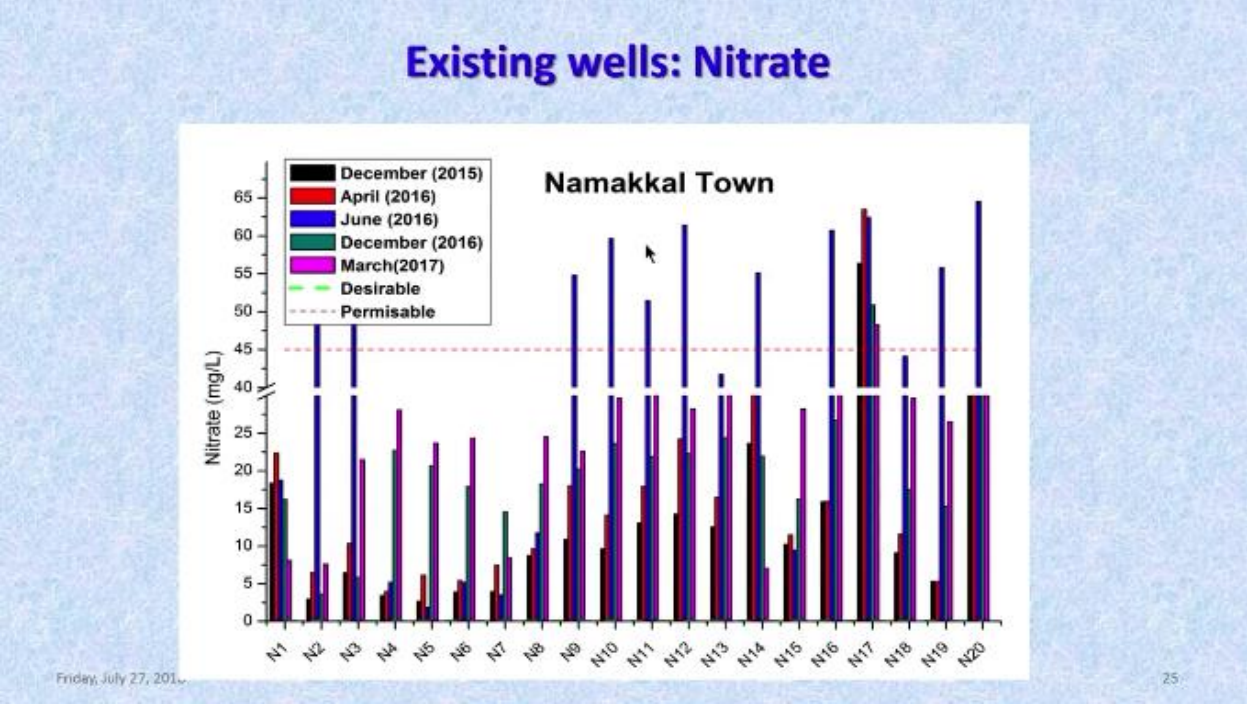



Same thing, not only fecal coliform, in fact, we had done this analysis for many other parameters. Here, I am showing with respect to ammonia, so, ammonia is also found more than you know 5 milligrams per liter in all the wells in Erumaipatti and Mohanur.

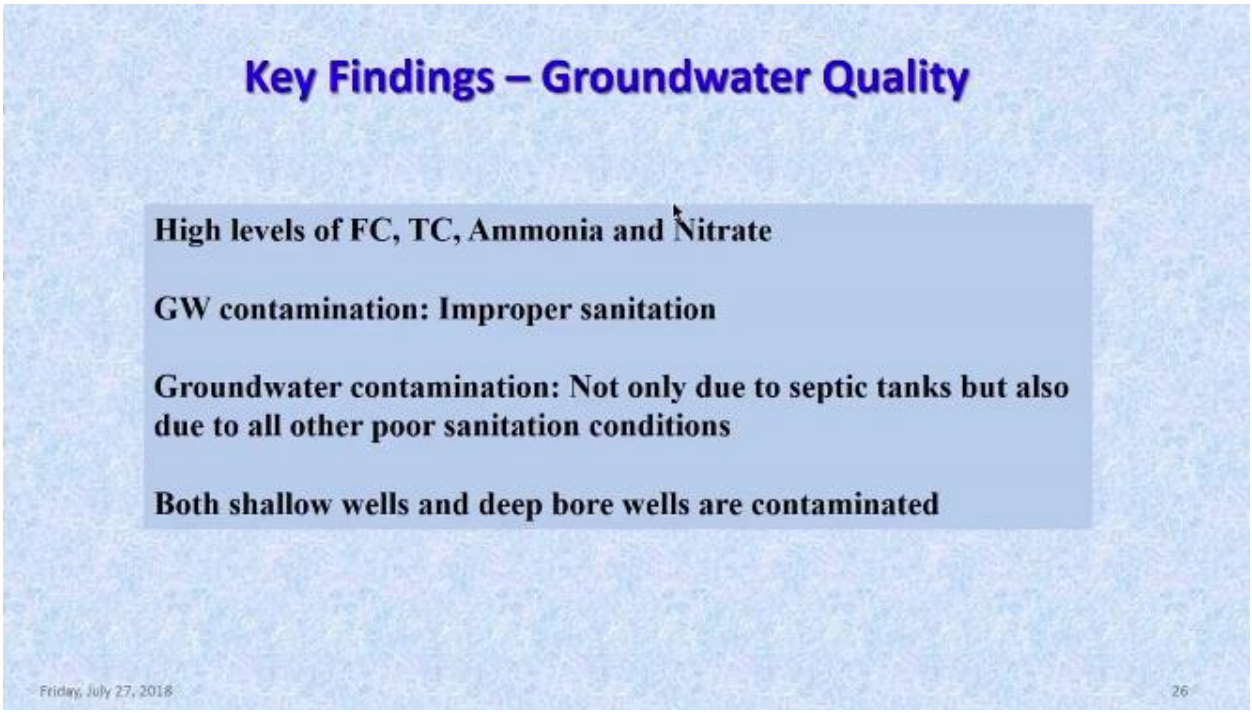





And Namakkal town also it goes as high as you know 140, and 120 to 140 in some of the wells and in general, it is it is about you know more than 5 in many wells in Namakkal town.

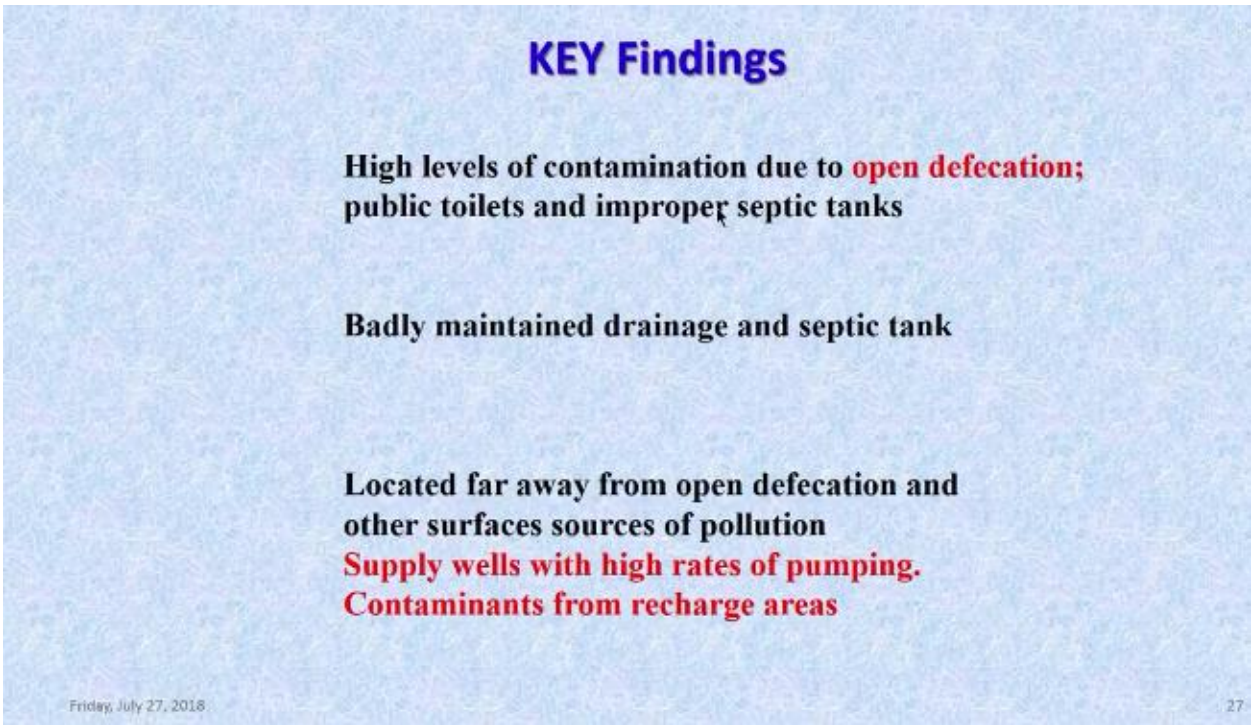



We had done the analysis for nitrate too, where we are showing this 45 milligrams per liter is allowable limit and in some of the wells it is more than that 45, and in many other wells, there is a presence of nitrate in existing wells in Erumaipatti and Mohanur. And the same thing is true for the concentrations of nitrate in wells in Namakkal town. Here again, many wells the concentrations are can go more than 45 milligrams per liter; these figures are showing for all the six samples in each of this wells.




So, what are the key findings as far as the groundwater quality is concern? Very high levels of fecal coliform, total coliform, ammonia, and nitrate, it indicates that the groundwater contamination is coming from improper sanitation. And all the wells are contaminated by fecal coliform and total coliform, which means that the groundwater contamination, all the wells wherever they are located, they are contaminated. So, it indicates that groundwater contamination is not only due to septic tanks but also due to all other poor sanitation conditions. As we have shown earlier the wells, the borewells located close to the place where they had a solid waste you know the management yard or the compost yard, that showed very high levels of the contamination.

Another interesting fact is, both shallow wells and deep bore wells are contaminated. We cannot just simply say that if the groundwater level is very, very deep then probably the chances of that water getting contaminated due to surface sanitation conditions is less, in fact, in this particular place only up to about 30 meters was weathered rock, and then below that they had fractured rock, and through the fractures, the movement of the contamination would be much, much easier. So, if the back, this contamination is not attenuated within this top 30 meters where they had topsoil plus the weathered rock, and once it reaches up to 30 meter then it is highly likely that it would reach the groundwater, however deep it is, so both shallow wells, as well as deep bore wells, are contaminated.




So, high levels of contamination due to open defecation, yes, public toilets and improper septic tanks. Badly maintained drainage and septic tanks are also causing this high levels of contamination. In some places, the wells are located in areas which are far away from open defecation and other surface sources of pollution, known surface sources of pollution, those wells were also showing contamination. But we found that these supply wells are in locations where there is a high rate of pumping, there is groundwater, was being pumped from these wells at a very high rate, and the contamination which is occurring in recharge areas is reaching these places through groundwater movement. So, we cannot simply say that you know by improving surface sanitation conditions in one location, we can improve the groundwater quality at that location, in fact, we have to go and then address the issue on a holistic manner. And the entire area we have to improve the surface sanitation conditions, not only the improve the conditions of septic tanks, but we have to improve other surface sanitation conditions.

## Site Selection for Septic Tanks, New Bore Wells and Leachate Collection Pits

**Places where**

- **Toilet is connected with a poorly constructed septic tank**
- **High concentration of FC and TC in Groundwater**
- **Sufficient space exists for the easy installation and periodical monitoring of wells and septic tanks**
- **Owner/ household is cooperative**

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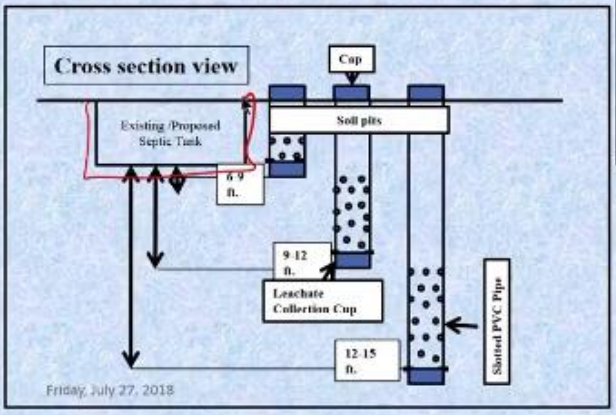
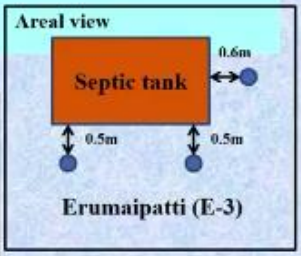
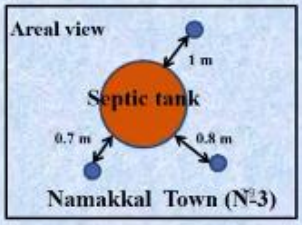
Then we had selected some sites, where we wanted to intervene, in terms of septic tanks. There are some so-called septic tanks were there, but then they were just simple leach pits, that means these are the septic tanks without any impervious bottom. So, there we said we would remove the existing septic tank which is the faulty septic tank and then put a properly designed and constructed septic tank. And in other locations, we said we will not intervene and then but we will monitor the quality of you know the seeping wastewater or how it is interacting with the soil.

## Leachate Collection Pits

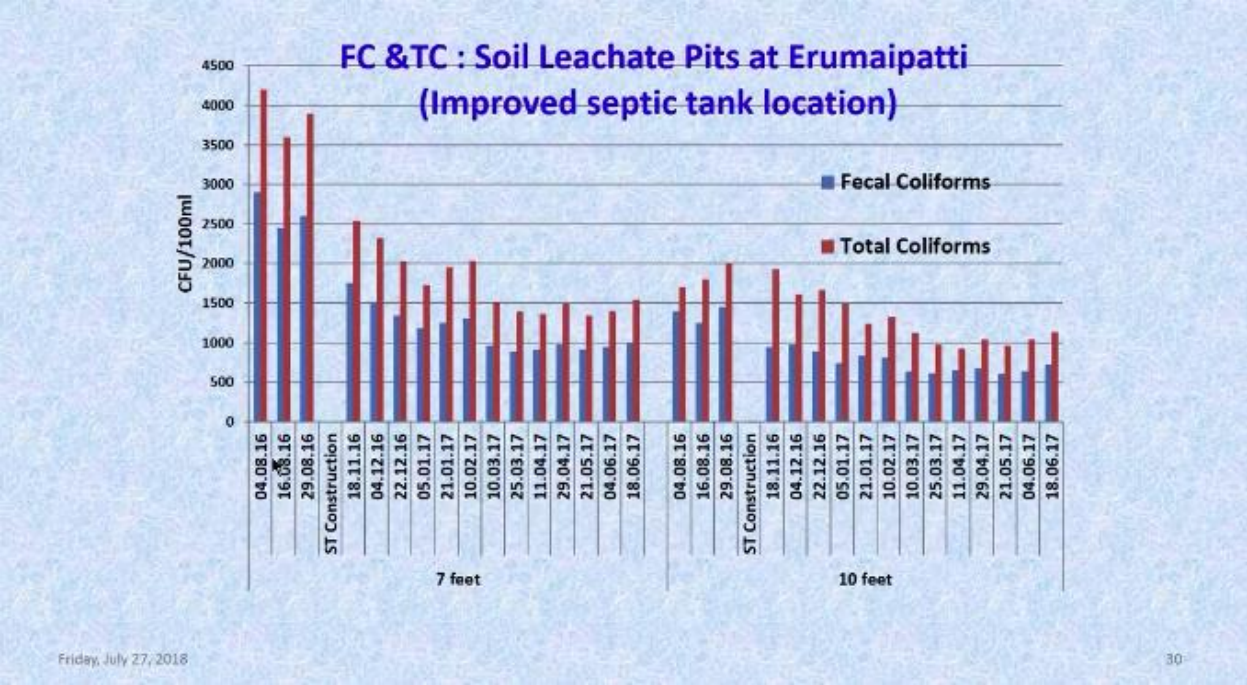
- **Soil pits at various depths to collect the leachate samples near to existing and modified septic tanks**
- **4 X 3 = 12 Soil pits**



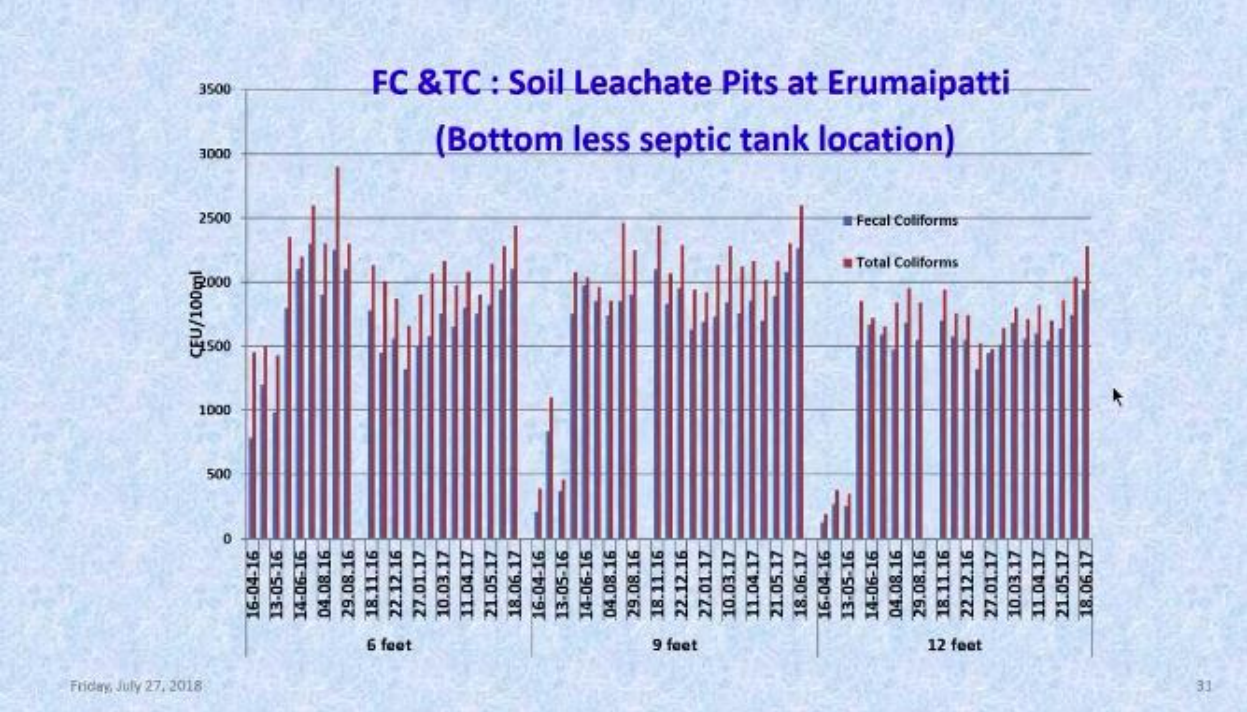



So, this is like we had an existing septic tank here, let us say that is faulty, so we put these pits here which are slightly away from this septic tank like this 0.5 meters here, 0.5 meters and 0.6 meters going to different depths. And then we collect that the seeping wastewater from these the leachate pits or the leachate collection pits. And then we analyzed them for the quality, what is the wastewater quality that is coming in this because that is an indicator of how much the loading contamination is loading is going to occur to the groundwater in that vicinity. And after monitoring, we intervened in some location and in one location, and we put a properly designed septic tank there and then again monitored after installation of that and then see what happens to this quality of this leaching wastewater into this leachate pits.

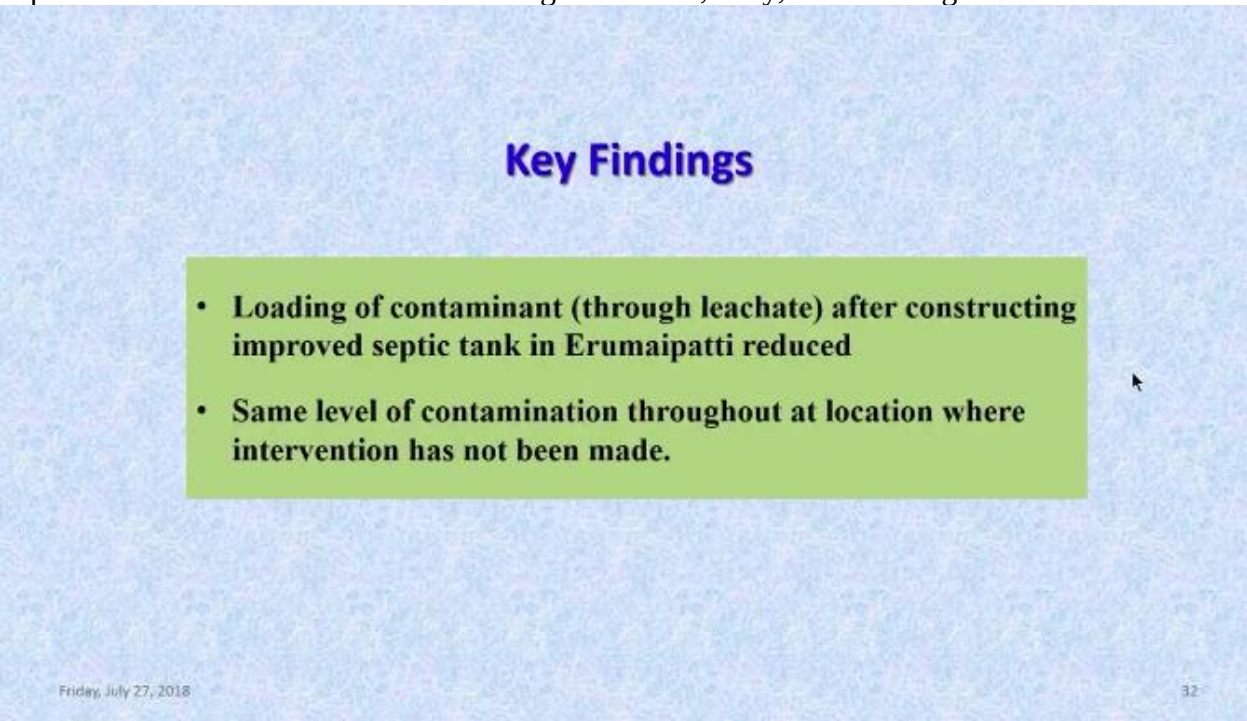



In one of the areas where we had intervened by replacing a faulty septic tank with an improved septic tank and until the construction, let us say we have taken the samples of this leachate from a depth of 7 feet and before we intervened this was the concentration of frequent coliform and total coliform at that location. For example, the total coliform concentration was going up to as high as 4,000, and then fecal coliform concentration was going up to 2,500. And after we intervened the concentrations have come down within that short distance of 7 feet, the concentrations have come down.

The same thing we found that before the construction of this new septic tank, the concentrations were as high as 2000 and then after the construction of the septic tank at a depth of 10 feet, we can find that the loading of the contaminant into the soil and then eventually into the groundwater has come down. So, this indicates the effect of or indicates through the level to which we can improve the situation by replacing this faulty, you know, septic tank or the leachate, leach pits, the conventional leach pits which people were using with a properly designed septic tank, we would be reducing the loading of contaminant to the ground.

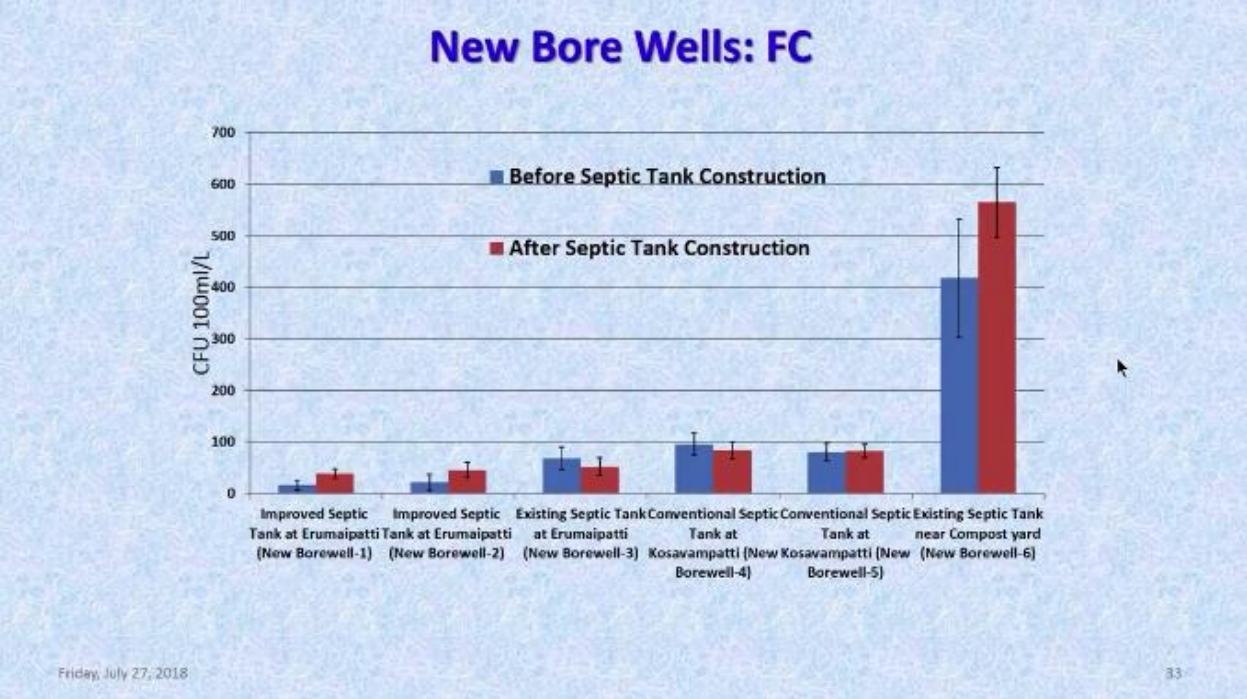



At a location, where we did not do any intervention you can see that throughout the period of our monitoring the concentrations were more or less remaining the same. There is not much of a change in at different depth, this is at 6 feet depth, and this is at 9 feet depth, and this is at 12 feet depth. You do not see that much of a change with time, okay, on an average.

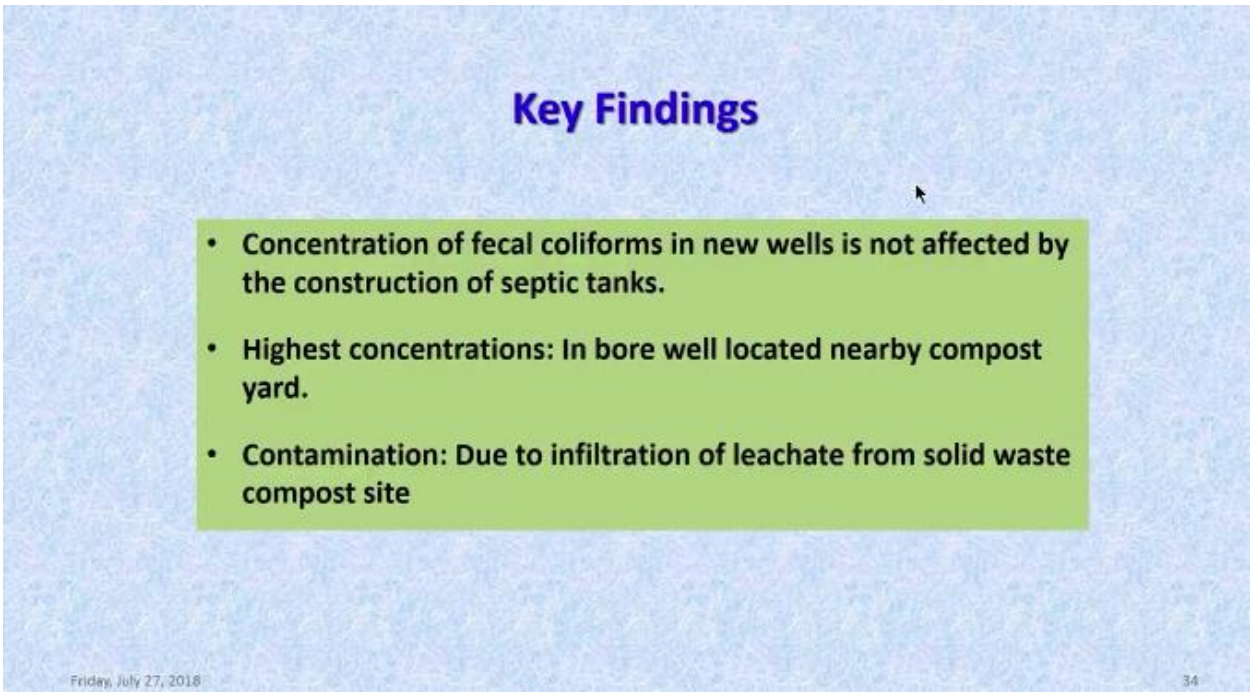



So, what are the key findings? The loading of contamination through leachate after constructing an improved septic tank in Erumaipatti has definitely reduced. And whereas the same level of contamination has been found throughout the time period where we have monitored at a location

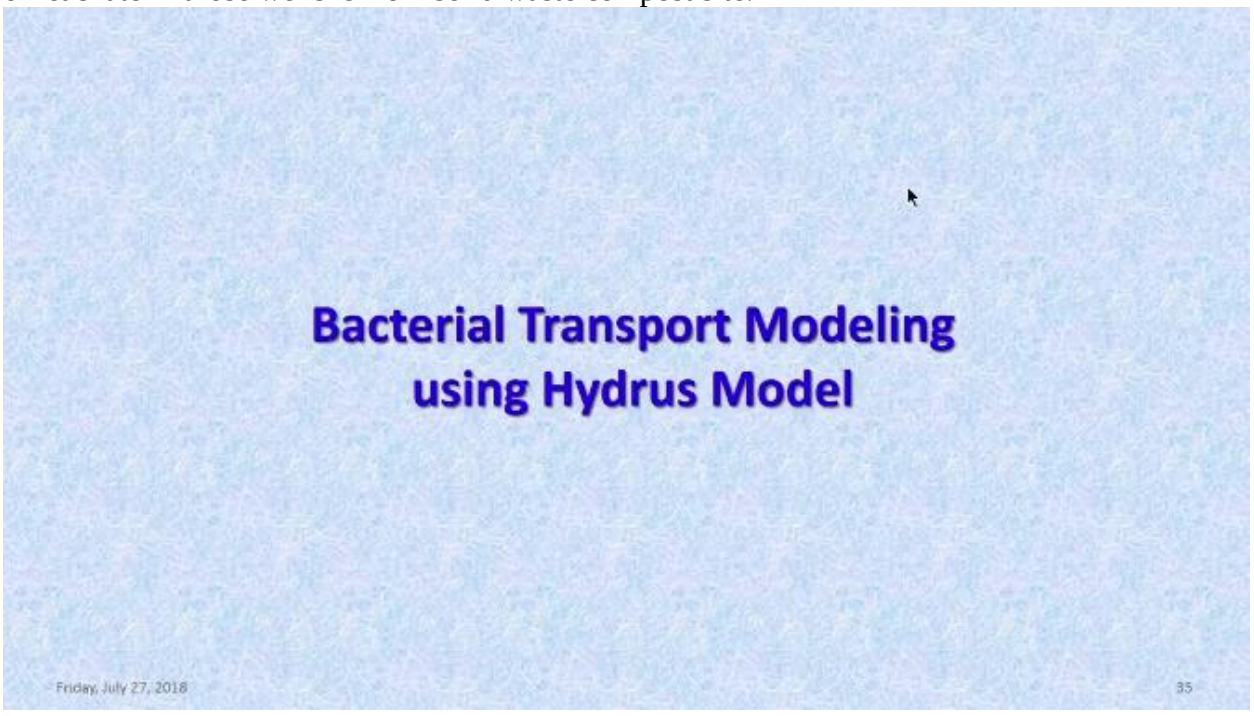
where intervention has not been made. We also monitored the bore wells, the newly constructed bore wells.



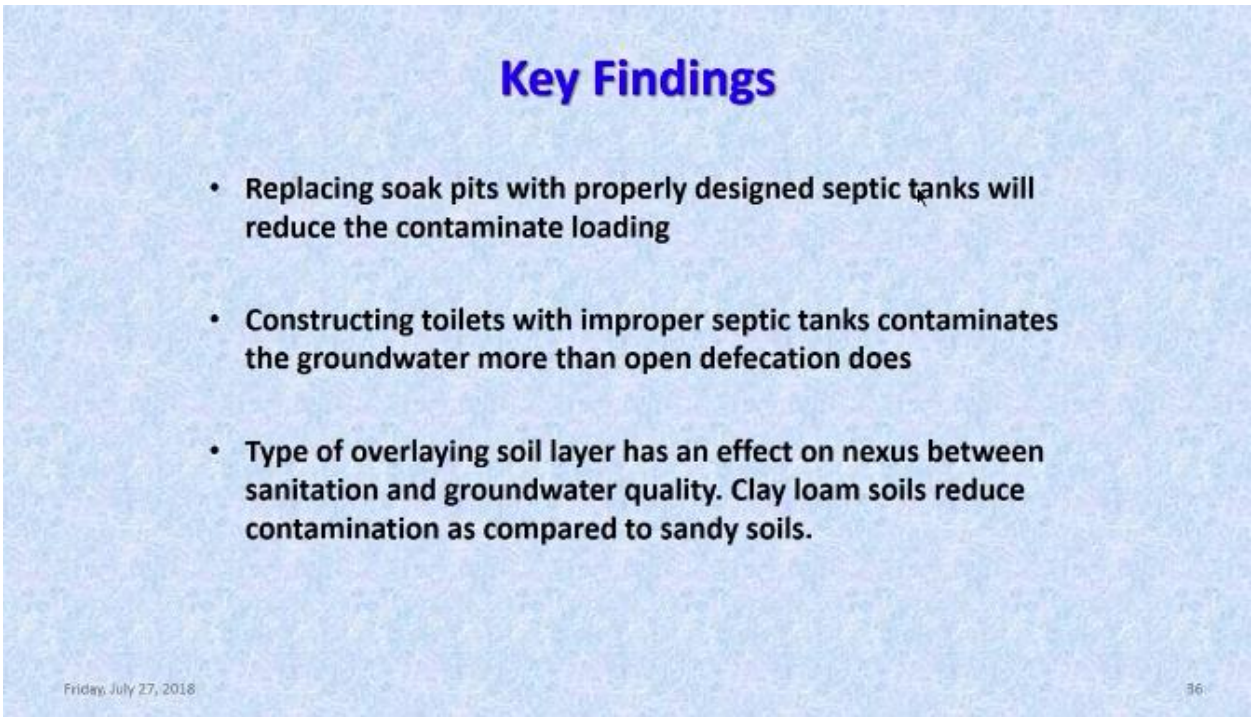

We had monitored in this newly constructed bore wells, what is the fecal coliform and what is the total coliform before the construction and after the construction. These bore wells are going pretty deep, and we can see that there is really not much change in the concentrations before and after the septic tank installation, of course, we had monitored only for a year. But this indicates that by simply going and then improving the sanitation conditions now we cannot expect miracles overnight, because once the groundwater is contaminated, it takes quite a lot of time to remediate that contamination, that we have to understand and then bare in our mind. And not only that, intervention at one location, is not going to make any difference. Just there is a well and let us say we want to clean up the well, by just simply going and then improving the sanitation conditions in nearby locations, we may not be able to achieve that because the contamination could be coming from somewhere else, so that is the thing.



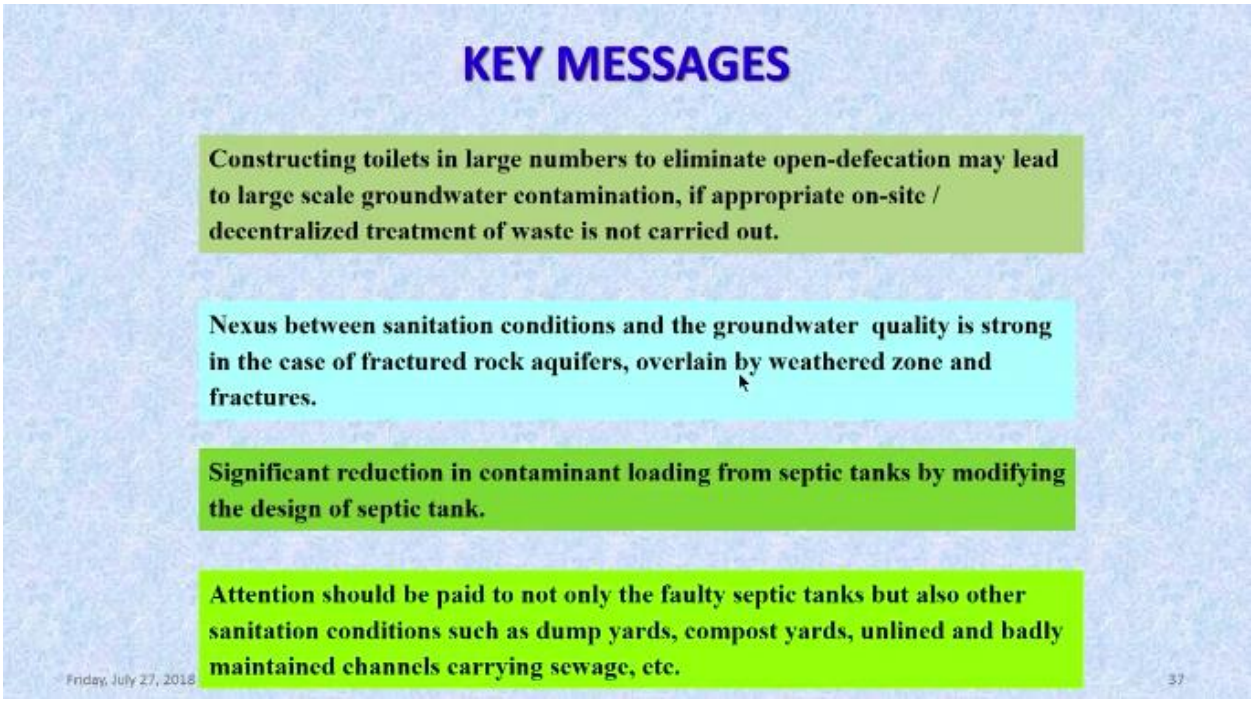

The concentration of fecal coliforms in new wells is not affected by the concentration of the septic tank, the construction of septic tanks. You know the highest concentration of course was found in a bore well located nearby the compost yard and the contamination is due to infiltration of leachate in those wells is from solid waste compost site.




We also did some what we call bacterial transport using Hydrus model for different types, I mean how the groundwater responds to different types of sanitation conditions or the practices.




And then what we found was replacing the soak pits or leach pits with properly designed septic tanks will reduce the contaminant loading. Constructing toilets with proper septic tank, improper, sorry, constructing toilets with improper septic tanks or just leach pits contaminates the groundwater, in fact, even more, than open defecation does. That is a very important finding that we, we, I mean we found. And then types of overlaying, this is obvious, the types of overlaying soil layer has an effect on the nexus between sanitation and groundwater quality, typically clay loam soils reduce contamination as compared to sandy soils. That means the interaction between the surface sanitation conditions and the groundwater quality is much stronger if in case of sandy soils as compared to the clay loam soils.




And so, the key messages are constructing toilets in large numbers to eliminate open defecation may lead to large-scale groundwater contamination, if appropriate if appropriate onsite and decentralized treatment of wastewater is not carried out. The nexus between sanitation conditions and the groundwater quality is quite strong in the case of fractured rock aquifers overlain by weathered zone and fractures.

Now there is a significant reduction in contaminant loading from septic tanks if you can improve or modify the design of septic tanks and the most important finding is attention should be paid to not only the faulty septic tanks but also other sanitation conditions such as dump yards, compost yards unlined and badly maintained channels carrying sewage etcetera. That means if I want to improve the groundwater quality in a particular area it is not only constructing, you know, septic tanks and constructing proper treatment plants for wastewater treatment but we also have to worry about other issue such as proper solid waste management. So, this particular lecture as I mentioned earlier is to demonstrate the interconnectedness when we talk about achieving something in the framework of sustainability.

Thank you very much.