Non-Ferrous Extractive Metallurgy

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Module No. # 01

Lecture No. # 32

Energy and Environment Related Issues in Nonferrous Metals Production

Friends, we have now come to the last module in this series of lectures. First 8 lectures dealt with extraction processes for specific metals and also, to start with some general principles of extraction and refining.

We could have discussed a lot more and if you refer to the books which are available on the subject, you get lot more details, many more details.

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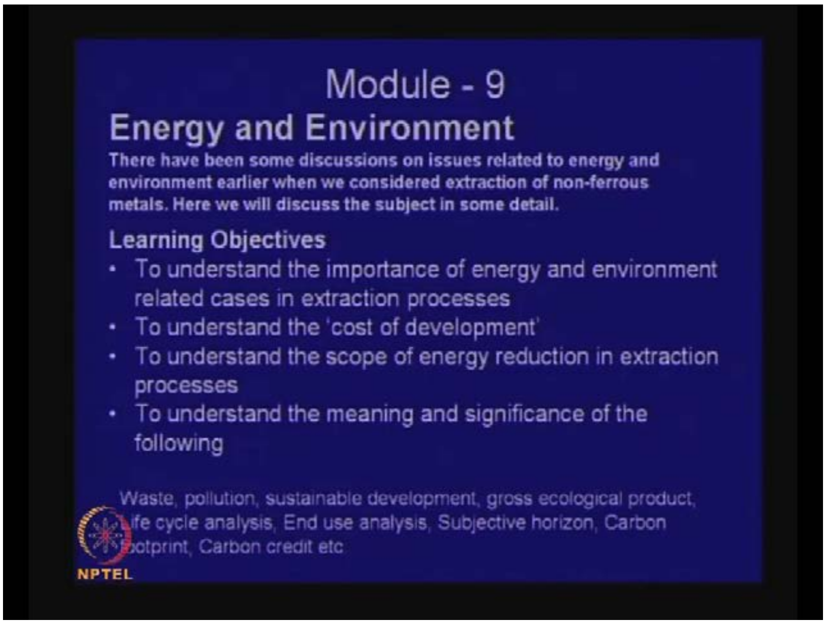

I have only selected the important metals and some of the important processes which are there in the industry and discussed some important issues which are relevant from the points of view of production. Also, some relevant issues which are important for understanding the theoretical basis of doing things the way we do.

In this last module, module number 9, we will not discuss any specific metal as such. The entire module is devoted to issues related to energy and environment. Of course, now and then, I will bring some reference to some particular extraction process, but many of the things I will discuss are of general importance. Not only in metallurgical non-ferrous metal extraction, but may be also of extraction of iron, steel, may be even other manufacturing process.

The question you can ask is why I am going to discuss it in a course on non-ferrous metals production. Well, the answer should be obvious to you because today, no matter what you do, environment is a central issue and perhaps you know the government has made it compulsory for every student, no matter what discipline is it, to be aware of the environmental issues. Be it law, be it medicine, be it engineering, be it pure sciences, it is now a compulsory subject.

Why is it a compulsory subject? Because environmental issues have become overwriting. It cannot discuss anything ignoring environmental issues. As a matter of fact, there is now a new word called industrial metabolism. Not many people have heard about this word industrial metabolism, but you will begin to hear more and more of that as you grow older. See by metabolism, human metabolism what we mean is that body takes in food, takes in air, so there is input to the human system in terms of materials and energy. Then, they are processed in the body and the body gains in terms of development of muscles, tissues, bones. So, there is a metabolism which depends on input from outside and the system also rejects some wastes.

Similarly, you can draw an analogy to any industrial system. The system runs because there are some inputs. The inputs in terms of materials that includes, water, energy, capital, labour and the industry sustained. It produces goods and services, but in that process, it also rejects certain matter. Ideally, the industry should be a green industry that nothing will be rejected as waste. Everything should be recirculated. If not recirculated, the waste should find useful application elsewhere. Actually, it is often said there is nothing which is a waste. Waste is only a raw material at the wrong place. Every waste can be a raw material for producing something else which is valuable.

So, in a green industry, there will be no waste and people are already talking about iron and steel industry, which one day would become a green industry. No waste was soluble. We might actually we are trying to mimic natural processes. Even in natural processes, everything is recirculated. Only there are two wastes in nature; I do not know how many of you are aware of that. These wastes are coal and petroleum.

The coal comes out of millions of years of geothermal processes of plant matter that fall on to the ground, decompose, petrify and go under layers of soil. So, under pressure and heat after millions of years, it goes through different stages of qualification and ultimately, it forms anthracite. You know you have peat, then bituminous, sub-bituminous, coal bituminous, coal etcetera and finally, anthracite. Similarly, petroleum is supposed to have come from millions of years of geothermal processes of marine waste that were deposited in seashores, finally got submerged and reactions took place of long time produced petroleum.

So, in natural processes, there was no way of recirculating coal and petroleum, but fortunately, they were benign wastes mean those waste cause no harm to anybody. They stayed under the sea, under the ground out of our sight, out of our reach. At least in the initial stages, benign wastes causing no harm to anybody. Actually, much of our problem today has come out of trying to explore those benign wastes because we are taking out coal, we are taking out petroleum. We have been burning them, we are processing them, then creating climate change, creating global warming etcetera.

So, those things that were benign wastes of nature have now come to own task. I should not digress from the main issue. The main issue is industrial processes ultimately should mimic natural processes, where things are recirculated. The CO2 that we exhale or CO2 that came out of natural processes at one time found sinks in two places. One is plant matter, vegetation. It absorbs lot of the CO2. About 30 percent CO2 went into the sea because sea also needs CO2 for growth and sustenance of the marine organisms. Be it algae, be it plants, be it animals, they all also need carbon that came out of the CO2 which has absorbed from the atmosphere.

Unfortunately, in the last 200 years or so, the industrialization processes that are based on combustion of fossil fuels, they are creating so much of CO2, that there is not enough plant vegetation on land or not enough capacity of sea to absorb that CO2. There is an excess CO_2. That is what is causing today global warming. Apart from also other gases, like methane, nitrous oxide and some others, but CO_2 is the main culprit, not because it is the most potent. Actually, CH_4 is more potent weight for weight but the sheer amount of CO_2 being generated by modern industry is what is alarming. That is why, we must know what the issues are and in these issues what role do industries play, what role does non-ferrous metal industry play.

Even if it is not that substantial substantive, it is our duty to see how things can be minimized. So, we will get into these issues and we will make some specific reference to non-ferrous metals production. Now, let us look at the slide. There have been some discussions on issues related to energy and environment earlier when we considered extraction of non-ferrous metals. Here, we will discuss the subject in more detail.

What are the learning objectives in this module? They have been listed as follows. To understand the importance of energy and environment related cases in extraction processes, to understand the cost of development. I will explain this term cost of development. We talked about development but development comes at a cost. To begin to live, live in a more prosperous manner, to become a more developed country, we have to lose out somewhere. Where we lose out, I would explain.

The third point is to understand the scope of energy reduction in extraction processes. There must be scope because there is always scope for reduction of energy consumption but we want to know to what extent we can go to. We have seen in the earlier lectures that if we recirculated scrap, then our energy consumption is less. That is one way of bringing down the energy consumption, but more important will be if we have an extraction process. How do we cut down an energy requirement and in consequently, the CO_2 generation would also be decreased.

Now, lastly and this is very important. There are many terms we often use very loosely. We have to understand what the exact meanings of these words are. The words are waste, pollution, sustainable development, gross ecological product, life cycle analysis, end use analysis, subjective horizon, carbon foot print, carbon credit etcetera. These are the terms which are becoming more frequently used in recent years and I think every engineer, every metallurgist should be familiar with not only there meanings, but the context in which they have come and why they are important, why we should learn about the meanings of these terms.

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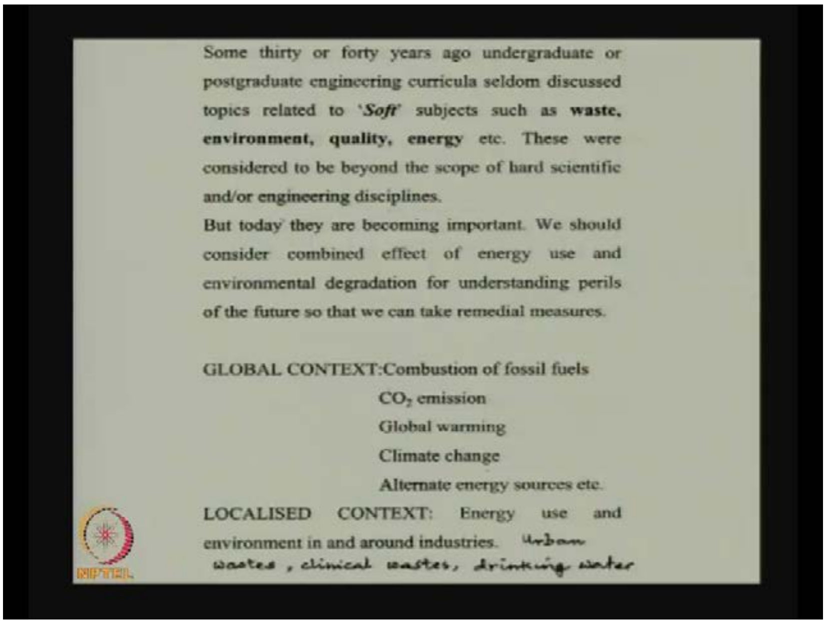

When we were students, I was an undergraduate student in IIT Kharagpur from 1962 to 1966. Now, at that time we had never had discussions on energy environment, quality, management principles etcetera. If I told they were mentioned, they were brushed off as soft subjects. Soft subjects are which you pick up as you go along in life, you join an industry. When you work, you begin to understand the importance of energy, environment, quality etcetera. So, by the word soft subject, which is meant that they were not very well defined and therefore, not worthy of being taught in under formal education program, especially in under graduate years.

The emphasis was on hard subjects. Hard not because it means difficult, hard means very well defined like mathematics, thermodynamics, electrical engineering, physical metallurgy very well defined. We knew what the things are to be taught, we knew where to find the books where these were discussed, we knew what kind of laboratories should be run to explain the principles, we knew what to expect from the students at the end of the course. Very well defined from beginning till the end, but nobody really knew about how to teach subjects related to energy and environment of quality because those things were not very well defined in terms of content or scope, but things have changed now. I have mentioned a little while ago. Energy has become, environment has become a compulsory subject and once you make it a compulsory subject, you have to find out what is to be taught, what should be the scope, how it is to be taught, how do we bring in laboratories or example to explain things.

I remember my experience. I joined IIT Kharagpur as a teacher in 1980 and I was beginning to think that the importance of energy needs to be emphasized to the students, at least in the graduate level. So, I proposed a course at graduate level with the title Energy and the metallurgical industry. Initially, there was reluctance to accept that as an optional course, but subsequently over the years, it has become a course which many people take and it is considered to be a very desirable course because the subject has become so able.

Now, it is fortunate that I had proposed that course and in the process of teaching, collected some materials, thought about it, talked to students, talked to colleagues and finally, I have been able to write a book on the subject to which I have referred here earlier is called Energy in minerals and metallurgical industry authored by H.S. Ray, B.P. Singh and S. Bhattacharya.

Now, that book came out of my concern for energy issues. Not so much I knew about environmental issues, but today, till today there is no good book on the subject of environmental issues in process metallurgy. Many people are working. If you go to plants, if you go to R and D laboratories, people are working and doing lot of good work on issues of environment. There are many places where in the graduate level, there is a course being given also, but still it has not become a well defined course at graduate or undergraduate level. I hope the due changes and it will change sooner or later.

Now, when I talked about a course on energy, I did not do the best I should have done. Later, I realized that you cannot talk about energy and environment separately. They are very much related and the environmental problems we are facing today, come largely out of energy use. So, 80 percent of the environmental degradation problems are coming out of energy generation and energy production. Perhaps you know this, but again something on this I will discuss later.

Actually, now people are talking about two things. We have to tackle the problem by first of all trying to see how we consume less energy and then, if we have ended up using energy what do we do for remedial measures. How do we tackle the bad effects? Then, the global context, the issues are combustion of fossil fuels, CO2 emission causing global warming and climate change. People are talking about alternate energy sources that will not depend on carbon. Now, here there is another word people are saying, we need decarburization of the industries, means cut down on carbon consumption. They say we also need de-materialization; we need consumption of less material because if you consume less material, you will produce less waste. So, you know the dematerialization is desired for world peace, but for world survival today, we need decarburization and dematerialization, cut down on carbon consumption, cut down on material consumption.

We are talking from the global perspective. In the local context, environmental issues are related to energy use, which destroy the environment in and around industries. There are urban wastes, chemical wastes; there is problem with drinking water. So, there are all kinds of issues related to environmental degradation. What are the basic issues?

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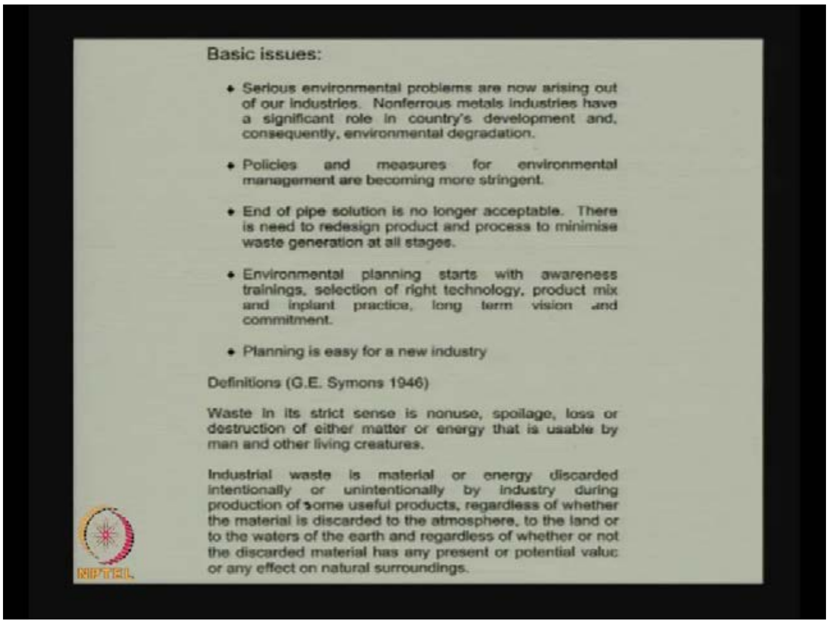

The basic issues are the following. There are today serious environmental problems arising out of our industries. Non-ferrous metal industries have a significant role in country's development and consequently, environmental degradation as well. Policies and measures for environmental management are becoming more stringent. Where the government is becoming more aware, there also social groups put pressure. At one time, people talked about end of pipe solution. What is end of pipe solution?

End of pipe solution means let things happen, let them go through the pipe. At the end of the pipe, if there is a problem, we will try to solve it. So, the emphasis was on allowing things to happen and then tackle the issues that created problem when things have happened. That is called end of pipe solution but end of pipe solution is no longer acceptable. There this is a long approach, like you know that somebody says I will eat whatever I like and if I have indigestion, I will go to the doctor. He will cure me. This is an end of pipe solution. That is no longer acceptable.

The ideal is not to eat things that can give you problem. You eat well; eat correctly, so that you do not have the need of a doctor at the end of the day. So, end of the pipe solution is, when problems are generated by a process, not changed in time or not changed adequately and if you have problems, you try to find technological solutions. There is now need to redesign product and the process to minimize a waste generation at all stages and by this waste, I mean gaseous waste, liquid wastes and solid wastes.

Then, environmental planning starts with awareness trainings, selection of right technology, product names and in plant practice, long term vision and commitment. So, if we do not want end pipe solution, then we need to do this that we be more careful from the beginning. Prevention is better than cure. We are not talking about curing, we are talking about prevention of the environmental degradation problems as far as we can and for that, we need to have environmental planning right from the beginning. To do that, we have to select the right technology and we have to train people about environmental issues.

We need to find out what product makes we should use, what kind of product we should product which would have least impact on environment. What kind of in plant practice we will have and we need a long term vision and commitment. Long term vision is another term for a longer subjective horizon. A subject horizon is means to what distance somebody looks at. Let me give an example.

Suppose, you have a car and you find that the engine is not efficient. You are wasting a lot of fuel and somebody says you buy this accessory which costs say 10,000 rupees, attach to the carburetor and your fuel combustion will be more efficient. You will be saving with the kind of running, you are doing 500 rupees every month, but you have to put 10,000 rupees now to get that attachment to be connect to the carburetor. Now, there are two kinds of thinking in this. Some people will say, 10,000 rupees that is far too much. I cannot afford it. This man does not have a long, the subjective horizon is short.

Like, if you go to those who are running commercial vehicles like buses or taxis, they go from day to day. They cannot think of a long term vision, but see what the seller has mentioned. If you are saving 5000 rupees, 500 rupees I mentioned, increase it a bit. So, make it 5000. 100 per month or let us go back to 500 rupees is all right. 500 rupees a month means in 6 months, it will be 3000. In one year, you are saving 6000. In 2 years time, you save more than what you had invested to start with and after the 2 years, you are at a profit of 500 rupees every month.

Now, if you have a subjective horizon of 2 years, means if you can think up to that far, you will find this to be a very profitable proposition, the real. Let me buy that gadget for 10,000 rupees, attach it to the carburetor. Up to 2 years, we are not getting. After 2 years we gain all the way. So, that is the idea of subjective horizon. This needs a long term vision. Many industries do not have it and when you have a long term vision, along with you must need a commitment, means it is not that you are committed on Monday and by Saturday you have forgotten about it. If you are committed today, will be committed six months, from now will be committed 6 years from now. That is the kind of management that is required today.

Now, let me go through some definitions. As far back as 1946, there was a definition for the word waste. There are many more definitions, but I happen to have this paper with me and I have always liked this definition. It says, waste in its strict sense is non-use, spoilage, loss or destruction of either matter or energy that is usable by man and other living creatures. So, please note, waste is not being defined in terms of non-use, it is being used in terms of use. I will read it again. Waste in its strict sense is non-use, spoilage, loss or destruction of either matter or energy that is usable by man and other living creatures. So, what you are not using, but is usable is waste. It is not non-usable.

That is how Symons defined as far base at 1946 when people were just beginning to aware of the issues concerning wastes.

Now, if we talk about industrial waste in particular, there is wasted, so-called wastable in this world. In industrial waste, we can define it as material or energy. Always think of waste, both in terms of material as well as energy. It is not only material, please remember. So, industrial waste is material or energy, discarded intentionally or unintentionally by industry during production of some useful products, regardless of whether the material is discarded to the atmosphere, to the land, to the waters of the earth or regardless of whether or not the discarded material has any present or potential value or any effect on natural surroundings.

So, it is a very comprehensive description that if an industry discards knowingly or unknowingly in the process of making useful products, it discards material or energy to the atmosphere, land or sea regardless of whether it has any value at the moment or in future. That will be an industrial waste. Let us move now.

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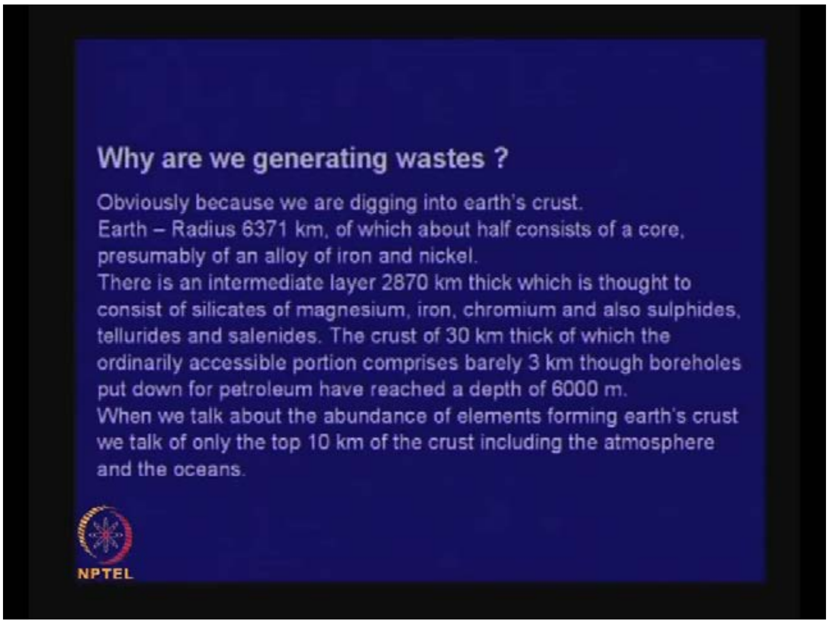

Question is why we are generating wastes? Most industries are generating wastes. Perhaps all industries are generating wastes because it is part of industrial metabolism. A human being also discards things, solid as well as liquid. They need not be wastes. They also have a potential use because if it goes for agriculture into agricultural field, they become growth promoters. They become nutrients for the plot matter. So, they are really not wastes, but we waste, we generate wastes in industries which go nowhere. Some industries only dump whatever they are producing in the river at night, so that others cannot see or in the sea or they let into the atmosphere all kinds of gases because they are not punished or they cannot prove to be guilty. May be they do not know, sometimes they know, but still they do because they think if they try to stop that, they will have to change the process or if they want to bring in remedial measures, they will incur additional expenditure.

Why are we generating wastes? Obviously because we are digging into the earth's crust. All our industrial processes and the metallurgical processes, we are getting essentially the first raw materials from the earth's crust. It is not only fossil fuels, but all the raw materials from metallurgical industry which produces materials which is going to other industries.

So, let us go back to this earth again with which I had started this course. Earth radius of 6371 kilometer has half consisting of a core inside presumably of an alloy, of iron or nickel. Then, there is an intermediate layer of 2870 kilometers thick which is thought to consist of silicates of magnesium, iron, chromium and also sulphides, tellurides and salenides. About this, we do not know too much, but people have found by many studies to come to such conclusion.

The most important thing which is of our concern with the crust, we say the crust of our 30 kilometer thick is ordinarily accessible portion comprised. That is what we call crust, but normally we can access only above 3 kilometer level at the top and this can be, samples can be taken out of this by deep boreholes. Some boreholes for petroleum have reached a depth of 600 meters, but generally we will say 3 to 4 kilometers is where we know what all things are available. So, when you talk about abundance of elements forming earth's crust, we talk of only the top 10 kilometer or so of the crust, including the atmosphere and this includes the atmosphere minding because when we think of crusts, do not forget oceans are part of that. Oceans are also top of earth and the atmosphere also is part of that crust.

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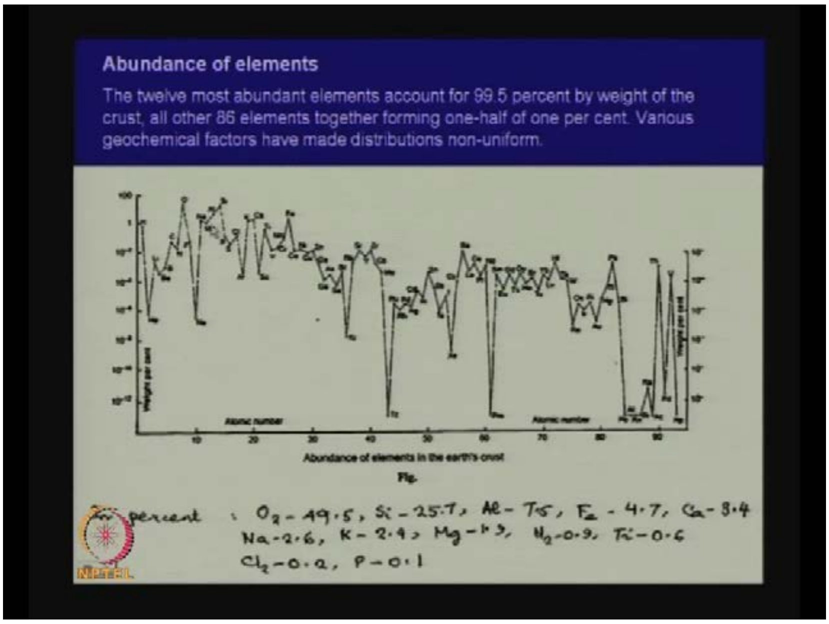

Now, I had given long time ago in the series of lectures, a table giving figures of relative abundances. Now, I am showing it in a form which is more friendly, viewer friendly. We are putting it in a logarithmic scale, in terms of abundance. This is the abundances logarithmic scale and these are the elements plotted according to atomic number. Now, you know out of all these elements, we have seen the very large numbers are actually non-metals. Non-metals are first of all which we call iron, take out halogens. They take out some elements, which are not considered metals because metals have certain features, but the large numbers of them are metals.

Now, if you look at the highest percentage is oxygen that includes the oxygen in the atmosphere also. Then comes silicon and then comes aluminum. You will find them all at the peak. There is aluminum, you will find iron here, then you find calcium between somewhere there, calcium, sodium is here, potassium, magnesium, hydrogen, titanium, chlorine, phosphorus. Now, very interestingly, it is not necessary that element which is very relatively more abundant is more common. I will emphasize it again and again. It is not so. It depends on utility value, it depends on how easy or how difficult it is to obtain from ores and minerals.

So, we may say, we see something is very abundant, but it does not makes it more common like silicon is the second most abundant element, but you do not see silicon so commonly in everyday use. It does not have right kind of properties. Silicon became very important when electronics came into human civilization. That is when silicon became very important, but in our everyday life, the silicon is not as important as iron or aluminum.

So, you understand that out of all these elements, we have discussed actually extraction of quite a few. May be at least 25 or so elements out of these we have discussed, others we have left out because may be they are not so important or process is very similar. Besides that there was not enough time as well, but please remember the 12 most abundant elements account for 99.5 percent by weight of the crust and I have listed the 12 most abundant elements. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, these are the twelve most.

All other 86 elements together form one half percent; various geochemical factors are made distribution non-uniform. That is why we are able to produce some elements. Although, relative terms in the earth crust, they should not be so abundant but somehow, they have been segregated in some pockets here and there and because that has happened, we are able to produce them. Had everything been distributed uniformly, it will be very difficult like it happens in the case of sea water. In sea water, there is a uniform distribution. So, it will be very difficult, but there are some places in sea water, when there are concentrated sources, sea nodules is one, some sea organisms are others which accumulate in them certain elements, so like iodine. Iodine was first found out from sea algae.

So, fortunately distribution is not uniform, but one or two generalizations we can make, which is very clear because oxygen and silicon are so very abundant. There will have lot of silica. That is why you have sand everywhere, also clay which has silicon, oxygen. Aluminum is also abundant, so we have lots of aluminum. Mostly has aluminum, silicate clay, we have bauxite, we have various aluminum ores. So, these 3 are abundant.

Now, till 200 years ago, nobody thought of much use of aluminum. Aluminium was not a metal which has produced in large quantities. It could not be produced in large quantities because there was no electricity, there was no Bayer's process before the middle of nineteenth century, but today we cannot think of a world without aluminium. Silicon, we still have not found why it is produced in our everyday life, but aluminum we have found. Interestingly, the metal with which we are most familiar, iron, it is only 4.7

percent in earth's crust, but still our age is based on iron for two reasons. Firstly, the properties that we get from steel and also we have deposits, which are rich in iron and it is relatively easy to extract iron from iron ore.

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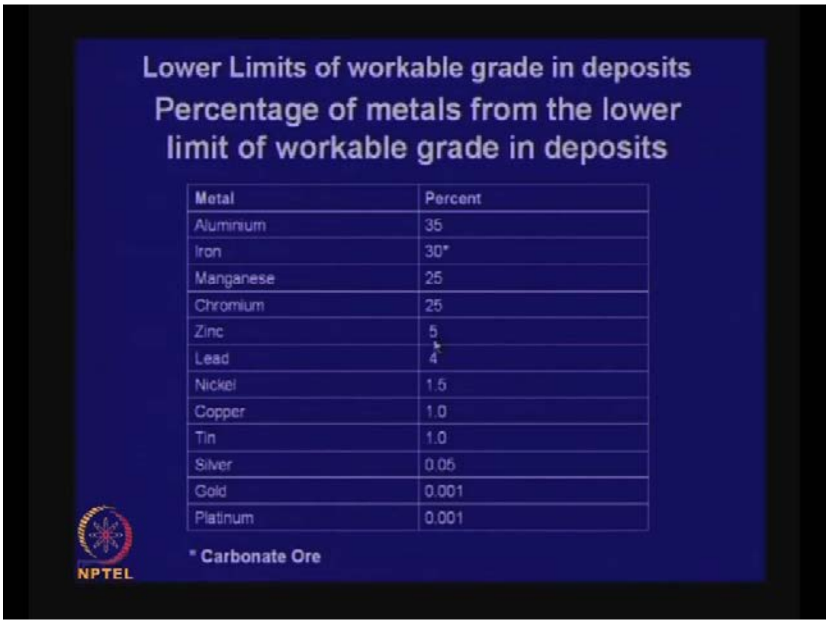

Now, our extraction processes are improving, but still there are some lower limits of grades from which commercially we can extract things. The pore at the grade becomes more complicated the process becomes. There will be more ejects, more environmental problems. Now, here I have given some tentative figures about the lower limits of workable grade of deposits. I have put aluminum as 35 or the mostly, we in at much higher grades, Iron-30 I have said, for carbonate ore, for oxide ores, 55-50-60, may be 50. That should be the minimum, manganese-25, chromium-25, zinc-5, lead- 4, nickel-1.5 and copper-1.0.

Some people think for nickel, it can go down to 1. We have known a technique, copper-1.0 because we have a floatation process which will take it to 1.25 or more in one step. Of course, we know that silver, gold, platinum deposits are of very low concentrations and till we have processes for extraction of these precious metals from pore grade ores.

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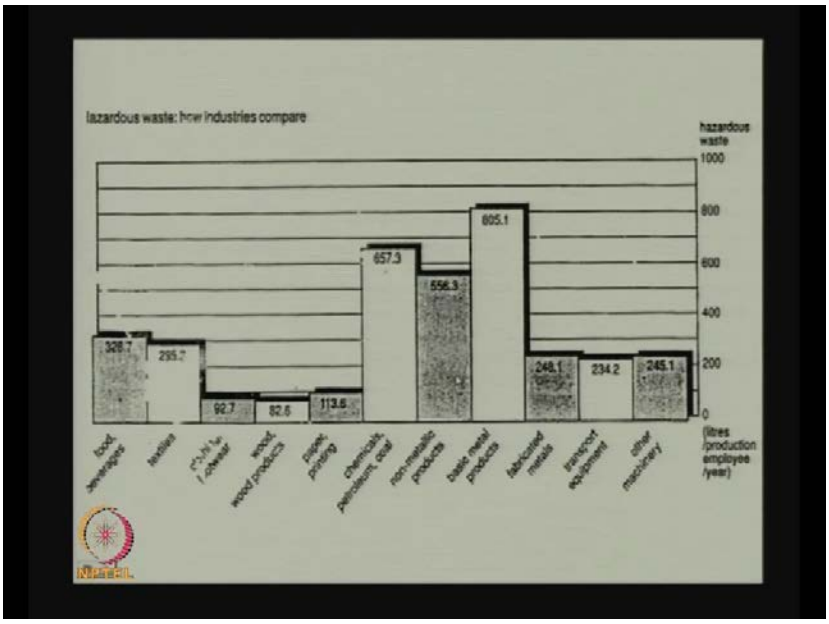

Now, coming back to the environmental problems that come in metallurgical industries, here is a comparison of hazardous wastes that are produced in different industries. This is hazardous waste, means something which is not benign waste. It is not a waste will cause no harm to anybody. These are wastes which are harmful.

Here is a scale in terms of liters production per employ per year. You have taken a strange kind of parameter. Foods and beverages, textiles, they all produce hazardous waste. Then, we have here I have to find out what this is. Wood, wood products, paper printing you see chemicals; petroleum and coal industries produce a lot of hazardous waste, non-metallic products also produce. Basic metal product is where the maximum hazardous wastes are produced, basic metal products. Then, we have fabricated metals, transport equipment, other machinery. So, the metal industries or industries connected with metal produce a lot of waste, good amount of heat hazardous wastes. So, there is tremendous importance of environmental issues in relation to metal industries. We can no longer ignore them.

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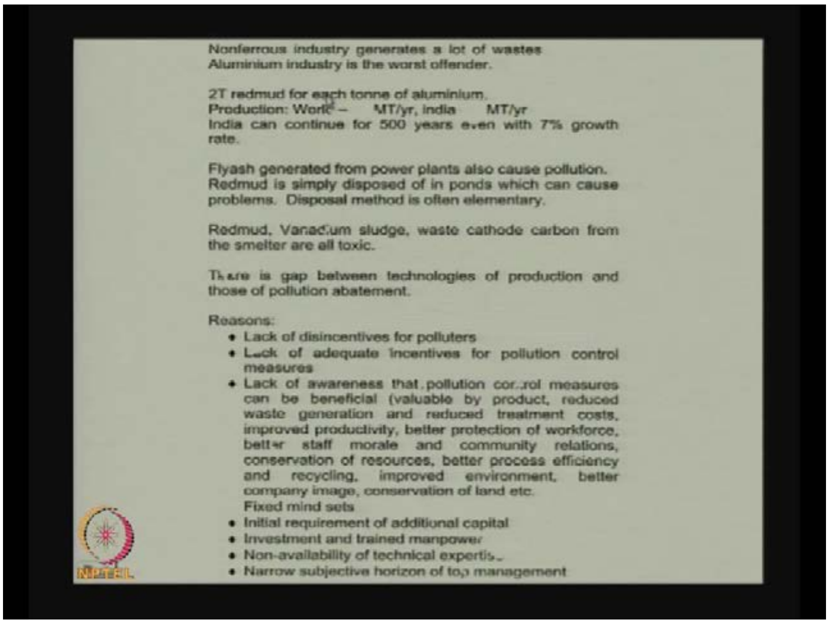

If we talk about non-ferrous metal industry in particular, this industry also generates a lot of wastes. The worst offender is aluminum industry where 2 tons of redmud is produced for each ton of aluminum produced. Imagine the magnitude of the problem. You have bauxite, which is leached in Bayer's process by sodium hydroxide. Aluminum rather Al2O3 is dissolved as sodium aluminate, but things that are there in bauxite and that are not dissolved going to the undissolved part and forms what is called redmud. The colour is red because of iron. It would also have titanium, it would have some undissolved aluminum and its volume would be huge, 2 tons of redmud for each ton of aluminum production.

If in our country, we produce 300 tons of titanium, 3,00,000 tons of titanium will produce 6,00,000 tons of redmud. Where I will be going to keep this redmud? We will keep it in open fields of course. We do not have dessert everywhere. Where you put this redmud, that land is not available for anything else anymore and not only that because redmud has come out of an alkali leaching process. It contains alkalis. It is not a very happy situation when alkalis come out of that redmud, dumps and go in the surrounding areas. As of today, till today, we do not find a bulk utilization of redmud. A bit of here from here, bit of there can be done, what you do with all that redmud.

The other thing is connected with power generation. It is not peculiar to non-ferrous metal industry. Whenever we are depending on thermal power, we are burning coal. When you burn coal, the ash is left behind, fly ash. Why we call it fly ash? Because it is in such a fine form, it flies everywhere. There is also we call something called bottom ash, which comes out of the reactors at the bottom which is course coal. It does not fly. See how much of fly ash will be used. Over the years, the grade of coal that we have mining has become poorer and poorer in our country. When we were students, 20-22 percent ash coals were found. Today, it has generally gone to 35-40 percent ash coal.

So, now many industries talk about importing coal from elsewhere where the ash content is less. When we have high ash content coal, we can wash them. We can try to wash away the ash part, but still everything cannot be removed. There is no beneficiation process to separate the carbonaceous matter and the non-carbonaceous matter ash because they are very strongly bound together. At base we can go down to 18 or 20 percent ash. Suppose, a coal has 20 percent ash, so if you burn one ton of coal, 0.2 of that is coming out as fly ash. It flies into the air, it goes all in the surroundings, it covers the fields, it covers the rivers, it covers everything and if you are careful to take it out at a certain manner, you have to put it at once place. What you do with this coal ash?

Fortunately, some users have been found for coal ash because coal ash is now going for making of embankments. People are trying to use coal ash. From coal ash, they are trying to make building material. They are trying to put coal ash, fly ash in the fields, agricultural fields to increase porosity that at least in the short term helps vegetation, but we forget about one waste and that is the CO2 which is going out in the atmosphere. That is an important waste. We are not doing anything about it. We will see what we can do. Now, do not say it is not a non-ferrous metal production problem because all non-ferrous metal industries that are using power from thermal power points are also contributing to this problem, fly ash generation.

Redmud, vanadium sludge, waste cathode from carbon, from the aluminum smelter, the waste from the limonite processing industry etcetera, there are many where you have waste being generated and there is always a gap between technologies of production and those of pollution abatement.

I will stop here and just explain why there is a gap. Technologies or production go on improving because all industries want to produce more, but they are not worried so much about the pollution problems because so far, there was not enough pressure on there. There were no incentives to develop technologies for pollution abatement. There were incentives for improving production metals because that gives them large production, they cut down on cost and things became more efficient.

So, the gap between technologies of production and technologies of pollution abatement have widened over the years. It is only now because of the pressure from the government, from the scientist, from the public that all industries have to think very seriously about pollution abatement. I will come to this and I will start with this once again during the next lecture.

Thank you.