Fundamentals of Nuclear Power Generation

Dr. Dipankar N. Basu
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Module - 11
Reactor Safety & Security
Lecture - 27
Lesson from TMI & Chernobyl

Hello friends, so we are into the week 11 the penultimate week of the MOOC course on fundamentals of nuclear power generation. And in this week we are going to have two lectures like in the previous one and today's one and also want to follow and over these two lectures we are going to discuss about the topic of reactor, safety and security, which is something very much relevant to the modern day concepts or also that is something like in the previous week that we have discussed about the effect of radiation on biological tissues on human being, which is something of a great concern to the common people; this is also something in the same category. And also I want to follow the next week that is again something we are very much concerned about the disposal of nuclear waste.

So, the safety and security of nuclear power plants is of paramount importance because whenever there is an accident in say in a common thermal power stations of course, there will be huge amount of loss depending upon the situation there can be a significant amount of loss of life, significant amount of loss of vegetation and also there can be huge amount of property damage.

But, generally that is an one time occurrence that is once the incident happens, the devastation will be instant on immediate and then once we move on with time for a few days or maybe one month or something like that then it will just remain as a memory; a horrible memory that accident. But that is not particularly true for nuclear accident because the radiation effect that any kind of radioactive nuclei contents that always remains whether it is inside a nuclear plant or it is somewhere outside.

And therefore, whenever there is some nuclear accident happening there is every chance that corresponding radioactive elements may get transferred to the corresponding surrounding environment, may get transfer to somewhere far, a far distance apart by the movement of wind and air or something like that. And therefore, it can not only it can

hamper a huge amount of a large population and also a significant area around the plant instantaneously, but also it can have long term effect; long means I really mean very long term effect because some of those isotopes like we have already seen certain isotopes of uranium and plutonium can have extremely on half life and therefore, if they are allowed to come out of a nuclear reactor and get transferred to the surrounding, they can keep on decaying over a very very long period. There we transferring those hazardous, beta and gamma rays to the human being and also to the neighboring vegetation. That is why the safety issues of nuclear power plant is something that we need to be much more concerned about compare to any normal cold based thermal power station.

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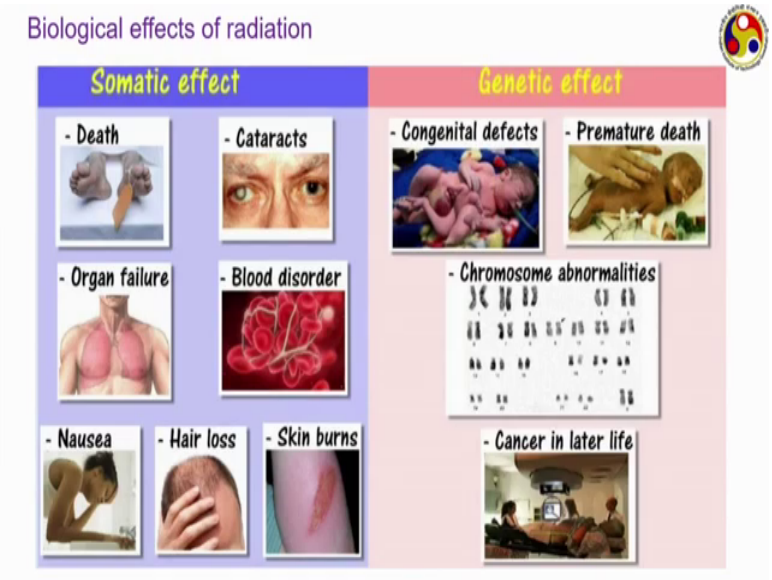

In the previous week itself we have discuss about this biological effects of radiation and I am just repeating that thing just to illustrate what kind of effects the radioactive decay can have. We can,. you know we can have two kinds of effects: One is the somatic effect, which is immediate and also may not be immediate actually, but it can be instantaneous, it can also span for; it can also appeared after a few years but still the same person who was exposed to radiation of for at some time will be suffering from these effect; like there can be cataract, it to goes into the eyes we can have different organ failure, blood disorder, skin burn is a very common radiation and damage that we can have and even that if the dose is high it can lead to death also.

But radiation can also a very significant genetic effects, where it can cause mutation to the gene and thereby can get transferred to the next generation, therefore having a very long term effect.

The congenital effects, congenital diseases can appear, premature death is also common because it can directly affect the prenatal face; it can directly affect during the prenatal stage as well, it can cause chromosomal abnormality, abnormal normality's, which can lead to different kinds of genetic diseases and the person who was expose to radiation can get cancer in later life even that can also get transmitted to the subsequent generations.

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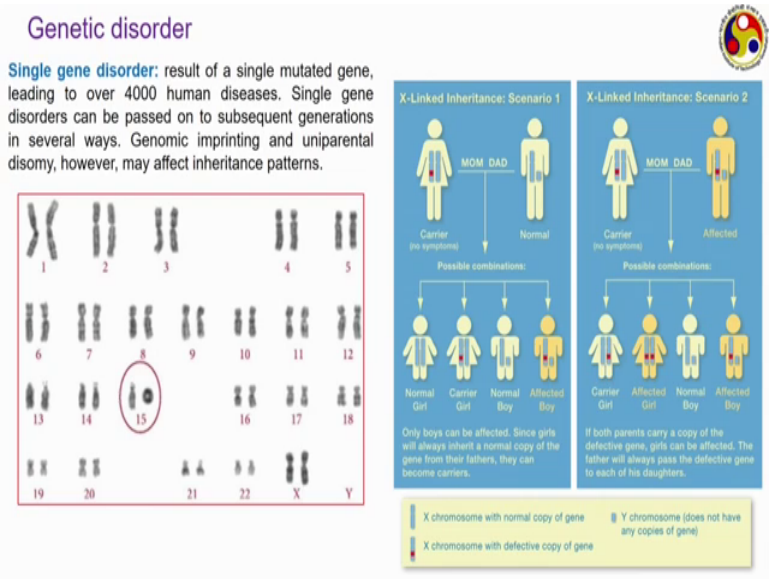

Genetic disorder subjected to not only radiation but any kind of genetic disorder commonly are of two types: one refers to the single gene disorder, where there is only a single gene which gets muted, because of radiation or because of some kind of medication or some other effect which can lead to more than 4000 diseases as per the present day knowledge.

Single gene disorder can be passed on to the subsequent generation is several ways; however, that depends on means; how much effective it will be the next generation, they will depends on the inheritance pattern.

Like you can see from this figure we know that a common human being can have 23 chromosomes out of these 22 are autosomes and 2 or 6 chromosomes, which determines the genetic sorry which determines our gender.

So, in this particular case you can see all the chromosomes are ok but only this 15 number one; that is having some kind of abnormality. So, this is what you refer by the single gene disorder; it is and it can subsequently get transmitted to the next generation causing some kind of genetic abnormalities.

This is an example of the same like here just be careful about the convention that you are using or the graphical convention that I mean. Here this particular one this long blue one, it refers to the Y chromosome, whereas this small blue one refers to the X chromosome and these are the normal copies.

Now we know that a male person contains X, Y chromosome; that is one X and Y one Y took of form appear whereas, female contains both X chromosomes. So, here we have situation, where the male is normal; who is having one normal X and one normal Y chromosome, but the female is having one normal X chromosome but another defective copy of X chromosome or another X chromosome with the defective gene.

So, once they combine there are four possible combinations we can have. Of course, we know that, during the meiosis process they will be exchanging their chromosomes leading to the form a four possible form combinations. Now, if you think about a girl, we will be getting one copy of X chromosome from the dad and one copy of X chromosome from the mom; whereas a boy will be getting one copy of X chromosome from the mom, but the Y chromosome from the dad.

So, think about the mom, sorry; think about the girls first. The girls as they are always getting one X chromosome from the one X chromosome from the dad, so they will always be having one normal chromosome, but out of there are two girl possible, one can have this particular X chromosome getting transmitted. So, she will continue to be a carrier of the same disease.

On the contrary for the boy there going to have the Y chromosome from the father, but they are going to have the X chromosome from the mother. And therefore, while one boy is going to have a normal situation, the other will get affected. As the girls are always

inheriting one normal copy of the gene from the fathers, so they will they will either even normal or they can become carrier, but the boy there is every chance that they can either be normal or can get affected.

On the contrary see the situation, where both the mom and dad are carrying one copy of affected X chromosome then there is a very big problem in the next generation. Every girl is getting one X chromosome from the dad, which is already affected; that is this one and they are also getting one X chromosome from the mom.

So, it is possible that the girls will always be having one affected X chromosome which is coming from the dad and they may get a normal chromosome from the from their mom like this case or they may get this effected chromosome.

So, in this situation they will be having two affected X chromosomes, which definitely will affect the girl. In the case of boys, they are going to have this normal Y chromosome coming from their dad, but they are going to have either a normal X chromosome from the mom; in that case with the boy remain normal or they are going to have this affected X chromosome from their mom making them affected.

So, in this case the girls can get affected, boys also can get affected and the girls can also remain carriers. So, there is a 3 out of 4 possibility of the next generation being either a career or getting affected by this. Therefore genetic disorder even in case of single gene disorder, we can have transmission to the next generation even have even as next generation can be get directly affected as well.

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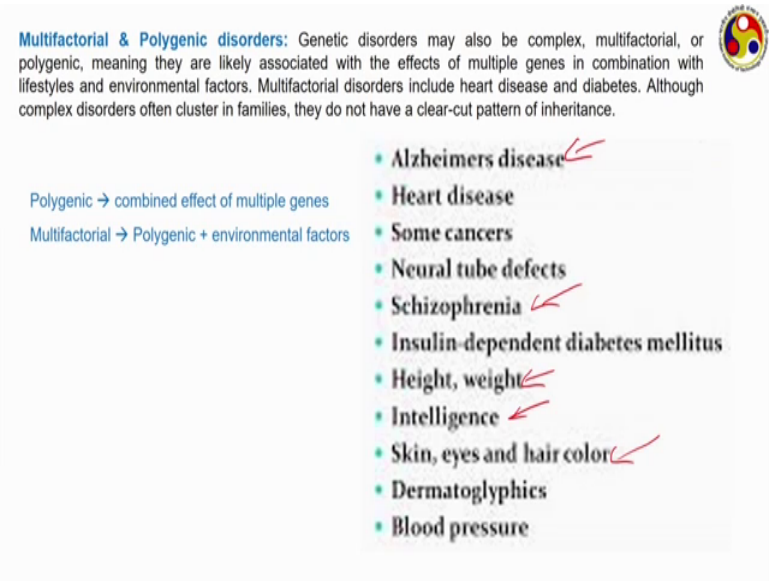

The multifactorial and poligenic disorders are, where we have much more complicated and multifactorial effects, which are likely to be the effect of multiple gene in combination with the lifestyle and environmental effects. The term multi; that sorry, polygenic, refers to when the result is the combined effect of multiple gene interaction and multifactorial refers to polygenic plus some kind of environmental or life style related effects.

So, there can be a several kinds of examples actually most of them are those referred as a lifestyle disease nowadays like; we can have diseases like diabetes or heart diseases and also, which comes from the from a lifestyles and also there can be several generical transmitted diseases such as the Alzheimer's, we can have schizophrenia kind of diseases, there can be problem related to the intelligence level, there can any problem with the height and weight of the next generation, there can be transmitted sorry; there can be mutation in the skin color or color of the eyes etcetera.

So, polygenic or multifactorial disorders can be much more complicated. And both this single gene and polygenic characteristics or polygenic types can be the results of radiation exposure.

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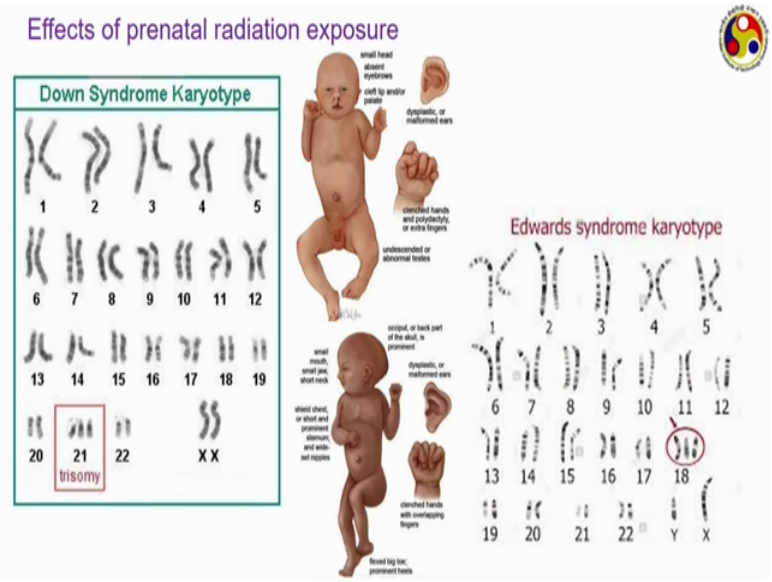

The effect of radiation exposure at the during the prenatals periods; pre-period can be even more devastating. There can be significant modification in the genital structure like look at this things, this refers to Down Syndrome; a quite common genetically transmitted diseases. And in this case you can find trisomy in the 21th number of chromosome.

Trisomy refers to instead of two there are three chromosomes; instead of having a pair, we are having triad. And this trisomy refers to trisomy in 21 chromosome; 21 slots refers to down syndrome, where the corresponding child will you born in several defects like, cleft lip or cleft palate, there can be small head, eyebrows maybe absent, etcetera.

Similarly, we can have this Edward syndrome, which refers to trisomy in a 18th number of chromosome. In this case also, we have several significant effect like, there can be malformed eyes, there can be shield chest and the back part of the skull can be very prominent; like in this situation and there are several other medical symbols, which they associated.

Similar, these are just two examples that can be several other cases where prenatal exposure to strong radiation can lead to trisomy of different chromosomes; accordingly, we can have several others like Jacobsen syndrome can be Jacobsen syndrome Jacobsen syndrome can be examples of such kind of in; so where another, where we can find the trisomy in another chromosome position.

So, in a nutshell all this things put up come in the previous module only, but still I am mentioning about them in this particular module just to let you know, what effect radiation can have. And here this effect radiation effect of radiation can be for because of any radioactive source, but now from now onwards we are going to focus mostly on the nuclear source.

And we are going to exclude the part related to medical radiation radioactive sources, but as a final thought there, medical radiation can also a very significant particular during this prenatal stage and that is one of the reasons nowadays a pregnant woman is not suggested to go for X rays or similar kind of therapies, because the radiation that is coming from their can significantly affect their fetus.

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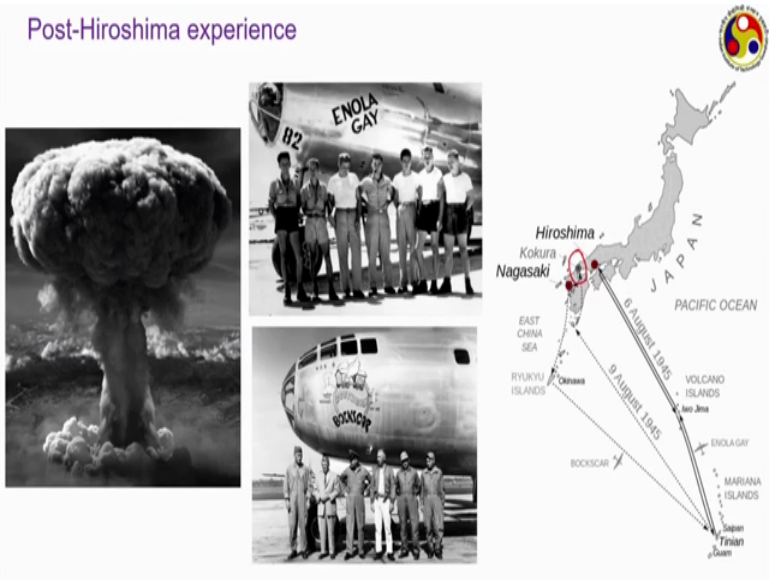

Now, we come to the purely nuclear based accidents or incidents, which lead to significant radiation hazards. And of course, we have to go back to 1945 to Hiroshima. We everyone probably has seen this particular image following the bombardment or following the atomic bomb, atomic bombing at Hiroshima on the 6th of August 1945.

We saw this kind of flume formation, huge amount of energy was released by this nuclear bomb which was I think the name was little boy and that you probably have a seen this images also; this Enola gay is the name of the aircraft which carried that little boy and drop that on Hiroshima, this was a picture with their with their crew members

and Bockscar was the aircraft which carried the next one that is a plutonium bomb towards Nagasaki on 9th of august.

You probably have seen this images also; this is the route map that was followed, that is they started from this transient location at Gunam; sorry Guam and from there this Enola gay travelled by this particular path on 6th August and the target was Hiroshima for this. It is quite; yes I do not know how to explain that, but you may know you may not be knowing also, Hiroshima, while it was very much planned event.

Nagasaki was not all the target; actual target was this particular place called Kokura. The event this second bombing the testing of that plutonium bomb that was initially scheduled to be on 11th august, but because of some weather conditions, they preponed that brought that follow to 9th of august and Kokura was the original target, but when the aircraft, this Bockscar that arrived Kokura it was unable to spot it because there was huge amount of bombing going on by the normal aircraft bombers.

So, the entire town was covered with black smoke and it was this Bockscar screw found is very difficult to spot that. There are two or three failed attempts and after that they decided to go to the secondary target, which was Nagasaki. And so they went to Nagasaki, where this plutonium bomb called Fat Man that was disposed off and they just about manage to come back to some kind of transit location. Actually I cannot remember clearly, but I think it has forced to make an emergency stop somewhere, because he just ran out of fuel. .

But our target is not to have a long discussion about what happened is Hiroshima; rather we were looking to looking towards, what effect the radiation had in Hiroshima.

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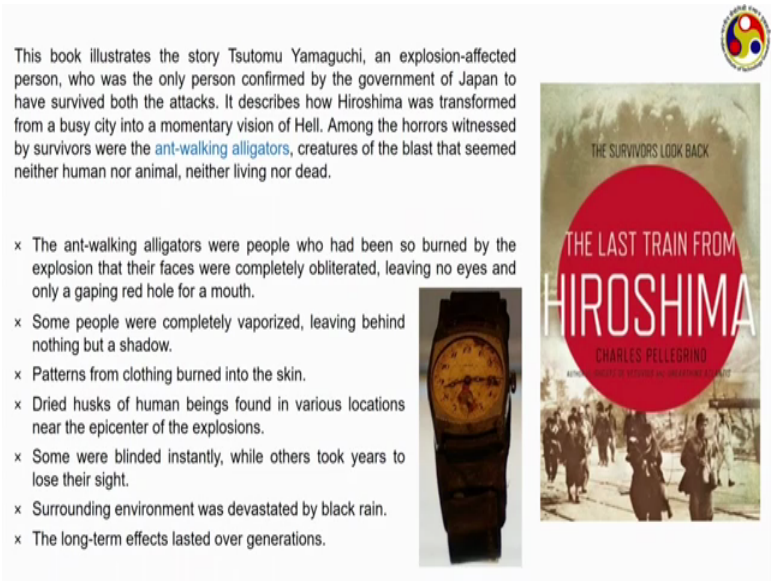

And for that purpose, there are several documents there are quite a few documentary is available on internet, which you can see to look into this. This is one book which was published in 2010; The Last Train From Hiroshima, the survivors look back by Charles Pellegrino.

It was published in 2010, but there was lots of controversies involved with this; there are several challenges regarding the source of the data that based on, which it is book was written and later on the publisher apologized and recognize that the source of data could not be authenticated and there the whole they discontinue the publication of this one.

But in 2015, I cannot remember the name of that modified version; the second edition of this book, but with a slightly different name that was published taken by a different prohibition.

But the inside the cover of this book, it illustrates the story of one Japanese person called Yamaguchi Tsutomu Yamaguchi; who was one of the double explosion survivor, what you can say. Because of some kind of he was an employee of a company and because of his official duty he was he went to Hiroshima or he was at Hiroshima on that 6th August morning and that fateful morning of 6th August he was at Hiroshima.

And just about 2 kilometers from the epicenter and then when the bomb stock he somehow he survived the event but he saw what happened there, he was able to pass

through a have some horrible experiences several survive through some horrible experiences.

And, then on the next morning along with several other survivors of that explosion, they took a rain and went back to his hometown. And what was his hometown; incidentally that was Nagasaki. So, he went back to Nagasaki; he and then next day he after going back to Nagasaki, next day went to the component to report the incident or the sequence of event that happened to Hiroshima and that particular day was 9th August, when Nagasaki was under attack and somehow we survive that one also.

It is said that something like about 165 persons; so where this double at a survivor kind of thing, but Yamaguchi was the only person who was confirmed by the government of Japan to have survived both the effects. .

This particular book general reading it; rotates around the; or it revolves around the experience that Yamaguchi and several others survivors have. They describes how Hiroshima from a quite busy town was transformed to a momentary version of Hell among the horror.

Of course, we do not want to go to the details of this, now whether there is any kind of validity about the experience, report in this book or whether it was very much exaggerated, we do not want to discuss that, but it mentions several it incidents that definitely happened there.

And along and to support the; there are several other photographic instances are also available. One of the most horrific experiences the survivors found was something known as the ant- walking alligators, creatures of the blast that seem neither human nor animal neither living nor dead.

I do not want to show the images of that, if anyone any of you have strong heart you can search on internet with this term and you can find those horrific pictures, but this ant-walking alligators; were referred to the persons who had been burned by the explosions to such an extent; there that their skin was completely taken off, their face was completely obliterated, they did not any eyes and their mouth was converted to just a hole.

Of course, they died, but maybe after a few minutes or a few hours, it should not be hours, but maybe 30 minutes or couple of hours; and during that period they kept on moving around the road quite aimlessly just like the ant and their skin was black and it was, so much scaled that it was something like an alligator skin; that is why this term ant- walking alligator came into play.

The people who are quite close to the epicentered in the outside, they were immediately obliterated, those who were close to some kind; those who were windows, but close to some kind of in window, which was facing that epicenter, they also had the same fate. Those who were inside and was not facing that kind of in that epicenter, they many of them survived, but with several incidents or several marks of radiation.

Like those who were wearing dark color clothes, suffer strong effects, those where wearing white colored clothes, were in a slightly better position. There are several photographs where you can see persons who are wearing some kind of stripe cloths they that particular stripe got printed on their skin.

Some people were completely vaporized, leaving behind nothing but a shadow. We know that; whenever some kind of radiation just think about maybe light. When light is coming from our from some source towards us then it will create a shadow. Shadow basically refers to a zone where light was not able to reach, because of our presence.

The similar kind of thing happened here because of the strong radiation effect, when some person was in the line of the strong radiation, it created a shadow of that person in the associated or in the near location; the maybe on the floor on some kind of wall, but the radiation so strong the person completely vanished, leaving behind the shadow.

The patterns from clothing the; that I just have mentioned which is burned skin, dried husks of human being spread husk refers to the temperature wind was so high, because of the explosion that the entire blood from the human body evaporated leaving behind something which resembles a dried husk. Also lots of people also did not die just a result of the radiation with a lot of people died, because of the huge storm or huge explosion that happens; because of which lots of trees were uprooted, there was the pictures 1300 year old campout tree which was uprooted.

And then things were blown away by strong air and lots of people were lots of people died by condition in this kind of trees and other heavy things, which were blowing with the air. Some people are blind instantaneously; some other took years to lose their sight, surrounding environment was devastated by black rain. And the long term effect of course, lasted over generation, which is the one big of biggest concern regression with nuclear.

Of course, whenever there is a bombing in some location, there will be several effects but that affect again will be limited only to a short instant of time. But relate to any kind of nuclear accidents or such kind of nuclear weapon use; the radiation effect will last there over extremely long periods.

And this particular image is synonymous to the Hiroshima; there are lots of wrist watches were found which has stopped around that 8:15 the time, when the incidence stuck there. So, but the in a nutshell there we are discussing about or I am mentioning about all this incidents just to show you what effect radiation can have, because of the use of nuclear weapon. And now let us come to nuclear power generation.

The use of nuclear just started from that 1945 and it is starting such an incident that from the very first generation of nuclear power generation, nuclear powers plants scientist were very much careful about the possible hazardous effect radiation can have and what can be the possible implications of a nuclear accident. And therefore, different safety measures were taken from very early generation plants itself; still there were quite a few actually I should say there are three quite prominent nuclear accidents, which happened over the over last 65-70 years of nuclear history.

And each of those accidents had the different reasons, which allowed the scientist through go back to the fundamental designs and mode find what are the sources of those reasons behind such kind of accidents and come up with some kind of modified and improve design.

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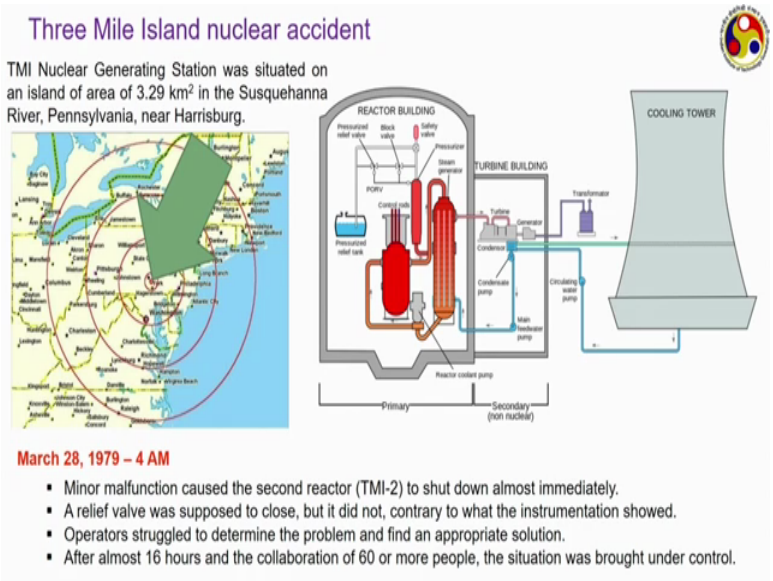

And the first one of them was the Three Mile Island incident. It was a small island, a small river island of United States; the location is shown here. This is schematic of their plant. Now, seeing the schematic can you say what kind of reactor it was? Yeah, you are correct, you can see there is a pressurizer. So it has to be a pressure water reactor.

It was a pressure water reactor pressurize; I should say it was a pressurize water reactor or p w r which in the schematic shows all the standard components of p w r. And the incident happened on the second unit of this particular planned on March 28, 1979 early morning. Some minor malfunction that caused the second reacted to shutdown almost immediately and a relief valve which was supposed to close, but it was it did not contrary to what the instrument instrumental panel showed.

In fact, some in some studies it also say showed that one light which was on the instrumentation brand that lead following indicating, that the relief valve was is still open, but the operator who was there he misunderstood that symbol and assume that everything is normal, the valve is working perfectly. And the result was; the when the accident starts the operators struggled between the problem and once they do not know what the problem is that; cannot find an appropriate solution as well.

So, the situation it took quite some time to take the get the situation under control; luckily there are not too many common people around the plant and it tooks allow 16

hours and constituent effort of 60 or more number of persons to get the situation under control.

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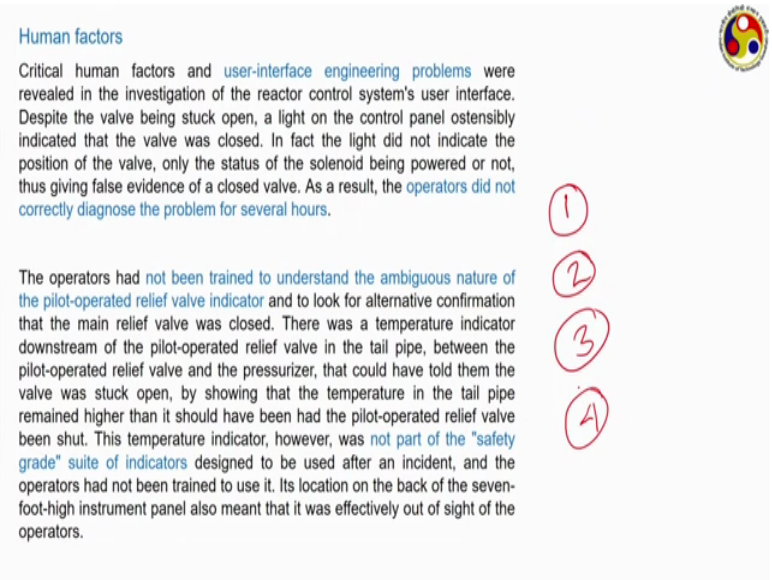

The if there were human factor, that I must mention about the reason behind this accident. Critical human factor and user interface engineering problems, where the primary reasons behind such an accident.

The valve was being stuck open, a light on the control panel ostensibly indicated that the valve was closed. But as I mentioned in some cases also mentioned that the operator misunderstood; the symbol that the valve the light was giving. The light did not indicate the position of the valve only, the status of the solenoid being powered or not, thus giving false evidence of a closed valve, and because of that the operators fail to diagnose the problem for several hours.

And such kind of incidents happened that came to know only after quite a few hours, when the situation started to go out of control. The operators probably were not properly trained to understand the ambiguous nature of these pilot-operated relief valve indicator and also they were not properly informed of they did not have proper experience to look for attentive confirmation that the main relief valve was closed.

There is a temperature indicator downstream of the pilot-operated relief valve in the tail pipe, between the relief valve when a pressurizer, that could have also given the

indication that the valve is open, that the temperature in the tail pipe should remained higher than it should have been use a relief valve was shut down, but the temperature indicator was not a part of their suit of indicators design to be used after an accident, and therefore, the operator did not know how to use that similar, what how to implicate the that particular symbol. It is location on the back of the seven-foot-high instrument panel also meant that it was effectively out of sight of the operators.

So, the principal reason behind the TMI incident; TMI means Three Mile Island. We can summarize as number 1: Proper training of the operators. They did not have any idea about how to implicate the signals given by different sensors, they did not had any experience of there also not properly qualified enough to decide what action to be taken against and unknown on new kind of incident. Number 2: The failure of that relief valve; the relief valve and also corresponding wrong signal given by the instrumentation panel. Number 3: Improper design of the instrumentation panel itself, the all the indicators were not properly placed this. Number 4: The lack of any backup option.

Like was a relief valve was kept open or it was stuck, only one indicator the plant was dependent only one indicator to show that the valve is open or close valve was, but the other symbols like other possible options of indicating the same like the temperature indicator we are mentioning here those things are not part of the safety panel and so there was no backup option corresponding to each such kind of signals.

So, it is grossly you can say a negligence from the part of the designers or the lack of experience from the part of the operators, which led to such kind of accidents.

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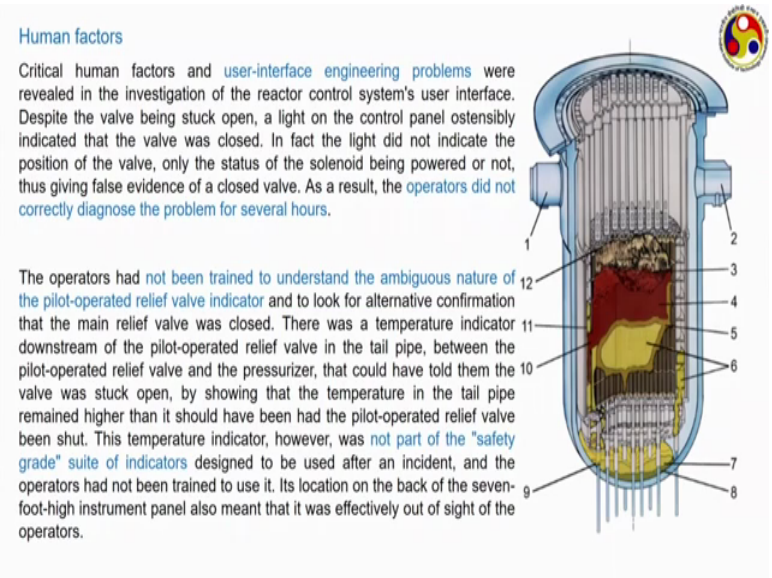

And this was the situation of the reactor core after the incident happened.

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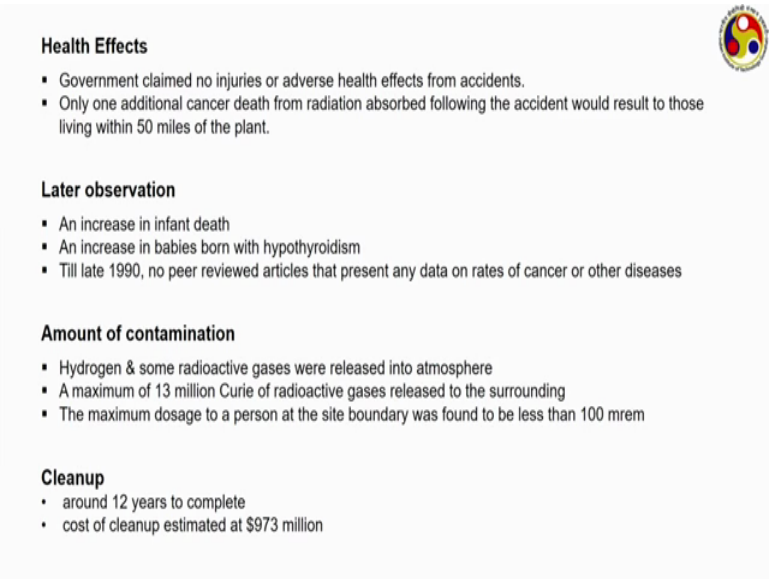

Now, the health effect of course, the governments try to suppress that incident, they claim that there were no injuries or adverse health effect from accidents. Only one additional cancer death from radiation absorption resulted within 50 miles of the plant, but later it was found that there is an increase in the infant death, also it was increase in babies; increase in number of babies born with hypothyroidism, which was the result of the spreading of radioactivity, radioactive iodine and caesium isotopes into the

surrounding (Refer Time: 33:15). Till about late 90s, 1990s, no peer reviewed article was present which provides reliable data about the rate of cancer or other effects in the posts TMI era.

The amount of contamination was quite significant, some radioactive gases and also hydrogen are released to the atmosphere. A maximum of 13 million Curie amount of radioactivity gases released to the surrounding. That was a quiet significant number at that point of time. The maximum dosage to a person at the side boundary was found to be less than 100 mrem. During the cleanup operation it took nearly 12 years to clean everything, the cost of cleanup was estimated to be a 973 dollars about 1000 dollars to get the cleanup and during a cleanup process again several workers were contaminated with the residual radioactivity. And the plant was did not reopen till about 1985.

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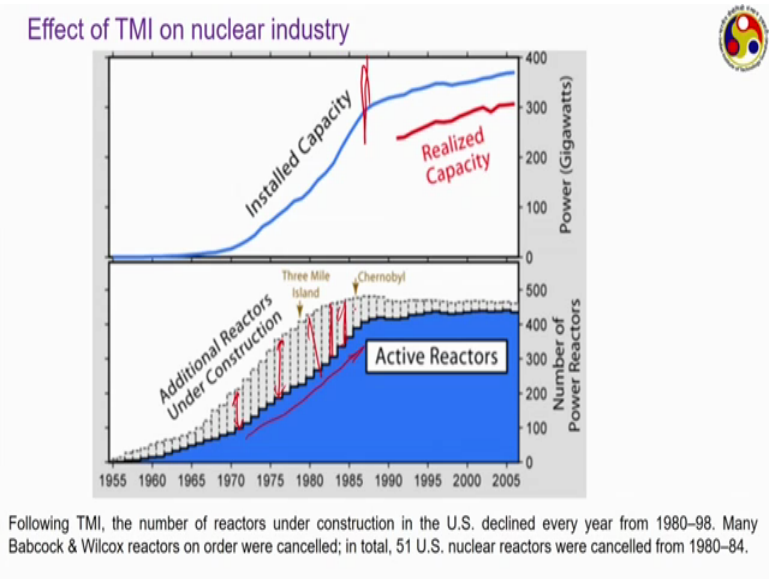

Following TMI, the number of reactors under construction in the U.S. declined every year from 1980–98. Many Babcock & Wilcox reactors on order were cancelled; in total, 51 U.S. nuclear reactors were cancelled from 1980–84.

Now, what was the effect of TMI on nuclear industry? Of course, there was effect there was radiations feed to the surrounding areas but the effect was effect of radiation was not that much because it was not situated in a highly populated area; rather has you have seen a earlier it was a river island and so apart from the workers or people associated with the plant, there are not too many common people around, but there was a significant effect on the growth of the nuclear industry.

As you can see from the first graph; the total installed capacity kept on increasing quite rapidly, and suddenly somewhere here it found a halt. This was active reactors refers to

active reactors which also kept on increasing, and there are additional construction that goes on. Again you can see the volume of this additional construction like it was something like this amount here, whereas around 1975 it was like this amount.

So, it also kept on increasing but suddenly there is a decrease following this Three Mile Island incident. In this zone, there is sudden decrease in the capacity addition, and then something that we are going to discuss the Chernobyl accident happened in 1986 and following that; they are there is almost saturation in a nuclear industry. There was hardly in a new construction that goes on; since that period of 1986 to something late 2005.

So, total realize capacity or installed capacity, that also got stalled and there are hardly any new growth in the nuclear industry. Following the Three Mile Island Incident, the number of reactors under construction in US declined every year from 1980 to 1998. And many Babcock Wilcox reactors is the primary supplier of nuclear reactor that time in United States; that were cancelled in total 51 nuclear reactors order of 51 orders for nuclear reactors are canceled between 1980 to 84.

So, there is a huge check up to the nuclear industry in United States to be particular; in particular in during the Three Mile Island incident,. But in other part of the world there were not big effect, particular in European countries till this period like; if you see from the graph Three Mile Island happens; somewhere here and but still over this period or something like 7 years from 1979 to about 1986, the total installed capacity kept on increasing shortly.

And while United States were started to shut down their plants or stop any kind of new constructions Euro continue to European countries continue to increase the installed capacity but then we reach 1986 when we had Chernobyl incident.

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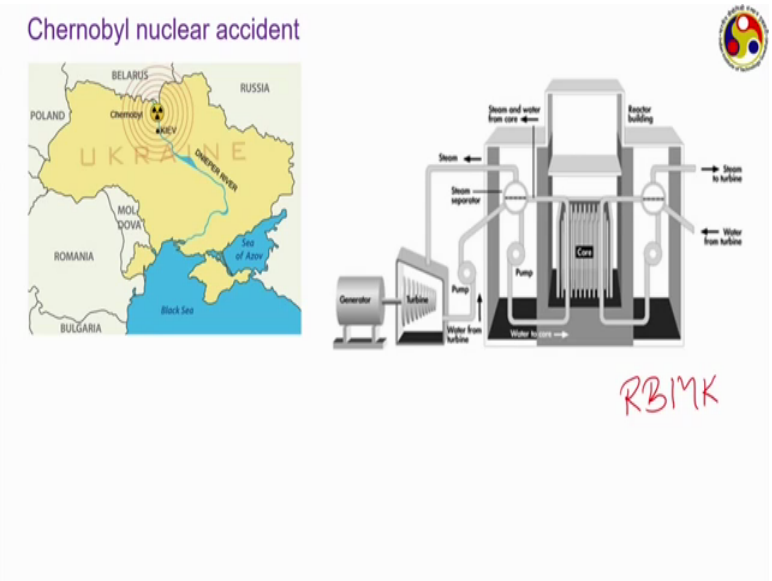

Chernobyl was a nuclear plant located in present Ukraine, which was a part of that time it was a part of the united USSR; this was the reactor core. From the reactor core can you get any idea about what kind of reactor it is? Let me see from the picture. .

You can see water is flowing around, so it is a water cool reactor; light water cool reactor, no other information is given, but ok. Then let me add it was a light water cooled reactor or l w r, but the moderator that was used was graphite. It was quite odd combination, in module number 7; you have discussed about different thermal reactors.

So, from there can you identify what kind of reactor it was? It was graphite moderated, water cooled reactors. So, l w g r or called RBMK; that time RBMK reactors are extremely popular in USSR and almost all nuclear reactors, active nuclear reactors in so (Refer Time: 38:13) were of RBMK type.

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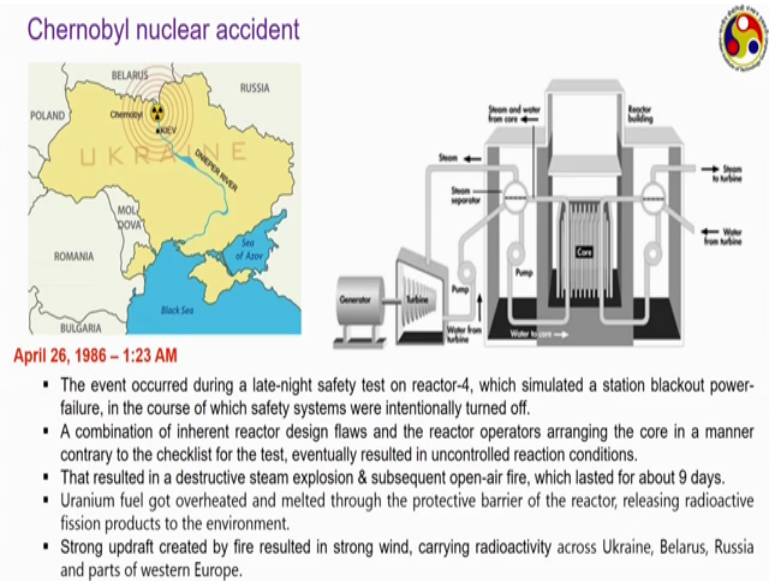

The incident that happened in are; I think that is the 6th unit of Chernobyl accident. It was April 26, 1986; sorry it was the 4th reactor. It take also happened again in very late night around 1:23 AM. It was not because of any faulty design, rather it was because of wrongly planned or very poorly planned experiment done by the operators.

The RBMK design had it is own fault, but till that moment all the RBMK plants in Soviet Union are operating fine; and so there were some kind some sense of overconfidence in the operators, which led to this particular situation; they are doing a late night safety test on the reactor 4; the test started on April 25, because of certain issues it was delayed to this late hours and they are trying to simulate station blackout power-failure, in which and during that experiment is a part of the experiment all the safety systems were intentionally turned up.

So, the system was; system did not have any kind of safety system under operation at the time of this experiment, which was the first major mistake that they made. Because of some inherent reactor design flaws and the reactor operators, who did not follow the proper procedure while doing the experiment that lead to uncontrolled reactor operation. You probably remember that RBMK reactors one big problem with their initial designs; like the one in Chernobyl that initial design, they had the problem of positive void reactivity feedback, which leads to an unstable reactor and that is what happened. The as

a reaction when uncontrolled, it result in destructive steam explosion and subsequent open air fire and that fire lasted for about 9 days.

Uranium fuel got overheated and melted through the protective barrier of the reactor, releasing radioactive fission products to the environment. And also a fire was so strong that it created a very strong updraft there by creating a high velocity movement of air around the plant. And as the fission products were emitted to the plant, by the melted fuel melted union fuel, they were carried by strong air to all the neighboring areas, particularly over in all areas of Ukraine and Belarus are most part of Ukraine and Belarus the present Russia and even in some parts of Western Europe.

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This picture shows some of the affected areas. You can see even countries like Romania, almost entire of Hungary that was that was affected by this radiation effect. Now, Chernobyl accident is only one of the two nuclear energy accident classified as a level 7 event on the International Nuclear Event Scale. The second one can you guess, what is the other one?

Chernobyl is the first one, which got a level 7 and actually level 7 I must mention is the last highest level on the scale. The other incident that happened in 2011; yeah I think you can guess now, it was the nuclear accident that happened in the Daiichi power station Fukushima Japan. That was also level 7 incident, but there the reason was something else and there nature played a big role, because the everything was initiated by tsunami.

So, from that point of view just Chernobyl is often termed the biggest man made nuclear accident to have to have stronger valve. The biggest manmade nuclear incident, that happened in the world. Initially only 2 persons died in the facility of following the explosion; one of the on one that almost instantly this is quite surprised it was despite such a huge amount of explosion only one person died on spot and the other died later due to deadly doses of radiation.

134 people were hospitalized with acute radiation symptoms, of which 28 which includes fireman and employees died in days-to-months afterwards from the effects of active radiation syndrome. One big problem big mistake rather was made by the authorities and even by the government also. They fail to realize the difficulty level of the situation and therefore, decided to is decided to ignore it virtually and the this send fireman and also several other construction workers to go to the site risky workers I should say to rescue the common person and the plant itself.

Approximately 14 cancer deaths among this group of initially hospitalized service, were to follow within next 10 years I should say; this is the data from 1996, so; it might have increased by now.

An excess of 15 childhood thyroid cancer deaths has been documented as of 2011. 600,000 more are involved in firefighting and clean-up operations; who and they are exposed to high doses of radiation. As per official reports, over 8,400,000 people in Belarus, Ukraine and Russia were exposed to the radiation. So, just by seeing the seeing this numbers you can get an idea about the magnitude of the event; I repeat this is called the largest manmade accident in the world.

This particularly; this particular bridge this a new picture, it is at there was a small town called Pripyat, which was just about 3 mile away, located at 3 mile away from the plant having a popular for around 50000 that time. In the early morning of that fateful night, they heard the huge explosion and rush to the plant, rush to the Chernobyl plant and on their way; there was this particular bridge which was just about 1.3 miles from the plant.

So, they stood on the bridge to see what is happening. So, they waited on the bridge and saw the entire incidents about they did not have any knowledge that they are getting greatly exposed to we high doses of radiation. Later on the medical investigation estimated that; the contamination that bridge the contamination level on the bridge was 8

times higher than, what is required to kill a human being. There are no study was done later on to understand; how many persons from this particular town died as a result of this incident, but this bridge has been named as Pripyat Bridge of death.

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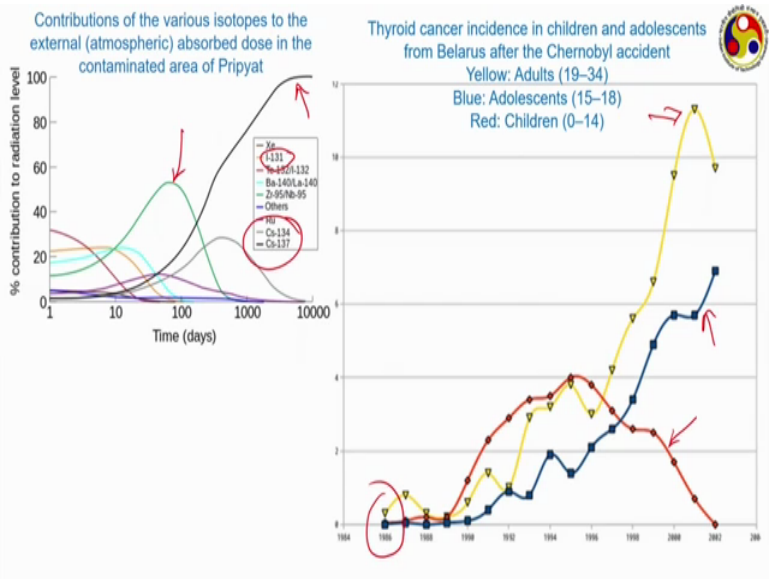

This is the contributions from different isotopes. As you can see certain isotopes died on quite quickly like, iodine 131, which is the big contribution toward contributed towards thyroid, because every short half life it died quite quickly.

This is another one which died even earlier just to less than 100 days, this is terrarium 132, but certain isotopes continuity to have a much longer life span like zirconium 95 is a continuously increasing, and then this start to decrease, because then be lots of work with the they are maybe; it increases initially and then it decreases, because it gets produced in radioactive bigger certain other isotopes also, but most interesting of them is this particular one, which refers to cesium 137, it actually keeps on increasing. And even after a period of 10000 days, it is extremely high and it contributes about 100 percent of the radiation level.

So, this is a very long living isotopes, while others have almost died down by now. It is still very active. This is another figure, which was taken from a study done by medicine practitioners that is which reflects the increase in the thyroid cancer among child and adolescent from Belarus, after the Chernobyl incident.

Here the vertical axis represents every 1000 incidence; 1000 such cases and you can see around 1986, when the Chernobyl incident happened it was quite small, but it kept on increasing rapidly; for the redline refers to the children it increases and then again drops down by 2002. The yellow line for the adults it keeps on increasing quite, sharply the same in the education period as well and certain isotopes like this iodine 131, this cesium isotopes they are strong contributors towards this thyroid cancer and therefore, they are still very much active and call in that Chernobyl and surrounding areas and leading to the appearance of this thyroid cancers.

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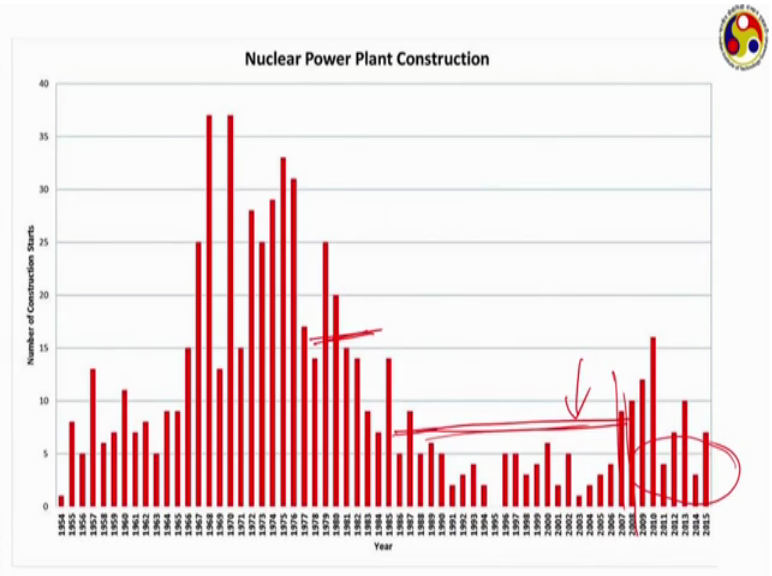

On the nuclear plant construction procedure we have already seen one picture earlier following TMI and look at this; the TMI happens here, after that there is a decrease and now this is Chernobyl and following Chernobyl over this entire period hardly and new construction happened, till about 2006 to 2007. And then it started; it was started to increase or still going random; because in this period of 2011 to 2015, it is quite small. It is a global picture not for new particular country.

So, following this Chernobyl incident, there was a huge [FL] in a nuclear industry as people have very much apprehensive about using nuclear power for commercial power generation just with the fear of having the repeat of another Chernobyl. But as a time goes on over this big [FL] period of about 15-20 years; scientists have came up with newer designs, the concept of generation 3 or generation 3 plus or even generation 4

nuclear reactors are which came up with newer designs of nuclear reactors with enhance safety features and so, then it has started to increase again; the total nuclear plant construction.

Finally, the lessons that we have received from TMI and Chernobyl; I am not mentioning about Fukushima here, because a conclusions will be quite similar.

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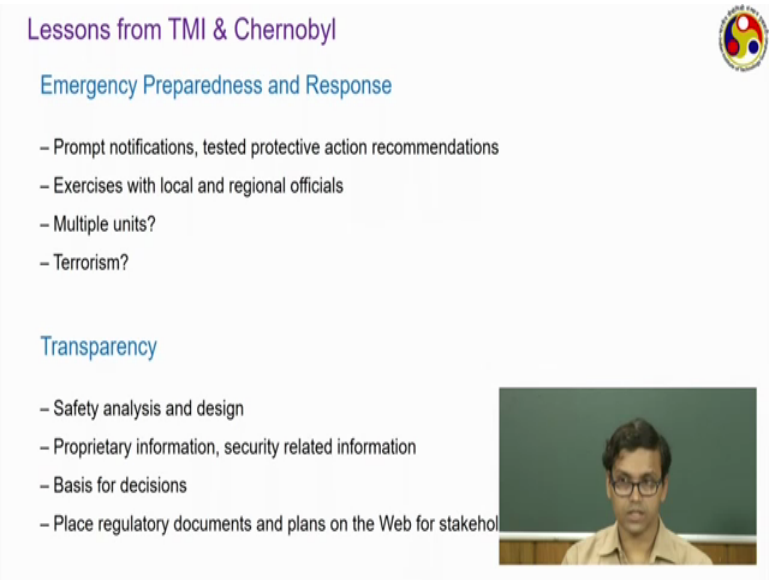

The two primary lessons are related to emergency preparedness and response and transparency in the procedure. So, if under emergency preparedness and response from notification is absolutely essential, which can be tested by a protective action, exercise all such kind of exercise must happen with complete (Refer Time: 49:21) with both local and regional officials because the absence of regional official source one of the reason of this Chernobyl incident. Local authority did not have proper idea about what is going on and therefore, they felt evaporate the sight.

Multiple units their needs to be question answered before setting up multiple units and again what can be the option; what can be emergency response in case of any kind of terrorism matter, which is becoming increasingly relevant nowadays. And other aspect is transparency, safety analysis and design must be done and the result should be made available to the concerned authorities. Then the proprietary information, security related information should be made public. Basis of decision should be made known to everyone

at least to the knowledgeable persons and place regulatory documents and plans on the Web for stakeholder contribution.

So, with all this lessons; now we finally come to the safety objective.

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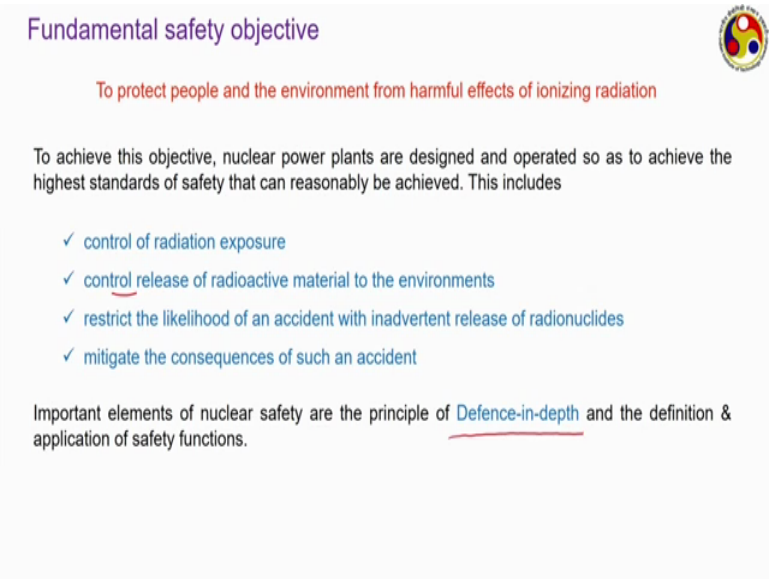

So, the fundamental safety objective of a nuclear power generation is to protect people and the environment from harmful effects of ionizing radiation. This is the paramount sentence or paramount objective that any nuclear plant designers should keep in mind, no way the effect of ionizing radiation should reach the human being and the environment. And the newer generation; generation 3 and particularly generation 4 spend lots of time, lots of effort during the design to ensure complete contamination reduction or complete isolation of the ionization radiation.

To achieve this objective nuclear plants are designed and operated, so as to achieve the higher standard of safety that can reasonably be achieved, which includes the control of radiation exposure, controlled it should be controlled release; control release of radioactive material to the environment during particular during the OS disposal procedure; which we shall be discussing next week. Restrict the likelihood of an accident with inadvertent release of radionuclides. Mitigate the consequence of such an accident means, what can be the possible types of accidents that we have to force and we have to prepare for that.

Important elements of nuclear safety are the principle of Defence-in-depth and the definition of application of safety functions. So, Defence-in-depth is the name that is given to the safety features, which are used in modern nuclear power plants and this one we shall be discussing in the next lecture.

So, I would like to finish today's lecture here itself. Today we have discussed about quite a few green topics; the sad incident that happened in Hiroshima for and then the nuclear accidents in Three Mile Island and Chernobyl, but I mentioned about all these incidents just to make you aware about the importance of having safety in a nuclear power station.

This is something that is a paramount importance and believe me at the very first about design; when the design of nuclear power plant starts the first thing operator or the designer starts to work with is the possible safety barriers, that they are going to put in which falls under this Defence-in-depth, we shall be discussing this in the next introduction so.

Thank you for now.