Introduction to Mineral Processing
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Lecture – 12
Sampling

Hello, welcome everyone to this actually third week of this course. So, last week I have emphasized that we must get a representative sample. If the sample is not correct, then your an entire effort of say characterization will be of no meaning. So, this lecture I would like to discuss that what is sampling, how it is being done. And so, so let us begin.

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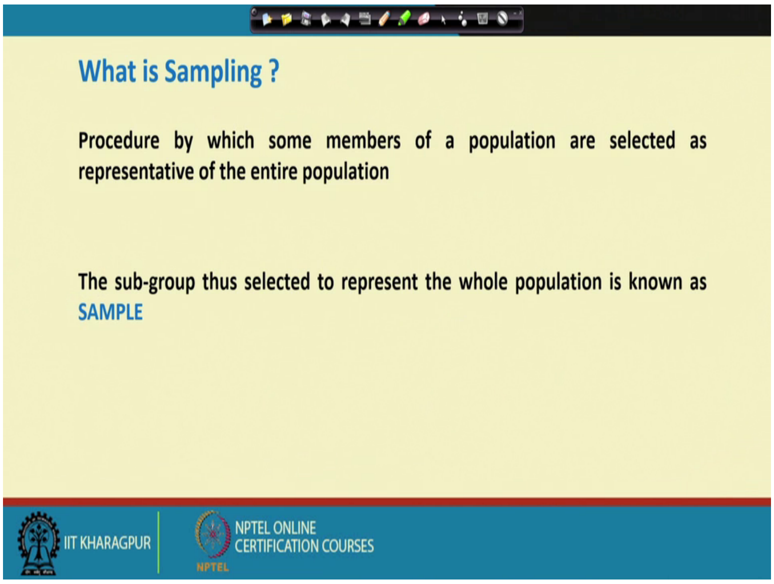

So, what is sampling? So, sampling is a procedure by which some members of a population are selected as representative of the entire population. What is the meaning of this?

So, suppose you have a you have an ore deposit of 200 million tons. And you have to decide that whether, we should mine that ore and if you mine what how we should process it. So, what is the essential? First thing that is you know very first week of lecture I emphasize that; it is, the contained value per ton. So, that means, what is the contained value per ton of your wanted material. Now how do you know that what is the average metal contained or say any other characteristics of that 200 million ton of deposit which is not yet mind.

So, you have to take a, if you take few samples which should ideally represent the characteristics on an average of that intact 200 million ton of deposit. So, the procedure which you adapt to select those members, or the select those portions of the material which you ensure that that is the true representative of the entire population. So, the subgroup thus selected suppose we have collected the 10 different samples from 10 different locations. So, each sample you collect that is each subgroup you select that is called a sample.

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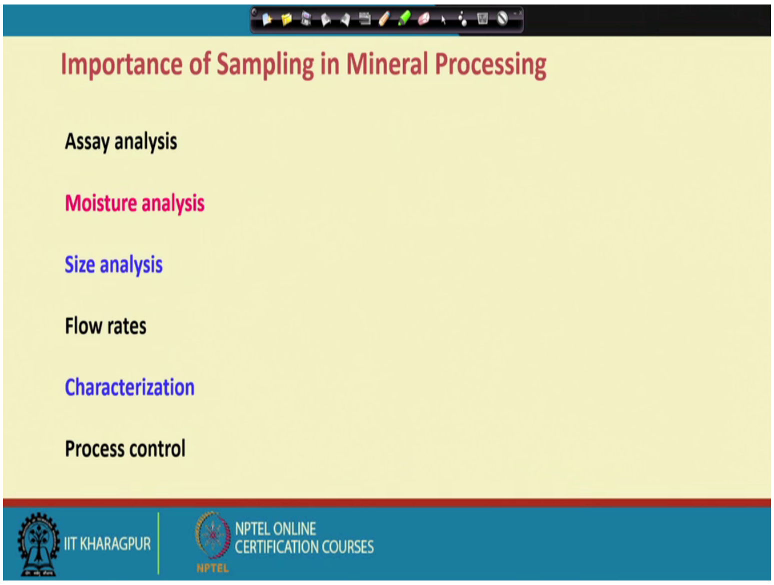

So, what is the importance of sampling in mineral processing? Now as I have said again and again that it is the contained value per ton; that means, suppose that is a gold ore. So, in that 200 tons said 200 million tons of deposit, what is the average gold content? Now based on that you think that I am going to mine it over a period of 10 years. So, per year how much you will be mining. So, actually what is that you will be selling? That is, per year how much of gold I will be able to sell after mining processing and extraction. And that is your basically the price you will get back against your investment in all these processes like, mining processing and extraction.

So, how much gold I will be able to sell? That will depend on that what is the average assay content of that material. Not only that. Even you have selected a mineral processing operation. Now we want to improve the relative percentage of your gold. So, each step, each upgradation step you want to monitor, that whether there is any improvement in my assay content or not. But remember that maybe my processing plant is having a capacity of 500 tons per hour. So, it is impossible to do the chemical analysis or assay analysis for gold for the entire 500 tons in every year every hour.

So, what you have to do? Now your chemists might say that I need only one gram of sample. So, how do I collect that 1-gram sample, which will help you to assess that how much of basically gold ore gold you will be extracting every day. So, that is the assay analysis, then, moisture analysis. Sometimes you also want to know that what is the moisture content of my material after processing. For example, say suppose if you are working for a coal processing plant, because it is a weight process most of the cases the beneficiation processes are weight.

So, some moisture will be entrapped into the surfaces of the coal particles some moisture will be entrapped into the void spaces created in between the particles. But you will be selling actually the coal. So, you want to do your client wants to know that how much of moisture you are also selling along with the coal. So, you want to minimize that moisture content. So, in essence you have to monitor that. So, you have to do it on a regular basis the moisture sample, the moisture analysis of their sample.

So, you have to take a representative sample. Like that you want to do the size analysis as we have discussed in the last week. So, even for size analysis in a laboratory I said that you need only a small amount of material. So, the small should be truly representative of the your actual deposit or actual material which is in say. So, maybe in tons or maybe thousands of tons or maybe millions of tons, then in a processing plant also you want to monitor the flow rates, because the flow rates control your productivity of each equipment. Flow rates of what flow rates of solid liquid mixture because we will gradually get to know that mineral processing mainly focuses on water base separations.

So, we have to measure the flow rates also. So, we cannot measure many times the flow rates say the original. So, pipelines. So, we have to take a representative sample from there. Then various other characterization like you want to do the; density analysis of your material may be radioactive materials, whether they are present or not in any other. Important minerals whether you are that is also associated with your is a main mineral what you are mining, and whether we can use it as a byproduct. Then in process control like when you are measuring the flow rates it can be volumetric flow rate it can be mass flow rate, then we can have because of the development of sophisticated instruments we can have, all stream analyzers, which will give you the assay analysis online may be size analysis online.

So, based on that we have got a model and simulation tools, and through which you want to control the process. So, importance of sampling in mineral processing is enormous. If your sample is incorrect in, all the stages whatever I have mentioned then your entire decisions or entire calculations will be incorrect. Now I have said say that your samples should be true representative of your entire population. Easy to say, but very difficult proposition, because by nature what you are mining the mined ore they are heterogeneous.

So, when you have a heterogeneous material that is very difficult to have a representative sample. So, before we go to the techniques of sampling let me discuss something which you all know probably, but for our recapitulation is the fundamental statistical terminologies.

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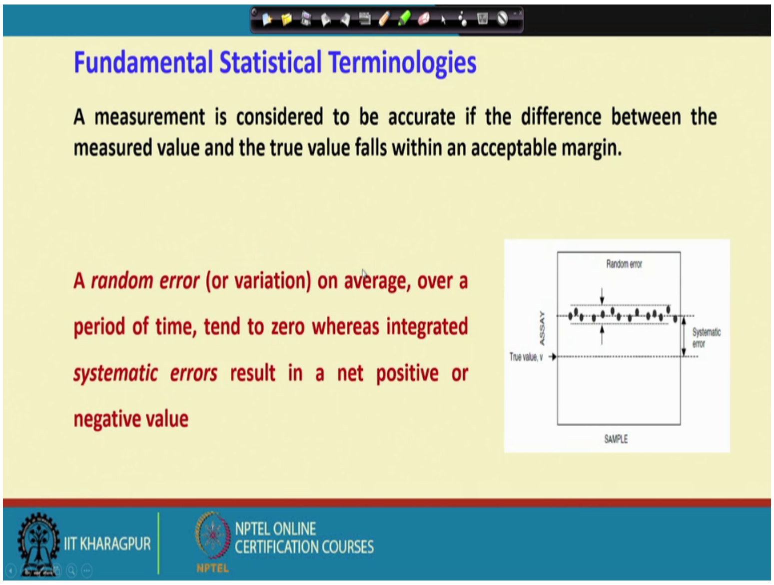

So, there are some terms like accuracy and precision. So, what is accurate? What is a accuracy? So, I would like to explain it like this. Like, I have got like I am a chemist, and I am doing the assay analysis or the sample which has been given to me by my mining colleagues or maybe mineral processing colleagues.

So, I have done very carefully the analysis, and we have got very sophisticated analysis analyzers, we have taken extreme precautions. And we have repeated the assay analysis so many times. And what do we do we try to see that what is that your deviation between each data. Suppose, that the first x the first assay I am getting 6 percent, next is 6.1 percent. Third one is 6.12 percent, 4th one is 5.98 percent. So, like that we get, and then we take a mean of that that is the mean value, and we try to see that how much is the deviation from that.

So, the more number of samples we analyze, the more precise is the data. So, precision means that how much, how less is the deviation from my mean value if I repeat the same experiment again and again and again many times. But say suppose I have got a mean value of 6.1 percent something of some assay. Does it ensure that your data is accurate? Probably not, and it is not; because I have done the analysis only on the basis of the small quantity of samples, which are given to me. If those samples are not truly representative of my entire population, suppose my deposit is 200 million tons, and I have done only 20 test on 20-gram sample that is one gram each.

So, even though I have got very sophisticated equipment, even though I have performed a test with a extreme precautions, even though the data is precise, we cannot guarantee the accuracy. So, what is the accuracy? So, accuracy suppose the true value is somewhere like 5.4. And your data is saying that the mean value is 6.2 or 6.1 whatever it is. So, that means, it is 0.7 percent in the higher side. So, the difference between this, that is your mean assay and the true value. So, the difference between the true value and the mean assay is called a systematic error. Please do not confuse get confused, that it is always in the heart side it may be in the negative side also.

That means if my true value is 5.4 percent, my analyst might say that that the mean value of 20 experiments is 4.8 percent so that is also not correct. So, the question is that is how do we find out these errors. So, this is called a random error on average, over a period of time, and this error might tend to 0, if we increase the number of samples which are analyzing.

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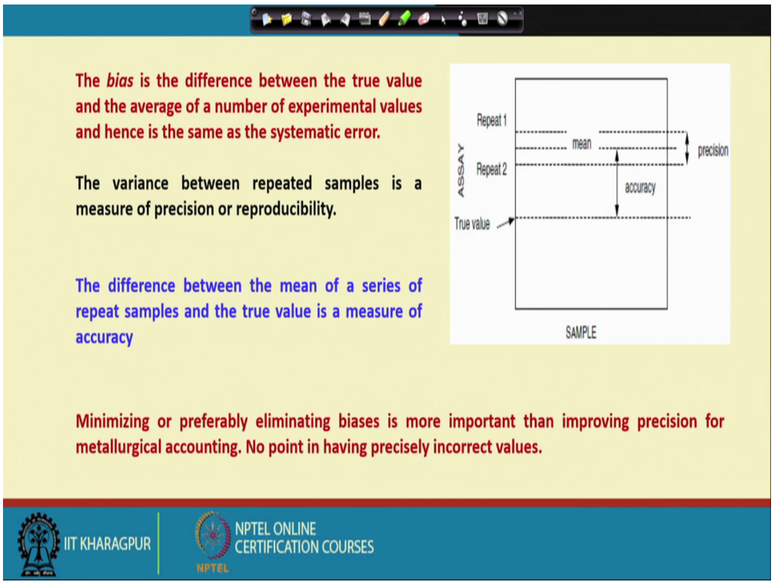

So, the systematic error is nothing but a basically it is called the bias. What could be the bias? So, say suppose that when I have collected 200 representative samples from the 200 million tons, and I have just taken the samples just from the say from only one location. And because of geological formation you know, that it is not guaranteed that whatever you are getting here, and the next site if you start mining will get the same thing.

So, if I have only concentrated here, that all the 20 samples I have collected from here only. And say suppose all the gold I have assumed that it is already concentrated here, but I am I will be mining here also here also, but they are bordelaise gold content. Than the original place from where I have taken the representative sample. So, that is a bias; that means, I am biased to that particular location. And that may be the reason for my over estimation. There is nothing wrong with the chemical analysis or the assay analysis. So, the bias is the difference between the true value and the average of a number of experimental values, and hence it is the same as the systematic error.

Through this diagram I wanted to show you; that is, the previous diagram and this diagram are more or less same. That this is the mean value and precision depends on how much the other data they vary from the a mean value and if this is the true value. So, this is a showing that there is a systematic error, so that means, it is biased. So, that is basically over estimating. If the data is somewhere here, so that means, this is under estimating. So now, how do I ensure that my sample is bias free is very difficult proposition.

So, and in statistical terminology we call it that that, the variance between repeated samples is a measure of precision or reproducibility. So, the difference between the mean of a series of repeat samples, and the true value is a measure of accuracy. I have already explained that. So, many times what we do we try to give more emphasis on the assay analysis technique? Suppose I do the assay analysis technique by a assay analysis by weight chemical method which you are probably familiar with that is the conventional tachometric methods or like that. That is, you convert all the minerals into a soluble form and then you go for titration and all this.

Now, there may be the human errors. So, to minimize the human errors, I have decided that we will have some modern sophisticated instruments. And then I started thinking then I have started thinking that my analysis is correct. So, everything is correct. It does not matter how accurately you are measuring how accurately you are analyzing your assay. But if your representative sample is not correct, then your entire effort is meaningless. That is why I have written that; minimizing or preferably eliminating biases is more important than improving precision for metallurgical accounting.

No point in having precisely incorrect values. Like, here if you see that the data is data may be precise, but that is an incorrect value because this is far from my true value. And this is what is called bias. So, that is the most important thing in sampling, that how do I minimize or possibly try to eliminate the biases. So, there is a lot of research has been done by many people. So many books are written. This is one of the most popular theory of a equation proposed by GY.

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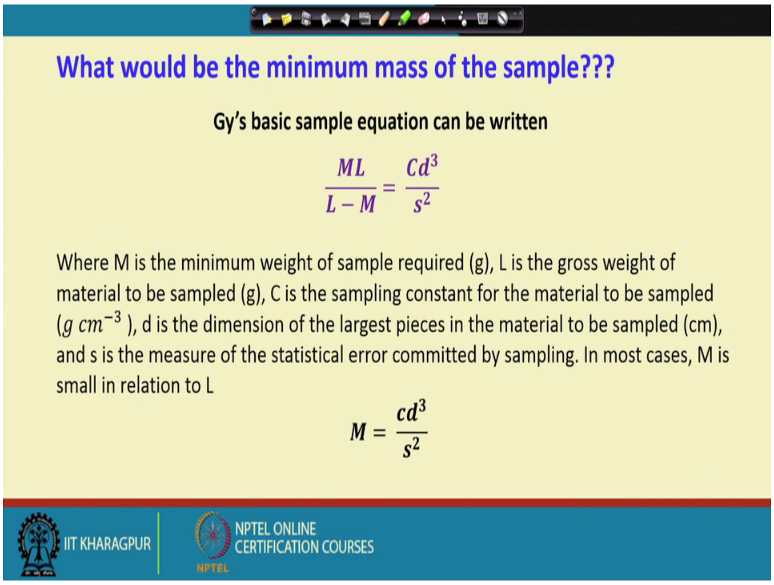

So, first question comes that if I have a 200-million-ton deposit, what is that minimum weight of sample I should collect to minimize the chances of having biases?

So, let us have a look at the GY's equation. These equation tells that it is ML divided by L minus M is equal to Cd cube by s square. Be careful about the units. You have to use the exact units. Where, capital M is the minimum weight of sample required. That is what we want to know. That is in gram. Capital L is the gross weight of material to be sampled; that means, how much a material we have to sample; that means, what is the deposit? What is the volume of that deposit? And from that out of that so, that is a L out of that how much of minimum weight of sample I have to collect. And that is in gram both are in gram. Capital C is a sampling constant for the material to be sampled in gram per centimeter cube.

So, capital C although it is a constant, but this is a material specific constant, I will explain you that what do you mean by material specific constant. Small d is the dimension of the largest pieces in the material to be sample that is in centimeter; that means, what is the largest particle size I have to sample. And s is the measure of the statistical error committed by sampling; that means, you have to adapt to procedure. So, what is the error in your procedure? That is, the small s. So, in most cases you know to simplify this the capital M; that means, how much of weight of sample you have to collect that is very less in relation to the L that is the entire your say ore body which you want to sample.

So, I can write because the M is very small. So, I can write L minus M that is equal to L because this is insignificant the same. So, this L L gets cancelled out. So, I can write capital M is equal to Cd cube by s square. So, this C is capital C. So now, question comes how do I find out this capital C and the s.

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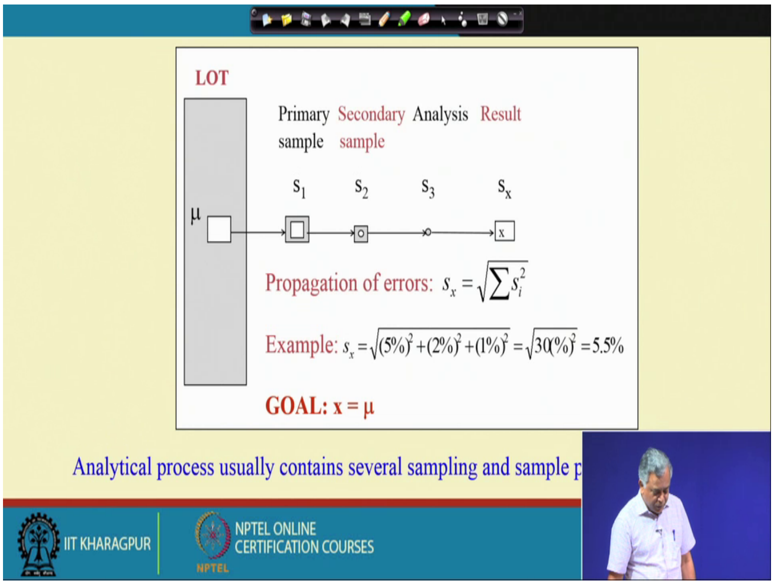

So, let us discuss about the errors that is very, very important. With this diagram what I wanted to show those are suppose, this is your entire deposit; that is called a lot. That is representing it just is assumed that this is 200 million ton of deposit. And it has got a assay content of say suppose mu, that is a true value.

So, out of that 200 million ton, my analysts the chemist, he wants only one-gram sample to get the assay analysis done. So, what we do we do it by in stages? Because your chemist may be sitting at a distance from the deposit, we have to consider about the transportation, and your how do I preserve the material. So, there is a delay time between your say taking out the sample and your analysis a lot of delay time. So, what you do? First you take a primary sample of a quantity which you have calculated based on the GY's equation. Now you have followed that 3 different steps in between that is s 1 for secondary sample there is a s 2 there is an error.

So, each stages so, whatever you do whatever experiment you do or whatever where you do sample there will be some error. So, suppose in these 3 stages each cases the errors are represented by s 1 s 2 s 3. So, what is my goal? That x that is the assay it should be equal to mu. So, what is the overall error? Overall error is the square root of sum of square errors, what is the meaning? Now so, suppose in this case the error was 5 percent in this case, it was 2 percent in this case it was one percent. So, what will happen? So, the example so that my total error will be sx is sum of square error and the square root of that.

So, 5 square plus 2 square plus 1 square, and that is you are getting 5.5 percent error. So, the goal is x is equal to mu. Now it depends on my on your strategy, that whether you are happy with 5.5 percent error or not or whether you want around 3 percent error. So, what I have to do? I have to I have to minimize the error first here. And you see that maximum error is contributed from this to this. So, I have to redo my sampling analysis maybe, I have to take precautions that how do I minimize the errors.

Actually, we find that analytical processes contains several sampling and sample preparation steps. And my personal experience is that that is here the error is most of the cases it is minimum because these days we have got trained manpower and very sophisticated equipments are available, but most of the errors they are coming here. So, this example is telling you that does not matter even if the error here is 0.01 percent, but by still my overall error remains more than 5 percent. So, we will explain you bit more on this; that is, how do I do it and all this, in my next lecture.

Thank you very much.