Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture – 60
Environmental Impact of Mineral Resource Exploitation (Contd.)

Welcome to the lecture and the last lecture of the lecture series on mineral resources geology exploration economics and environment. Since this lecture recording is actually going on much before you people would be going through these lectures. So, we know that there will be many things that will be coming up in between for discussions and many of the things that could be needing clarifications, but it has been a long journey.

So, before we come to the close of this lecture series let us discuss another very important aspect of mineral resource exploitation. Although these subjects would better be discussed by people who are better experts on this, but since this is the first level course on mineral resources it is important, it is worthwhile to go for to discuss this aspect here.

And this is been one of the burning issues not only a national, but an international issue which actually pertains to the environmental impact of exploitation of the nuclear energy resources or the problem of the radioactive waste disposal.

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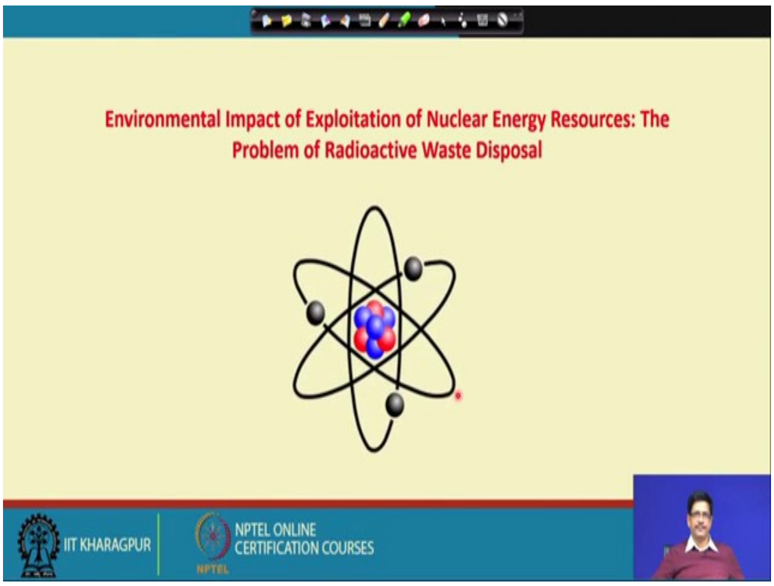

Many of us right from our childhood have been hearing about these issues about the effect of the radioactive material being dispersed into the atmosphere, which to the environment, to our habitation in various ways.

And we all live in such a situations and where we always think of the possibility of a nuclear explosion and the accidents in nuclear reactor or the worst possible case of a nuclear bomb being used by any of the country anywhere in any corner of the world. Many of us were born even after the Second World War which has the bad memories of the atom bomb in one of the countries of the world we all know.

But, the situation is that we need the resources for nuclear energy, for energy generation. And if we think that the fossil fuel resources which essentially are used for generation of electricity and was the non renewable resources like coal, petrol and natural gas, there will be eventually more and more use of a nuclear energy and there will be more of such a nuclear reactors producing energy for our day to day requirement and our energy resources energy demand is always on the rise.

So, then we are using this minerals which are the resources for nuclear energy. We all know them; uranium and thorium bearing minerals, present in many types of deposits which you have seen in our course of discussion of the mineral deposits, all the uranium bearing deposits and thorium being mostly enriched in the form of the monazite sands and as a mechanical concentration deposits in as in the form of beach placer.

So, we are talking about how mineral resources are utilized for generation of energy in a nuclear reactor. So, let us first have a look as a matter of general knowledge for all of us that what actually is known as the nuclear fuel cycle.

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So, here this is the diagram, this is the nuclear fuel cycle being represented here.

So, nuclear fuel cycle actually starts with a mining of uranium ores, whether it is any type of ore where the uranium ore is being mined. And we all know that even the richest of the uranium mine that we know hardly 1 percent, 1.5 or 2 percent of U3O8 and in most of the cases like for example, the Indian deposits where the uranium concentration in form of U3O8goes to 0.04 or 0.06 percent.

That means 0.95 or 0.94 or 0.96 part, or 95 to 96 percent of the sorry 99.5 or 99.6 percent of the material is actually the waste. So, in the mining itself they being the anywhere there is a uranium mine it will already be considered as a source of radiation, in excess of what is the background radiation and then these uranium mine the uranium ores will be mined from the mine and eventually need to be processed or milled for enrichment of an extraction of the uranium in some form.

So, the extraction has to follow a certain route like we discussed before, when they occur in silicate rocks they can be very well acid leaching process is set up for extraction of the uranium. If they occur in carbonate kind of host rock then some kind of alkali leaching kind of process is set up. In any case there is going to be process in which the uranium metal has to be extracted in some form which will be utilized.

So, that is in the process of milling what happens is that when 99.5 percent of the material in case of the uranium deposits which we see now closed very pity. So, there 95 99.5 percent of the material will be discarded in the form of tailing as we have seen before in case of multi metal sulphide deposit.

So, here the tailings; there the concentration is not reduced to 0, so they do have some amount of radiogenic present in them. So, whenever they are accumulated in huge quantity in the tailing dam then they are also a source of radiation which is in excess of what is the background radiation.

In addition to that whether it is a uranium mine being worked out or whether the tailing dam there is one major issue that comes up sometimes is the emanation of the radon which is a gas which come comes out from the disintegration of the uranium radio nuclei. So, that radon by the radioactive disintegration of U-235 so that radon which we will be seeing in a short while. So, that is believed to be toxic or believed to be rather carcinogenic known is causing lung cancer in people allegedly I mean its theologically not very well proved, but there is a belief.

So, once the milling is done, then this process of extraction takes place from the concentrate. This process of extraction as I said goes by the process of acid leaching by use of series of the chemicals which are also discharged their effluent to the surrounding. And what is obtained in this process of the extraction of the metal is something which we know is as yellow cake or the diuranite of magnesium of sodium because once they are treated with some acid leaching kind of process then for their conversion.

They have to be again reprecipitated back by some chemical process and they are finally, obtained in the process of magnesium or sodium diuranate or the yellow cake. We all know that it is a mixture of uranium 238 and 235 and a proportional 1 is to 130 or, 137.8. So, roughly very small percentage or, small proportional there is actually U-235, that is the radio nuclei which is the target because that undergoes the efficient reaction to release the energy that is what we are looking for.

So, here there has to be some process of enrichment of the original material where to at least increase the proportion of the U-235 to some extent, and that is done in a solid because they are mass U-235 and U-238 are so very close so by physical in the in the solid state; the enrichment process will be rather difficult.

So, they are converted to their hexafluoride state in a gaseous state and by which there is some kind of a selectively permeable membrane is used where the diffusion of the U-235 is possibly controlled where the material could be obtained with a little higher proportion of U- 235 compared to what was originally present. And they also could be put into some kind of ultracentrifuge where the material could be enriched with respect to U-235.

And then this material are formed into the pellets by sintering and they are basically the pellet which are made out of the product which after the enrichment process. And they are put into fuel rods and then to fuel assembly and the fuel assembly is put in the nuclear plant where there are controlled fission reaction which goes on with use of moderator like lighter element or heavy water or graphite and then the energy is liberated.

So, here these pellet which are put into the rods and that that makes basically the fuel assembly and that fell assembly which is put into the reactor core of the reactor where the controlled fission reaction take place and the energy is liberated. So, here you could see that as the energy is liberated by the process which is known to us by heating the water in the form of steam and making a turbine move and the electricity is generated here.

And then, but what remains is basically that these kind of fuel assembly the fuel rods in a nuclear reactor, they stay for about 2-3 years. And then they have to be by the time become inefficient or the energy that is they become less energy producing or they have to be discarded or they have to be discarded from the reactor. So, once they discarded if in a stage that they cannot be used any further then they are basically the waste material. So, they are the materials of most concern to us that there the spent fuel and they have to be discarded.

So, before they are discarded the spent fuel as will be going into a little bit of details. They do, they do content lots of short lived radio nuclei and they have highly active and very hot and producing lots of heat energy. So, immediately they cannot be disposed to the environment, they are stored water pools for dissipating the heat and also most of the short lived radioactive radio nuclei to actually disintegrate and reduce their concentration to a substantial proportion.

And then finally, but ultimately these spent fuels have to disposed somewhere in some form. But then with a major concern remaining that they will always be posing threat to the life in general no matter where they are being disposed off whether they in the deep in the ocean or anywhere.

So, there are some ways that this they spent fuel rods after they are actually taken out from the reactor, they again can be reprocessed and for many other purposes. And then could be finally, reprocessed and recycled and there could be many intermediate process which can which can go on depending on what the purpose is.

So, you will not be discussing about the details of the different types of a reactors like the pressurised heavy water reactors or the first is the reactor etcetera because of lack of time, but one can always see what they are for general idea. So, this is what essentially the nuclear waste is.

now here in this process the waste which is generated as the as the tailing in the process of milling is actually radioactive waste. But we know that they are the in terms of the concentration of a radio unit guide is low. So, they do not pose that much of threat as the ones which is posed by the spent fuel or any other product that comes out during the process of this nuclear reactor which will see them a little bit.

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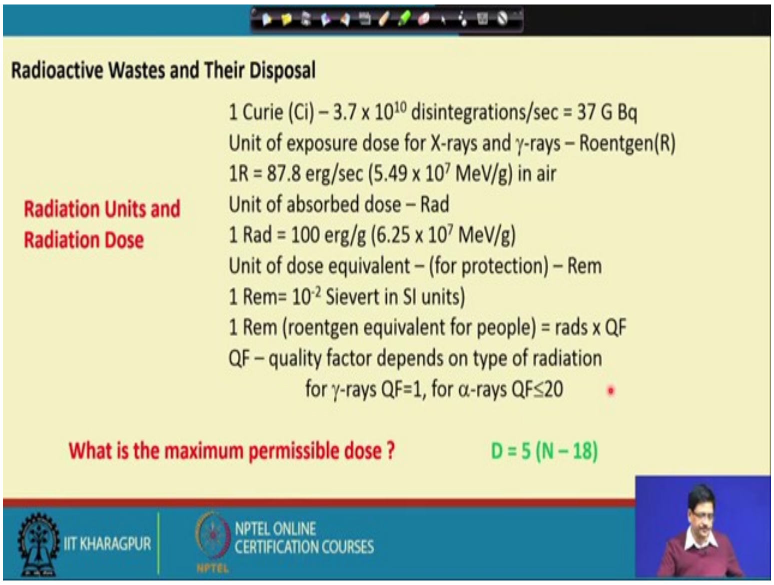

So, before we go to the radioactive waste and their disposal we have some general idea. So, we know the units that we use for the radiation dose. So, 1 curie is essentially 3.7 into 10 to the power of 10 disintegrations per second and sometimes the unit which is used for radiation dose which is Becquerel.

So, this is actually one curie will be equal to 37 Giga Becquerel and the unit of exposure dose for X-rays and gamma rays which is in terms of roentgen. So, one roentgen is 87.7 ergs per second. You could imagine the kind of energy that is released or 5.49 into 10 to the power of 7 of omega electron volt per gram in air. And the unit of absorbed dose is in rad, so 1 rad is 100 erg per gram that means, equal to 6.25 into 10 to the 7 mega electron volt per gram.

So, when it comes to the radiation does, so in terms of this rem; the roentgen per equivalent the roentgen equivalent for people which is for m is essentially a rad, 1 rad which is 100 erg per gram or 6.25 into 10 to the power of 7 mega electron volt per gram into a quality factor. That means, it is actually the human beings are getting does in terms of rem, in this rads multiplied with quality factor. So, in case of gamma rays or X-rays the quality factor is one whereas, for alpha rays the quality factor could be as high as 20.

And there is something like the maximum permissible dose are there are some times some empirical formula which is in use that the it should be 5 into N minus 18. So, N would be the age of the person minus 18 into 5 so that would be the dose. So, there are many international regulatory bodies and many laboratories and maybe in sometimes there are some national bodies which also fix such kind of limits that what could be the radiation dose that a person should be receiving per annum which could be thought as safer, beyond which could be could be unsafe or potentially risky in terms of the health, I mean we know the health consequences could be anything very drastic as well.

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So, the nuclear waste, the radioactive wastes have as concerned, they are either divided into as a low level or high level or a low level intermediate level and high level wastes. So, the low level wastes are the ones which are likely to be having in terms of the total amount of radiation is the minimum. So, they are generally the uranium mine tailings, potentially dangerous is landfill. Sometimes, there are instances where these kinds of tailings were unknowingly used as landfill on which there were human habilitation and construction of houses.

But they finally have to be demolished because of because once it was observed that they are emanating huge amount of radon and those radons are actually accumulating in the air in the houses and posing serious threat to the human life. And there are instances in the past where such kinds of habilitation have to be totally demolished because of this problem.

So, the large volume of waters has come from the nuclear plants. There are laboratories and hospitals which also use this radionuclide for medical purposes and their wastes contaminated lab equipment protective clothing and the animal parts.

So, these are the low level waste and their disposal strategy is a little different. They could be stored, could be put into some kind of trenches and could be put in solid concrete and put into the sea as has been done in the past by many. So, these are essentially low level waste.

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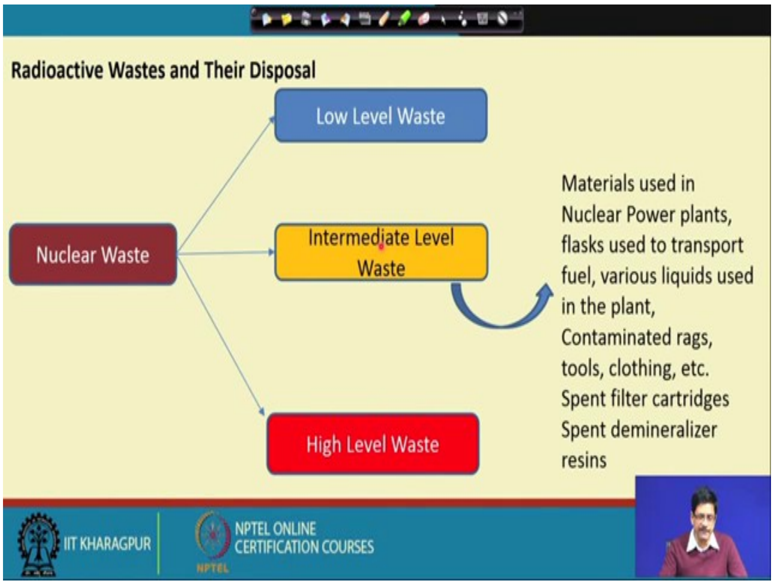

And there are intermediate level waste which are the materials used in nuclear power plants like flasks used to transport fuel, various liquids used in the plant, contaminated rags, tools, clothing etcetera, the spent filter cartridges, spent demineralizer regime.

So, because this kind of a demineralizer regimes and this cartridges are used for recovering the radio nuclei in the from the liquid wastes in the nuclear power plant, and those are also considered as intermediate level waste where the radiation is higher than those which are considered as low level.

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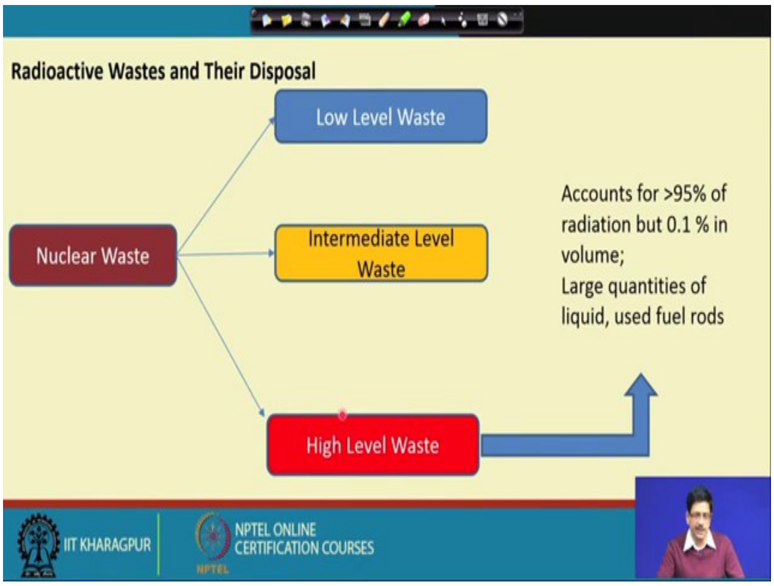

So, in terms of quantity if we see the high level wastes are essentially our spent fuels. The large quantities of liquids they use to fuel rods. Actually volume wise the high level waste actually are about 0.1 percent in total volume of the total radioactive wastes that are produced, but they account for 95 percent the total radiation.

So, as we know that they are the spent fuels they are high level waste. So, major concern lies with this kind of a radioactive waste.

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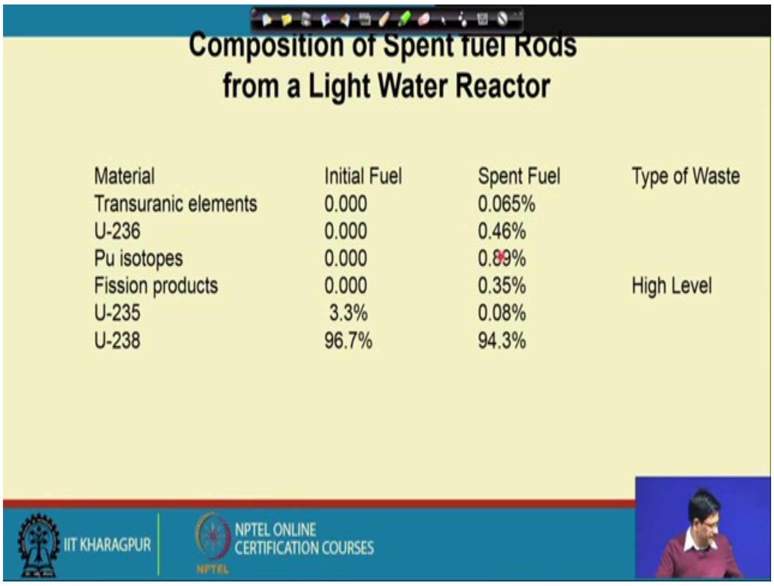

So, if you could look at what happens to a situation is a comparison for this high level waste. So, this composition of the spent fuel rods from a light water reactor; if the initial fuel as we all know that the concentration of this U-235 was raised to about 3.3 percent by process of enrichment by conversion to U-236 and centrifuging them or through diffusion through a semi-permeable membrane. So U-238 is 96.7 percent. So, by the time the fuel could be called as a spent fuel to be discarded. The U-235 has reduced to 0.08 percent and U-238 to 94.3 percent.

But you could see here that some trans-uranic elements; if their concentration has gone up to 0.65 percent very short lived radio nuclei U-236 or 0.46 percent. The plutonium isotopes are 0.89 percent and the fission products when they are all 0 at the beginning and the initial fuel.

So, they have obtained such kind of very high concentration level which is considered as the high level a waste. And these are essentially as you could see here if not the full range of the radio nuclei that are present in the spent fuel, some range is shown.

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So, here they the isotopes, that the radio nuclides that are generated in a fuel assembly in the fuel assembly in the fuel rod by the time deficient reactions controlled fission reactions are over and this where the fuel can be called as a spent fuel. There the cobalt 60 which is got the shortest of the half life which is 5.2 years and as long as the high one is the uranium 238 we know what is the half life of it.

So, here we could see that something like we can call as a short half life which is within less than 31 years which up to cesium 137. And after that the radio nuclides americium 241, radium 226, carbon 14, plutonium 239 they do have a much longer half lives. So that means, these fuel rods, the spent fuel rods, even if they could be stored in some places for a for like in a pool for a good number of years . Many of the radioactive nuclide will be their concentration would be diminished.

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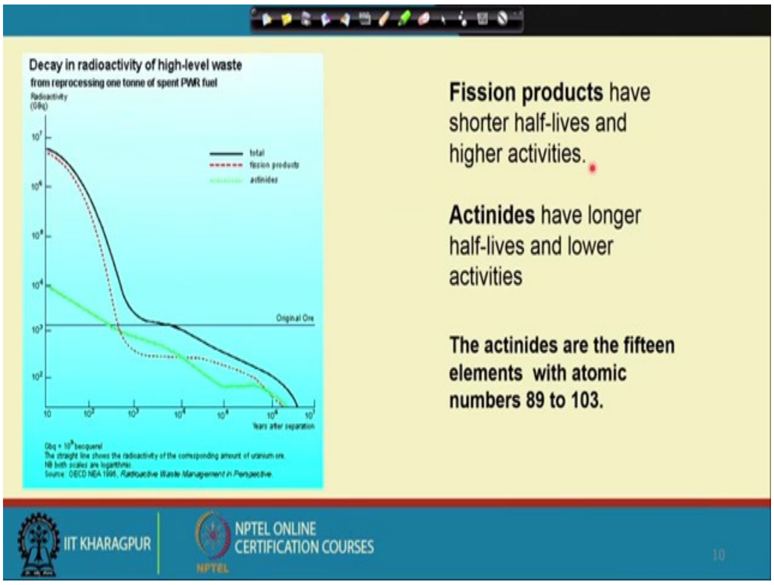

We could look at a diagram like this which has been taken from the nuclear energy agency, so here this is also schematic diagram. So, this is decay in radioactivity of high level waste from reprocessing 1 ton of the spent. This is pressurized water reactor type of reactor fuel.

So, this green line is actually actinides and we could see that their activity is falling to very low values within time of 1 million years and what we could see. So, within about 1000 years the activity is actually decreasing by 4 orders of magnitude. So, this black line is actually for the total.

So, the spent fuel just initially once it is discarded from the nuclear reactor whose radioactivity in terms of Giga Becquerel which you can convert to curie is nearly about bit less than 10 to the power 7. So, this is decreased to almost 4 orders of magnitude within a time span of over 1000 years.

And if they are reasonably I mean stored somewhere about for a 100 years; generally they are stored for about 30-40 years for the activity to significantly come down by an order of magnitude or so. But then this diagram shows that the activity is very much there even we take time of the order of 10 to the power 6, than 1 million years.

So, then the deficient products have short half lives and higher activities. So, actinides have a longer half life. The actinides are the 15 elements within atomic. So, these are the trans-uranic elements from 89 to 103.

So, this gives an idea that the spent fuels they definitely pose good amount of threat to the environment and then the disposal of this radioactive waste is a major concern.

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So, there are many regulations, there are many ways people think of how to dispose them off. Possibly one of the choices is that maybe they could be buried in the deep in the deep ocean where they will be get buried in the ocean floor sediments and they can be there or they could be deep geologic burial sites. These are very interesting things and here the role of geologists also comes as very important.

There are two examples in the case of the deep geologic burial sites they could be either in salt domes because of the reason that salt domes are dry, they do not have much of fluid in them. And these discarded radioactive wastes; they need to be put in some place where they should be free of fluid, because fluid can carry or dissolve a lot of this radionuclide and can disperse them into the water.

And there are many such calculations because even if this high level waste like for example, this fuel rods even a very little of them are dispersed to the atmosphere they will be almost be equivalent to almost a more than a year dose for the whole population.

So, there are many such calculations and from that the magnitude of their effect on human beings can be imagined.

Salt domes are one of the places where people explore to put them. So, these discarded fuel rods are just not discarded in this way, they are put into structures which are called the canisters which are cylindrical kind of barrel which are made into a very complicated structure where they could be very properly sealed. And then they are disposed off or they are finallydisposed to wherever disposed your disposal site that one might choose.

The salt domes were some time one of the favoured locations for disposal of this radioactive wastes but then ideas also came that salt domes also do have fluid inclusions in them or some of them sometimes they do have very briny fluid which are entrapped in them as pockets and they are not that very free of danger. So, crystalline rocks like for example, granitic terrain that would possibly be one of the choices for disposal of this kind of radioactive waste.

So, one such interesting example can be sited that there is a place called the Yucca mountain range in Nevada in United States. Where all sorts of scientific work was done and that that particular mountain range Yucca mountain range in Nevada was found out to be suitable for disposing this high level waste for this fuel rods to be put in canisters. And there are many such kind of structures also were designed in terms of galleries, tunnels kind of things to be drilled to that and these things to be disposed off.

But there have been lots of politicization of such kind of disposal of the high level waste. It possibly is true for any country in the world where there will very serious concerns are expressed, as and when come it comes to the disposal of this kind of high level radioactive waste. So, without getting into any further details which can be seen in any source, which are very open these days and open in public domain knowledge or sources of information are there for what is happening even in the in the situation. It can only be said that in a very consensus or anonymous decision or a very full proof or the safe mechanism for disposal of this kind of radioactive waste is yet to be agreed upon.

But then the fact remains that yes we will be exploiting our nuclear energy resources for generation of electricity. Till the time that we possibly have a safer more clean resource energy resource for ourselves.

Thank you so much. So, that brings us to the end of this lecture series. It has been a long journey starting from the scientific principles of formation of mineral deposits to exploration to economic aspects and the environmental.

Some of the concepts have been intentionally exposed which may not be covered in very fundamental text books on a mineral resources. But this has been done with a purpose because this is the time that from this stage if we get exposed to certain things that we possibly the interest will be generated to learn them and their interesting areas for higher studies as well as research. And so thank you all and I will definitely look for feedbacks from all of you.

Thanks again.