Fundamentals of Nuclear Power Generation
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Module - 10
Biological Effects of Radiation
Lecture – 25
Radiation dose & gross biological effects

Hello friends we are back with the one of the later part of the modules of this particular course Fundamentals of Nuclear Power Generation. We are reaching more or less the closing stages of this particular course as we have already completed 9 weeks and if we just look back starting from very basics of a simplified model of atomic structure we discussed about different types of nuclear reactions. Particularly the con fusing the concept of binding energy and mass defect you are introduced to 2 different kinds of nuclear reactions fission and fusion.

Then from there we discussed primarily about the fission reaction where we start with the topic of artificial radioactivity, then to induce such kind of artificial radioactivity we discussed about possible neutron nucleus interactions. And then the factors which affect the rate of such interactions which are nuclear cross sections and also the neutron flux distribution you have got a clear idea of that hopefully.

Then we discussed factors like reactor control, different mechanisms of reactor control both the both instrument point of view or mathematical point of view we have discussed. And also we have discussed about different kinds of reactors thermally efficient reactors, and fast fission reactors or fast beta reactors and in the last week we have discussed about the fusion reaction.

Now, all these topics are actually could have been discussed in much more detail I could have added some more chapters or I should say some more topics and one or two more lectures can always you could have always been added to that. However, because of the positive of time because of the limitations on the number of lectures I have I had to (Refer Time: 02:21) that.

Because at the very beginning of this course that is in the introduction section I promised to give you some idea about some of the bonding issues and the hottest of them means whenever there is some discussion of setting of a nuclear any new nuclear installations always there is apprehension of radiation reactor effects.

And whenever you mentioned the term nuclear to some common people the first thing definitely is going to feedback to you is what will be the radiation effect and that is what we are going to discuss in this particular topic as I have promised by the end of this particular course you will have some more idea about all these bonding issues and you can have or you will be in a better position to participate in those discussions.

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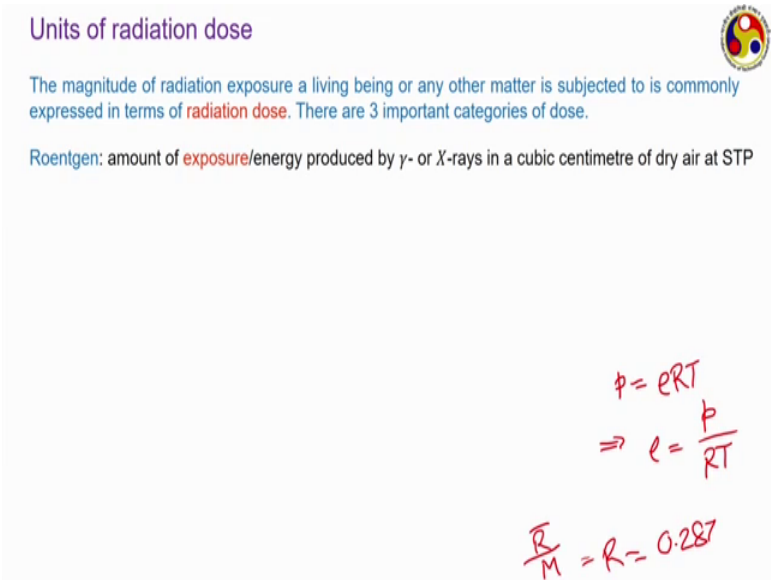

So, the topic for this week is biological effects of radiation. We have earlier introduced 2 different units of radioactivity one is curie and other is Becquerel. Curie of course, is a bigger unit which refers to the activity of radium 226 or I should say initial activity of 1 gram of radium 226 which measures something like 3.7 into 10 to power 10 disintegration per second, but curie being a very large unit quite often we use Becquerel which is 1 disintegration per second and Becquerel again is a quite small unit. So, we generally need to go for kilo Becquerel or mega Becquerel kind of ranges.

But whenever you are talking about the effect of radiation on either on living being or some other element we need to define some new units. And here the first term that I have to mention is radiation dose which actually refers to the magnitude of radiation exposure a living being or some other kind of matter is subjected to that is the amount of radiation or magnitude of variation we are receiving from whatever with the sources that is refer as the radiation dose.

And there are 3 important categories under which you can define this radiation dose or I can say there are 3 different units. The first one is Roentgen of course, you can immediately get the idea from where this name came in this is definitely to honor the inventor of x-rays William Roentgen.

And Roentgen or that unit Roentgen refers to the amount of exposure or energy produced by gamma or x-rays in a cubic centimeter of dry air at standard pressure and temperature. Actually Roentgen is a unit of exposure; exposure is the first thing that we generally try to calculate while calculating in a radiation dose.

And Roentgen is a corresponding SI unit of that or I should not say SI unit rather Roentgen is a common unit for that it refers to the amount of energy that 1 cubic centimeter of dry air at standard temperature pressure is receiving by gamma or x radiation.

And generally whenever a particle or something like say air molecules here oxygen molecules or nitrogen molecules they are subjected to some kind of gamma or x radiation. The result invariably is emission of electrons that is they will go through some kind of beta decay kind of process and they will emit electrons.

So, by measuring the total amount of electrons that is coming out from that particular volume of air we can get also a measure of this exposure and 1 cubic centimeter of dry air at standard temperature and pressure; so it is quite easy to calculate the corresponding mass of air that we are talking about like assuming air to be air to be an ideal gas and also a single gas that is instead of considering air as a mixture of different components. If we consider air as a single ideal gas then we know that as per ideal gas equation of state P is equal to rho RT or rho is equal to P by RT.

Now pressure here we are talking about standard temperature and pressure. So, temperature is 300 Kelvin sorry temperature is 25 degree Celsius which is 298 Kelvin pressure is the atmospheric pressure and R for air is 0.287 kilo joule per kg Kelvin. So, here of course, R we are not referring to the universal gas constant rather we are talking about the individual gas constant for air which is the universal gas constant divided by the molecularity for air and that comes to be 0.287 kilo joule per kg Kelvin.

So, putting these values you can always calculate the density of air, and as the volume given here is 1 cubic centimeter.

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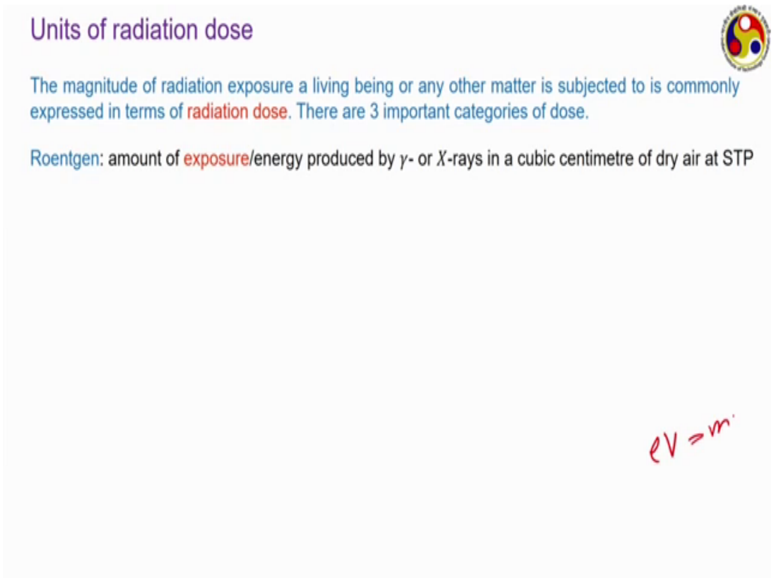

So, if we multiply this density with volume which is 1 CC you will get the total mass of air that you are considering while defining is Roentgen; so the amount of energy received by this particular mass of air which whose volume is 1 cubic centimeter as STP that is referred to as a Roentgen. Second unit is radiation absorbed dose in short rad.

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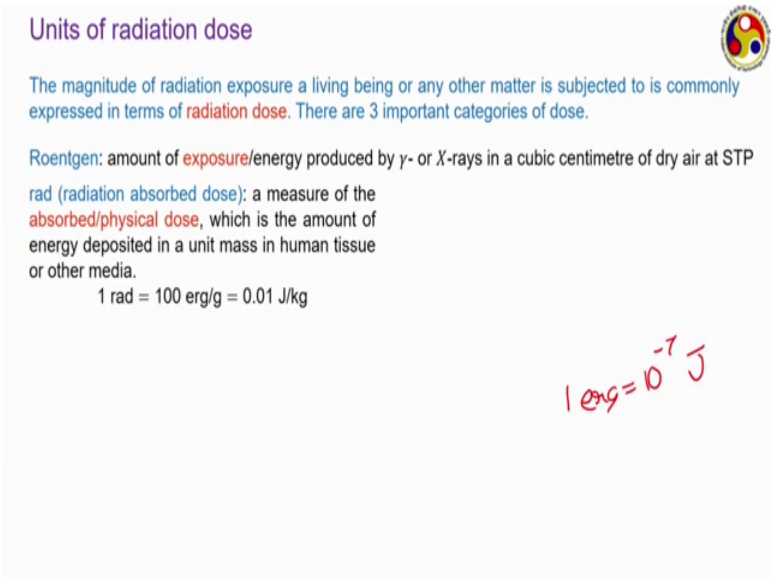

So, it is a measure of the absorbed or physical dose which is the amount of energy deposited in a unit mass of human tissue or any other media. Basically Roentgen is a unit that refers when you are talking about air as the receiving component or receiving media whereas, when the receiving party is a human tissue or maybe some other media other apart from air we use this rad, this is particularly relevant to human or living beings.

So, it refers to the amount of energy deposited in a unit mass of human tissue and 1 rad is equal to 100 erg per gram, erg is the old unit of energy the cgs unit and you can find the relation generally one erg is equal to 10 to the power minus 7 joule you can check the conversion. And once you put this then we get this to be equal to 0.01 joule per kg; that means, if 1 gram of human tissue receives 100 erg of energy, or 1 kg of some human tissue receives 0.1 joule of energy. Then we call corresponding physical dose or absorb dose to be 1 rad.

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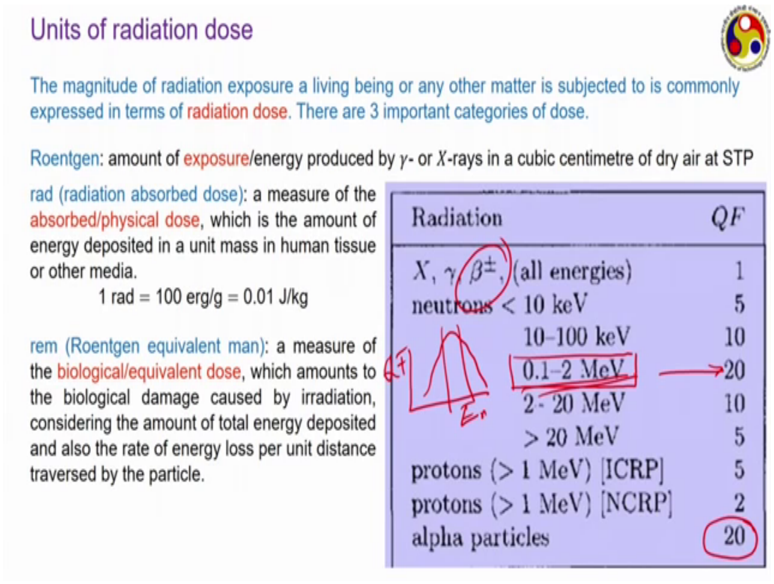

And then Rem which is Roentgen equivalent man it is a measure of the biological or equivalent dose which amounts to the biological damage caused by irradiation. But here we are trying to find out like Roentgen or rad gives us the amount of energy that has been deposited to the receiving party.

And Rem refers to the amount of damage or it tries to quantify the damage that irradiation has caused and the while considering the damage you need to consider 2 quantities of course, the amount of energy received that definitely matters so that is the first one. But also the rate at which this energy loss per distance per unit distance traveled by the particle that also matters in define in this rem.

So, Roentgen equivalent man or Rem means gives a measure about the damage that has been caused by a particular irradiation and generally these 3 together are called 3 R s of radiation Roentgen rad and rem. So, these are the 3 R s gives us a clear idea about how much energy or that has been received because of radiation by say living being and then how much of energy that has been absorbed in the living tissue that is given by rad and finally, the Rem gives you the damage caused by gas.

But in order to calculate this Rem that is damage we generally use something called quality factor, the amount of damage caused by despite having similar energy level the amount of energy, amount of damage rather caused by a particle that also somehow depends upon the total mass of the particle.

And therefore, for different particle the amount of damage caused is different. Beta particle being the lightest one that generally is the less like or least likely to cause any kind of damage whereas, alpha particle generally being the heaviest one among all this radiation that we are talking about that is expected to cause the largest amount of damage.

And accordingly we define a quality factor this QF, where the value of quality factor is given to be 1 for beta particles where beta plus and beta minus there is both electron and positron you are talking about whereas, for alpha particle is specified to be 20 and these are the 2 extreme limits, one corresponding to very light particles like the electrons and positrons and also x and gamma gamma rays. Actually x and gamma rays as I have mentioned ultimately gives ultimately leads to the beta emission.

And alpha is a heaviest so it is it is fixed at 20 and then all others somewhere in between like neutrons depending upon different energy level it can have different values particularly it is interesting that this point is 1 to 2 MeV energy level it is it is most likely to cause any kind of damage corresponding quality factor is 20.

But when you are at a lower level it is 10, similarly when you are at a higher level that is also 10 and it reduces. So, value of quality factor if we plot QF on one side and neutron energy on the other side you are likely to get a distribution somewhat like this with this peak appearing corresponding to this particular energy 0.1 to 2 MeV.

And now to get the value of Rem of course, Rem is more a qualitative quantity and that is why you need to define this qualitative factor, but Roentgen or rad they are physical quantities because they refer to the amount of energy absorbed and definitely can be measured quite easily.

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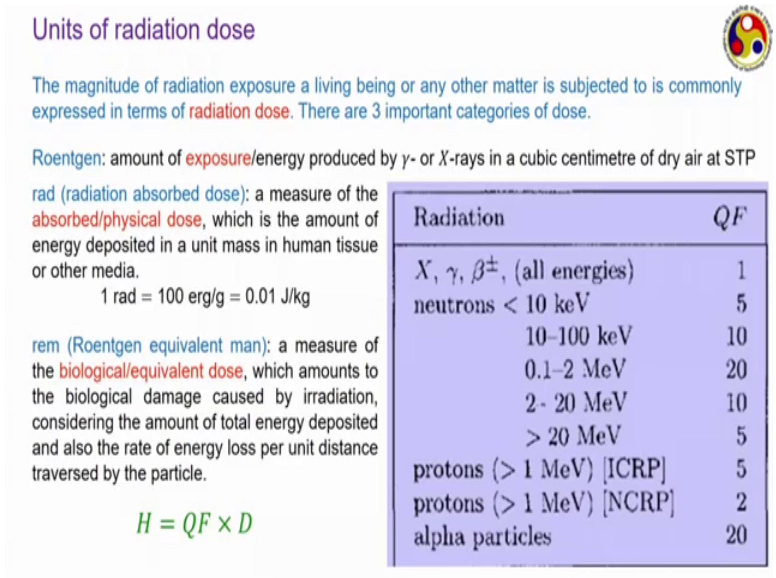

And Rem echoed then is given as H equal to QF into D where H is Rem this is H that is basically H is this biological or equivalent dose, D refers to absorbed or physical dose and multiplying that with quality factor we get the value of the biological or equivalent dose.

So, H is equal to D into quality factor a gives a relation between this absorbed dose and the biological dose or in a way if somehow we can say that if somehow we can get an idea about the amount of energy absorbed by a certain human tissue then we can calculate the rad from there.

Because that is the amount of energy absorbed divided by the mass of that human tissue and once you get rad then you have to identify what kind of particle we are talking about so that gives you the value of quality factor and then multiplying rad is quality factor or multiplying that absorbed dose with the quality factor we get the biological dose accordingly we have H is equal to QF into D.

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Type	Unit	Definition
Source activity	Curie (Ci) Becquerel (Bq)	3.7×10^{10} disintegrations/second 1 disintegration per second
Exposure (X & gamma rays)	Roentgen (R)	2.58×10^{-4} Coulombs/Kg in dry air at STP 1 Coulomb per 1cc dry air at STP
Absorbed dose	rad Gray (Gy)	0.01 J/Kg 1 J/Kg 1Gy = 100 Rad
Biologically equivalent dose	Rem Sievert (Sv)	QFR x (dose in rad) QFG x (dose in Gray)

$1\ Ci = 3.7 \times 10^{10}\ Bq$

Now, this summarizes all the 4 units of radioactivity or 4 types of units that we are defining for radioactivity. The first one is the source activity which is given in curie or Becquerel sorry which is given in curie or Becquerel as I have already discussed in the second module itself definitions you know 1 curie is 3.7 into 10 disintegrations per second whereas, for 1 Becquerel it is just 1 disintegrations per second. So, 1 curie is 3.7 into 10 to the power 10 Becquerel.

So, the activity of the radiation source is measured in terms of curie and Becquerel, but the amount of energy this source is emitting because of all this radioactive phenomenon that is going on there we have to see where this energy is being deposited and that there comes the role of this exposure. Particularly when you are talking about x and gamma rays we use the term exposure and not for nonliving quantity (Refer Time: 14:34) particularly for air I should say generally you use this exposure for air.

So, corresponding unit is Roentgen and sometimes we can also refer to this cgs unit of coulomb per kg 1 Roentgen equal to 2.5 8 into 10 to the power minus 4 coulombs per kg. And we using the amount of energy emitted by the source and by measuring the amount of dry air which is being subjected to this radiation we can calculate the Roentgen.

Then absorbed those rad as I already mentioned which is 0.01 joule per kg, but now comes a SI unit of absorbed dose which is gray Gy we use Gy and 1 gray refers to 1 joule per kg.

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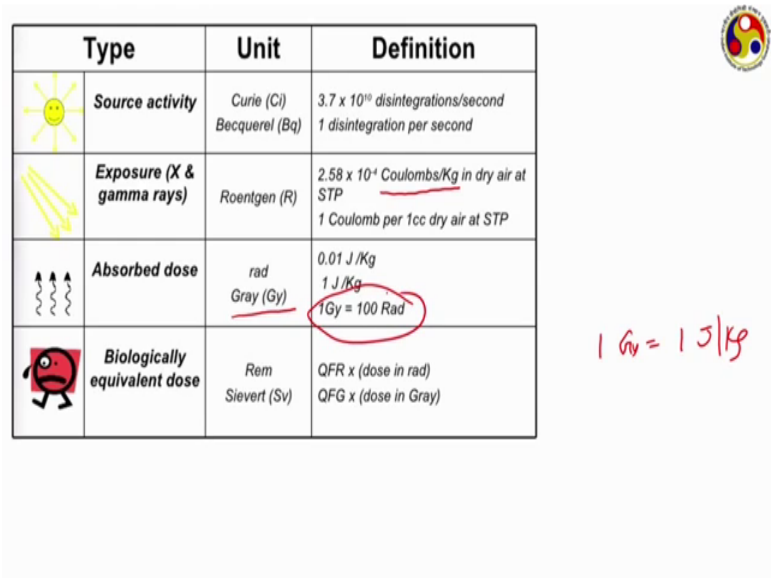

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1 Gy = 1 J/kg

So, 1 Gy is equal to 1 joule per kg that is when a human tissue measuring 1 kg receives 1 joule of emission or irradiation then we call the absorbed goes to be 1 gray and relating that to the definition of rad we get one gray is equal to 100 rad. Similarly for biological dose while the common unit is rem, but the same it is sievert or Sv.

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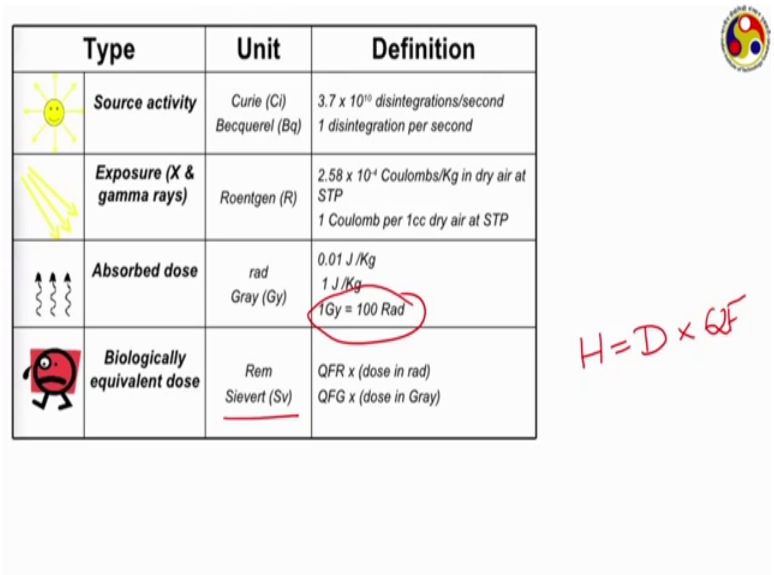

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$H = D \times QF$

And as the relation we have seen in the previous slide H is equal to D into QF. Now QF is given once we know the nature of the irradiation whether it is a beta particle or neutron of certain energy level or alpha particle you know the value of QF.

And now to get H we have to put the value of D, if we are using D in terms of rad then H will be coming in form of Rem if we are putting D in the form of gray then sievert will be coming or H will be coming in the form of sievert.

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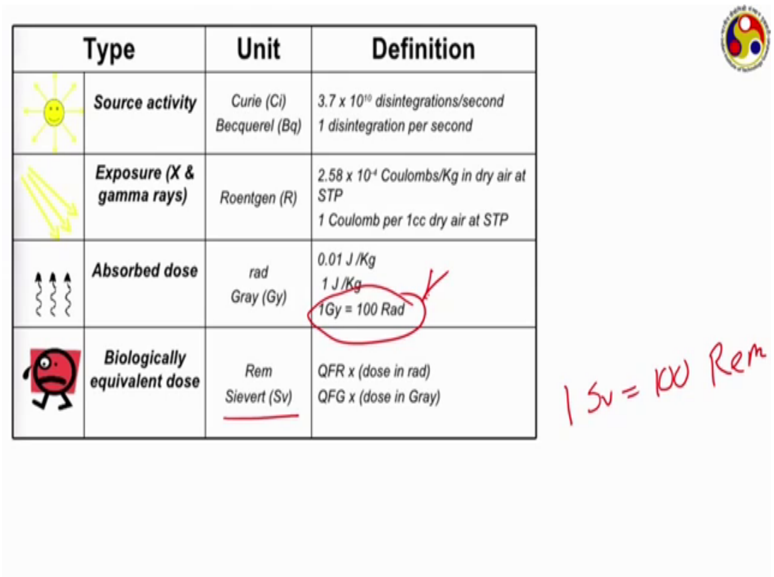

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So, quite similar to these gray we can also write one sievert is equal to 100 Rem or instead of capital generally small letters are used. oh Actually I was correct in the previous case it is R capital and em because R refers to Roentgen this Rem generally is the way we write Rem. And 1 sievert is equal to 100 Rem quite similar to this particular relation.

We can use these relations to calculate the total amount of energy received by any quantity once you have some idea about the strength of a source. Like suppose it is mentioned that I am trying to arbitrarily form just from my memory I am trying to form a numerical.

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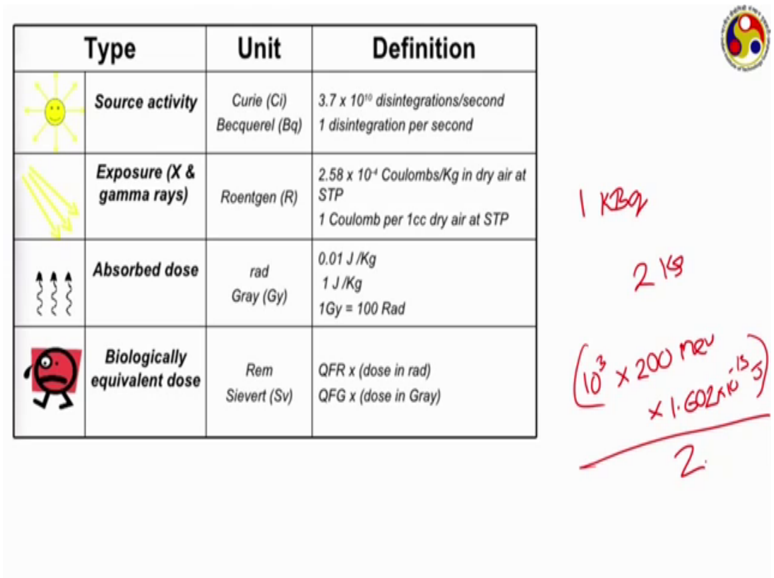

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Suppose one source is emitting 1 kilo Becquerel of energy it is emitting 1 kilo Becquerel of radiation and that amount of radiation is being received by 2 kg of dry air then you have to calculate the corresponding absorbed dose. So, 1 kilo Becquerel is the rate of this emission or there is a disintegration that is happening that is the rate of activity I should say, the rate of activity that is going on the source.

Now if the amount we need to know the amount of energy that has been released because of such activity if this is fission reaction that is going on then total amount of energy released during this will be 1 kilo Becquerel means 10 to the power 3 number of disintegrations that is happening per unit time multiplied by the amount of energy released for the disintegration is the total amount of energy that has been released.

If we are talking about say fission reaction as this disintegration then 1 fission reaction typically uses 200 MeV of energy and MeV and joule relation also is known to us 1.602 into 10 to the power minus 13 joule that refers to the conversion between MeV to joule. So, this is the total amount of energy that is been released by the source and that now that is being received by 2 kg of air.

So, if we divide this by the mass of the constant air that gives us the absorbed dose which are looking to identify and now if we know the nature of this radiation if it is a neutron or something then multiplying this absorbed dose we are going to get the biological dose or biological equivalent dose. But there is also something called effective dose.

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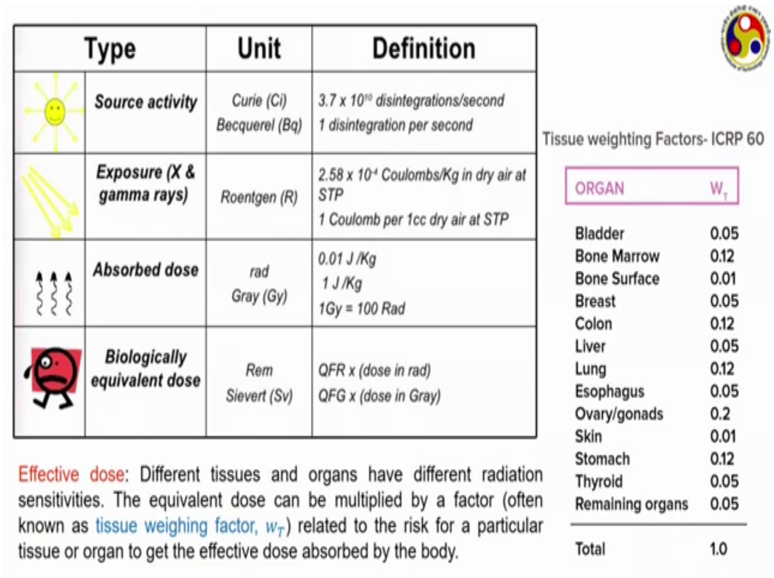

The response given by different tissues towards radiation are not same they are all different like the way our skin responds to radiation it is actually always exposed to radiation the radiation coming from the sun or from all extraterrestrial bodies that is being directly intercepted by the skin.

The so the way skin response to radiation some of the inner organs may not respond the same way they may be much more sensitive to radiation and that is given by this effective dose to calculate this effective dose we need to multiply these biological equivalent dose with a tissue weighing factor to get the effective dose.

And the value of tissue weighing factor can I we identified from here as you can see where certain quantities like the skin or maybe the bone surface they have extremely small weighing factor. So, just 0.01 that is whatever biological equivalent dose the skin is being subjected to only 1 percent of that is being absorbed by the skin effectively.

But there are certain other substances also like if you think lung it is 0.12, so whereas, for over your gonads it is 0.2 which is 20 so, that is significantly larger and this total of course, has to be 1. But the total response given by different organs towards a given radiation will not be same they will vary following this tissue weighing factor and hence for every organ we can calculate an effective dose differently.

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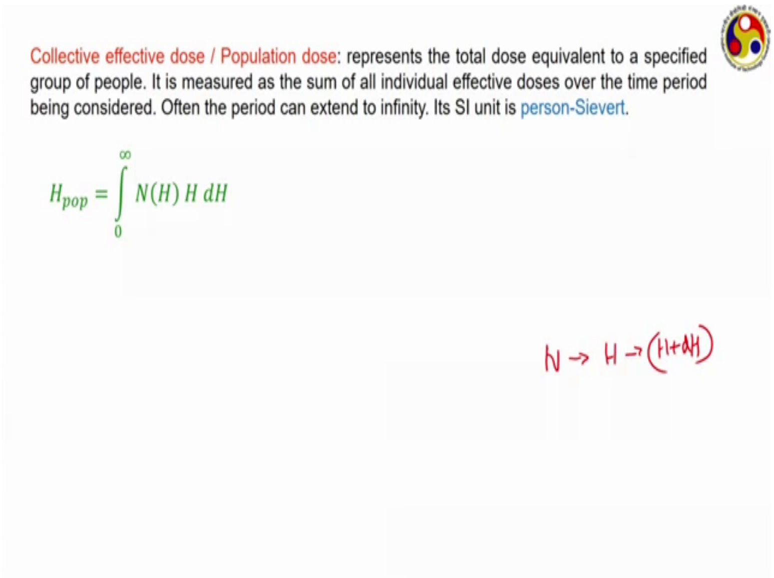

Finally, another definition collective effective dose or population dose it represent the total dose equivalent to a specified group of people here we are not talking about one individual because for a single individual we can get this effective dose or biological equivalent dose can refer to a single individual and then how much part of that has been absorbed by different organs that is given by the effective dose.

But instead was single individual when you are talking about a population a group of persons then what you get is this collective effective dose. It represents the total dose equivalent to a specific group of people if it is measured as the sum of all it is measured as a sum of the all individual effective doses over the time period being considered something like this.

If suppose N refers to the total number of persons who are being subjected to an effective dose of H to H plus dH then corresponding collective effective dose is given as integration of N H H dH a integration limits it can be some 0 to some highest value of H, but practically H can have any value and hence we often perform this integration.

Generally we need to integrate this over a period of time for which we are doing this calculation and therefore, that generally this is often tends to infinity because unless all the radioactive isotopes have decayed the radiation will keep on happening and hence we may have a situation that the same population is being subject to radiation of course, we change in changing in magnitude or change in magnitude, but for a infinite duration of time. This type of concept is particularly useful when you are trying to identify what is the effect of some kind of failed nuclear experiments on the neighboring areas.

Like if we think about the explosion at Hiroshima at 1945. Now, if you want to know what is the total dose or what is the effective dose that corresponding group of people has received or receiving since then we have to go for this collective effective dose.

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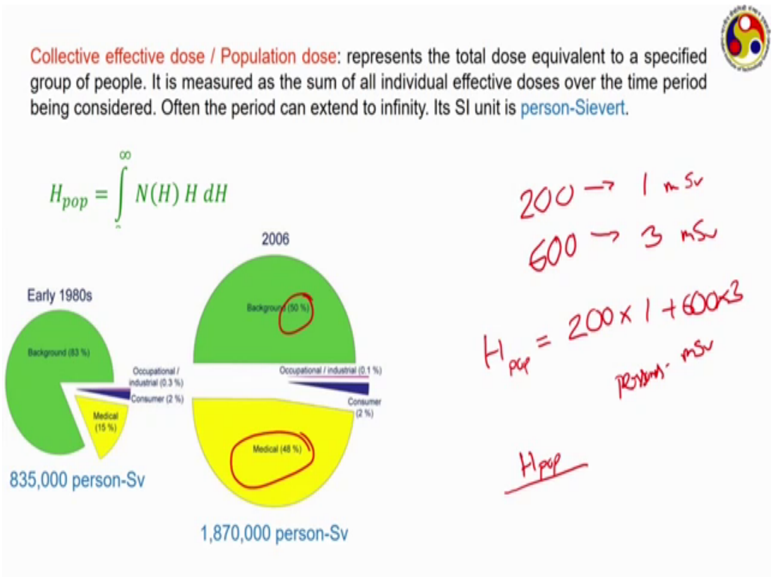

The value of collective effective dose of course, keeps on changing with time and also contribution coming from different factors that also keeps on changing. Like these are the data for united states in early 1900 80s you will find only 83 5 835,000 amount of collective effective dose the persons are subjected to by the way the SI unit is person's sievert, because we are basically multiplying the effective dose with the number of persons involved there.

So, it was only 835,000 persons and also you will see that the total contribution having from the background radiation is 83 percent. Here this background means we refer to the extraterrestrial radiation we our body or all the living beings and also nonliving objects are contains living subject to extraterrestrial radiation or cosmic rays coming from the outer atmosphere and also from the terrestrial bodies.

So, in the early it is 83 percent comes from this background radiation and only 15 percent because of the medical devices. Whereas, coming in 2006 only in about 25 years the total value has gone to 1,870,000 person sievert which is more than double than the initial value and now background contribution is only 50 percent whereas, medical has gone to nearly 50 percent again.

So, we are receiving increased amount of radiation contribution coming from the medical devices that you are using accordingly the collective effective doses also continuously increasing. If we want to calculate the collective effective dose for a group of person suppose 1 group of persons say some nuclear incident has happened in a particular town which contains 800 number of persons out of these 200 persons are being subjected to an effective dose of 1 millisievert. And remaining 600 persons are being subjected to 3 millisievert.

Then the collective effective dose or population dose that is H population can be just calculated as 200 into 1 plus 600 into 3 millisievert or I can say it should be persons millisievert. So, the total collective dose received by the population is given and even unger effect on an individual or average amount of dose receive by an individual then it should be H population divided by total number of persons that we are talking about.

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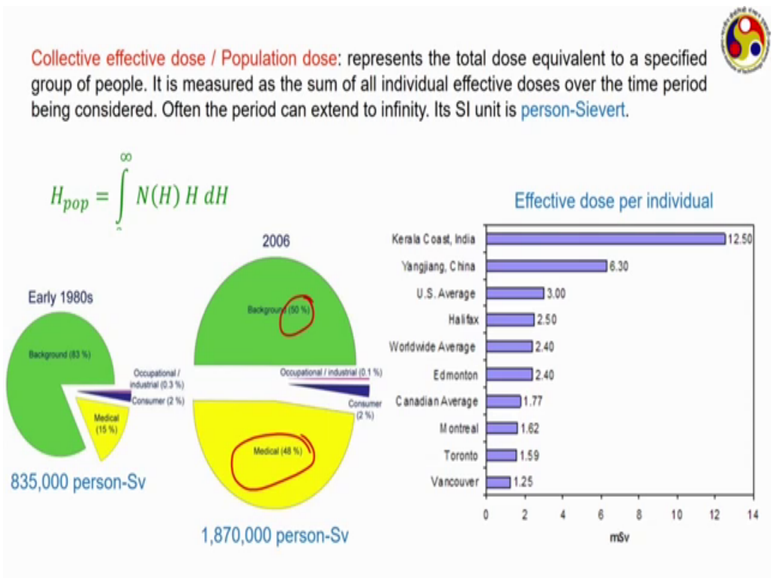

This is some data from different parts of the world about the amount of energy received by a single person then you will find that at Kerala coast of India where it is 12.5 millisievert in certain regions, like in Canadian average it is only 1.77 and all this Canadian countries are quite low. So, depending upon the location the background radiation can change accordingly total effective dose can also change or collective effective dose?

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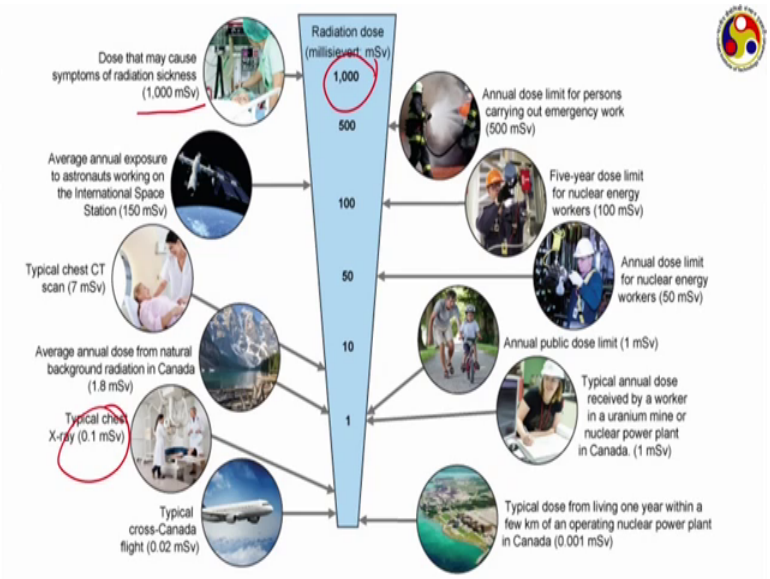

So, these are to provide you an idea about this quantity of energy that you are talking about how much is 1 sievert of effect or 1 sievert of radiation dose just you compare with this like when you are taking a flight a domestic flights. They are traveling from Delhi to Mumbai then the typical level of radiation will be subjected to is in the range of 0.02 millisievert whereas, when you are undergoing an x-ray it is 0.1 millisievert.

And if we go on increasing further then a person who is working in an uranium mine and he receives about 1 millisievert of energy over annual over an year corresponding annual public dose limit is also 1 millisievert whereas, certain other situations you can find the average annual exposure to astronauts working in the international space station is 150 millisievert which is much higher than this.

Similarly, the radiation dose keeps on increasing with different kinds of application and also depending on whatever the occupation levels a person is having like when you reach something in the level of this 1000 millisievert of effective dose then the symptoms of radiation sickness may start to appear. So, this 1000 millisievert is an important criteria and applications which requires energy higher than these are higher level of radiation should be quite careful now.

So, there because the typical annual dose that we can suffer is only in the range of 1 millisievert. In fact, when you are going through some kind of CT scan or chest x-ray then this is 7 millisievert sievert amount of energy that gets absorbed in our body, but is it much lower for an extreme. So, like we have seen the previous slide also because of this medical reasons there are lot more radioactive emitting particles that has been added to the system.

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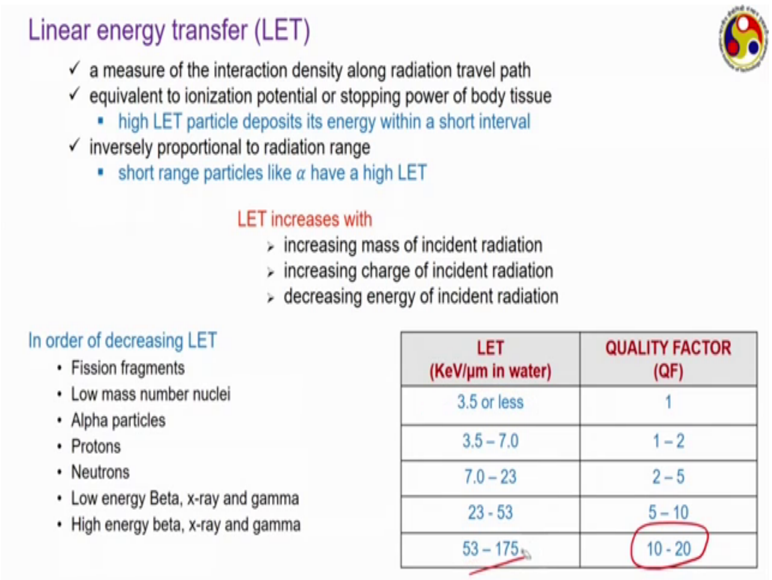

And now, we with this knowledge we define another term called linear energy transfer. Next we define a quantity which is known as linear energy transfer or let which is defined as a measure of the interaction density along radiation travel path. LET is very important in quantifying this radiation doses it is equivalent to the ionization potential or stopping power of body tissue. Like radiation dose earlier all those we have defined Roentgen rad, or Rem there we are talking about the dose that has been received by a living being and corresponding damage caused by this.

But once the energy radiation it has entered the human tissue then the amount of energy that we can transfer that is being quantified by this LET as it is equivalent to the ionization potential. High LET energy particle deposition energy within a very short interval whereas, like alpha particles etcetera can deposits is energy in a short interval, but lighter particles may take much longer. And also this LET is found to be inversely proportional to the radiation change.

So, short range particles like alpha have a very high LET, LET increases with 3 factors increasing mass of incident radiation that is instead of neutrons or electrons if we use alpha particles as a source alpha particles being heavier the corresponding value of LET also will be high.

Similarly the charge of incident radiation cannot be increased to increase the LET as well and finally, decreasing energy of incident radiation in order of decreasing, LET we can put a list like fission fragments generally found to have very high LET values and low mass number nuclei as well then alpha particles protons and neutrons come at the slightly lower level and beta particle of course, is the at the end of this LET.

LET can be related to the quality factor which we have defined earlier when the quality factor is one let which is having a unit of KeV or micrometer in water that is when the particle has traveled 1 micron inside the water then corresponding energy transfer is measured in terms of KeV to calculate the value of LET, and for this correlation factor our quality factor rather it is low LET is just 3.5 or less whereas, when it is the high quality factor like 10 to 50 the LET can be significantly higher 53 to 175.

So, like knowing the nature of radiation we can identify the value of the quality factor and using quality factor we can calculate the value or rather relation between H and D similarly you can also calculate the LET and which can letter can be used to quantify the damage inside the body.

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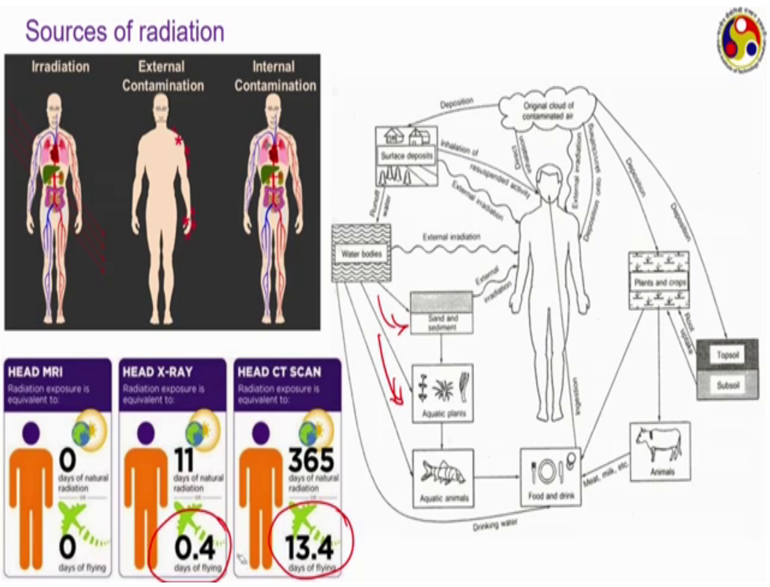

Now, what are the sources of radiation our body is subjected to generally that can be of 3 kinds irradiation that is a radiation which are directly following our body, then external contamination. Here the amount of energy being transferred when the body or external surface of the body comes in contact with some radioactive elements and third is the internal contamination with someone mistakenly has eaten up a radioactive eaten up some kind of ray particle or may be foodstuff which contains radioactivity.

This is a much bigger chart that you can find this actually follows if there is some kind of nuclear accident like in chernobyl a cloud of contaminated air has been formed and from that cloud there are several ways in the radiation related a particles or hazardous particle can enter party enter the human body like there can be direct transfer or there can be deposition on to the skin which comes under this external quantum category.

And also we can have other types of external relation coming from water bodies or surfaces as the body has to be in equilibrium thermal equilibrium with them. There are several ways by which we can have internal contamination as well like this contaminated air because of rain and others it can get deposited to the ground from where it can come back to the come back to the plants and roots.

And this plants and roots once you eat that can rarely go to our body also the plants and crops eaten by the animals can enter our body through the form of milk, or flesh, or egg or similar kind of animal product.

And similarly the water bodies also can receive this contamination and then this water body can lead to sand contamination sand which can act as an external contamination also it can go to the aquatic life. So, because of all this our body can receive a significant amount of radiation can going to our body both from internal sense and external sense.

This is an example as it was shown earlier the modern medical equipments (Refer Time: 33:54) a huge say in deciding the amount of radiation that we are receiving and this is the example of certain diagnostic tests done on our head when in the we go for some kind of head MRI there is no radiation effect because MRI works on magnetic resonance.

But when it is x-ray then x-ray particles is involved or x-ray photons are involved and corresponding energy release is equivalent to 11 days of natural radiation. Natural radiation here refers to the extra terrestrial radiation or cosmic rays. Whereas when someone goes for a CT scan then the radiation it receives from the scanner that is equivalent to a full year of natural radiation.

Also another very interesting factor is that when you are flying particularly at higher altitude then we are also subjected to certain amount of radiation effects. The headaches where then corresponds to while eleven days of natural radiation at you also corresponds to 0.4 days of flying, but in case of CT scan it is equivalent to 13.4 days of flying. Radiation effects are somewhat responsible for the exhaustion that we feel after a long flight on this.

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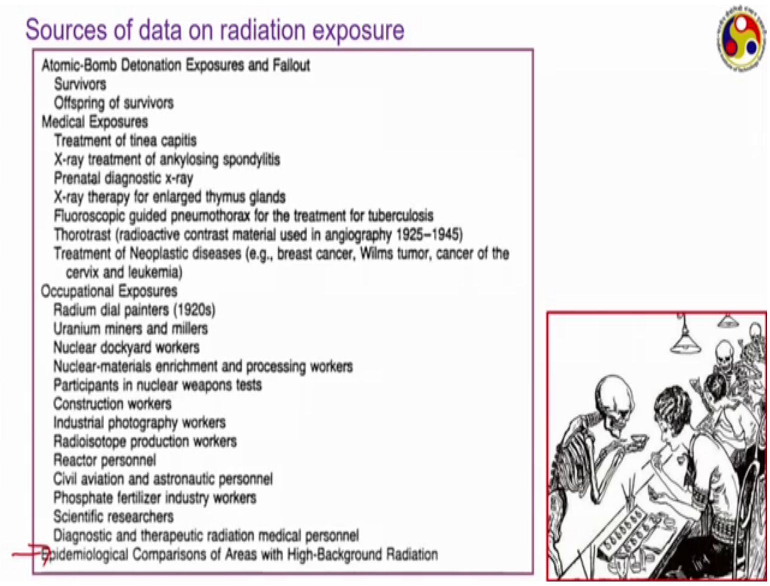

Now, to in order to identify what are the different ways radiation exposure can damage the human bodies we need to have proper data set. Unfortunately the data set that we have here is quite limited because people started to be cautious about the effects of radiation only in the last decade of 19 century or maybe the earlier part of 20 century. So, we are talking about only a span of 100 or 110 years rather the inter process paid up means people started to be really careful about the radiation damage only from 1930s onwards.

And then only people started to put the data in, put the try to collect the data from different possible sources and there are primarily 4 kinds of sources that we can have. The first one is of course, the survivors from the atom bomb at Hiroshima or their offspring's. You definitely have heard that there are still lots of radiation related disabilities and other abilities have been found in human bodies or newborns so that gives a strong case of to act as a source of data.

Second the medical exposure all the different kinds of medical exposure that we go on today most of them have some hazardous radiation effects like the x-rays, the fluorescent guided processes, thermo crate, and also the CT scan kind of equipment.

Third is the occupational exposure depending if you are working at a place where which is bound to have significant amount of radiation then that can also significantly hamper the very famous case there is that of this radium dial painters, these girls used to paint the dial of radium watches.

So, while painting they use to use a dye which contained radium in that and now at the before putting their mass you have to get a very very thin line they used to put the brush into their mouth like shown here they use to put the brush into their mouth just to make it very very thin.

And then they use that for painting the digits or the lines in on the clock dial, but that allowed a direct supply of radium into their body and then about 50 girls they were severely affected by the radiating incidents or radioactive effects only after 1920 that came into public and then people start be careful about the possibility of radium and other particles later on.

So, different occupational exposure the persons or miners working in the uranium mines they can also be subject to serious amount of radiation. And another fourth kind of data source that we can get that comes from here that is the epidemiological comparisons of areas with high background radiation. There were certain places where the radiation is quite high the background radiation like people who are living at higher altitude and if we have sub kind of data coming from their source then also we can use this.

So, with all this data that we can collect we are in a good position to predict what can be the effects of radiation over a period of 30, 40, 50 years that is some kind of a mid range kind of period, but if you are interest is to know the effect over a span of say 100 years or more then we still do not have sufficient data.

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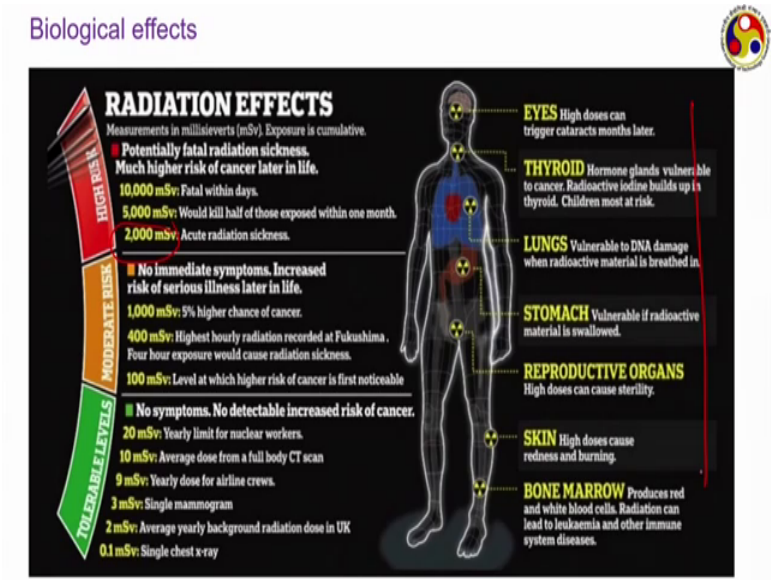

And this can be the effects I am not going to the details of this, but as long as the exposure is limited to something like twenty mSv or millisievert there is no detectable increase in the risk of radiation related illness and there is hardly any symptom also.

But when you go to the model trench starting from this 100 millisievert to something in the range of 1000 millisievert the risk of cancer is definitely much more. There may not be any immediate symptom, but the illness may start to spread later on. And third is in this a high range when you are in this range of 2000 millisievert or even higher here we may have acute radiation sickness and also it can be fatal. These are the different kinds of effects that we may identify from radiation for all different organs.

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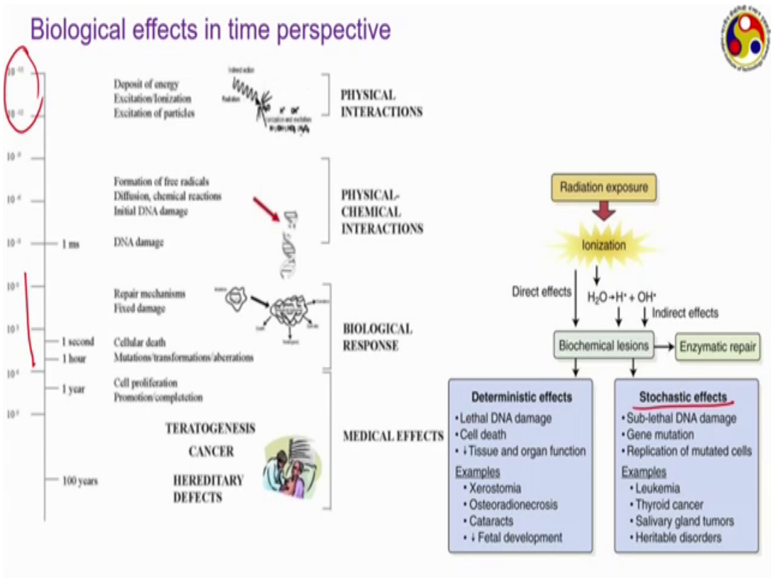

From time perspective if the body is subjected to radiation within 10 to the power minus 15 seconds or up to something 10 to the power minus 12 second then the energy is being deposited and particles are being excited. Then at the physical chemical interaction we discussed about the formation of free radical diffusion we are going to talk about that again.

And when their time is in the range of 10 to the power 0 that is of the order of 1 second 10 to the power 6 second we are going to get the biological response because we may face something like cellular death modification transformation of or aberration and also 6 dimension of the cell. And finally, when time is more than 10 to the power 9 seconds then medical effect is essential.

The radiation exposure can lead to 2 different kinds of effects one is the deterministic effect, other is a stochastic effect. Deterministic effect refers to the effect the severity of which keeps on increasing with the duration of exposure that is more it is a more the tissue is exposed to this radiation more will be the effect something similar to the sunburn that we have the longer you are in the sun, the larger will be the amount of tan.

But the other is stochastic effect where of course, the risk of having the illness that keeps on increasing with the increasing the radiation potential or radiation dose or in other way I can say that the longer the person is exposed to radiation the higher is the probability of facing the radiation related illness. But there is no guarantee that the illness will always appear, but if it appears the it can cause permanent damage and it can have much larger amount of effect.

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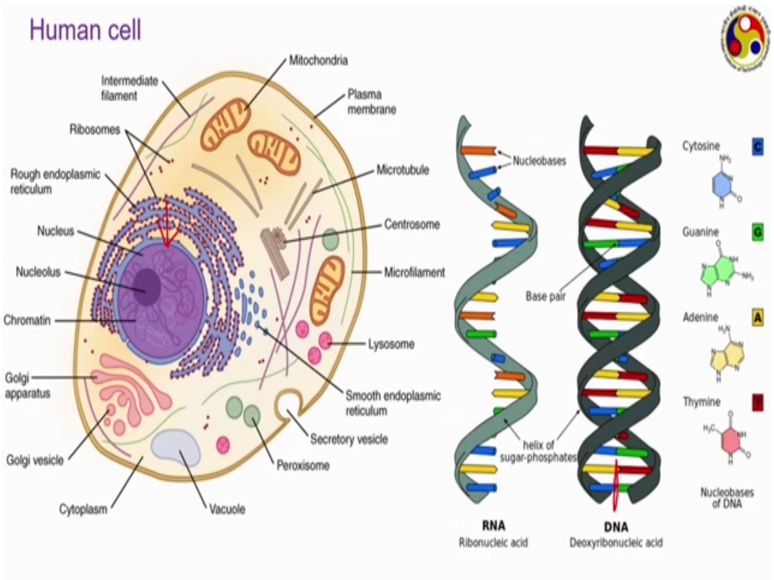

This is a very brief view of human cell which you have definitely seen at your school level biology inside the cell we have this nucleus which is filled with a chromosomes, and inside the chromosomes we have the DNA this is the structure of a DNA of course, ribonucleic acid or RNA is found in the body of a several other kind of animals. But now, it is for modern group of mammals we have the DNA only the RNA is often visualized as the previous form of DNA.

Now inside DNA we have this double helix kind of structure 2 strands, or 2 strands are rotated one top of the other or 2 strands just go like this and they are connected by these 4 different types of protein particle this cytosine, guanine, adenine, and thymine. And generally they are connected by 2 different particles. These 2 strands are connected by 2 different proteins and the combination often being like you can see this one it is adenine and thymine.

It is this A-T combination you will always find whereas, the other case you will always find this which is C-G that is cytosine and guanine. Here they will always form a combination like this that is a will always get connected t and c will always get connected with g and this point where they are connected here generally we have a sugar molecule which binds these 2 proteins together. Now, this is the normal structure of a

DNA, but there can be significant change in this significant mutation in this or modification in this because of the effect of radiation.

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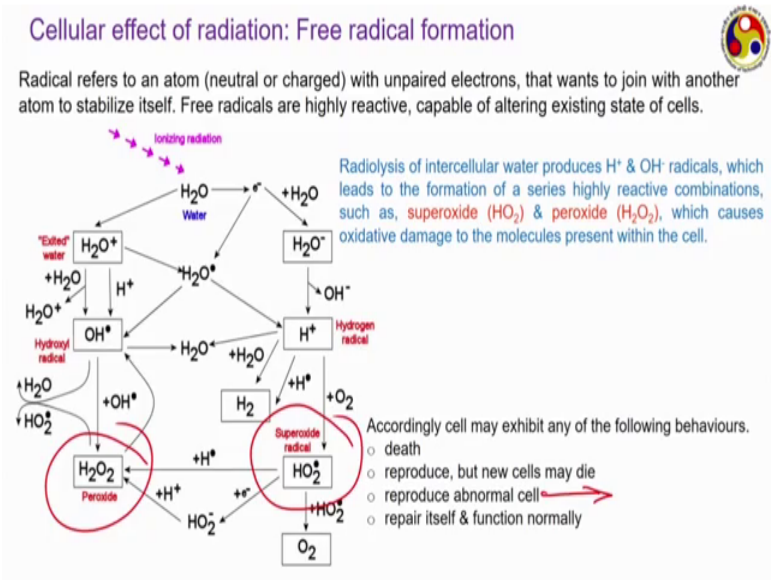

Radiation on human cell can have primarily 2 kinds of effects one is a free radical formation radical refers to an atom which may be neutral or may be charged which has unpaired electrons and therefore, it is looking to combine with another atom to get stabilized and they are highly reactive and therefore, they are capable of altering existing state of cells. This is something that may happen inside the cell if I quickly go back to the previous slide the human cell the all these parts of the human cell are covered in cytoplasm and cytoplasm the primary medium of cytoplasm primary component of cytoplasm is water.

And this water when it is subject to such kind of ionizing radiation that goes through the hydrolysis process; that means, it becomes this H 2 O plus and electron comes out and because of this hydrologic process you can go through this diagram. There are several kinds of subsequent reactions possible this electron and this H 2 O plus radical can react with other water molecules and can lead to the formation of several very important and highly reactive radicals.

Particularly important of them is this superoxide which H O 2 and the peroxide H 2 O 2 which can be highly reactive and they can oxidize the molecules present inside the cell. So, the ionizing radiation can cause hydrolysis of water and correspondingly we get the can get the formation of several kinds of oxidizing radical including the peroxide, and superoxide.

Accordingly cell may exhibit any of the following behaviors cell can die the cell can reproduce a new cell, but the new cell may die it may not have sufficient strained to survive it can reproduce a new cell which is abnormal and also there is a fourth possibly the cell can fight the situation can repair itself and function normally which is of course, possible.

But generally with radiation we get if the radiation is quite strong we get these 3 kinds of a effects this abnormal cell formation is extremely important because the new cell that is appearing that may have some permanent kind of defect into it which can lead to cancer in future.

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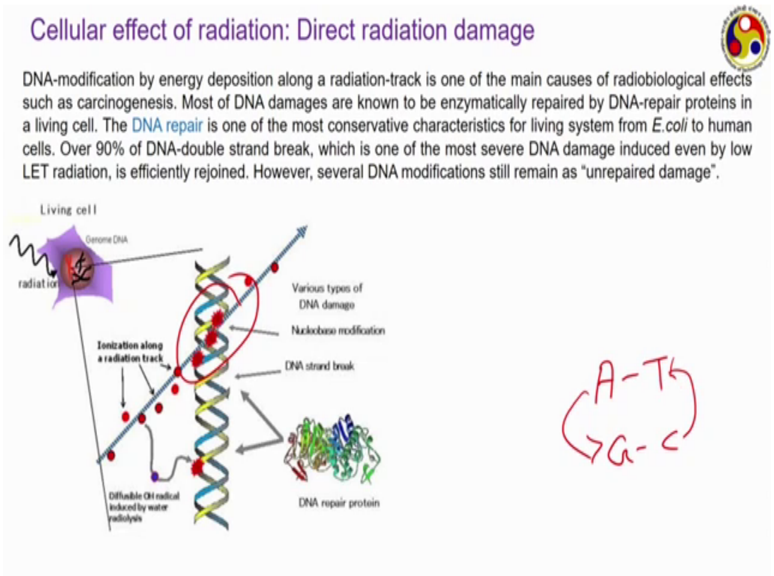

The other effect the cellular or other cellular effect this radiation can have is the direct radiation damage particularly to the DNA; DNA the deoxyribonucleic acid it contains the gene particularly subjected to this direct radiation the strands this particular strands they may broke with each other.

um The DNA repair proteins are there inside a living cell which is which tries to repair this and get the DNA back to its original portion position, but most often because of this strong radioactive effect at least over 90 percent cases the double strand breaks and leading to several kind of damage to the DNA.

Now, we know that the number of pairs of DNA that we can have inside the body of a mammal is fixed like humans have 23 pairs of chromosome and chromosome contains DNA out of that 22 pairs are the normal chromosome or autism and 1 pair is a 6 chromosome which decides the gender.

And the DNA is the most important part of the chromosome and now whenever there is such kind of permanent damage caused to the DNA by this radiation then the during the next reproduction part of this particular cell this damage DNA will be transferred to the newborn cells and there it may have its own kind of mutation and accordingly we may find several new kinds of mutation that may happen because of this.

Of course, or none of them are desirable in fact, it has been observed also that instead of maintaining that A-T and G-C or C-G combination. Nowadays there it is also able to we are also able to find a commission which is say adenine, guanine or between cytosine, and thymine or certain others that is the basic structure of DNA that is also getting modified when the concerned person or concerned living being subjected to very strong radiation what is sustained period of time.

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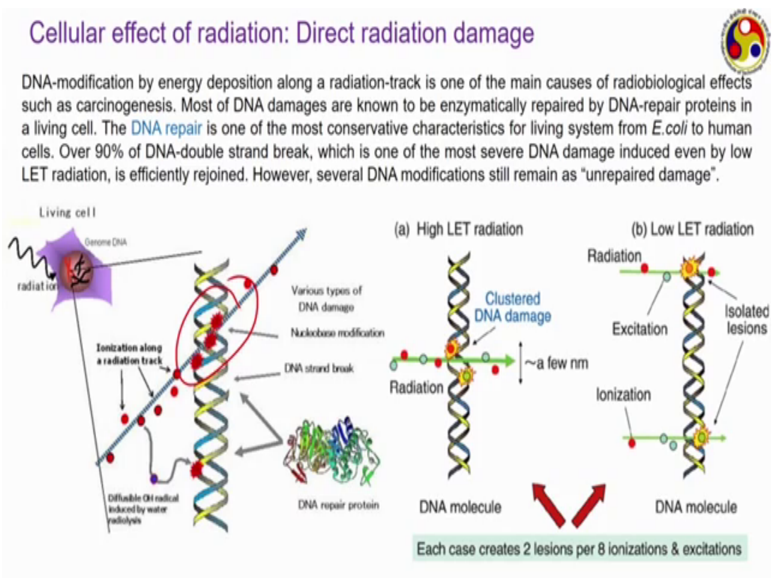

Depending upon the LET of radiation you can have 2 kinds of effects also like we can have this clustered DNA damage for high let radiation whereas, for low let radiation we may have isolated damage like one at this location and other at this location in, but both cases we generally find 2 lesions formation per 8 ionization and excitation.

So, because of such kind of damage caused to the DNA by this ionizing radiation, ionizing radiation the next generation can phase safe or next generation of cells I mean they can have significant amount of difficulty or significant amount of distortion in their own structure. There can be a whole cell mutation in the gene structure as well which can lead to several kind of damage or illness to the concerned person.

So, in this lecture I would like to keep it here in the next lecture we shall be deciding discussing a bit more about the effect of radiation on human body and then we shall also be seeing the way we can measure the radiation, and finally if you means of getting ourselves protected from such kind of radiation this. So, for today I am stopping here.

Thanks for your attention. Bye.