Life Cycle Assessment
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Lecture – 12
Environmental Data Collection and
LCA Methodology (Contd.)

Welcome back to the second module of the week 3. So, we have been looking at the instruments, we have been looking at the analytical method like methods the calibration curve and how the data is collected and all that. So, in this particular segment we will be looking at some of the instrument that is used to make to generate these data.

So, I will look at some of these analytical instruments which goes into generating this data. So, let us start reviewing them one by one again I will not go in great detail about each and every instrument again this course is on life cycle assessment, we are looking at these in instrument just from the perspective of which instrument is used to collect what kind of data. Since you should be aware of some of these aspects before you if you are working with data you should know where the data came from and how the data is generated. So, just to have that aspects covered I am giving you a very brief overview of the different instruments and how it is used. So, will spend some time on may be 5 or 6 instruments which are the common one these are not the total exhaustive list of instruments these are the common ones.

We already saw one, the spectrophotometer used a lot for doing a bunch of analysis in environmental lab whether you are talking about COD analysis or we are talking about even you can do like a iron you can do arsenic, you can do chromium, you can best like a spectrophotometer has method for lots of analysis which you can do over there. The problem is when you have the coloured sample then it cannot be used. So, let us look at some of the other more sophisticated instruments.

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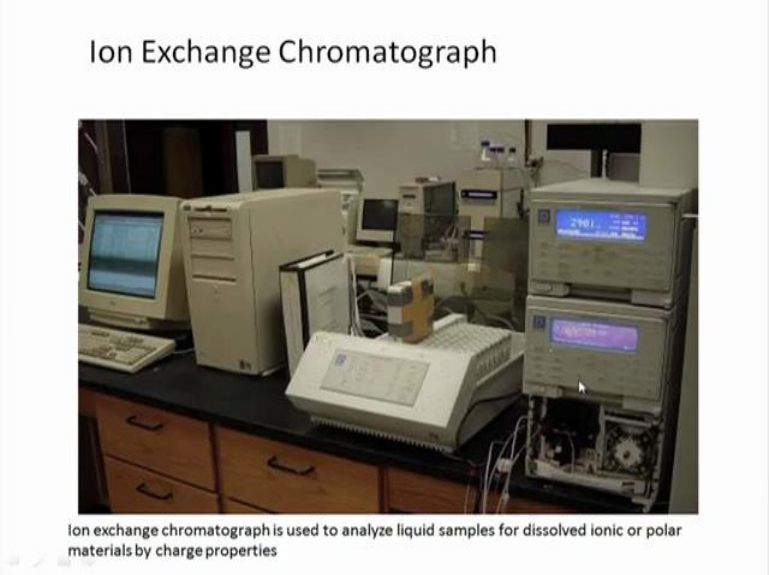

So, the number one is an ion exchange chromatograph. This is an older version of ion exchange chromatograph a newer version looks much smaller, the thing in the middle is our which is known as the auto sampler. So, here the computer is connected to the machine, again as you can see these are the little bit older machine and here you have your ion chromatograph IC which runs on a it has a column either for ion, for anion or for the cation and the middle portion is your what is known as auto samplers we can load the samples and the samples will be automatically analysed and there is a computer software which is connected to the machine and so that as I said earlier the computer software is there these days to help you with the celebration curve and with the detection of different analytes present there.

So, what it is used for? It is used to analyse liquid samples for dissolved ionic or polared materials by charge property. So, that is what it is used for, how it is works? It has a column, the column as what it does is basically you at the very beginning you add a what is known as a packing material basically you add a chemical in the column. So, all the adsorption sites all the sites where the different chemicals can go and get adsorbed and in a Layman term you think about that there is like a pipe or maybe a circular very very crude way if you can describe it.

So, you can think about there is a long hall in a circular, it looks like a circular its say hall where people are there are bunch of chairs out there and first we send a group of people at to occupy all those chairs. So, those chairs are signifying that binding sites and then we add the sample in such a way, so that the samples have this chloride, bromide, iodide, whatever and this chloride, bromide, iodide, has the more affinity for those finding sites. So, it will kick those people out, kick those chemicals out which is already present there and take it occupies this is space.

At the end you send what is known as aluvent the aluvent is the highest affinity for this binding sites, so the element will kick off all these different elements different compounds that is present, or different anions or cations that is present, but since different anions have different kind of affinity towards that binding material. So, first you will have the things which anions coming out which has the least affinity then followed by the one which has like higher affinity than the least one and then it kind of goes off as your affinity goes from in ascending order. So, then different ions will come out of different time, so that is what is known as a retention time.

So, ion exchange chromatography is used a lot for essentially for anion and it also used for cations. Anions is your chloride, bromide, sulphite, nitrate, nitrite those things are your anions and then cations would be your magnesium, sodium, potassium, and all those things are cations. With the use of ICP now in most of the labs ICP is available or ICP AES or if any lab as an access to an ICP people are not using this cation columns much in many of the labs it is mostly (Refer Time: 05:32) rule is now stick to an anion column. So, it is that is how it is being its being used.

So, that is ion exchange chromatograph next chromatograph as I said it is a basically separating different fraction. Next we have the gas chromatograph the gas chromatograph is an instrument to separate complex gas or liquid. Although, it is called gas chromatograph its liquid can also be injected that the liquid gets converted to gas before it is analysed.

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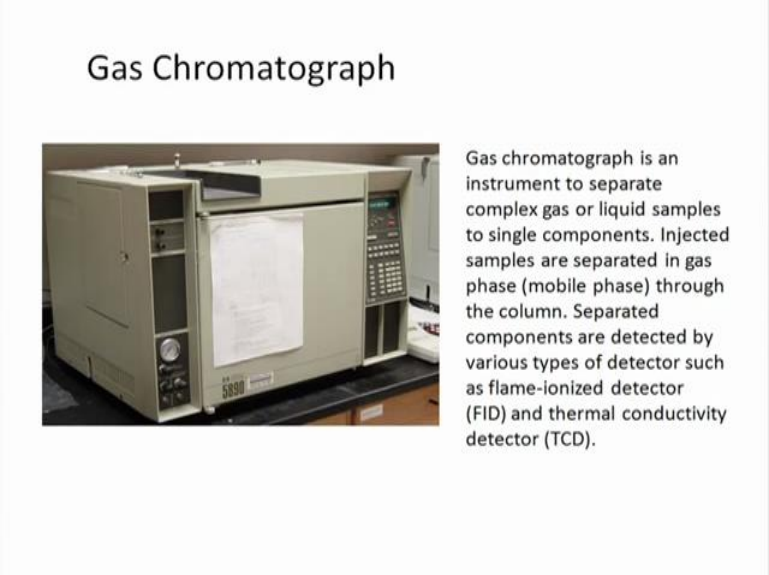

Injected samples, injected samples are separated in gas phase which is the mobile phase through the column, the separated components are detected by you by different kinds of detector it could be a flame ionization detector which is FID or it could be TCD which is the thermal conductivity detector ECD there are different types of detector out there. So, based on the analyte different types of detectors are used. So, at the gas chromatograph very similar to the iron chromatograph again chromatograph means separation of different chemicals.

So, you will have this different samples being carried through in the gas media and in the gas media while passing through the column it gets separated into different fractions and different components and the different component comes out at a different retention time. So, that is how this the gas chromatograph works.

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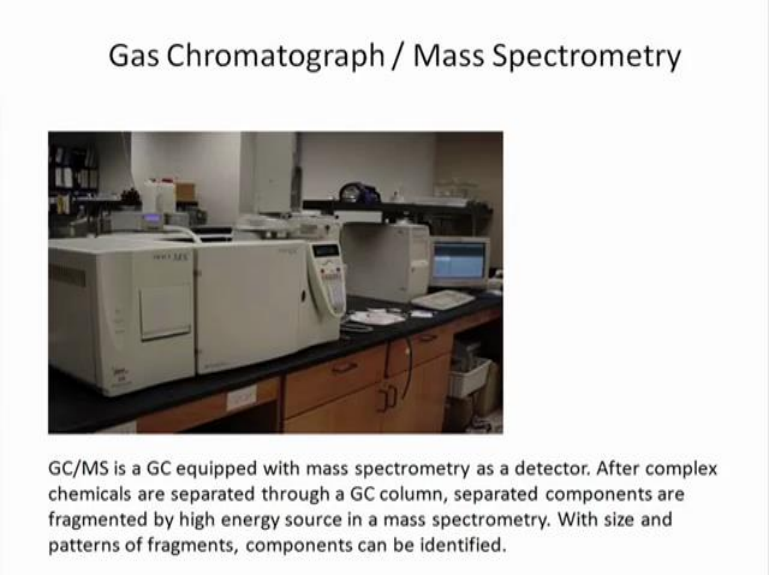

Then you have a gas chromatograph mass spectrometer which is known as GC MS here the difference between GC MS and GC and a GC MS is, GC, usually GC comes with a comes with a detector like a GC FID or GC TCD, GC ECD, but here we our GC is couple with the mass spectrometry at a detector. So, what happens here is that in terms of GC FID or GC TCD you already know what chemicals you are trying to measure? So, you say you have a salt sample you want to measure pH, your water sample you want to measure certain organic chemicals. So, you already know what you are targeting. So, you know what pretty much also you know at what best different methods you use, you can find out what would be the detention time for that particular analyte, but that is may not be the case in for all the samples.

Many times you have certain environmental samples for which you do not know you have no idea of what is in there. So, you have some guess, but you are not really sure what is in there. So, far that your MS actually helps, MS is like an mass spectrophotometer spectrophotometry is like an library has comes with a library where based on the mass and charge ratio it looks at what could be the person possible chances, what are the this mass by charge ratio could be could be there for certain different types of chemicals.

So, based on that it tells you that this chemical looks like, it looks like this is this chemical or look it maybe between something around this particular line. So, it helps you to pin point what chemical it could potentially be there and then for that particular chemical you can go back and run it again on GC MS or you can run it on GC FID DTC based on what chemical it is and what kind of detector is used for that. So, that is the benefit of having a GC MS. It helps you in terms of the identification of the different components.

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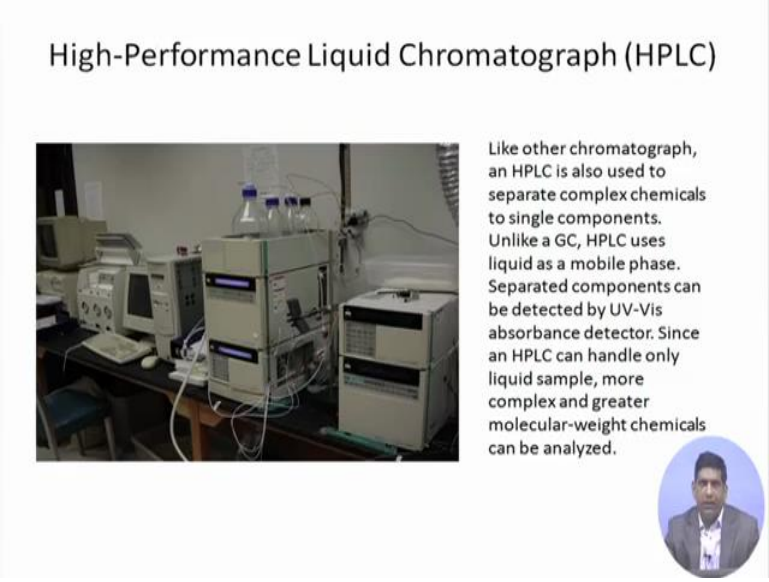

Then HPLC very similar to IC, but like very similar to your IC, but here HPLC is used to separate complex chemical into single components, here the mobile phase is liquid because high performance liquid chromatograph, so mobile phase is a liquid and the separated components can be detected by UV-Vis absorbents detector since an HPLC can handle, it can only handle water more complex in greater molecular weight chemicals can be analysed. So, HPLC is mostly just used as, use it for the liquid sample.

So, you can do many complex and greater molecular weight chemicals. Many times say you have pharmaceuticals personal care product those things are used using an HPLC.

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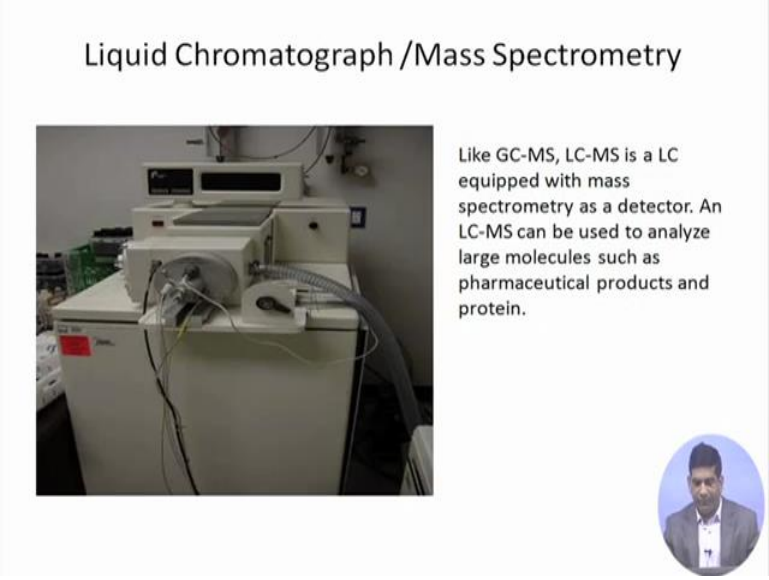

Similar to GC MS we have LC MS - Liquid chromatograph mass spectrometer again mass spectrometer, same procedure, same concept and it is used for molecule looking for large molecules such as pharmaceutical products and proteins and other and what not. So, those are used to analyse for these chemicals are there.

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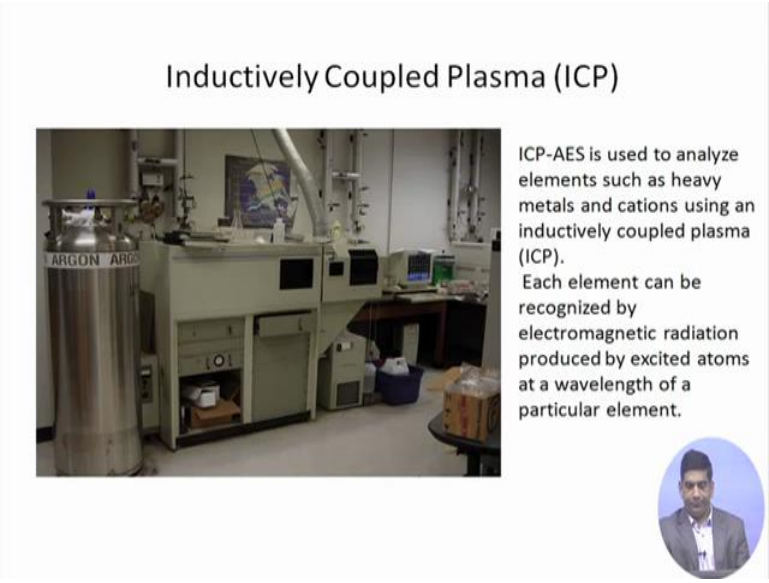

Then ICP which is a very popular for heavy metals and for inorganics again particular ICP that you see over here it is pretty big machine, but if we look at the newer machine they are becoming much smaller, there are now bench top like ICP MS available as well or, but some of the older machines were pretty big. So, as you can see it over here.

So, this is a computer which is controlling the machine, that is the machine right over here, several electronic electrical stuff was there, that is your argon gas cylinder which supplies gas this is where the plasma chamber is where things, this is where the torch is this is where actually the plasma chamber where things gets like a through the nebulizer the sample is and there is a auto sample which is kind of over here you cannot really see very well, but it is between the computer and the machine, the main machine main part of the machine there is an auto sampler and we have this samples injected into through an like a nebulizer over here into this chamber and there we have your things getting like excited.

So, how the concept of ICP-AES is what height as you probably know ICP works at very high temperature 5000 to 10000 degree centigrade. So, the concept of this ICP-AES is that you have this sample, you atomize it, you take it if you remember your modern physics the Rutherford model you see you take your atoms present in those samples at a higher excitation, excitation state and then you let it go down lower excitation state. And the when it goes down to the lower excitation state it release energy and that energy if you remember e is equal to h c upon lambda and the lambda is the wavelength. The wavelength for each element is unique different elements have different wavelength.

So, for that matter your e h c upon lambda c is the speed of light h is the Planck's constant. So, since lambda is unique to a certain element. So, based on the emission light that is coming out if you know the wavelength of that light you can relate it to what element it belongs to - whether it belongs to sodium, whether it belongs to potassium, whether it belongs to arsenic, whether it belongs to led and, so based on that you can always predict which element is present at a higher concentration.

So, again as you saw in the previous module there will be a calibration curve involved here. So, you will run a calibration curve and you calibration curve will be prepared

these days softwares does the job for you many times you do not realise what was got done. So, you have a calibration curve prepared and then you run your samples you need to have a celebration check samples in between, the machine gets like heated up used typically what I have seen based on my practice is when you run around 100 to 150 samples and after that you may have to go back and recalibrate. Because re-calibration goes off as a machine gets heated up either you stop up for that particular day or you come back.

Most of the typical ICP MS or ICP-AES they take 3 to 4 minutes a sample. So, if you started early in the morning and run it throughout the day with maybe a 1 or 2 calibrations in between you can end up solve like a analysing around 500, 300 to 400 samples per day. So, that is a pretty good like a here throughput for an ICP-AES. So, like 400 samples like if you look at 3 minutes a sample, around 1200 minutes. So, 1200 minutes is around 20 hours. So, if you run it for throughout like 20 some hours. So, it is like a one day work you can run 400 samples. So, that is not bad.

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One of the other is your atomic absorption spectrophotometer here works again you are doing it for heavy metal, one advantage of being a ICP MS or ICP-AES is that you can analyse for usually sometimes 26 to 27 elements at one time. The drawback, that is what

that is the drawback of atomic absorption spectrophotometer here we use we can do only one sample at a time, so if you have to look at several analytes then it becomes a very time consuming for each sample, each analyte you run the sample then you find out the data then you change the lamp and do it for another sample. So, that is why it becomes more time consuming as opposed to doing everything together as we do it in ICP.

So, these days with ICP-AES or ICP MS becoming more affordable as compared to earlier days, so you do not see many labs trying to use (Refer Time: 14:58) that much its they potentially go for ICP most of the time. There are some matrices for some elements for then which ICP does not work very well. So, we like to go and run graphite furnace atomic absorption method to do those kinds of analysis.

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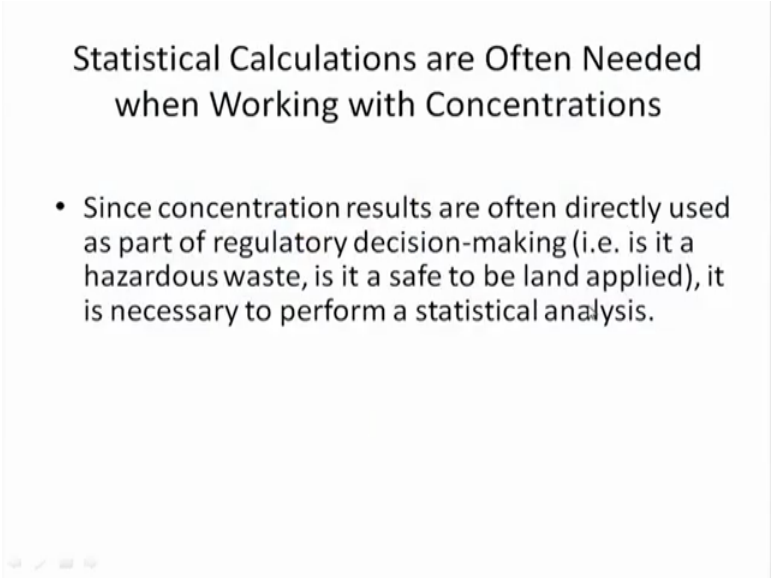

So, that is how we get all these different. So, these instrument which are used to get the data and, so this so far if you look at what we have covered in this module and the module before we were looking at the environmental data, how the data is collected, we looked at the calibration curve, we look at the method detection limit, we also looked at what do we need to be careful in terms of the calibration curve, what we need to be careful in terms of the detection limit, machine will give your number, but you need to make sure the number is correct.

Then at the same time you have to understand how a like a broad understanding of how these different machine works, you may not have a we do not expect you to have a very thorough understanding of for each of these machine works, but at least have a broad understanding the basic principle at which these environmental instruments are working. So, that you can you can defend your data or if there is a problem with the data you can try to find out where the problem could be because if you are aware of the methodology at least in I would may not have a like a great detail, but at least in terms of big picture you should have an idea how the particular technology works, technology for the instrument works.

So, in terms of data, once the data is collected many times we may have to do some statistical calculation statistical calculations are needed while working with concentration. So, the concentrations results are often directly used as part of regulatory decision making. So, for example, if it say hazardous waste or whether it could be land applied it is necessary to perform statistical analysis. So, for the hazardous waste for example, you do a TCLP test which we will talk about that in a minute. So, if you want to find out whether a waste is hazardous waste or not, we do certain test out there or if you were to find out whether a certain things is safe for example, the bio solid is safe to be land applied we test that bio solid say it to find out whether it will land applied or not.

So, that decision is based on the data, now if a data has to be good and the data has to be statistically tested as well. So, we do lot of statistics on it and again if you go back to your statistics class remember that population mean and the sample mean. So, for any environmental sample say for example, you have gone to a contaminated site and it is a contaminated soil. Now this contaminated soil its needs to be treated or you want to find out what is the real concentration level. So, for that you have to collect what is known as a representative sample, now how will you know what is a representative sample.

More the heterogeneity better the higher the number of sample better it is for heterogeneity, if it is a homogeneous mix you do not have to its becomes easier. So, for the water to certain extent, wastewater you may probably do not need too many samples for that particular water like we usually we try to have at least three because that helps us to get the standard deviation and do little bit of statistics even basic statistics on that, but

they do not need more than three for water or wastewater sample of for that matter even a sample, if it is say like a nice will make system.

But if you talk about soil system or solid waste are hazardous waste where there could be lot of heterogeneity, municipal solid waste its lot of heterogeneity like if you look at just the two garbage pile although they may look the same, but it will look more carefully if you as a Layman it look the same, but you look at very carefully with as an environmental engineer you will find that there are difference in there. Some may have more plastic, some may have less plastic means difference in calorific value and same thing some may have more biodegradable matter than the other; that means, the other one is probably not good for anerobic digestion, we need by and look like a biological biodegradable material present for the anaerobic digestion. So, those kind of things we can make the decision as an engineer when we look at some of the stuff. So, and we do have to do a statistics on that. So, to say for the contaminated soil sample or the solid waste sample you go there you have a pile of soil.

Now, how to collect the representative sample from here, you can collect 1 2 3 4, but is that enough? If it say, again if it is nice mix soil maybe that could be enough, but if it say heterogeneous mix as we have mostly in the waste management site it may not be enough. So, the site concentration results are often directly used as part of regulatory decision making this is a hazardous waste land applied. So, it is necessary to perform a statistical analysis, so that whatever is the sample mean or the sample information you collected that can be extrapolated to the population level. So, that is how we talk about the sample and the population.

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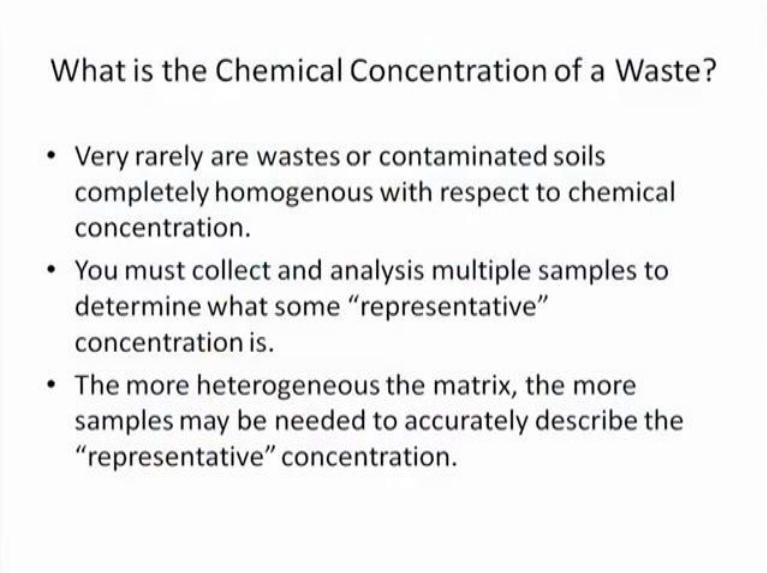

So, what is the chemical concentration of a waste? Very rarely the waste or the contaminated soil is completely a homogeneous, if you look at think about the waste in terms of water probably its better, but in terms of waste we do not see very rarely you will see waste of contaminated soils completely homogeneous with respect to chemical concentration. So, what we need to do is we must collect and analyse multiple samples to determine what some representative concentration is. We need to do some multiple samples, do some collection of the multiple samples.

he more the heterogeneous the matter is the more samples may be needed to accurately describe the representative concentration. So, as you can see in the last bullet more the heterogeneity more number of samples are required. So, that is again very very careful.

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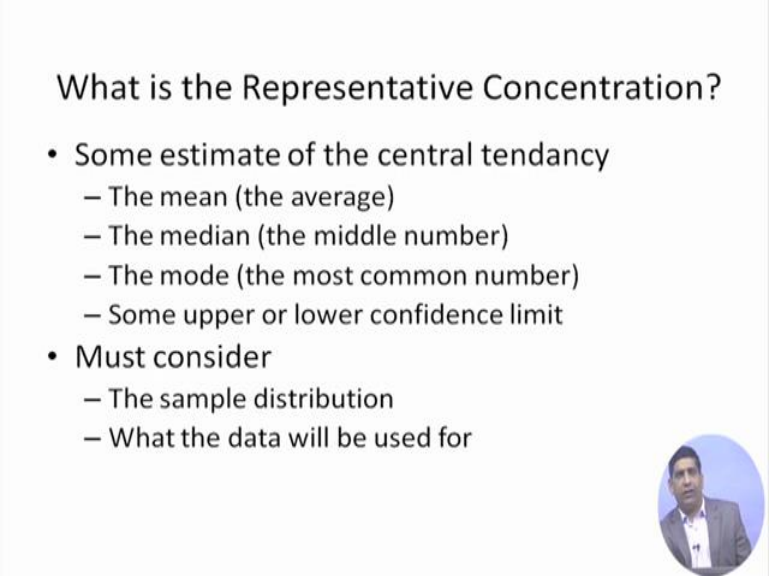

Now, what is a representative concentration? Representative I terms of the statistics there are some estimates of the central tendency, we talk about the mean which is the average, median which is the middle number, the mod which is the most common number, then there are some upper and lower confidence limit as well which is also used in terms of statistical analysis. And some things you need to consider is the sample distribution - what kind of sample distribution we have, what the data will be used for, what is the use of the data, what it will be used in terms of implementation or in terms of just general calculation general design.

So, based on the data requirement what kind of data, how detailed the data is required we can decide in terms of what we need to do in terms of statistical analysis. But some of the things that we definitely need to consider is what is the sample distribution. As you can see in items of representative concentration we need to find out what is the sample distribution - whether it is a normal distribution, log normal distribution and we will talk about that how to find that and what the data will be used for. So, these are some of the information that you need to know in terms of the collection of the data.

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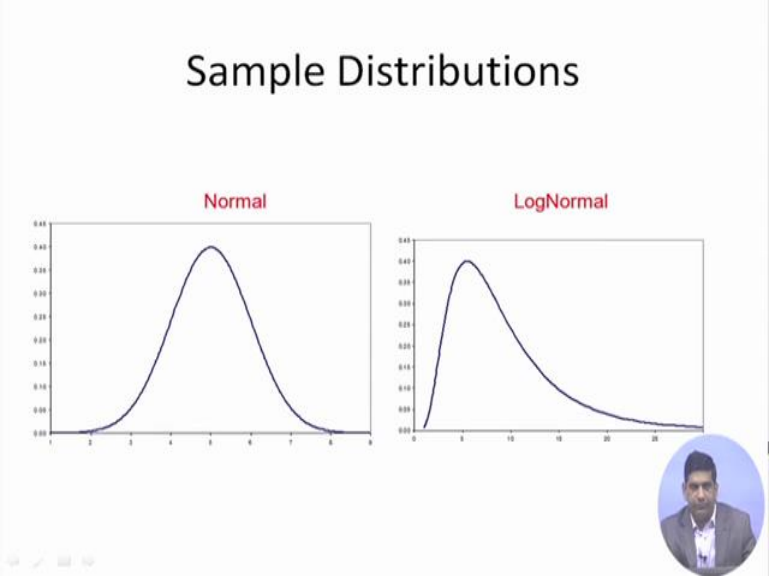

So, in terms of sample distribution if you look at this particular graph here too say sets of two graphs. So, here we have first one on the left hand side, this is the normal distribution very like very common you may have seen it in classical like a statistical distribution and then on the left hand side, sorry on the right hand side what you see is a log normal distribution. So, this is the normal distribution and this is the normal distribution. So, the log normal distribution is typically what we see in the environmental sample, we do not see that much of a normal distribution. So, normal distribution we will talk about that in a minute.

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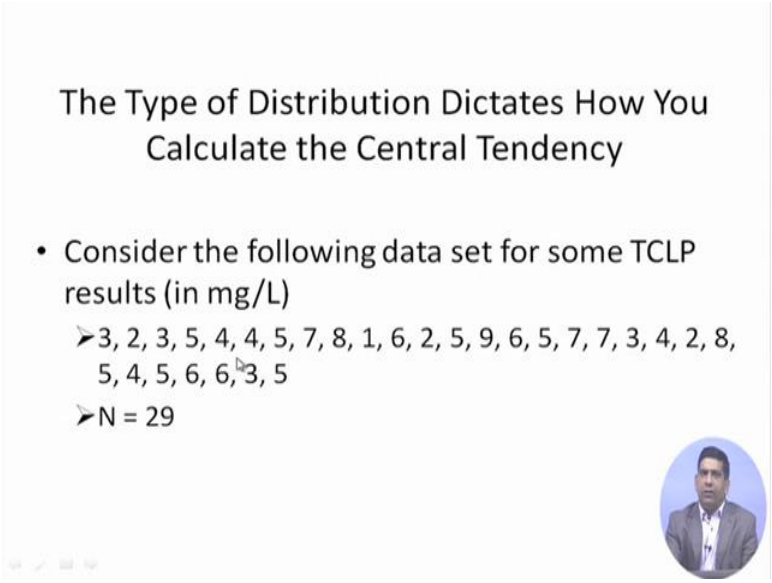

So, if you look at some of the examples, say if you have a type of data type of distribution dictates how you calculate the central tendency. So, it depends on what kind of like a type of distribution does have an impact on how to calculate the central tendency. Now let us look at some example this is one example where we have the data say this is was done on some TCLP test, TCLP stands for toxicity characteristic leaching procedure, I have not defined the steps so far, for your class here you can just think about that this is a test done on soil sediments, solid waste to find out whether it is that particular has west is a hazardous waste or not.

So, this is just a like a citric acid and ETA solution which is mixed up together say like, we have like TCLP is your what you are trying to predict what will happen in a municipal solid waste land fill. So, you will have this acetic acid and sodium hydroxide which is mixed together to make the TCLP solution and then you take 100 grams of samples and two litres of the TCLP solution, you run the extraction and after like 1 day 18 hours you have the concentration. And the data here shows concentration for 29 samples, as you can see on that data if you look at carefully here we are wearing from data of one to the maximum; the minimum value is 1 and the maximum value is 9.

So, that is a quite a variability in the data set which I was trying to explain earlier that

environmental data at many times say is a its a heterogeneous sample. So, in heterogeneous sample you will see these kinds of variability and with N is equal to 29.

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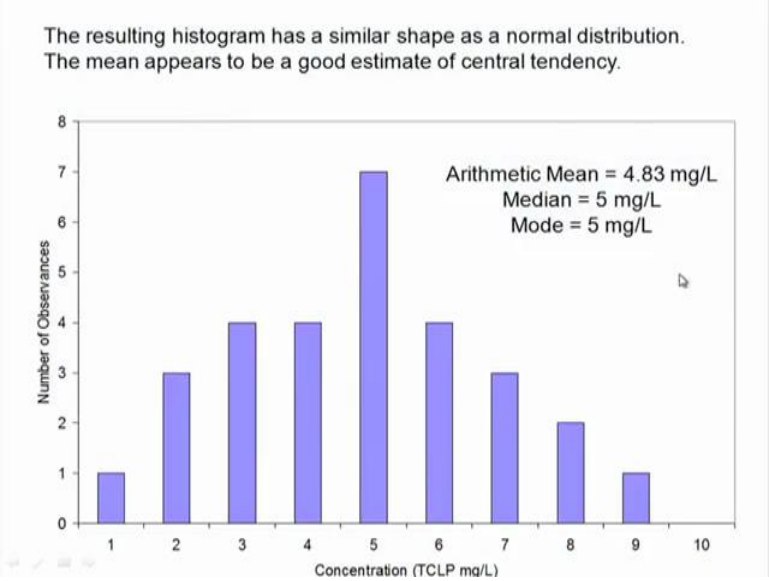

So, you plot it, you plot this data and then you see that there is a arithmetic you find the arithmetic mean 4.83 median is 5, mod is 5, and this one is a classical distribution that you see this resulting histogram is a similar shape is a normal distribution as you can see from the graph the mean appears to be a good estimate of the central tendency. So, this is, you can think about like a nice classical safe graph and with arithmetic mean, median and mode is present there.

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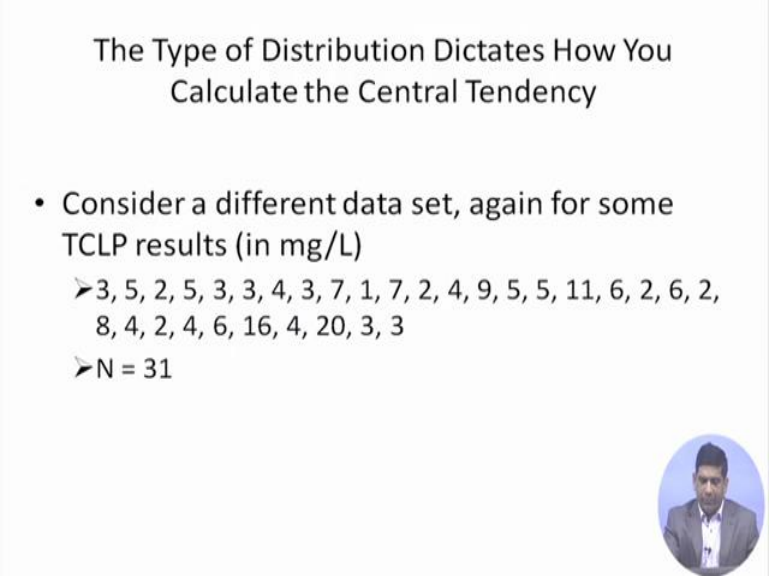

So, this is, if it is like a arithmetic mean. So, now if you have a data set if you would consider different data set again for some TCLP results where you found results varying from 1 to 20. So, like lot of variability and N is 31 numbers of samples you plot that data.

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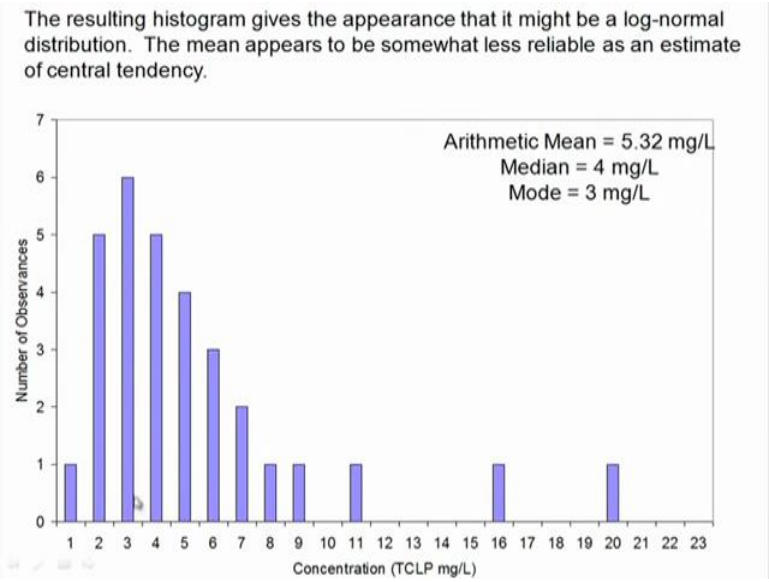

You see a like a long tail, long tail usually means log normal. So, that is what it means that it is a log normal distribution and here you see arithmetic mean of 5.32 median is 4 and mode is 3. So, this is another example and what we will do is in our next module we will kind of continue this distribution further. So, you will have to remember these two data points for your next module, but you will always have the access to the pdf files. So, you can look at that up as well.

So far what we have learned in this particular module for last 30 some minutes we started with looking at in terms of different instruments, what are the different instruments out there those are again not the total exhaustive list of the instruments, these are some of the common instrument available in the Indian labs. So, that is what the instrument was then how the each of the instrument works got some idea on that, then we also looked at some of the statistical aspects associated with environmental analysis, how this statistics play a role and then when you look at this distribution of the data like a normal distribution log normal distribution what are they mean. So, we had some examples of that.

So, with this will like a wrap up this particular module and then we will look at in the next module which will be your module number 3 of week 3 and then we will continue this particular discussion on this TCLP data and the statistical analysis because we have some statistical data to show there as well. So, that is, let us kind of wrap it up for this particular module and then again I will see you in the next module.

Thank you.