Fundamentals of Nuclear Power Generation
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Module - 12
Waste Management & Economics
Lecture - 29
Waste classification & Disposal of Mill Tailings

Hello friends. So, we are back in the MOOC's course on fundamentals of nuclear power generation and it is a quite hot afternoon outside, it go what you, which welcomes you to the twelfth and the last week of the course. Over last 11 weeks we have discussed about different aspects of nuclear power generation, some of the modules or some of the weeks. So, where quite theoretical in nature, like when we discussed about the fundamentals of the nuclear power generation, the source of nuclear energy, different types of nuclear neutron introduction, the fission and fusion reactions etc, etc.

Whereas some other lectures or some of the other modules were more practical in nature, like different types of nuclear reactors we have discussed, we have discussed about the fusion technology and also in recent weeks we have talked about additional factors like the safety aspects of nuclear reactors and also the radiation effects on living beings particularly.

So, we have more or less covered all the aspects that you need to know, to have some basic idea about the nuclear power generation and only a small power that is left to finish up the course which we are going to do in during today's lecture and also the one that is going to follow and to end this particular course of course, we are going to discuss about something very everything ends that is the topic of waste management. Waste probably, you are very aware about with this term, it refers to something that is not having any kind of value and therefore, we need to get rid of this. Similarly, nuclear plants also waste definitely refers to the spent fuel and also quite a few other kinds of resources which we cannot use for any further nuclear power generation and hence, we need to dispose that.

Now, waste management not only for nuclear, but in any other kind of coordination also, that is of a huge concerned, like if you think about a coal waste power station, the waste that we get from coal waste power stations are fly ashes and handling bottom ashes not that difficult, because we can convert the bottom ash to some kind of slurry form and then, use some kind of hydraulic transport to store take that to some kind of storage location, but fly ash is very - very difficult to handle. Like, if you have experience of visiting any power station, thermal power station that is or may be in the neibourhood area, you will probably find that in a general size power plant around, if we draw a circle and imagine a circle of something like say 18 kilometer radius, taking that planned itself as the origin or the central, then you will find the entire area being covered by fly ashes.

It is a real menace, the handling a fly ash there are definitely lots of inventory regulations and protection acts, which requires the plants to treat the fly ash. We instead of disposing that to the atmosphere and are different agency or trying different kind of disposal, like some of the agencies are trying to make bricks out of the fly ashes, some of the agencies are trying to use that fly ash for production of cements and similar kind of other materials, but just think about say, 500 megawatt thermal power plant. Coal waste thermal power plant can produce a few tons of fly ash everyday and handling such huge quantity of waste is not a matter of joke.

The additional factor in nuclear plant is that definitely are going to have waste, but also we cannot convert that waste to any kind of form, like the bricks or cement that I just mentioned about, because they may have some kind of radioactive nucleus in inside also and therefore, even for the waste, also in to be careful about the possible radiation hazards, it may cause and hence, we need some kind of special technology to store and dispose the nuclear waste. In fact, disposal and storage of nuclear waste is probably the most discussed about term. Whenever we discuss the probability of setting, I mean in the nuclear power plant like there is a common notion among general public, that the waste that we get from nuclear plants are of infinite life and they are going to lead to radiation hazards for infinity which is actually not true.

Again, from the very beginning what I am repeatedly telling, that kind of a notion can be partially attributed to the lack of knowledge and in this module, whatever we are going to discuss, I am just going to touch up on different ways of managing the nuclear waste and after understanding these concepts, probably you will be able to be in a good position to explain to the common public about what are the real hazard that nuclear waste can produce and exactly what are the common practice that presently, we use to curve such kind of menace, but before we go to the waste management issues, we need to remember a few points..

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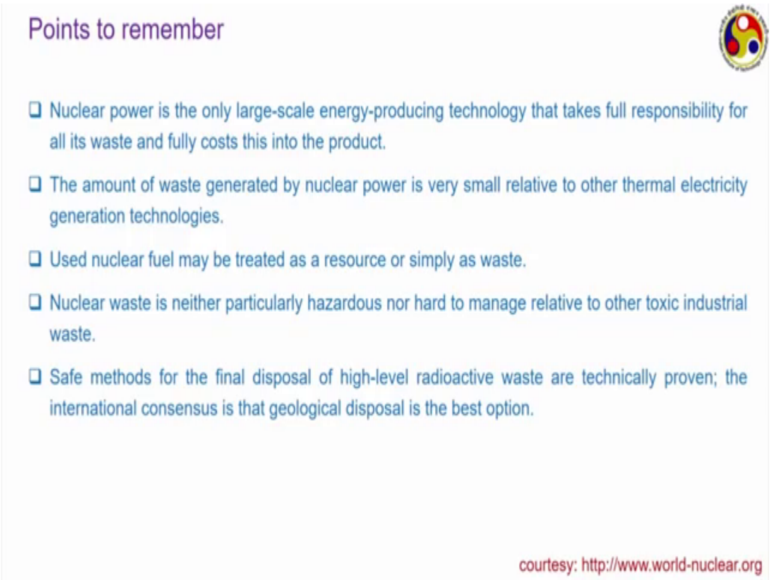

These are points which are associated with those common beliefs of general public. Firstly, nuclear power is the only large scale energy production technology which takes full responsibility of all the waste and ensures that they all properly disposed of, which is not done by any other kind of power stations but coal waste thermal beat gas turbines, or whatever they always leave a huge amount of waste to the environment without bothering about the environmental regulations.

But in nuclear, 100 percent of the waste are taken care of the amount of waste generated by nuclear power plant is also very small compared to other thermal electricity generation technologies. This is somewhat related to the amount of energy that we get from, say 1 gram of uranium and 1 gram of coal. We have compared it very early in your course and we have seen that the energy that we get from the same quantity of these two fuels, from uranium or from nuclear fuel, we get something of the order of 10 to the power 6 or 10 to the power 7 times larger than what we get from coal corresponding amount of waste production, also will be significantly smaller from two plants of similar capacity.

The nuclear fuel or nuclear waste, rather which comes out, that can also be used as a resource by the breathing technology. We can always convert some part of this nuclear waste to generate some further fuel, like earlier we have seen the reprocessing and replacement technologies that you used by virtue of that. We can always recover a part of the spent fuel to produce new uranium oxides or even sometimes the mocks, the mixed oxides and also certain gases, a nuclear waste can be used for some other kind of applications as well, some other kind of industries, sometimes for research purposes. So, whatever comes out of a plant, everything is not waste rather that can also have some kind of values or technical values, I should say.

Nuclear waste is neither particularly hazardous nor hard to manage relative to other toxic industrial waste, lots of a industrial plant uses some kind of hazardous chemicals from very corrosive acids or alkaline agents and just disposes that to the environment, maybe to the corporation. So, assistance maybe to the river which leads to huge amount of environmental pollutions, that is not at all valid for a nuclear power plant because the chemical effects and minimal and also even the radiation effects also can properly be taken care of and finally, the disposal method for high level radioactive rays are very well developed as per the modern technology.

We are in a very good position to handle the high level radioactive waste. What you mean by high level? I shall be coming shortly, but for the moment you can consider that the strongest possible radioactive waste are the most hazardous radioactive waste also can be taken care of properly. Why the present technology and also there is international consensus about which one to use and which one is not that much suitable. How to treat different kinds of waste materials, there is a good amount of consensus.

Geological disposal, generally considered to be the best option, we shall be coming to that shortly. So, whenever you are discussing or you are participating in any kind of our discussion, regarding the management of nuclear waste, these are the points, but not always remember and try to trace upon, that it is not that. The wastes that we get from nuclear power plant are going to cause huge amount of public issues. Now, what do you mean by radioactive waste? In order to know the sources of radioactive waste, we also need to know.

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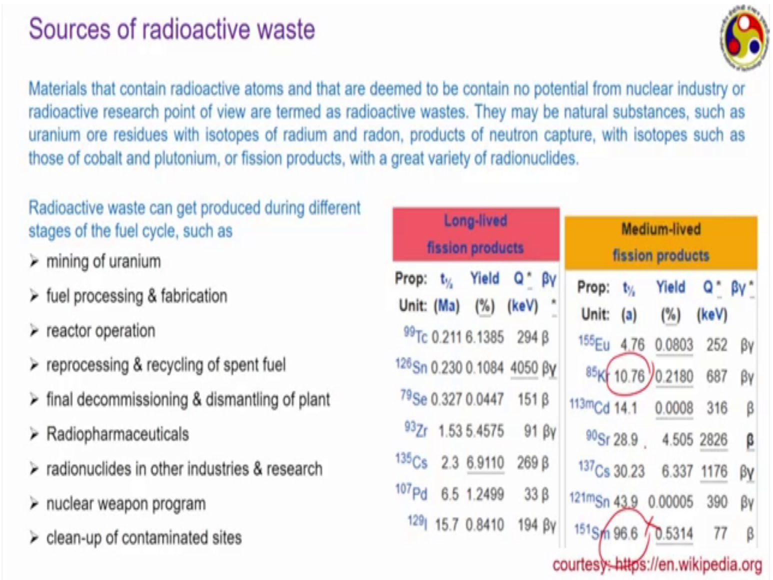

What we are referring by this particular term here. By using the term radioactive waste, we are referring to the materials which contain certain portion of radioactive atoms, but the radioactivity level of those atoms or the combination of the atoms. So, small that does not have any kind of potential from nuclear energy point of view, even from research point of view as well.

So, the radioactive waste differently contains some amount of radioactive nucleus, which can go for further radioactive decay there by releasing both ionizing radiation and also energy, but the amount of radiation that we are getting from this is wastes. Materials are not at all of significant amount. They does not have any kind of photon, they do not have any kind of potential to be used as any kind of nuclear fuel or even you are in any other industries also, then only you calling that as a waste as long as it has even the smallest possible potential available, we would like to use that.

So, radioactive waste maybe just natural substances such as uranium ore residues with certain radioactive isotopes of radium and radon, it can also contain some fission products. Some products of which have a very high neutron capture cross section like those neutron poisons. It can also contain isotopes of those like cobalt and plutonium and definitely fission products can be there, fission products themselves radioactive in nature. So, they can go to series of radioactive decays. Find to get converted to some kind of stable isotopes at the end of the chain.

Now, radioactive is, we can get from different stages of the fuel cycle and also from a few other possible sources like mining of uranium is probably the biggest source of radioactive waste. We shall be coming to that shortly, but you can get the idea, say if you are talking about coal from the mine, we do not get the coal directly. It is not that whatever you harness from the mined that can be directly fake to the coal waste power station or any other application of coal is used. Rather, you generally get coal coupled with rocks and some other kind of materials. So, by using some kind of chemical or mechanical treatment procedure, we have to separate out the coal and then only we can apply that to the industries and the same is applicable to any kind of nuclear fuel like uranium as well.

Lots of unwanted material, that also comes out during mining and that constitutes a large portion of the radioactive waste next is the fuel processing and fabrication part from that uranium. Earlier, you have seen the fuel cycle, after mining we go through the process of enrichment and after doing the enrichment, you go for the production of fuel itself. During this entire processing period, we can have lots of different kinds of nuclear produced, which can act as a radioactive waste - the operational, the reactive itself which probably from observation point to be the most common kind of a waste. This is just the counter part of the ash that we get from coal waste plant that is once we have loaded a reactor with certain amount of fuel.

So, certain type of fuel maybe say, natural uranium, only at the end of the process while initially there was 0.7 percent uranium, 235 at the end of the process or end of the operation of the reactor also, you will find there will be small fraction of uranium. 235 will be left, but that amount maybe solo, that is not going to affect her significantly, the operation or operating zone or also it is not going to; it is not suitable enough to harness some kind of power from there. So, we need to get rid of that and that also can be a very high level reactivate waste, the reprocessing and recycling of this spent fuel during the reprocessing also, we saying get lots of isotopes being separating out, which maybe radioactive in nature and final decommissioning and dismantling of plant.

Once, the life of a plant is over like earlier, we have seen the generation to reactor, say life cycle, life period of 40 years, some of them still working to something like 50 years, whereas the generation to reactors are respected to have a lifespan of something around 60 years, but once that lifespan is over, then the plant needs to be completely dismantled and during this dismantling procedure, there is a lot chance of priding of radioactivity to the neighboring areas.

Now, next are radiopharmaceuticals. We have already seen how the medical industry is increasingly depending on radiation base resources. Earlier, we use to have only X rays through with the radiation was used, but now there are several other kind of techniques also where radio isotopes are regularly used and whenever we are using those kind of radiation based medicines at the end of the process, that also will lead to some point of radioactive waste. Next is the radio nuclear which are used in some other industries and also for research purposes in different research labs and the nuclear weapon program which is probably the biggest source of the most hazardous radioactive nucleases or nuclei that you can get.

Finally, the cleanup of contaminated site like, if we have done some kind of accident, involve some kind of experiments, it say involving nuclear material or using some kind of radioactive nuclei or if there some kind of, because of the where kind of situation, if some nuclear weapons are implied to obtained kind of places, then the end of the day, we have to clean that. So, that the common human life is restored and to do that, we have to clean up the contaminated site and then do cleanup process. Also, the purpose for involved in this cleaning operation may get affected by the radiation and also the entire neighboring areas also can get accepted or can get affected.

These are certain isotopes which are commonly found in the radioactive waste. Some of them are very long lived fission products, some of them are medium lived fission products. Here one important thing, the unit of this half life is M A, where M A refers to mega annum or 10 to the power 6 annum. So, whatever number we are getting in this column that need to multiple the 10 to the power 6, like iodine 129 is having a half life of 15.7, 10 to the power 6 years which is an extremely long period talk about, but there are certain other isotopes which are having smaller half life. Like this particular isotopes, T N is having a half life of only 0.23 years and cesium 135 can have 2.3 into 10 to the power 6 years.

Sorry T N 126 is 0.23 into 10 to the power 6 years, also the medium lived isotopes which half life or smaller than this, some of the medium lived isotopes. Here, the unit is here itself. So, like Krypton, 85 is a M A, half life only 10.76 seconds, where as even the longest one in this which is 151 samarium M 151, which is about 96.6 6 years and as for the generation, three concepts, the expected life period of a nuclear plant is something around the range of 60 years. So, you can see apart from the last one all of them are having a life period within that.

Next, we need to classify the radioactive waste. Different countries use the if their own method of classification like the method way radioactive waste are classified in US, that is quite different from the way it is done in UK, but to get a more generalized idea, actually in all the different classification process, you will find similar kind of terminologies used, but the way they are quantified, that can be different, but to avoid any kind of confusion we are following the classification proposed by IAEA, that is international atomic energy agency which is the international body related to the atomic energy and has several nuclear power countries as its member including India and United States and UK.

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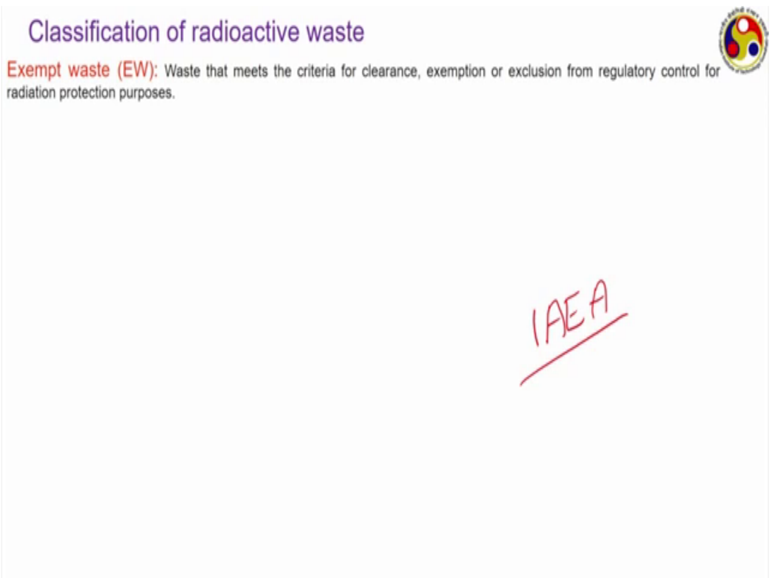

So, the classification IAEA as provided according to that, we can classify radioactive waste into 6 categories and the first one of them is exempt waste or EW. This is the waste which can be treated just as normal waste, it the radioactive effect that we may have some from this kind of waste materials are well below the corresponding clearance limit and therefore, they can be treated just like we treat the fly ash from coal waste power plant.

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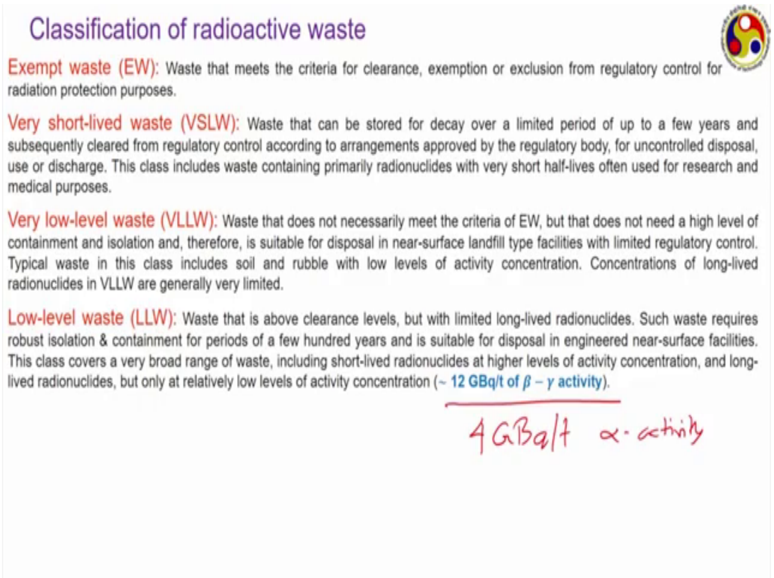

Next is very short lived waste, it involves the waste which contains radioisotopes which decays. What is very short period of time that is, if you the half life of this radioisotopes maybe in the range of just 1 or 2 years and therefore, with unlimited period of a few years, they can completely get destroyed and subsequently, this shortly waste material will get converted to the exempt waste, that is we need to provide a quite small period of containment during which all the radioisotopes present in the waste material will get decayed to a stable nuclei and then, we do not need to provide any further containment.

It low level wastes refers to those kind of waste materials which does not meet the criteria of exempt waste, but also it does not need a high level of containment and isolation and therefore, we can dispose it with quite less amount of effect. So, radiation dose is there, but the radiation dose is coming out from this very low level wastes are generally very - very small. And therefore, to quite close to the ground, we are quite close to the surface of the earth.

We can dispose this waste with us. Some while follow a certain regulations and generally this kind of waste involves soil and rubble of with low level of activity concentration and the concentrations of long lived radio nuclides in V11W are generally very - very limited. This now, you have the low level waste. This low level waste probably compresses about 90 percent of the total radioactive waste that we may have, but the radiation dose, that is contributed by this very low level waste that is just off the order of 5 percent of what we have globally from the radioactive waste.

So, under this low level waste category, we can have several kinds of isotopes with a limited long life limited half life's, they go through the contentment procedure for a few 100 years and then, and we can dispose these containers in a near surface facility, quite similar to the low very low level waste. A broad range of waste comes under this category, which includes which can have both kind of options, it can have a short lived radioisotopes, is very high level of activity where is it can also contain long live radioisotopes with quite limited activity and generally, that is measured by a this kind of parameters, 12 gigabecquerel per ton of beta gamma activity, that is during the radioactive decay of the corresponding radioisotopes, it will go to either beta or gamma decay or maybe both, both together and the total amount of radiation that you are receiving from this should be less than 12 gigabecquerel per ton of beta gamma activity.

Sometimes, it is also written as 4 gigabecquerel per ton of alpha activity, that is whatever amount of energy release or radiation dose that we get, responding to an alpha radiation in terms of that, if we compare 4 gigabecquerel per ton of energy that will be released by this low level waste. Next is the intermediate level waste, these are again the waste that requires a greater degree of continents.

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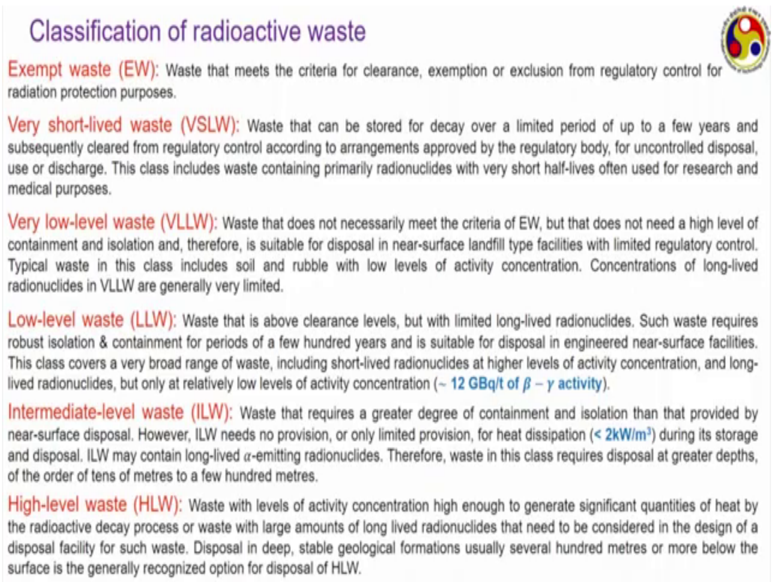

And isolation than that is provided by the near surface disposal; however, their temperature is independent of their temperature or I should say the energy released by them are generally quite small to be considered and therefore, this intermediate level waste are considered or the storage, the way we treat this intermediate level waste, their those storage were designed only considering the radiation effect, but not the thermal effect. Generally, the heat dissipation is limited to 2 kilowatt per meter cube or 2 kilowatt per unit volume of the waste material and as long as the radioactive effect is significant, but the thermal energy release is less than this, we can call that an in intermediate level waste.

And finally, we have the high level waste with level of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or sometimes the waste with large amount of long leave radioisotopes that need to be considered in the division of disposal facilities, need to properly designed and now the near surface disposal is not work, rather this kind of waste need to dispose several 100 metres underground the total volume of a high level waste that we get.

Maybe just about 3 percent of the total radioactive waste or the high and intermediate level waste that combined to something like 10 percent, where remaining 90 percent comes from low level wastes or very short very low level wastes, but the total radioactive dose that we are getting, maybe this high level waste itself can contribute more than 60 percent.

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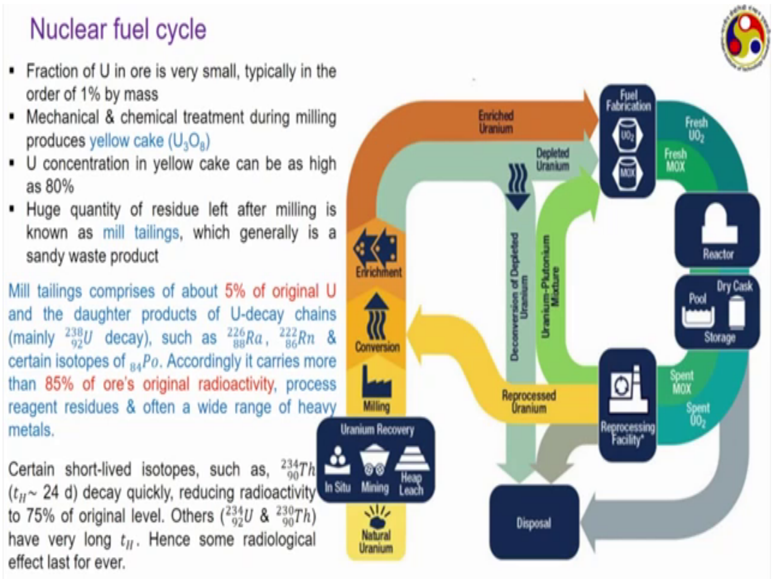

Now, this is a nuclear fuel cycle, is a diagram which we have seen earlier also. This refers to different kind of processes; the uranium goes to since the mining of the uranium from the core, from the ore. The mines now fraction of uranium that we get from the ore is very small, typically of the order of 1 percent by mass. In certain cases, it can be as high as 20 percent, but generally it is less than 1 percent, the mechanical and chemical treatment is done in the milling. So, fun of mining it goes to the milling process. You have learned again by this is some kind of mechanical and chemical treatment and that uranium is separated in the form of uranium oxide U308.

This is conventionally called the yellow cake, which we have heard earlier also and yellow cake, the concentration of uranium can be as high as 80 percent at even higher in certain situations. Huge quantity or residual left after milling is known as the mill tailings, which generally is a sandy waste material. So, this is the first kind of radioactive waste that you are getting. Actually, we have term mill tailings is quite common term related to any kind of mining activities. Whatever left in the mine after getting the targeted material is, can be called ready mill tailings, but here had you talking about a radioactive mill tailings and hence, we to be careful about handling these mill tailings.

But the issue is that, total amount of uranium in code is very small, but would you choose residue process, we can increase the percentage of uranium in that yellow cake, that is that U at 6 to something as high as achieved 90 percent. Sorry, I am not sure exactly, I told the correct thing or not that is why I am repeating again. So, the uranium that we get from the ore, the fraction is quite small less than 1 percent typically it can be as low as something like 0.3 percent, but after processing in the milling, we get the yellow cake, where is concentration can be more than 80 percent.

But what is left after this milling process, that is from here that is what we are concerned about, which is the mill tailings, mill tail is comprises of about 5 percent of the original uranium and the daughter products of uranium decay chain mainly uranium 238, because in at least uranium, 238 comprises more than 99 percent of the total volume more. So, as 19 more than 99 percent uranium, 238.

So, most of the isotopes that you get are because of the decay of uranium,238 itself something like radium, 226 radon, 222 and certain isotopes of polonium, they can all appear there. Accordingly, it carries more than 85 percent of ores. Original radioactivity and also, there can be several kinds of process chemical residues, which you are used using the chemical procedure in the during a milling process and also a wide range of heavy metals, certain long lived isotopes such as thorium 234, it has quite, I should say shortly there are half life is quite shortly thorium 234 half lived is something like 24 days therefore, they can decay very quickly and just after period of 24 days or maybe a month.

So, during their procedure over this period of say 1 month, their radioactivity is completely gone and then, its total level of radioactivity can get reduced to 75 percent of original volume. Certain other isotopes like uranium 234 and thorium 230 are very - very long half life of the order of 10 to the power 7 10 to the power 8 years. And hence, they are radiological effect to will last forever.

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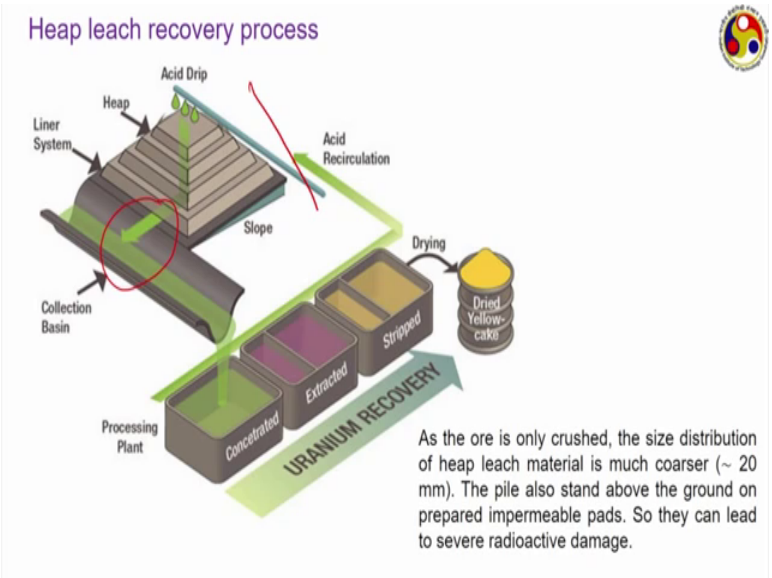

And this is another source of or the significant source of radioactive waste disposal or which generation I should say that is a heap leach recovery process, while conventional union is hardness from the ore, the sometimes the stone, the stones which are suppose to contents, show small amount of uranium or I should say, is just stone certain slabs of stones with very small union fraction are put in a pile like this, their heaped into a pile like this and then, some kind of acid is supplied on the top on the effect of the acid.

The portion of these rocks that are melted and that comes out to this part into the collection basin, from the collection basin that goes through three kinds of so, after the heap leach process is done, we get a liquid or we get two different kinds of liquid. One which can be reach in your area, but the other one which is having a significant amount of waste material, is giving left there, when the as the ore is crushed during a conventional milling process, the size of the particle will quite small of the 73, 75 micron.

But in this process, we are thinking about just harnessing the material from slabs and therefore, while during the milling process, we can get size of the order of a few microns. Here, the sizes of the particle much - much larger, something in the range of 20 millimeter and this pile are also left over above the ground on some prepared impermeable pads. So, they can have severe kind of radioactive damage, these are the different types of tailings that we can get the sentence line was tailing, generally come from the milling process for the sorry and the liquid one comes, most from the heap leach state energy, as you can see.

Here, the most important part for the sand waste case, the total radioactive that is involved is 26 to 100 picocurie of radium, 226 indices and 70 to 600 PCI of thorium 230, where as any compare that with liquid thing, then the total level of radioactivity that you are getting is 20 to 7500 picovalue picocurie of radium, 226 and 2000 20,000 of picocurie of thorium 230.

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Type of tailing	Size (μm)	Composition
Sand	75 - 500	SiO_2 plus ≈ 1 weight % Al, Fe, Mg, Ca, Na, K, Se, Mn, Ni, Mo, V silicates and metal oxides; approximately 0.004-0.01 weight % U_3O_8; with H_2SO_4leaching process: 26-100 pCi $^{226}Ra/g$ and 70-600 pCi $^{230}Th/g$;
Slime	45 - 75	SiO_2 and Na, Ca, Mn, Mg, Al, Fe silicates and metal oxides; Concentration of U_3O_8 and ^{226}Ra ≈ 2 x concentration in sands; with H_2SO_4 leaching process: 150-400 pCi $^{226}Ra/g$ and 70-600 pCi $^{230}Th/g$;
Liquid	-	with H_2SO_4leaching process: pH 1.2-2.0; Na+, NH_4+, SO_4^{2-}, Cl-, PO_4^{3-}; dissolved solids ≈ 1 weight %; approximately 0.001-0.01 weight % U_3O_8; 20-7500 pCi $^{226}Ra/l$ and 2000-22000 pCi $^{230}Th/l$;

So, there is a significant level of difference in the radioactivity that is content by the corresponding mill tailings and hence, the way we dispose the sand or slime type of mill tailings that has to be different with the way we treat the liquid once.

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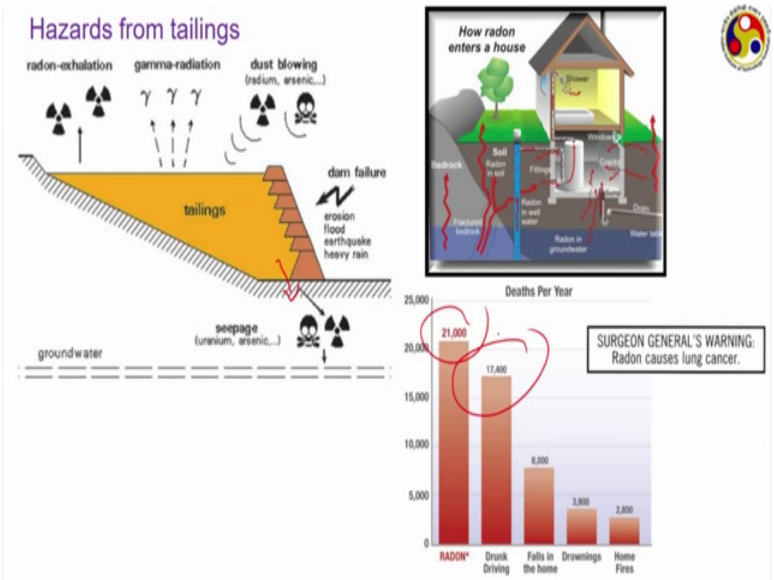

These are the possible hazards that we may have from the tailings. We can have radon exhalation gamma radiation. The trailing material can get blown away by the dust, accordingly in the dust, wherever it falls will spread radioactivity. There the failure of the dam lead to spreading of radioactivity, again because of some flower of natural calamity and also the tailing materials or corresponding chemicals can sip through this bottom surface and can get absorbed into this area.

There are several very - very hazardous elements like uranium and arsenic that can sleep through this and can go to the groundwater. There were getting spread to the entire community, radon particularly is extremely dangerous to have. These are the different ways radon can enter a house and then cause different kind of radioactive effects. Particularly, the effect of radon is too close, cause carcinogenicity and that is cancer and such kind of carcinogenicity disease are actually increasingly common, like this A data from United States, where we can found that the amount of people dying because of the lung cancer caused by the radon is more compared to the key number of drunk driving. So, it is definitely a very - very weak concerned to deal with.

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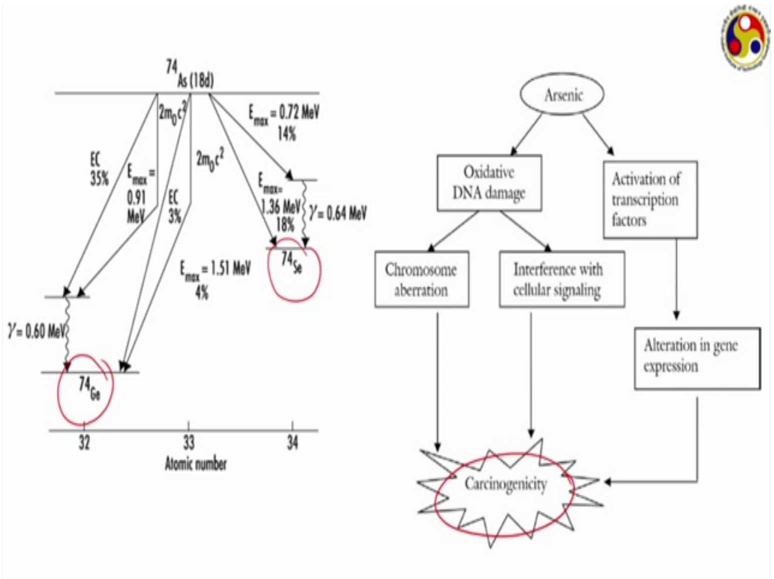

Arsenic is another particle of consideration. Arsenic 74 can decay IR direction. You can either form it, can either suffered an increase in atomic number. Accordingly, you can have the function of selenium 74 or we can have formation of germanium 74, depending upon what kind of reaction that is happening and the effect of arsenic on the community can be classified. Two categories oxidative DNA damage and assessment of activation of transcription factor can lead to the alteration in gene expression, where as the oxidative DNA damage can lead to chromosomal aberration and on. Also, interface with cellular signal, all of them and lead into carcinogenicity and therefore, the radiation effects from arsenic should be very - very carefully captured.

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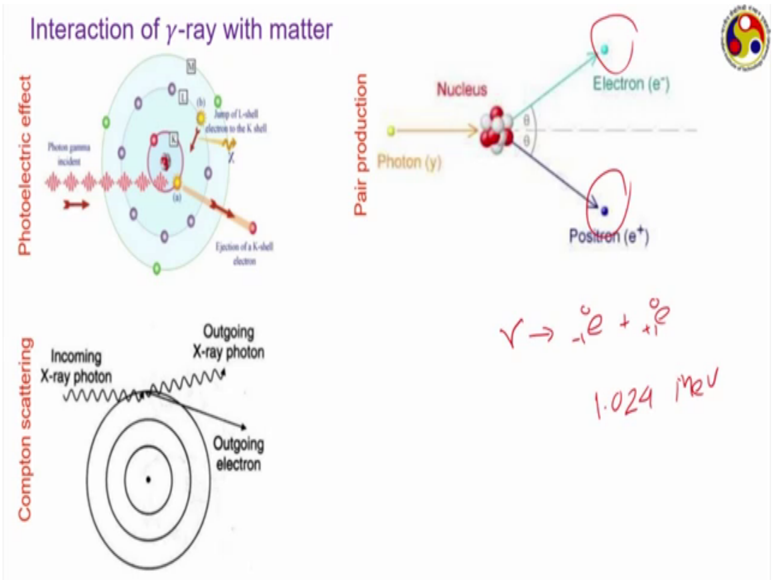

The gamma rays, I could have shown the slide earlier also in an earlier module, but this one I kept here. Gamma ray, can they are generally intrusive the matter into three different ways depending upon your own energy level, like when the energy level is small we get photoelectric effect. Like the gamma ray is coming, it is striking one electron and transferring entire of its energy to the electron. So, that the electron can go out of this atom with the same amount or out of this nucleus, I should say with the same amount of energy the Plasmon suppliers, the second case is Compton scattering.

Here, the energy level of this incoming photonics X ray photon is shown here, where the same is application for gamma photon. Also, here it transfer is a part of this energy to outgoing electron and it continues as a photon of laser energy, which we call the Compton scattering and finance a pair production, when the energy level is quite high. Then, the photon, when the energy level is quite large, then it can lead to the formation of 1 electron and 1 positron.

Now, electron and positron, both having extremely small mass of the level of 31 kg or 10 to the power minus 4 a mu. So, this electron positron formation from this photon, which we are calling pair production, is an example of energy to mass conversion and also the photon that we are having here, that need to have sufficiently high amount of energy. So, that it can go for this electron positron formation. Like here, we can write this introduction as gamma leading to the formation of minus 1 e zero plus 1 e zero, where minus 1 e zero refers to the electron. This one refers to the positron and therefore, the mass that is getting produced, if you do the calculation net total gross energy has to be something like 1.0 to 4 Mev on or 1.02 Mev and hence, this photon must have at least that level of energy so that, we can have this pair production phenomenon.

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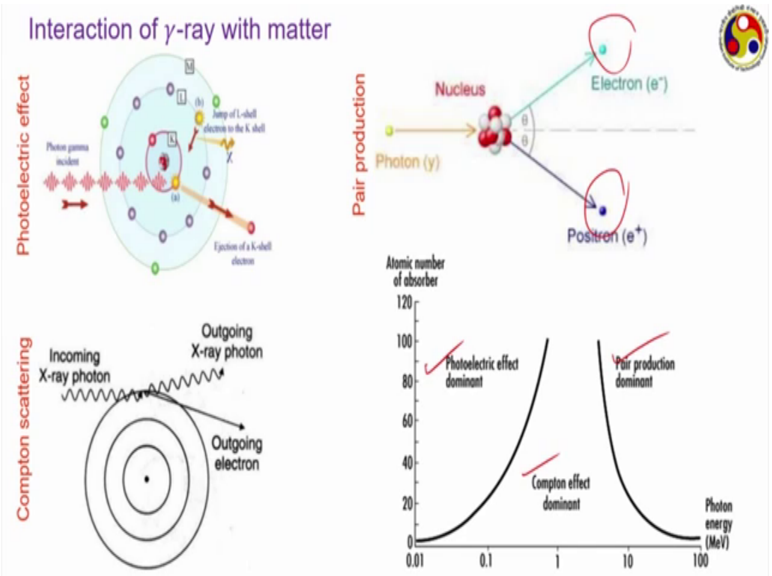

This is the graph shows the possibility of different on each of these three phenomenal, depending upon the energy level of the photon. When energy level is low, it is a photoelectric effect, which is more dominant with energy level is high. You can have the pair production to be dominant Compton effect is dominant more or less in this, in between portion. So, similar to radon, we can have also problems with the gamma ray radiation and also we can receive significant amount of environmental effects because of arsenic and also uranium.

So, considering all this effects, we have to be definitely very careful to while dealing with this mill tailings and another factor to consider here, is the large volume of tailing that we can getting. So, while the concerned as I am repeatedly telling while the amount of radioactive effect that tailings are corresponds tailing is correspond to are, is quite small maybe just about 5 percent of the total effect that we get, but still the volume of a tailings consumes 9 more than 95 90 percent of the total waste material and therefore, we have to very careful about how to dispose that.

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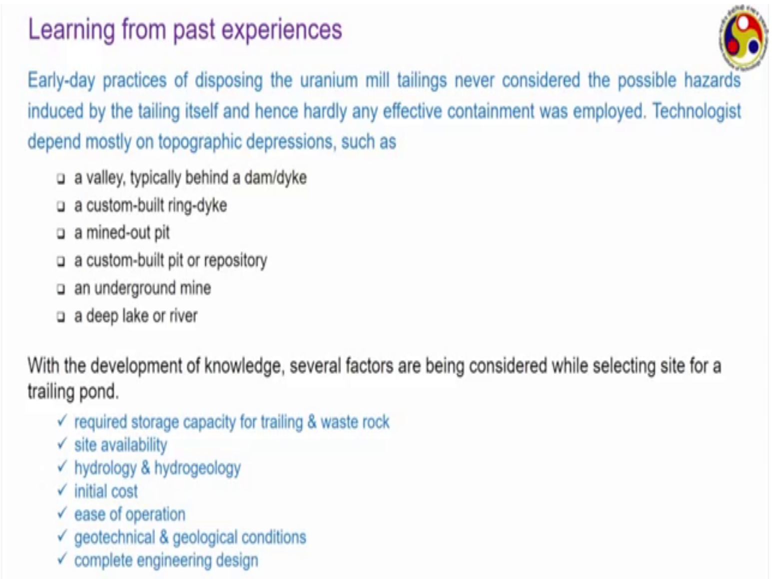

Earlier and there need to be disposed to any kind of location without being bothered about the corresponding radiation effects without being bothered about putting any effective containment and generally, some kind of topography depressions were implied like say, valley is behind a dam or dyke. A custom built ring dyke a mind out pit from here, all the metal has been taken away and therefore, the pit needs to filled up with something and mill tailings were also used in their as well as some as a part of that something that custom built pit or repository can also be an option and underground mine can be an option. They will even in a life mine, also I may have lots of empty spaces which or lots of empty tunnels, which we can fill up, we need to fill up with some kind of material.

So, there also, the tailing can be employed or use to get employed and a deep lake or river, but as time goes on, we kept on getting more and more information and also had a better idea. Now, about what you should do to, or exactly how we should dispose these tailings, from there came the concept of this tailing pond, the tailing pond is generally large structures to get the uranium mill tailings, are generally deposited but while selecting on tailing pond or designing a tailing pond, there is several factors. You have to be careful of like the required storage capacity for the tailing and waste rock; of course, it is just not for 1 year that you are going to store it. We are going to store it for a few years and so, the total storage capacity corresponding to the entire life span of the reactor should be considered.

So, another can be site availability. The location for this should be quiet flows to the uranium mine, otherwise there will be chances of spreading of radioactivity because of transportation hydrology and hydrogeology can be affected as the water, that is flowing in the local areas should not pass through the tailings, otherwise this water itself will get contaminated. The initial cost you would always like to be low and is of operation, is definitely needs to be considered finally, the geotechnical and geological conditions can also play big role and at the end, we have the complete engineering design which will design the tailings design, the mill of and also the entire union circuit. If all these can come, we combine together, then that can lead to an it your very - very efficient methodology of tailing disposal.

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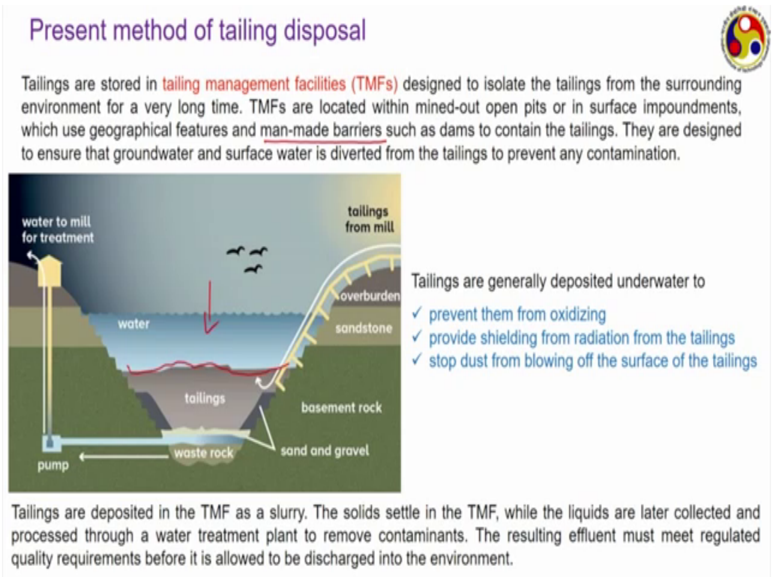

Present a methodology corresponds to tailing management facilities called TMF, these are isolated locations from where the tailings are kept for a very - very long time. They are generally located in mined out open pits, in surface impoundments which is the geographical feature and features and manmade barriers, these are the new cofactors that is coming in cause even before the earlier days also, even before also this kind of mined out pits or surfacing impoundments were in use, but nowadays, this manmade barriers or manmade protections systems which were introduced to keep that keep the tailing. So, within a certain boundary and also to restrict the corresponding radiation effects the groundwater and surface water, also is to be diverted from the tailing to prevent any kind of contamination.

This is one possible kind of design who had you can see the water is there and the trailing is below the water at this particular portion, we shall be having some kind of separation. So, that the water does not come immediate contact, the tailings and the waste rock. At the following or from the bottom surface and then, water is also allowed to flow through the tailings in order to take the heat generated inside the tailings and then, that can pumped out for some kind of treatment. There are tailings are always general deposited under water to prevent them from oxidation, as it is not allowed to come in contact with airs. So, you does not get oxygenated, provides shielding from radiation from the tailings and also as the water layer is there. So, the dust is not allowed to flow away from the surface of the tailings.

Tailings are deposited in the TMF as slurry, the solids settle in the TMF while the liquids are later collected and processed through a water treatment plant to remove the contaminants. The resulting effluent must meet regulated quality requirement before it is allowed to be discharged into the environment.

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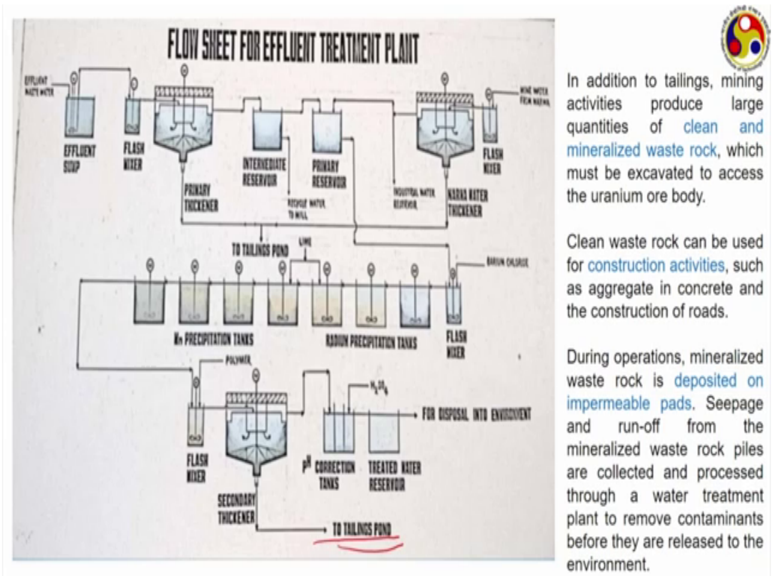

It is a possible flow sheet for this effluent treatment, they effluent that we are getting that goes to a series of reservers. Each of the reserver is own roll like a in this portion, radium is separated, amine is precipitation in this particular portion and Ph is connected in this particular tank. Accordingly, the effluent is allowed to go through series of chemical actions and so that finally, what comes out, what is going to the tailing ponds is much more safer compared to what we have started with other along with the tailings. We also have something called a waste rock, because when you are harnessing the uranium from the ore, from the mines, rather along with the ores, lots of rocks also will be coming out.

And some of those rocks will be clean rocks, where some others will be mineralized rocks. So, you have to get rid of these waste rocks also, the clean rock can be used for construction activities such as the construction of roads, etc, etc. Whereas, this mineralized rock, it can be use depending upon what kind of mineral content it has. It can be use in certain chemical industries or in similar kind of industries or it can be deposited on impermeable pads. Also seepage and run off from the mineralized waste rock piles are collected and process for water treatment plant to remove contaminants before deal. They are released to the surrounding. So, both waste rock and effluent requires treatment, but the treatment is generally quite standard.

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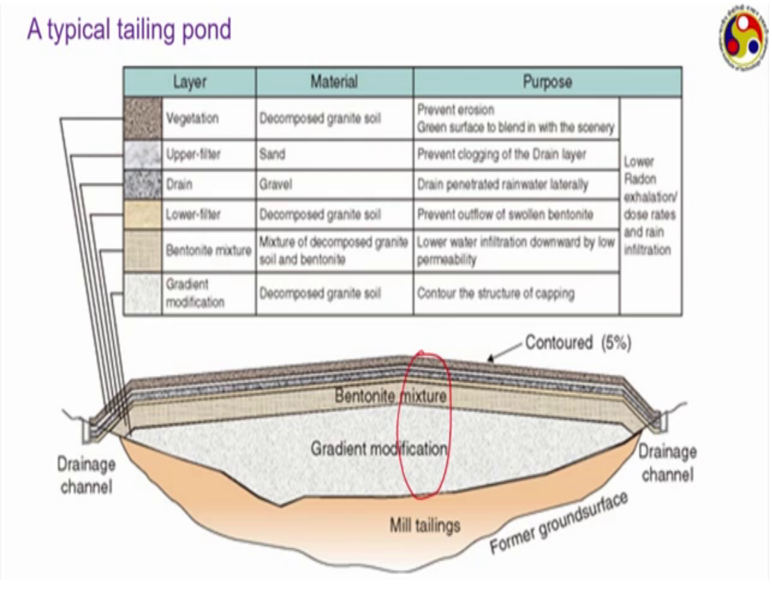

Layer	Material	Purpose	
Vegetation	Decomposed granite soil	Prevent erosion Green surface to blend in with the scenery	Lower Radon exhalation/ dose rates and rain infiltration
Upper-filter	Sand	Prevent clogging of the Drain layer	
Drain	Gravel	Drain penetrated rainwater laterally	
Lower-filter	Decomposed granite soil	Prevent outflow of swollen bentonite	
Bentonite mixture	Mixture of decomposed granite soil and bentonite	Lower water infiltration downward by low permeability	
Gradient modification	Decomposed granite soil	Contour the structure of capping	

So, this is a typical nature of these tailing ponds. As I have mentioned earlier, we may have water in this portions and then, the tailing below and you can see this particular cross sections, how many layers are, they are there are several layers of protection to separate out, the water and the tailings, this table shows the composition of all this water is just for your information. So, I am not going to detail of this you can take a look at this table and get a better idea what different layers.

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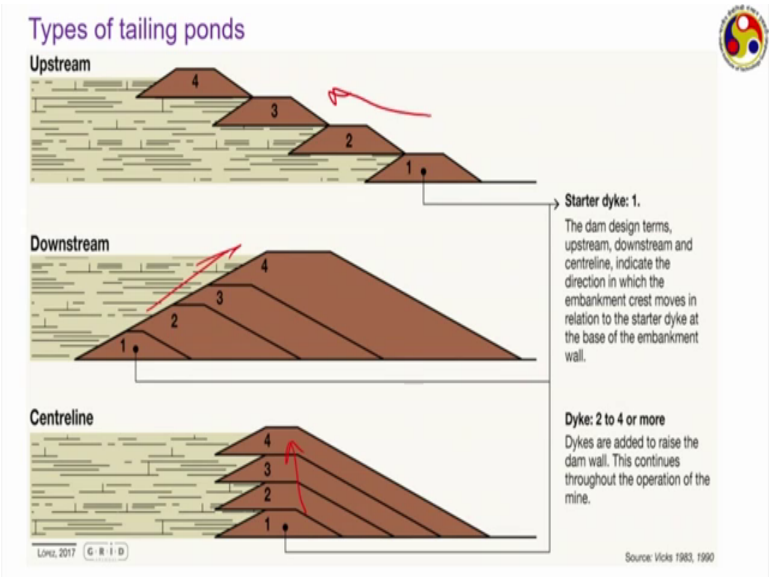

But what is important is this tailing point can up three kinds of designs, upstream downstream or centre line depending upon the orientation of successive dams in all the cases. The dams’ start with a starter dyke or starter dam all the cases, the first one are a starter dyke - starter dam. Which is the starting point and then, on top of the starter dam, we add more and more dams in case of upstream dam. If you look carefully, we are moving into the upstream direction, means more and more dams are towards the inner side.

Whereas, in case of downstream, the ration we are moving towards outer side and again, dams are proposed in that direction. In case of the upstream dam, while we are going in the upstream direction, in case of downstream dam, as you can see and moving in the downstream direction, we are using central line you are moving straight upwards. So, different dykes are added and as we are continuously adding dykes, we can change the height of this, but each of these three categories has their own advantages and disadvantages from construction point of view like the upstream one, generally is quite low cost.

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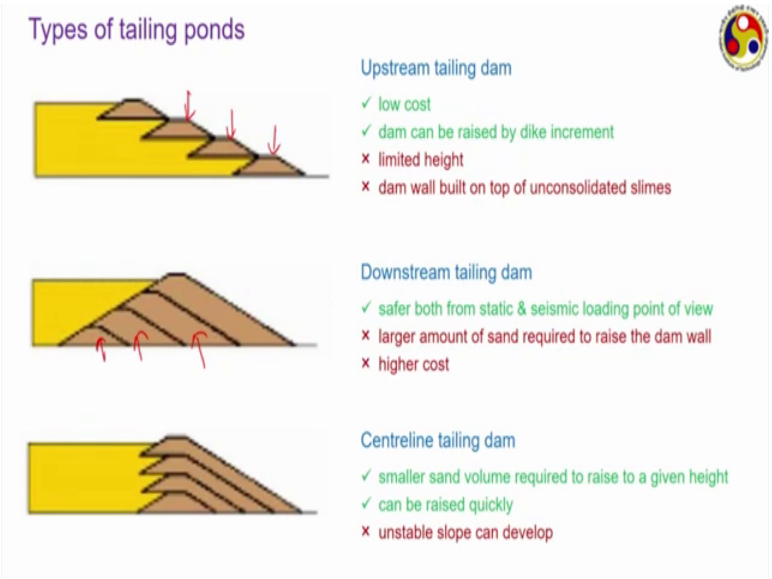

We as we are adding the upstream sides. So, just by adding this dyke, we can keep on increasing, but the issue is the height can be limited and also on what or what is below this again, dyke that is only on unconsolidated slimes which take some time to consolidate.So, this structure can be a bit; can have its own issues. Particularly, if it is subjective, some kind of earthquakes, the downstream tailing dams. Here, this is the starter one and see how we have build the second one or the third one on top of them. This is definitely much more stable design a very - very safe design.

Both from static loading and seismic loading point of view, but the issue are the total volume of the dam for the amount of sand required to raise these dam wall. Here, like if we go back to the upstream design, all this number 1, 2, 3, all them look more or less the same and therefore, the material required for each successive dykes are more or less same, which is not true. Here, whatever is the volume of the starter one, the second one is having slightly higher volume, and third one is having even higher volume.

So, as we keep on adding more and more layers, the volume is increasing accordingly. The cost will also be increasing and first is, last is the centerline tailing dam. Here, the volume requirement for can be quite large whereas, and so, the total space requirement also will be quiet high whereas, in case of centerline, I am as we are moving straight upward, it can be raised quite quickly and smaller sand volume required compared to the downstream tailing volume, but answer is slope. Slope can in the new or structure for this.

So, each of them has their own advantage and disadvantage and all the three types of tailing ponds are in use. All three designs are in use in different parts of the world, but of course, the designer should be very careful about choosing the type of them. They are going to use total expected volume of radioactivity ways. Say from 20 years from now, from 30 years from now, should be taken into consideration.

So, today's lecture, I am keeping up to this, where we have discussed more about the tailing ponds or different kinds of nuclear waste classifications we have done and tailing ponds. Now, can you guess under which category was telling ponds are falling? They are definitely low level wastes, may not be very low level, but definitely a low level wastes, which are very high interns of volume, but very small or very not I should not say their insignificant, but the total radioactive dose is quite small.

So, in the next lecture, which is going to the final lecture of this course, we are going to discuss about the other types of radioactive waste. Particularly, the intermediate and high level radioactive waste and their possible methods of disposal so, thanks for the attention of the day. See you in the next lecture.