Geoenvironmental Engineering (Environmental Geotechnology):
Landfills, Slurry Ponds & Contaminated Sites
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Lecture - 23
Subsurface Monitoring Around Landfills - Part 1

Welcome back to the class. Today we are starting a new topic on monitoring around landfills, since landfills are repository is a waste, we are always bothered whether they are polluting the environment, adjacent to it, we may designer very well engineered landfill, we may put a cover we may put a liner, but still we are bothered about is it causing dust pollution is it releasing methane to the atmosphere is it causing bad odor is it contaminating the groundwater is it contaminating the surface water.

So, we need to monitor landfills and lets understand that the monitoring a landfill above the ground or on the ground surface is similar to monitoring any industry right. So, in an industry, you do air pollution monitoring and you do water pollution monitor. So, how do I do water pollution monitoring in an industry? I have water which goes in to industry and I have water or waste water which comes out of the industry. So, our environmental monitoring always means checking whether the water which is coming out from the industry is polluted or not and against what standard do we check that is it worse than the water which went into the industry or is it better than the water which went into the industry or is it the same.

So, ideally whatever is the water which we supply to an industry whether it is used as cooling water or whether it is used as process water when it comes out of the plant and goes back into the drain it must be as good as what it went into the industry. So, that is the way we monitor liquids. Similarly, we monitor the air around the industry, if you are bothered about dust pollution if you have bothered about socks and knocks coming out of the out of the chimneys and then we have to monitor the emissions.

Now, typically it is easy to monitor water because it comes out in a pipe or in a drain there is no difficult to monitor air pollution because some of it will be coming out of the chimneys. So, you can monitor it where the emissions come out, but you have construction site dust pollution where are you going to monitor it, it is not coming out of

a chimney, then you have to do large area monitoring or you have to monitor at the parameter in a landfill, I am going to not talk that much about the air pollution and I am not going to talk that much about the water pollution because these are standard practices you will treat a landfill just like a factory or an industrial plant and you will use the same techniques that you used in industrial plant for environmental monitoring.

What is important about a landfill is the subsurface monitoring which is not routinely monitored everywhere he may cursorily monitor it, but we do not routinely monitor it. So, let us look at sub surface monitoring around landfills first, we will take the we will develop the overall view and then we will look at the specifics.

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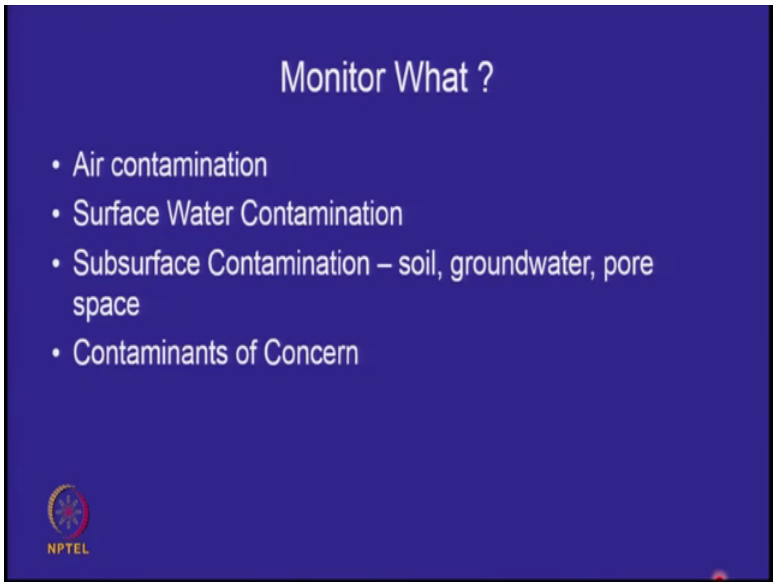

So, what do we monitor? As I said we monitor air contamination, we monitor surface water contamination in landfills and we also monitor subsurface contamination.

When you do air contamination you are only dealing with the gaseous phase and when you do surface water contamination you are dealing with liquid phase, when you do subsurface contamination, you are dealing with all the 3 phases the solids in the soil, the liquids in the in terms of groundwater and if you have the unsaturated zone then in the pore space you will have some moisture or you will have some pore gas. So, you are doing 3 phase monitoring for subsurface contamination it simpler to monitor the saturated zone because you can extract the groundwater and monitor it easily and before you undertake any monitoring you need to understand what are the contaminants of

concern which is the contaminant you want to monitor you cannot say, I will monitor this landfill without having pre specified what is your contaminant of concern.

So, in a landfill for example, in air though we are not going to talk about it, what would be your contaminants of concerns in air, you will be bothered about methane emissions, we would be bothered about volatile organic compound you will be bothered about smell you will be bothered about dust you will be bothered about smoke. So, you have different contaminants of concern in the air. So, if you are going to monitor all these then you have to put up the sensors or the samplers which we can address this contaminate. So, concern, right.

So, up suspended solid or a dust monitor is not going to be the same as a methane monitor. So, you will have different samplers and different techniques for monitoring different contaminants of concern where do you monitor where means at what locations well if I have a industrial plant I would like to monitor let me just take an example.

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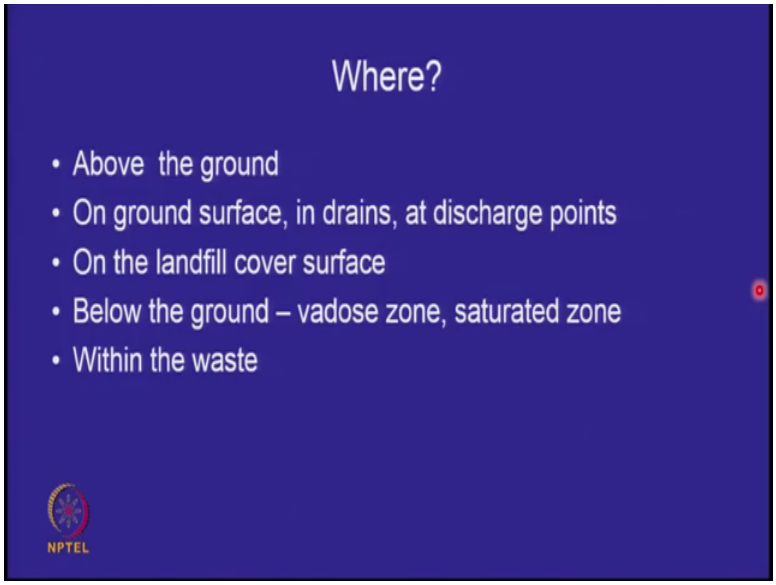

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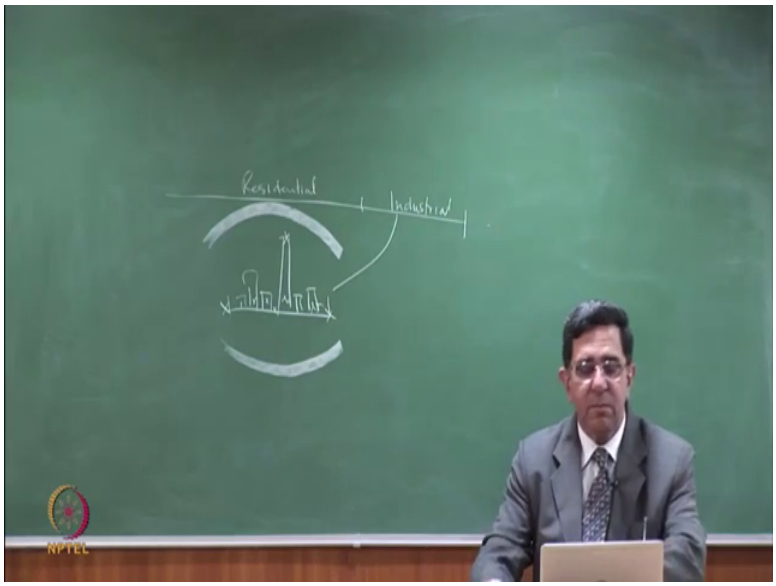

That is my urban environment this is an industrial area this is residential and within that industrial area you may have a particular industrial plant within the boundary, right. So, I want to monitor the; I will have to monitor the environment. So, it says we should monitor above the ground. So, I would like to monitor here, am I sending out something into the atmosphere, I should monitor along the ground surface, am I allowing something to flow out on the ground surface and when I am talking of that; I am talking of drains and discharge points in the landfill in the landfill, I will also monitor on the landfill cover here, there is no landfill cover and there is no landfill cover here, but in a landfill, I will have to monitor the landfill cover also and then I want to monitor below, I want to monitor below the ground surface; then finally, what is the contaminant of concerned unless I monitor inside, unless I know what are the process which are taking place inside I am not going to able to identify the contaminant of concerned. So, maybe I will monitor here I will also monitor here I will monitor here.

So, if I look at what is listed here for a landfill monitor above the ground monitor on the ground surface in the drains your storm water drains, you have pipe drains at discharge points, you monitor on the landfill surface, where the cover is there on top of the cover you monitor below the ground in the Vadose zone that is the unsaturated zone and in the saturated zone and you monitor within the waste and how do you monitor; how do you monitor what you want to monitor, well, I can take a sample and take it to the lab, but some of us would want real time online monitoring. So, maybe I will have a sensor

which you place there and it will start giving you readings please understand the accuracy is may not be that high.

For example, if you want to monitor a particular contaminant of concern, if you take a sample to the laboratory you will target determining that contaminant of concern, suppose it is total dissolved solids then you will evaporate the liquids and determine the total dissolved solids, but you say no, no, I want an online monitor which can tell me instantaneously what is the online what is online reading of the total dissolved solids well you can have a sensor, but it may be a indirect monitor instead of measuring the total dissolved solids it will measure some electrical conductivity and then it will use some correlations. So, online may be fast, but may not be that accurate.

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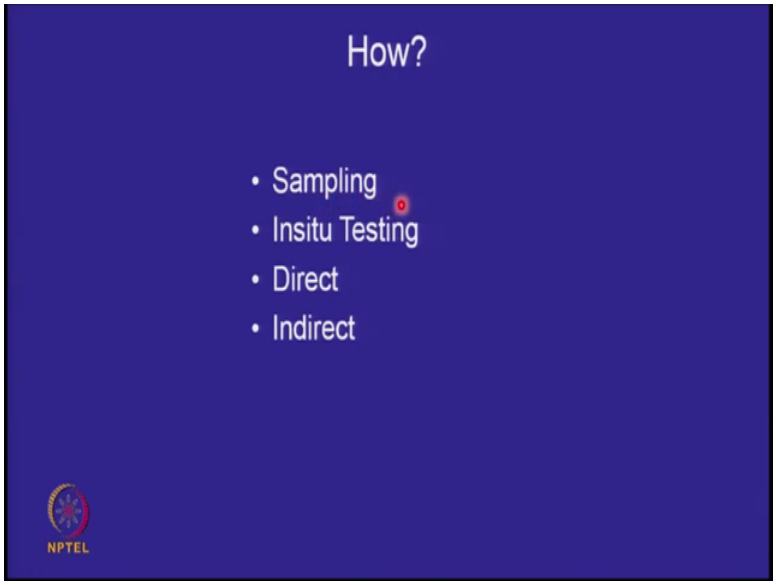

So, you can do sampling and lab testing you can do in institute testing or into indirect monitoring and normally direct and sampling is the most accurate and indirect and institute requires recalibration time and again.

So, those are the philosophies that you can have for monitoring how often would you like to monitor? Every second, every hour, every day, every week, every month, every year, every 10 years?

Any ideas; how often would you like to monitor?

Student: (Refer Time: 10:31).

So, it is been said if it is hazardous, we will monitor more; any other thought how often you should monitor?

You should monitor after the end of every season and presuming that we have a season which changes every 3 months is saying he would like to monitor every 3 months from monitoring dust from a site then a once in 3 months does not make sense and dust may not be that hazardous like arsenic, but would I monitor dust more often or I would I monitor arsenic emissions more often.

So, the issue is I am trying to monitor something if it does not change very rapidly I do not have to monitor it very often value changes gradually, but if it changes very rapidly then I have to monitor more often the idea is; I should be able to capture the peek, I should not be losing the critical concentration is that right, basically I want to know. So, it is very easy not to be able to catch the critical contamination very easily, in fact it is very difficult to say, alright, I have got the most critical reading of the contamination.

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So, I can do it either said I could do it hourly, I could do it daily I could do it weekly, I could do it monthly I could do it annually or biannually and I could do it after extreme events and the important thing for you to remember is if it is changing very fast then I have to monitor more often.

If the dust emissions are going to be high during high wind or they are going to be high during a particular event on an activity taking place at a construction site, I should have my readings going on, but at what speed does groundwater travels through the ground the rate of movement of water and the rate of movement of air is much higher than the rate of movement of groundwater, I told you a groundwater may travel a feet in 1 year in low permeability soils and several 100 feet in a year in a high permeability soil, but in the same 1one year, water may have travelled from the Himalayas to the Bay of Bengal because it travels much faster. So, if you doing something below the ground it does not have to be done every second, it does not have to be done every hour, even if you do it once a week once a month you may still not lose the critical event.

But if you are looking at star commission well I would star to commission or chimney emissions to be monitored continuously, why the whole day the chimney does not throughout anything while you are sleeping its starts bellowing out a lot of smoke and lot of other substances. So, it all depends on how often it can change what are the locations we already said above we said below.

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But if you look at the locations you have to identify the locations in plan I did not even show the plan of this factory, but I have to look at it in section, but the ideal answer is I would like to monitor everywhere, I am not going to let you get away with it, I want to monitor everywhere is that possible seems utopian.

So, maybe I will monitor along grid points maybe I will monitor along lines the perimeter my concern is that the industrial plant of the landfill should not be impacting the people outside industrial plant or the parameter. So, maybe I will want to do it on the parameter along grid points I definitely want to monitor at inflow and I definitely want to monitor at outflow. So, I must know the quality of air which is coming in. So, there will be a wind direction the wind direction you change you need the wind rose diagram, but you must have for the purpose of saying that something is been contaminated you must have the inflow reading and you must have the out flow readings.

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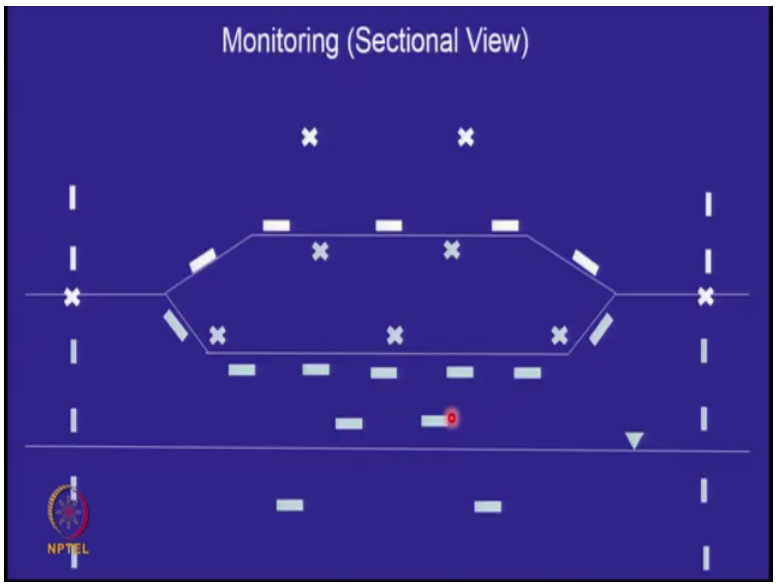

So, you need to monitor at these locations and if I am looking at a landfill just few symbols this is the landfill partly above the ground partly below the ground I should monitor on the landfill surface. So, this are some sensors and I would like to monitor here as well and I would like to monitor here, if this is the inflow point, if the inflow drain is here, I would like to calculate the contaminants in the inflow water and if this is the outflow point discharge to drains, I would like to monitor here, I would also like to monitor here above I may miss it something I go like this. So, luckily for us in gases and in liquids mixing takes place as you go a little further.

So, you will hopefully be able to detect something at some location then I would like to monitor within the wastes because I cannot get my contaminant of concerned unless I am not taking out my Leachate samples and seeing what is the contaminant that we are want

to do depend on the type of waste and I might want to monitor inside the gases, we are saying methane is coming out of municipal solid waste, but if I have hazardous waste which or volatile organic compounds are we going to monitor for. So, you monitor within the waste then you monitor immediately beneath the landfill you want to detect early if there is any leakage.

So, you want to know is there any leakage I detect early. So, I put a range of sensors and I put some sensors in my 3 phase media; that means, you want to know how fast it is traveling I have got something here, but there is no reading here. So, may be it has not reached the groundwater table, then I want to monitor the groundwater, but as I said if the ground water is flowing in this direction I want to monitor everything at the boundary inflow outflow. So, if I have a petrol station or if I have volatile organic compounds may be they will not reach the ground water, you need to know whether the petrol fumes are going out if I have total dissolved solids I need to know, what is going out if I have heavy metal I need to know.

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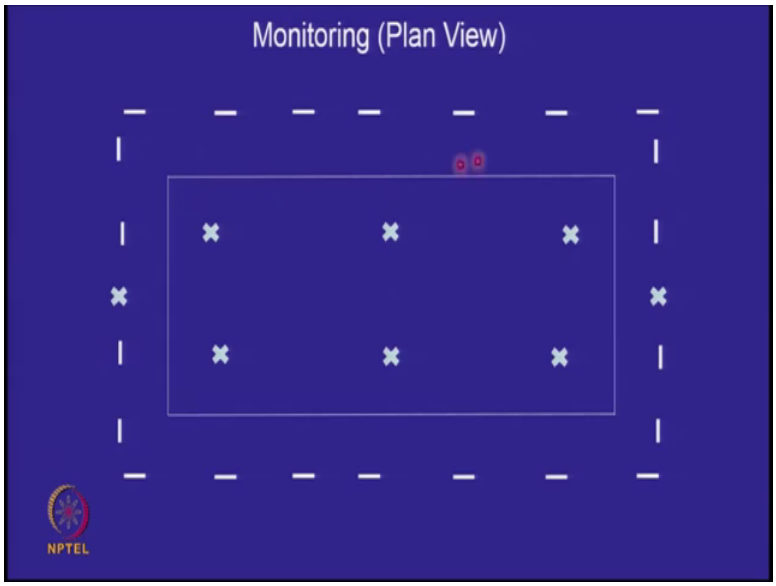

So, you need to monitor on the boundary this is only the diagram on the section in idealistic diagram this is in plan if this is my landfill base of the landfill, then I would like to monitor at all these locations on the parameter, if I one inflow point for water and one outflow point for water, I should monitor that is there a single inflow point for here no ours is not a controlled chamber, I do not have a huge dome which is on my site, if I

had a dome on my site, then I would say here is the inlet there is the exhaust. So, I will monitor where the exhaust is there, but I do not have that. So, I need to monitor here all over the parameter and I need to monitor the ground water all along my parameter, but water I can monitor and on the surface within the waste beneath the waste you will have several monitoring points.

How you are going to monitor we are not talking, but what we want to monitor looks very complicated lots of points, but we need to optimize this we need to be sure that we detect what is coming out.

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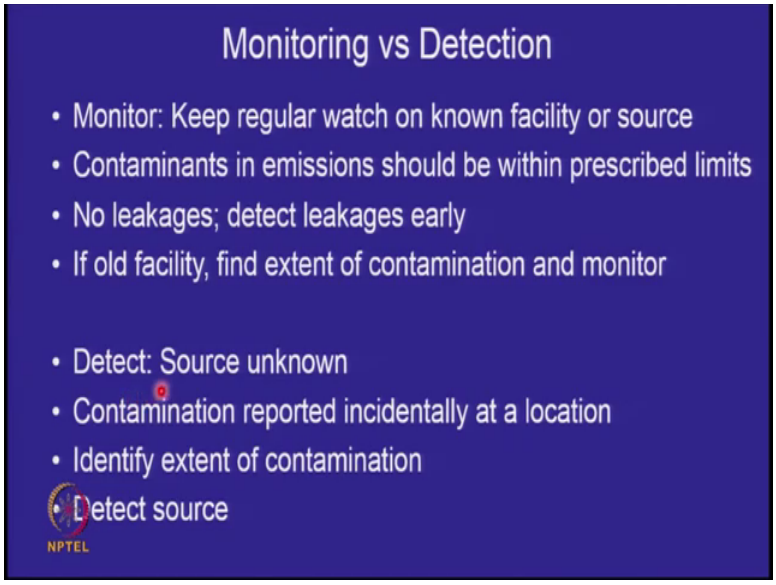

We do not need to put a large number of infinite instruments also remember the difference between monitoring and detection monitor is you have the facility you have to keep a watch on it the facility becomes the source. So, landfill is the source of contaminants and I have to keep a regular watch on it and our main purpose of monitoring is that contaminants should in the mission; should be within the prescribed limits that is one and secondly, there should be no leakages, but if leakages do occur we should be able to detect leakages early.

In an old facility above I have an old waste dump it is not an engineered landfill, I have to monitor, but I can only monitor if I know the extent of the contamination which was already occurred because I will find the extent of contamination and then I will monitor where at the boundaries of the contamination. So, both I will have a landfill and the

plume has travels suppose I have an old dump and the plume has traveled now I cannot start monitoring inside the plume.

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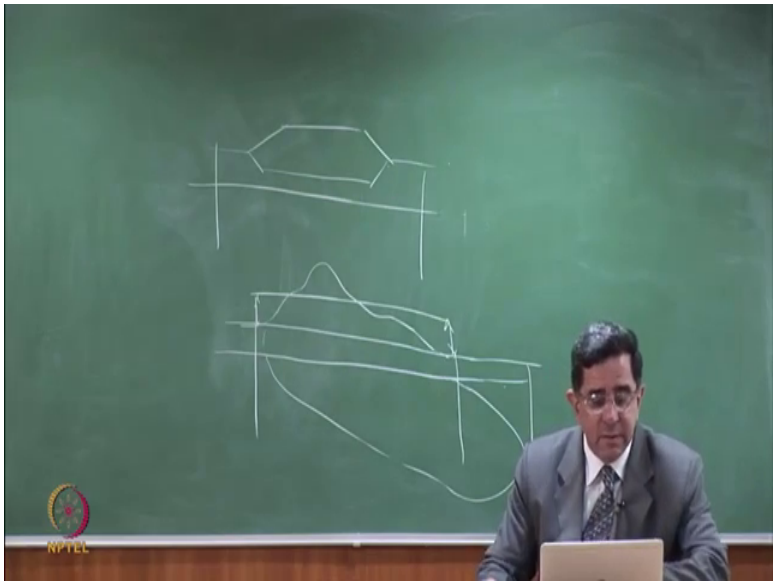

So, as I said, if I have a new landfill which is well designed, I can monitor here and I can monitor here, but you have in old dump where the contaminant plume one says, this is the water table and the contaminant plume over 25 years old like this my monitoring points have to be how does the plume expand or extend or how does it become bigger, if I am going to monitor here I am going to get the contamination. So, in old facilities find the extent of contamination and then monitor along the boundary. So, remember this may be your landfill boundary on the ground surface, but your plume may have cross the boundary. So, you will need to set up the monitoring points outside the boundary of your landfill. So, that is the difference between an old facility and a new facility.

Detect in detection; we do not know the source. So, a report comes to you that that the groundwater which is coming out of the tube, well, next to next to Hamadri hostel is showing high nitrates, you do not know the source in monitoring, you know the source in one case you have got the containments. So, you monitor within that, but in another case it is an old polluting dump you monitor beyond it, but if you are doing detection it means one tube well will report to you some problem then you will go and start checking all that tube wells round of the hand pump around that area [FL].

When you say some tube wells are having a problems others are not then you will say this is the boundary of contamination then you start checking the concentrations and then you will identify the source where is the contaminant coming from is it coming from a buried dram is it coming from a drain is it coming from somebody is injecting something at night because you does not have treatment facility. So, in detection the sources unknown contamination is reported incidentally at a location, we have to identify the extent of contamination; that means, do a site investigation to see how far this contamination is and then on, the basis of a results we have to identify the most probable source in industrial areas.

There can be more than one source, but typically its quite important to be able to identify the source sometimes see contaminant of concern will tell you the source because you would like to know which industrial processes are using that source that contaminant, then will be able to identify, then other cases, you will have to make a controversy of concentration and then come and you know home in that this is way the concentration is the highest and therefore, it appears to be a emanating from around this area.

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We are going to focus in this on monetary. So, as I said these are the various locations in which you have to monitor above the landfill, on the landfill surface within the landfill along the parameter beneath the landfill at critical locations at discharge points what are the critical locations in a landfill. Specially, if I am talking of subsurface contamination,

what do you think is a critical location where leakage is likely to occur in a landfill? Where in a landfill will Leachate always represent?

Student: (Refer Time: 23:52) bottom.

Bottom, yes, everywhere in the bottom, but where; which is the critical location?

Student: (Refer Time: 24:00).

What is the sump? The leachate goes along the base of the landfill to a sump from where it is pumped out. So, the sump always has leachate it is not bold drive it is like you know trying to have a glass and you put a straw on it and say that I can make this, I can pull out all the liquid with the straw can I? No, what do you do then you tilt your glass and you want to have the last drop of your very tasty aerated drink you can, but you cannot tilt a sump. So, there will always be some leachate. So, sump which collects the leachate where the well is there and you pump it up is a critical location, right.

It is like in your drain in the house where which point of a leaks, it is not the pipe, it is the Horthy or the drain sump where the water goes in collects and then goes out or the joints or the places where the water is being diverted. So, sump is a critical location, if you have an a fluent treatment plant on site that will become a critical location wherever you store leachate; suppose you are collecting leachate and you are storing it in a leachate holding tank, if the leachate holding tank is above the ground, then you can see the leakages, but if the leachate holding tank is below the ground, then it becomes a critical location.

So, you are going to do monitoring all over here, but this is both for all kinds of parameters above the landfill you will monitor for gaseous emissions from the landfill mainly methane in municipal solid waste landfills and volatile organics in hazardous waste landfills, but you will also monitor the air there are lots of issues about dust pollution there is a lot of issues about fires and smoke. So, air quality is important that is above the landfill on the landfill surface again you will monitor methane emissions you are interested in how much is the landfill settling. So, you need to monitor settlements of the landfill and this is important because landfills can settle by 10 to 15 percent of the height depending on the amount of organic content they have and you also want to know

about erosion are erosion gulling forming on the landfill surface. So, you would like to monitor erosion.

Within the landfill there are 2 aspects which are of great interest to us the leachate and the gas. So, we want to know the leachate quality and we want to know the gas quality because that will tell us; which is the contaminant of concern. So, even before you go start sampling your groundwater you go to your landfill pick up your leachate do a complete analysis of it for heavy metals for organics for inorganics for dissolve salts for chlorides for sulphates and say in, this leachate this is all above permissible limits if when it is going to mix with ground water or when it is going to go through the Vadose zone it will be attenuated, but finally, these are the contaminants which have to be measured. So, you find the critical contaminants those contaminants which are those constituents which are within limits they are not something you need to be bothered about.

So, within the land fill check about the leachate, within the landfill cache, the gas you have the gas collection layer you have the gas collection walls take out the gas samples and analyze them also analyze the leachate head means how much leachate is pounding up in the landfill. Sometimes your leachate collection and removal system may not function efficiently or it may become clocked. So, you must know is the leachate head building up in the landfill or not along the perimeter as I said you will monitor the glass or the air you will monitor the surface runoff and you will monitor the groundwater quality.

Beneath the landfill, I will monitoring groundwater simplest to monitor is groundwater it is easy to extract you can monitor it, I will be monitoring pore gas what is the gas in the Vadose zone the partially saturated zone and I will also monitor the solid particles of the soil at critical locations, I will be monitoring at sumps at leachate storage places at a fuel treatment plants and at all discharge points, if I have a gas flaring unit, I will be looking at the flaring unit if I have chimneys or If I have gas wells which are doing passive venting I will monitor that at all pipe outlets. So, this is where we have to monitor various parameters.

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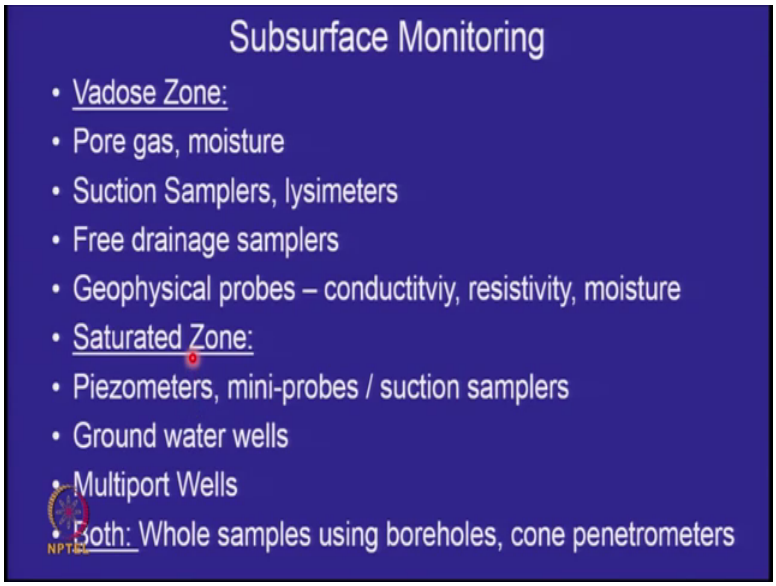

So, the philosophy now we are going to focus more on subsurface monitoring the philosophy of Vadose zone monitoring is different from the philosophy of saturated zone monitoring saturated zone monitoring, we have first indicated that something is wrong is if the ground water sample gives you something which is abnormally high in comparison to the background level how do you monitor this Vadose zone, how do you monitor the partially saturated soil zone can you take out ground water from a partially saturated soil it will not flow under gravity, if you want to force something to come out you can apply some suction maybe some soil moisture will come out depending on how close it is to saturation.

So, Vadose zone monitoring is good if you want to monitor pore gas and this is done extensively around petrol stations petrol tanks, but otherwise its more cumbersome. So, let us see in the Vadose zone, you can monitor the pore gas and you can also monitor the moisture is the soil becoming more saturated with time is the soil becoming more saturated with time that if it is if the moisture content is going up you know that something is leaking into the soil right you basically use suction samplers nothing is going to come out in a bore hole under gravity flow moisture will be held under suction.

Gas will also be held unless there is a gradient and the gradient can only be established if you put some suction you can put free drainage samplers, but they will only work if the soil becomes saturated, if waiting front is traveling down then you may get free drainage,

but that is pretty late and off course you can put some geophysical probes in the Vadose zone, you can measure conductivity or resistivity and if they change with time one is a seasonal change because its wet and dry wet and dry that limits, but if something more happens then you know something is different.

In the saturated zone you will basically use Vadose piezometers ground water wells piezometer, basically stand pipe piezometers and the you will collect the ground water samples using many probes or suction samplers going down the piezometers are going down the ground water wells we will also use something called multi port wells which I will introduce to you. In this class I am presuming you know are ground water wells and therefore, you have to differentiate between ground water wells and multi port wells, but here again the issue is you are only analyzing the liquid phase if you want to do a very exhaustive analysis about your contamination, then you do what is called whole sampling then you do not dry and suck out the moisture from a soil you do not dry and suck out, the groundwater table ground water from a soil you pick up, the whole sample whether it is saturated or unsaturated this is called whole sample analysis and what you do you bring it to the lab.

Now, if I go to the partially saturated sample in the lab I will bring it in a sampling tube duly sealed and then from the sample I can take out the gas by suction I can take out the moisture by suction I can apply much more suction in the laboratory then I can a apply in the field, right. So, I can take out quite amount large amount of moisture from the soil and I can look at the solid matrix. So, whole sample analysis requires you to get an undisturbed sample and please differentiate between undisturbed sample for site investigation or foundation design, what is an undisturbed sample for foundation design.

The mechanical properties should not have not modified means your strength should be the same as in the field your compressibility should be the same and your permeability should be the same, what is a whole sample for environmental concern not only should the all that was applicable for foundation design, but nothing should chemically change you should not while you are taking out the sample the gasses kept you are taking out the sample the waterscape. So, you should be able to keep it whole. So, whole sampling requires very careful ceiling of the sample as soon as it comes up.

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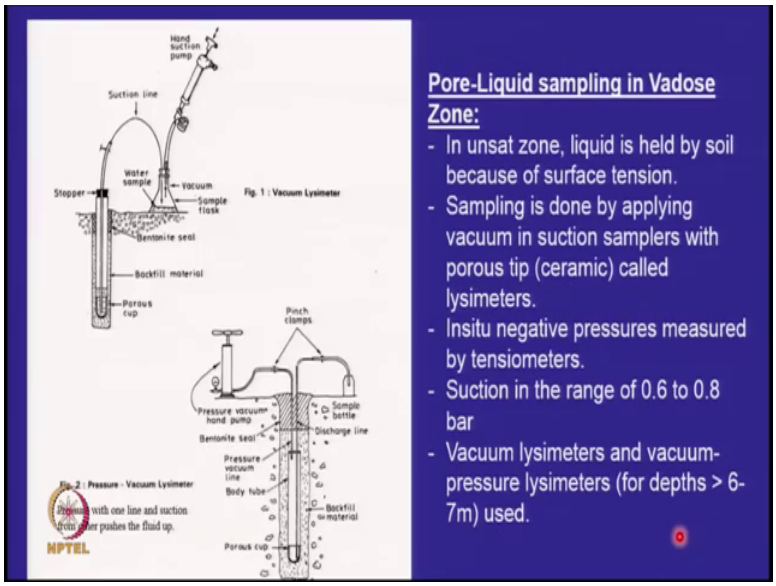

So, whole sampling down the bore hole or using cone penetrometers very briefly you can read up about pour liquid sampling in the Vadose zone on something called lysimeters we do not use lysimeters in soil mechanics. So, much, but a lot of agricultural engineers use lysimeters and basically what is it? It is a kind of a tube with a ceramic or a porous cup and you apply a suction in it and you hope that the water will come into this tube and then you can pull it out by suction if it will not come out through suction, you can put some pressure in it and it will come out the fundamental thing is you burry something into the ground which is got a pore step; poro step; poro stone ceramic tip piezometers that poro stone allows water and air to come in, but does not allow solids to come in when you apply suction in it, if there is moisture which is if the suction inside the lysimeter is higher than the suction being applied by the soil grains to the moisture; the moisture will go into the ceramic cup or the poro stone and then you extracted by suction or by pressurizing.

So, in the un-saturated zone liquid is held by soil because of surface tension sampling is done by applying vacuum in samples with poro step as you can see this institute negative pressure is measured and suction is in the range of 0.6 to 0.8 bar there is a limit to how much suction you can apply otherwise it does not work and these are the kind of devices.

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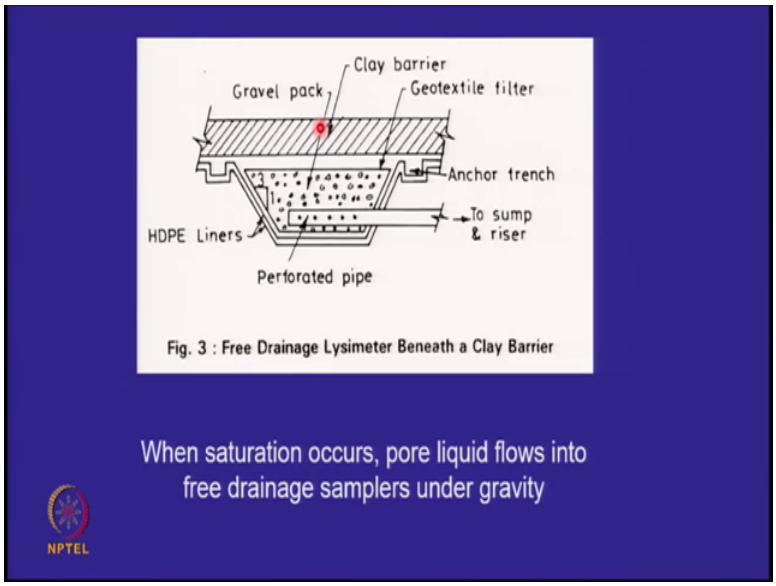

You can use if you are wanting to do free drain samplers; that means, I only want to know when the liquid is coming out I am not interested whether it is held as long as it is held it is not going down. So, here for example, is your clay warier underneath that you can make a free drainage lysimeter not under suction we just put a gravel pack put a filter between the clay and the gravel pack and put a pipe and it will be sloping and coming towards a sump at the site.

the idea is that if this becomes saturated and water starts to drip down from here it will get collected in the gravel between the clay and the gravel there has to be filter here it is showing a geotextile filter, but you can also soil filter layers. So, that the finds zone travel into the gravel.

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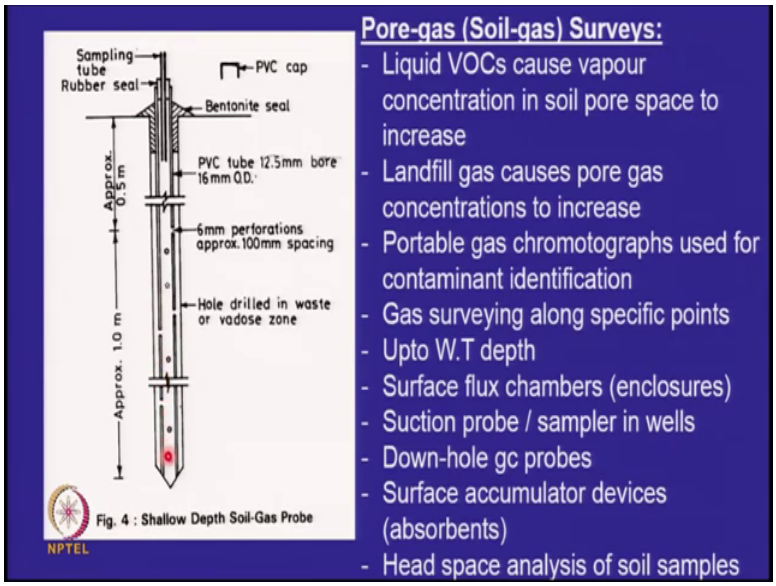

So, it is just a simple free drainage sampler beneath the clay it is easier to sample gas in the Vadose zone. So, please remember most of the time it is not the liquid that we are after we are after the gaseous samples. So, liquid VOCs can call vapor concentrations in the soil space to increase landfill gas can also cause pore gas concentrations in the vapors to increase.

Now, luckily for us we have a device called the gas chromatograph which helps you analyze gas samples and this is luckily these are also portable devices you can actually carry a gas chromatograph in a hand held right and take it to the field and you can get online measurements of gas concentrations. So, portable gas chromatographs are used for contamination identification sometimes these are called landfill gas analyzers or the word landfill gas analyzer is just a pseudo basically there are portable gas chromatograph. So, you will you know you can walk with them you can say, I want a methane analyzer. So, the analyzer is designed for methane you can walk over a landfill and get some readings.

So, gas serving is done you can do it only on the surface or you can do it in bore holes up to the water table depth and 3-4 devices can be used you can make a bore hole and you can send a probe in you can make a borehole you can apply suction, right or you can make a bore hole and put a chamber on top in which there is an absorb it. So, you set it use for this gas this is a good absorbing material. So, I will leave the chamber there for

one week because I am not getting adequate concentration, but in one week that gas would rise and this absorbent will keep on absorbing like and then you take the absorbent way and analyzer that in one week how much of the gas I have absorbed in it. So, you can have surface flux chambers you can have suction probes you can have down the whole probes and you can have absorbent surface accumulator devices.

So, typically its nothing if you have a tube, it is a metallic tube conical tape with holes in it perforations it you can drill a bore hole and put the tube in it you need to seal it from the top because nothing should come in from the top you can put a bentonite seal and in this, if you apply suction, if you apply suction in this space, gas just like in a tube well in a groundwater well water will come in gas will come in come out and you can use the gas analyzer for determining the gas concentrations.

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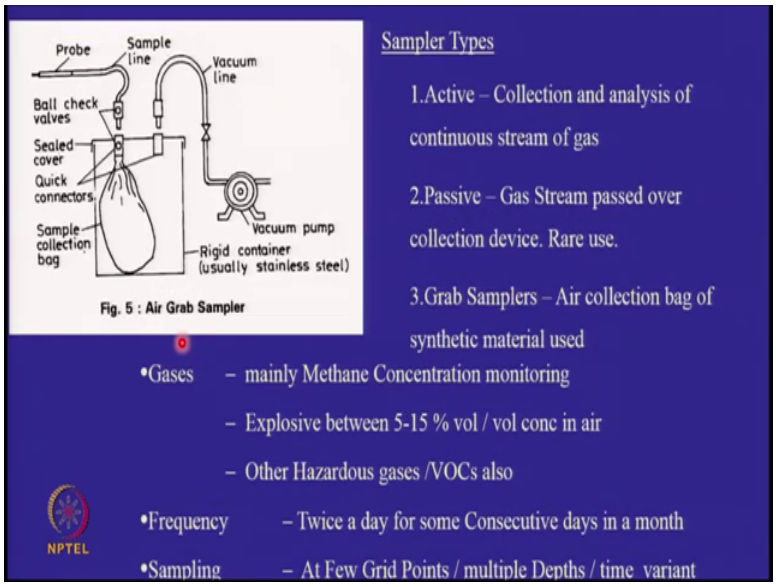

I will not talk about gas samplers, but there can be active samplers passive samplers and grab samplers you basically need a sampling tube this is a grab sampler, I mean this is a bag which is collapsible you will collapse it completely and then you will inflated by applying section in this chamber outside and here all the gas will be trapped and you can take it to your lab and then determine your concentrations.

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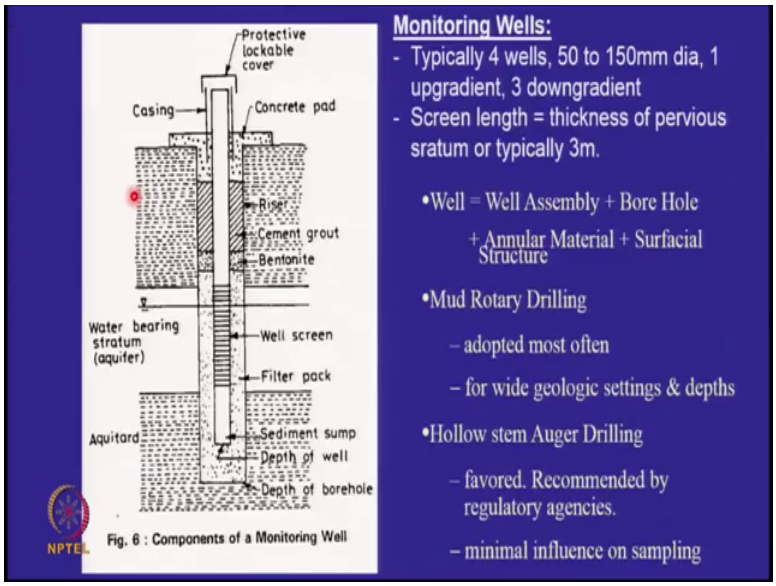

But let us come to our main business which is ground water monitoring and monitoring wells. So, first stage how do we make monitoring wells. So, I have made some lines here. So, that is a well that is a well and what is it look like it looks like it is basically a pipe which is sent into the ground and if you send in a submersible pump groundwater will come out of it if there is groundwater which will flow into this pipe, right.

So, first let us look at the elements of this and then we will see how it is installed. So, let us come back to this diagram you make a borehole just like you make a bore hole in your site investigation techniques. So, how do you make a bore hole in your site investigation technique auguring percussion drilling wash boring jet chiseling anything else, many many more, but you make a bore hole. So, suppose your ground water is available at 20 meters below the ground surface and you know that there is a pervious zone so. Firstly, you need to have a water bearing strata in which is pervious where water will flow. So, you make a bore hole down to that level after you have made the bore hole you will stabilize the bore hole and then you will put a pipe in it what is the diameter of this pipe 50 to 150 mm 2 inches to 6 inches.

In this pipe there will be a screen; that means, there will be a lot of holes or preparations in which the water can flow into this pipe, right, first you make the bore hole how do you keep the bore hole open in solid mechanics how do you keep a bore hole open.

Most of the time we do not use the casing? Yeah. So, do not give the answer in an inverted way we can use a casing if we are going very deep path if I am not going very deep, I will use bentonite and if I am using wash boring then the drilling fluid is bentonite slurry it keeps the bore hole open. So, now, you got the bore hole which is open which is full the of bentonite slurry you are putting the pipe in it with screens in it and then you put gravel all around it what I am calling a filter pack is typically a gravel pack the idea is that when water flows from the soil, it will come into the gravel then it will going to the screen the fins will not come in. So, you need a filter pack or you need a material which is pervious enough for the water to come in, but does not allow the fines to come in and then in this pipe you can send a submersible pump and pump out the water.

Normally you will seal the screen will only be in the region where you want to take out the groundwater from. So, here it says typically 50 to 150 millimeters dia screen length thickness of the pervious stratum are typically 3 meters. So, this may typically be 10 feet or 15 feet long, right; that means, water will come from this region into this and you can pump it out you will seal this, this gravel at the bottom, but you will seal it with the cement or a cement bentonite guard. So, that nothing else falls from the top and contaminate, this water contain water which you get out should only come from the soil and there you can have the pump and then you will have the riser pipe and water will be taken away.

So, a well is basically a bore hole with some angular material the filter and a well assembly and the drilling most often adopted is the rotary mud rotary drilling or the wash boring for environmental studies hollow stem auguring is preferred because remember when you do drilling with drill fluids you are actually putting into the soil some foreign material your bentonite slurry is coming from some other place some other state, it is in a bag you mix it with the water when you put it into the ground, then you say I am going to do environmental studies to check to ground water contamination are first you please check the contamination of the bentonite slurry which you have put in pumped for 2 days before you are able to reach the full depth.

What are you going to check if you are going to use an material which is imported which itself may not be clean, the bentonite may have been made by any manufacturing process which would have put some chemicals in the bentonite itself. So, therefore, say instead

of using a wet drilling always use a dry drilling when you have going to do environmental drilling and the dry drilling technique have done, it is called hallow storm argon, the hollow steam organ allows the bore hole to remain open its a continues slide organ and in the inside the hollow storm organ you put your pipe and as you with draw your hollow storm organ you fill the gravel pack behind it.

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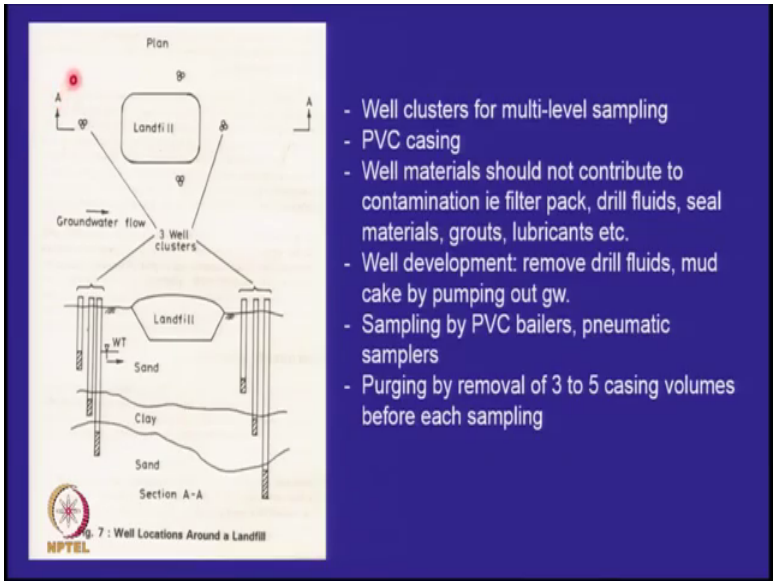

Typically we will need four wells if this is the ground water flow direction let us say this is the ground water flow direction one well on the upstream side. So, that you know what is the quality of ground water coming to the landfill and 3 wells on the downstream side forget about this word well cluster at the moment one well here and 3 wells, here why may be the ground water plume will spread like that you do not know may be you have put a well here and inflow is fine, but water goes like that will miss it. So, typically you must put at least 3 wells around your landfill. So, if I look at in plan, now that is my landfill or that is the shape of my landfill and I know my groundwater flow is like that which is not very precise, I will defiantly put a well here.

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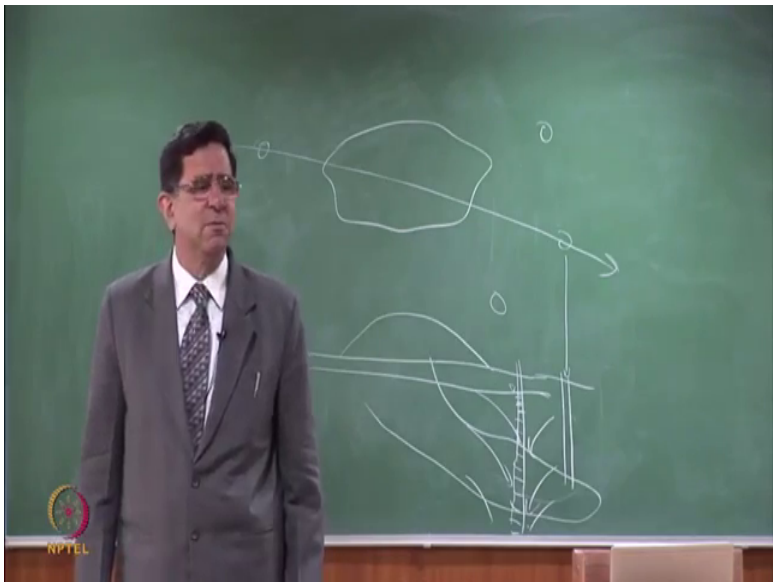

But I would like to put at least 3 wells here. So, that I can capture if there is any contamination which is taking place.

What is the concept of well cluster why do you need a cluster of well the issue is that we do not know at what depth the contaminant we go we have take a section in here, let us say this is above ground landfill, let us say the water table is close to the ground surface and I put my well here right or if you want to look at this well is here. Now when I make a well my upstream well is here I need to stay where will my screen b why because then I will be collecting the groundwater from that area. So, can you tell me where I should put my screen in this should I put the screen here or here or here maybe you will make a well in which the screen is here you will say I will detect because may be the contaminant will flow you put it like this, but the contaminant is actually going like that you will miss it your well will not get that contaminate unless your screen is in the way.

So, if you want to pick up samples from 3 depths then you need to have; well Mandeep will say [FL] I made a 20 meter long screen, how beautiful I do not know from where the contamination is coming, why when I suck out the water the water is falling through the gravel pack, what is happening when I take the sample the water is falling through the gravel pack this becoming as a mix sample, I will say [FL] from which what depth is the contamination; sir, it can be between 5 meters to 25 meters below the because my well is correcting the sample from 20 meters no that is already for drinking water [FL] water

should be drinkable and you have a thick 25 meters for its not, alright, for environmental solids. So, well cluster means you are trying to pick up 3 samples from 3 different depth which are isolated from each other water should not mix. So, in this in this diagram which is shown to you if I want to get water samples from 3 different depths I want to get water samples from 3 different depths.

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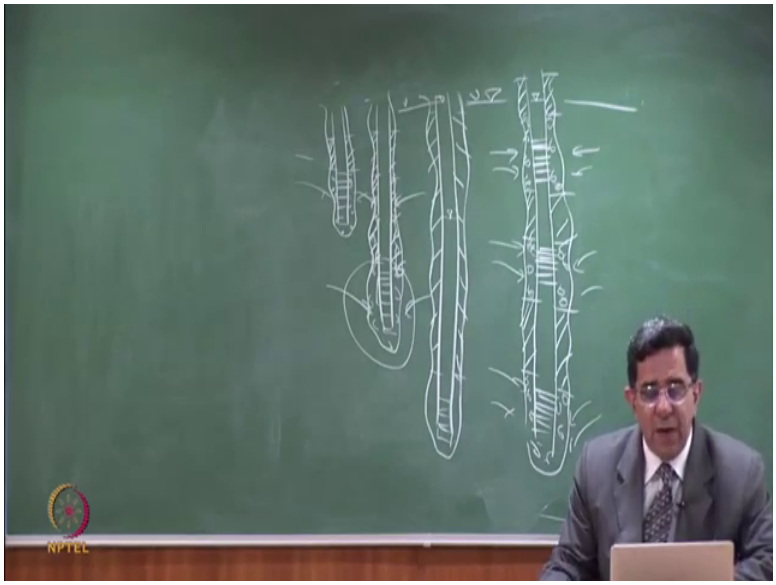

Let me try and articulate this one option is to put my wells in 3 separate boreholes please note this is called a well cluster I have 3 separate bore holes these are my bore holes tell me where will be the gravel pack in the first bore hole where will you put your seal and where will you put the gravel pack in this bore hole water has to come from here I will put my seal here and I will put my gravel pack here agreed when I draw out the sample the water will come from this area where should my gravel pack be in this should I put my gravel pack from here put my seal here is this, correct, my screen is here water will come from here, no, this is not correct when, I start to pump out the water the water level inside will form water will want to come in it will come from here definitely it will come from here, but it will also come from here and since there is gravel here it will fall down and which will visit.

So, your seal should be all this should be sealed if you want the water to come from this zone there should be a seal above that zone that when you take out the water sample

water is only coming horizontally from that zone. So, 3 different wells; 3 different wells to give you 3 samples from 3 depths [FL].

So, the question is can we put the 3 seals in the same hole let me try and do this; why should have to make you know drilling 3 wells was much more expensive than drilling one well, can I put the 3 seals in one hole let me make the full let me send the pipe let me seal this [FL] let us say the water table is here what will be the water level inside the well now I have got 3 locations, when I suck the water will come from here the water will come from here and the water will come from here it will not mix from these areas agreed.

So, I have got 3 locations is well [FL] if I am not doing any pumping. If I have any well what will be the level of the water inside the well at any point of time whether it is an open dug well or a tube well. Ground water table; so, at without pumping the water level will be here, now you come today and say I want to take the sample I want to take the sample from this depth what happens you send in a pipe and suck out the water, but once you start sucking out the water this water will also rise the column is mix in the water you have now separated the 3 water will not come from this layer.

Water will always come from this layer and water to this will come from this layer, but inside the pipe its getting mixed because [FL]. So, the water column itself is not isolating the water whereas, here its only the water coming through this soil that you are able to pick up see here also the water table will be here agreed, but the water in this column has come from where it is only come from here no water has come into this column from this site.

When you pump this water will water level will fall more water will come from here. So, now, if you read this we have to use well clusters for multilevel sampling here I am using the 3 well cluster with 3 different depths well material. Firstly, you do not use steel pipe most of the time you have been using steel pipes. Now we are go on to PVC casing switcher perforated with screens well material should not contribute to contamination that is the filter pack the drill fluid the seal material the grouts in the lubricants each one of them has to be tested that they do not cause contamination into the ground, we have to develop the well by removing drill fluid suppose I have used some fluids I have to keep on pumping out the well for a few weeks which is called well development. So, what

will happen then the whatever I have injected into it is taken out then the well is ready for sampling. So, we have to do well development and I have to do sampling using bailers or pneumatic samplers PVC samplers.

And please remember please remove 3 to 5 casing volumes before you sampling you are going to come to this well and say sample every week. So, the well will have water to the top before you take a sample you have to remove 3 times that water 3 to 5 because that water which has been stagnating in that well for the inside the tube is not the representative water you take it out, once it will fill up, again you take it up again it will fill up again 3 times, you purge it, then the sample which is come inside is now representative of the sample which is coming from this location or this location.
So, purging has to be done for by removal of 3 to 5 casing volumes before each sampling. So, that is the way, in which we extract the samples, but there are devices which are called multi port devices in one in one well, these are highly sophisticated devices in one well we are able to take out samples from different locations are these are called multi port wells but in this there is a difference I do not pump out, I send a sampler to each level this port can be closed and opened remotely.

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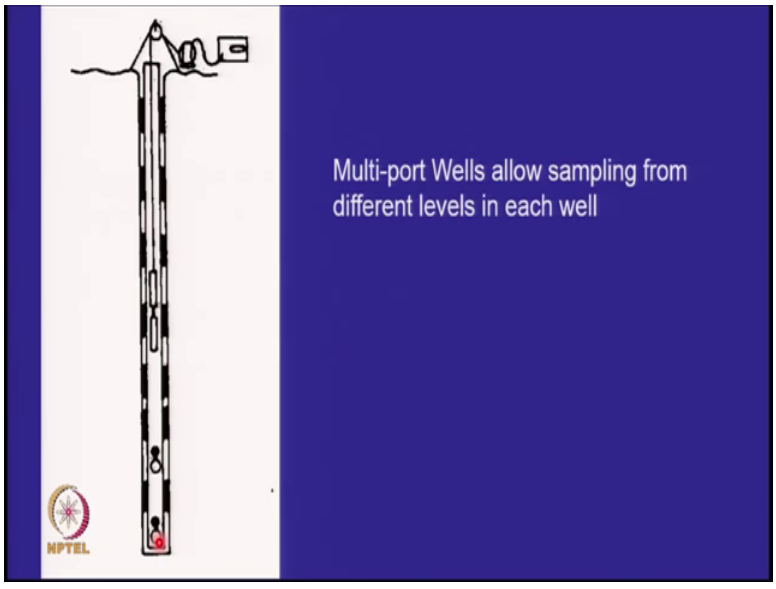

We send the sampler to each level and extract the sample from that port and we will do this in the next class as to how to take samples in a single well using multi port devices the problem is this is a very sophisticated well it takes a lot of expertise you to install it

once you install it, it works very well, but I will come back to this. So, far we were talking of sampling by suction [FL], but I use the word sampling by a PVC bailer. So, what I would like to do is suppose, I want to take a sample inside a river a water sample inside a river at different depths; how do I take out of water sample in a river from different depths how would you do it one very normal photography since person putting a bottle into the river and take in order sample or you will go in a boat and you will put a bottle sometimes will be attach to a long road and you will put take, but that is also official sampling I tell you that we are going to take a sample in the river Yamuna from 12 meter depths can you tell me how you will do it.

I will put a pipe to 12 meter depth and I will suck out everything from the pipe and lot of water will come into the pipe as you suck out.

Student: After some volume.

So, that water into the pipe will also not be from 12 meter depth the first will be from 12 and the other will be from all around.

Student: Sir this 3.

There is no screen it now we are in water. So, let us say the we send a pipe and the bottom of the pipe is at 12 meter depth, how are you going to take out the water from that 12 meter depth and not from thirteen meter depth and not from eleven meter depth in your sample I am doing a I am doing a sampling with every half a meter how am I going to do it.

So, you need to send in a sampler which opens at that depth has vacuum inside it and sample that and closes and when you bring it up it does not mix with anything on the way. So, when it goes down it is not open. So, let me take sampling bottle in which there is air pressure with the ball valve and because the air pressure the ball valve keeps the bottle closed you reach 12 meter depth you release the air pressure.

What will happen the ball will fall inside water will come in from that area only then you pressurize again and the wall will close now you bring up the sample. So, that is the mechanistic issue the issue is you need a sampling device which goes to a depth picks up the sample from that depth and as it goes down and as it comes up it does not allow any

liquid to come inside it. So, that is what we are talking of using PVC samplers which open at specific depths and these are what are used in these multiple port devices, but even in these wells instead of trying to suck out you do 3 to 5 casing volumes of purging, but next you can send in your sampler which is like sampling in a river send it down and pick up the sample only from the depth with the screeners do not try and pump out the whole water all the time.

So, we can have different samplers pneumatic samplers and PVC samplers where you can actually get the sample from a particular depth and look at this in the next class. So, we will stop here today and all that I have introduced to you is how do you make a well and how do you take a sample out of a well and how a well will not give you a sample from a particular depth, it will give you a sample which represents the entire zone in which the filter pack is there your screen maybe at the bottom, but if the filter pack is there typically in all wells where we are trying to get out drinking water there will be a huge filter pack all around it.

Why you want to maximize the amount of water which can come into the well. So, there that is not an there is not a time to find what is the groundwater quality at a particular depth. So, you have to make these special monitoring wells where you can get the ground water sample from that specific depth.

So, in the next class, we will look at multiport valves and we look at other devices through which we can monitor the subsurface environment. So, any questions then we will stop here.