Indian Institute of Technology Madras

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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

NUCLEAR REACTOR AND SAFETY

AN INTRODUCTORY COURSE

Module 04 Lecture 02

Biological Effects of Radiation

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So good morning. I hope you had a good dose of radioactivity of course without causing harm because I am going to talking about radioactivity, but be assured it is not that bad to worry about. I will continue this radiation we talked about the exposure, the doses and we also had a look at the natural radiation which we get from the cosmic rays, from the soil and how we are getting lot of amount of exposure due to medical diagnostic tools.

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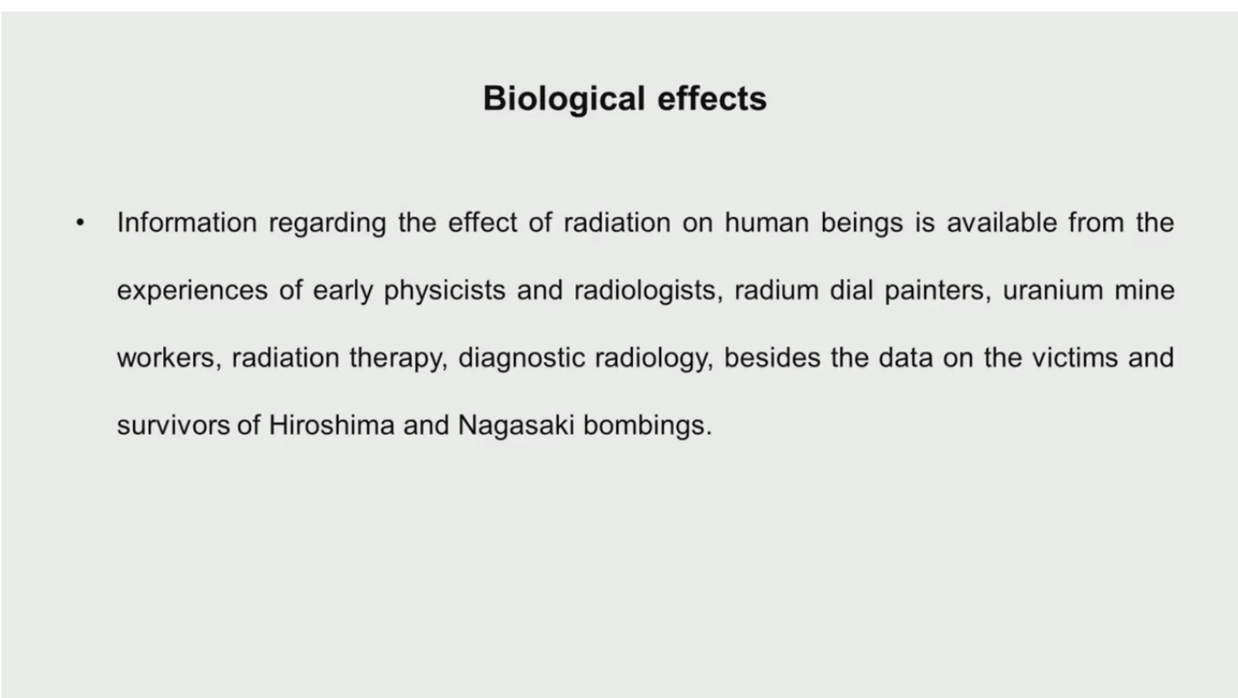

So we need to minimize wherever we can. Now we also talked about how the damage can happen on the cells, but how do we know about all these biological effects, how do we -- how are we knowing that in the last three to or four five decades after the Hiroshima, Nagasaki as I mentioned you follow up of these survivors has been going on. Even the scientists working on radiation. They have also been from time to time given the results of what are their observations and all these has been collocated and also uranium mine workers, data on the uranium mine workers we have got from the therapy, radiation therapy, diagnostic radiology; everywhere.

So one important point here to note is because of the fact that we felt that radiation could be damaging after the Hiroshima and Nagasaki bombings, we really took care to document and also today with growing signs we have got very good instruments which can measure accurately the radiation doses. That is also one more point which has grown in the last three to four decades. It is a very very important contribution in knowing that earlier we couldn't detect but today I can detect even millionth of radiation that is harmful.

So all this information on the health effects are available from these data.

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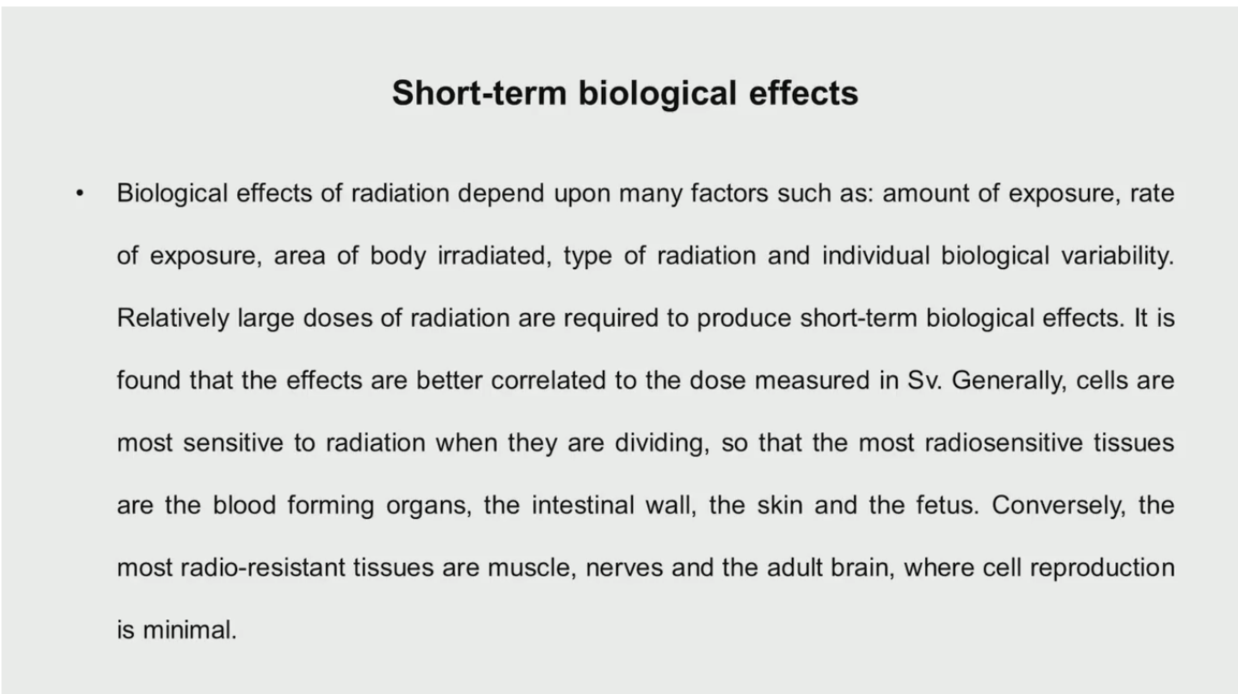

Now the effects, the biological effects we say we are not talking about any material we will talk about the biological effects depends as we saw; how much of exposure, how much is the rate of exposure, how much rate of exposure do I get? Then which portion of my body is getting the exposure? What is the type of radiation? Is it is it a neutron? Is it alpha? It is beta or gamma? What it is? All these factors finally are to be considered in assessing the biological effect of radiation.

Now if you look up short term biological effects are there and if it is a genetic, we call it as a long-term biological effect. And we correlate it or we measure the dose in terms of Sieverts. Now it is noticed that these cells are more sensitive to radiation when they are in the process of dividing. Now the most sensitive or radio-sensitive tissues are the blood-forming organs, the intestinal walls, the skin, and the fetus. They are highly sensitive to radiation. Then what are the non-radio resistance or less radio, the radio resistant, not less most radio resistant are I should say the muscles, the nerves and the brain where cell reproduction is minimal. Many of you may be aware in the brain if the cells died they do not get produced. In fact with age also with cells dying the dementia also starts, the forgetfulness starts, but luckily God has given us such a shielding on our body that our brain does not get affected by radiation.

So these are all some of the things which we need to keep in mind.

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- If enough individual cells are damaged by ionizing radiation, then specific clinical symptoms will be evident. Most of these symptoms and effects can be classified as deterministic. A deterministic effect is one in which the severity of the effect is a function of the dose, and there is a threshold below which there is no observed effect. As the dose is increased the effect gets worse, often until the point where there is some maximum effect. Radiation sickness is a group of symptoms that includes diarrhea and vomiting, nausea, lassitude, hemorrhaging, emaciation, infection and if the dose is very high, death.

Now if few cells are damaged you may not come to know but if quite a significant number of cells are damaged then you get the clinical symptoms. In fact, in most cases only by the clinical symptoms you come to know that okay some effect has taken place.

Now so these symptoms and effect we refer to the deterministic that is yes he is exposed to radiation. This is a clinical symptoms is happening so that is a deterministic effect. But again if you are looking at a definition it can be told it is one -- the deterministic effect is one in which the severity of the effect is a function of the dose. That's all. And of course there is a threshold below which there is no effect. Above that there is an effect and that effect is proportional to the dose. As the dose is increased the effect gets worse and maybe after sometime it saturate, there is a maximum effect.

Now what is this disease or what we call? There is one term called as radiation sickness that is any sickness caused due to radiation. It is not a single one. It consists of lot of things called it could be diarrhea. It could be vomiting. It could be nausea. It could be some sort of a hemorrhage or could be infection and maybe if the dose is very high could be death also.

So all these things happening due to radiation is we call as radiation sickness. It does not mean that you get a nausea or you're affected by radiation, not at all. So one of the causes of nausea could be radiation.

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Acute Dose & Health Effects

EFFECTS	ACUTE DOSE (Gy)
Blood Count Changes	0.5
Vomiting (threshold)	1.0
Mortality (threshold)	1.5
LD50/60 (minimal supportive care)	3.2-3.6
LD50/60(supportive medical care)	4.8-5.4
LD50/60 (Bone marrow or stem cell transplant)	>5.4

LD50/60 is used to refer to a lethal dose that without treatment will be lethal to 50% of the population in 60 days

Let us look at at what dose levels some changes or health effects take place. The blood count changes. You know the blood we take that white corpuscles and the red corpuscles and the total counts also we take. Beyond 0.5 gray there is a change of the blood counts, and if it is beyond 1, vomiting is there in the patient. Then beyond 1.5 could be a death. Then there are some terminologies which is called as lethal dose. Lethal dose means practically you know a person will die. There is a terminology called LD50/60 which is used to refer to that dose where without treatment 50% of the people will die in 60 days. So that is the thing it will be LD50/60. If such sort of a population you take you give some supportive care maybe they may be still able to survive 3.2 to 3.6 is the threshold. If it is beyond 4.8, 5.4 they really need to have a real supportive and this higher thing needs bone marrow transplant which is quite a severe sort of treatment but in many cases where basically after the Hiroshima, Nagasaki some of the bone marrow transplants have helped and off late this stem cell transplantation started that gives you the resistance of the body of the stem cells taken from the family persons and stored and safely stored. It can be helpful.

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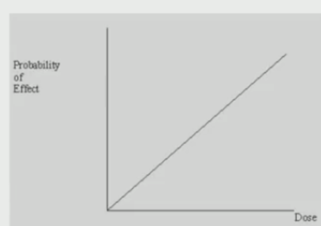
Long- term biological effects

- The major long-term biological effects from large, short term doses, or from smaller doses received over a longer period of time, are an increased risk of cancer and hereditary effects.
- **Cancer :** Cancer induction is a stochastic effect, in that the probability of the effect is a function of dose, perhaps with no threshold. This is illustrated in Figure . The shape of the function is uncertain; however, it is probably sigmoid in shape, as shown, but is conservatively assumed to be linear.



Then what are the long-term biological effects? The major long-term biological effects basically when I mean very large doses but short term of doses or smaller doses again as I mentioned one has to look at integral energy deposited in the tissue in an integral manner. So dose into the exposure into the type. This is most button and some of the things could be cancer and could be hereditary or what you call as the genetic effects.

Now cancer let us take. Cancer is a stochastic effect. What we really mean? It is not that a particular amount of radiation will give you cancer in all persons. It may give it is a probability that with this the probability -- some probability that a person may get cancer. You may get caner due to different things. Not that cancer came after we started the nuclear reactors or the nuclear diagnostic, etc. in medical diagnostics, etc. It has existed but today we know okay cancer is there. Cancer is curse. Cancer is causing death. That we know very well aware. Now so what is this effect is the probability that a person will get this disease above a certain threshold. So this is just graph the figure shows it is a function. It is not really a very linear function as you are told but probably you know sigmoid but we just assume it to be linear because when we do not know things we take that it is proportional to the thing. So whenever we do any estimation we take a proportional but actually it is not.

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- Some organs are more sensitive to cancer induction than others. Among the sensitive tissues for tumors are the female breast, the lungs, bone, thyroid and skin in that order. All radiation-induced cancers have a long latent period before they are detected. The shortest latent period is about 10 years for leukemia, and about 20-30 years for solid tumours. The current best estimate of the fatality risk from radiation-induced cancer is 5 per 100 person-Sv. This means that if 10,000 people were each given 1.0 mSv, 0.5 of them may die 20-30 years later due to a cancer induced by that dose. In that population of 10, 000 people however, about 1600 would die from “normal” cancers in 20-30 years.

Now again comes some organs are more sensitive to caner induction than the other organs. Now what are the organs which are sensitive? The tumors in the the female breasts is one of the thing which is sensitive. Tumors basically tissue tumors in the breast. The lungs. The thyroid and the skin. And the order is same. Tissues for the female breast, the lungs, the bone, thyroid and skin in that order. Now this radiation-induced cancers isn't sudden. They've got a long latent period before they are detected. That means you get the clinical symptoms much later not immediate. For example if you have to get leukemia the latent period must be something like 10 years and some of the solid tumors in other parts of the body this could be as well as 20 to 30 years, and the best estimate risk currently for fatality from radiation-induced cancer is something like five per one hundred person-sieverts. That is one hundred person-sieverts you get about five fatal deaths. In other words, if 10,000 people are given one millisieverts then 0.5 of them may die in 20 to 30 years due to cancer.

Now anyway if you just take a general deaths that in 10,000 people among 10,000 people about 1600 would have anyway died due to normal cancers. So where is a question of 0.5 and 1600. How you can really? It is a very very

very small. Let me tell you one thing you get cancer after such a long time how do you know it caused due to what? It's such a latent period. Cancer is caused due to so many things even our diet, smoking is one of the cause of cancer. Why smoking? You take many of the beautification agents that is a contains chemicals they are called chemical carcinogens. And they can cause you cancer. In fact one of the reasons for cancer increase has been attributed to indiscriminate use of chemical fertilizers and today we get organic vegetables which are produced without you know using chemical fertilizers. So you cannot pinpoint that radiation cancer has been caused radiation. Let me tell you very simple way I have a sore throat. I go to the doctor. Is my sore throat because of talking too much in the class giving lectures or was it the ice cream that I took one or two days back or my drinking very cold water or it is due to some sort of an infection which I have inhaling something from the outside or some pollen? How does the doctor tell you which is the causing effective. We just do not know the causing effect but we know this much that cancer can be caused by radiation but remember cancer or radiation is only one of the causes of cancer not the only. This I think has to be imprinted in your mind.

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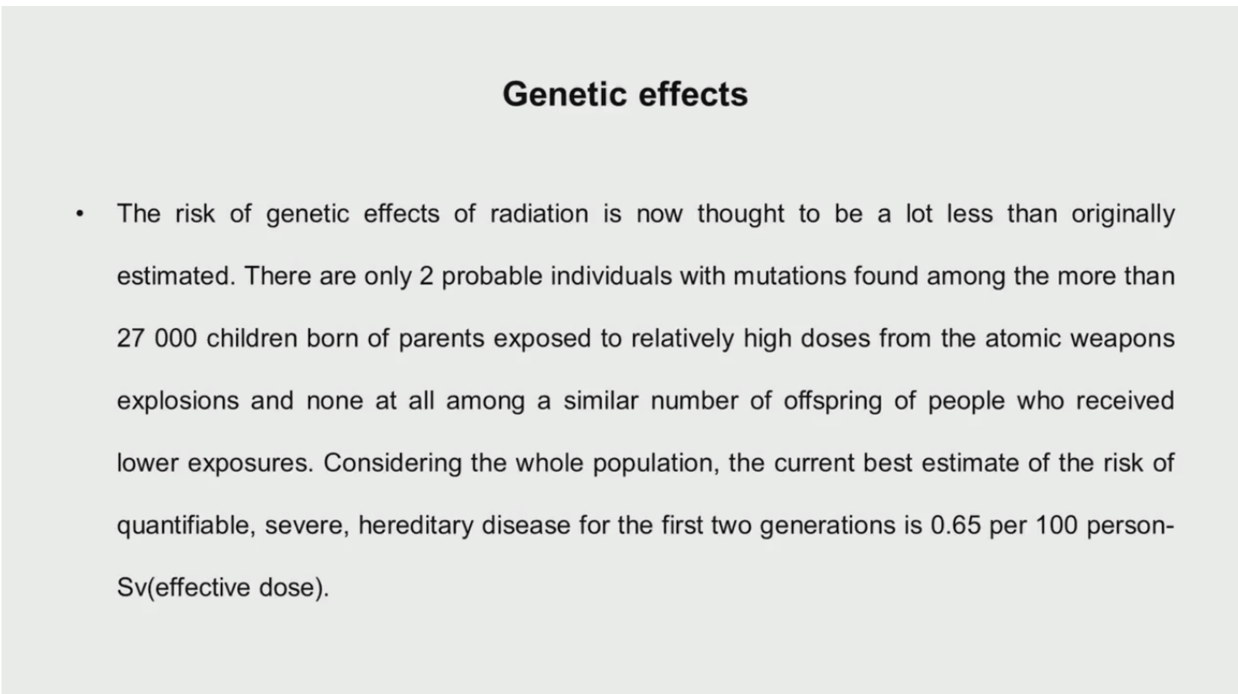

Now as I mentioned in the beginning, after the Hiroshima and Nagasaki bombings and why even after the Fukushima immediately the fear is that many people will get cancers. Many people will get genetic defects. Now if you really take up the data based on the Hiroshima, Nagasaki bombings it is found probably maximum two individuals with genetic mutations are found among more than 27,000 children born to parents who are exposed in the Hiroshima, Nagasaki bombings. That is they are the survivors. So their genetic progenies if you take maybe some two people what is this compared to the other things which are existing even otherwise. So it is very wrong to say that okay radiation means only why -- then why that people get that fear. Simple it cannot be smelt. It cannot be heard. It cannot be tested. So I am not able to see. Say for example we are able to withstand a chemical being diluted or from the factory getting into the thing we are seeing oh it is color. We are ready to accept it but radiation so it is a fear of the unknown. Nothing else. There is nothing to fear.

Then concerning the whole population as a whole, the current best estimate of the risk of quantifiable hereditary things could be something like 0.65 per one hundred person-sieverts effective dose. This could be what is a reasonable estimate but again if you see the risk is not high. So what I want to convey that risk there is not much risk which you are taking by radiation through say worrying about genetic effects.

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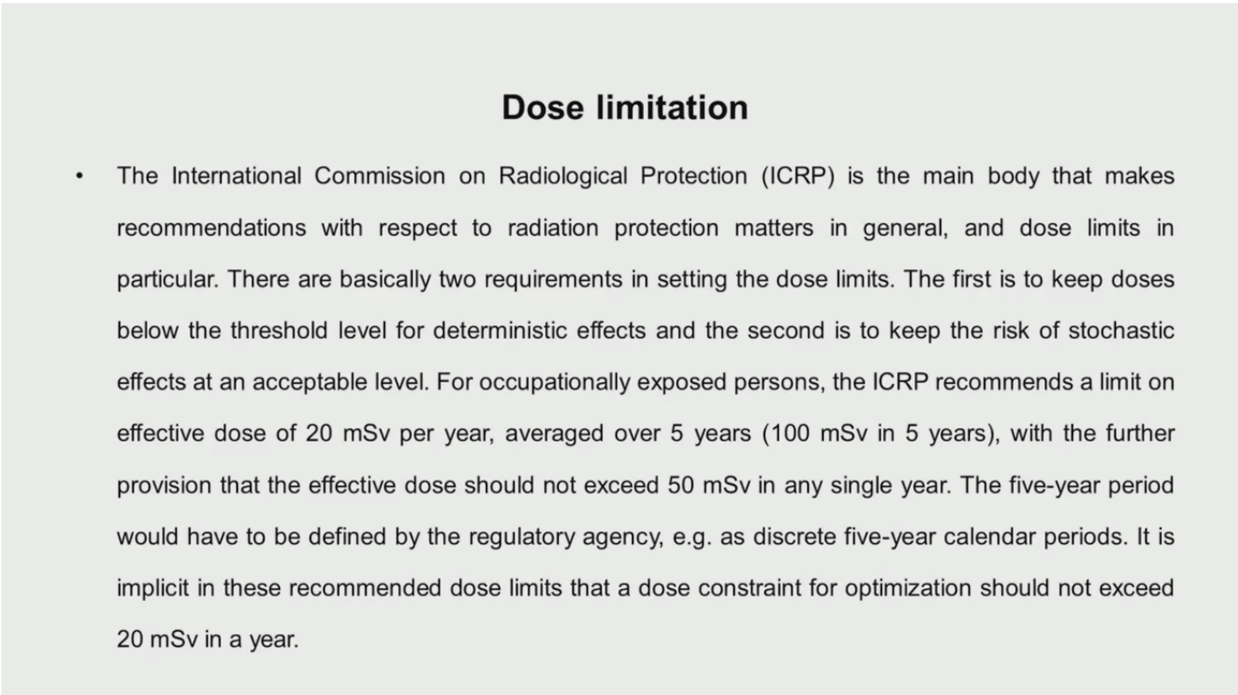

Then the dose limits. As I mentioned to you the International Council sorry, International Commission on Radiological Protection ICRP is the body which makes the recommendations as regards the matters of radiation protection. It tells that those limits basically the major role is to tell the dose limits. Now how -- what is the basis? Now they should keep the dose below the threshold level for deterministic effects. That is above which above the threshold you get effect. So you should be below that threshold, first, and below the threshold with some margin not there just exactly below that threshold. Now what is the limit for occupationally exposed persons means people who work in the establishments which involve usage of radiation or medical diagnostics or anything they are called the occupational workers or the occupationally exposed persons. The limit is 20 millisieverts per year averaged over five years. That means he can get on an average in a five year period on an average 20 millisieverts. Then there is a further provision that in a particular year okay suppose you say okay 20 millisieverts per year for five years 100 millisieverts so okay one near itself if he gets 100 millisieverts, no in a particular year it should not cross 50 millisieverts.

Now the five year period which is to be defined has to be very clearly defined by the regulatory agency as five calendar periods or what it is so it has to be very clearly monitored. That is where we have the health physics people who are maintaining the dose exposure levels at in different areas of any nuclear establishment. Now there is also a need that we should optimize the working conditions in such a way that to the best extend you should not cross 20 millisieverts per year. That should be our effort.

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- The occupational exposure of women who are not pregnant is the same as that for men. However, if a woman is, or may be pregnant, additional controls have been considered to protect the unborn child. Once pregnancy has been declared, the conceptus should be protected by applying an additional equivalent dose limit to the surface of the woman's abdomen (lower trunk) of 2 mSv for the remainder of the pregnancy and by limiting intakes of radio nuclides to about 1/20 of the annual limit of intake (ALI).

I mentioned to you that the human fetus basically fetus means when the woman is pregnant, the fetus is there in the womb that is quite sensitive to radiation related you to the other parts. So for the occupational worker, if she is a woman and pregnant it is not the same because we need to consider that the fetus should not be affected by radiation. So once we know that a lady is pregnant we should apply additional factor so that the woman is safe. Here again it is a matter of safety, more safety, relatively more safety we have put a limit for the abdomen portion about 2 millisieverts because maybe some X-rays may need to be taken. So 2 millisieverts but the inhalation or intake that is the inhaled radio nuclides should be only 1/20 of the annual limit because when you are living or working in a condition where some of the radioactive pellets are there some of them will be inhaled also. So that inhalation limit is there out in the case of such ladies which should be only 1/20.

So all these having very carefully what you call standardized so that it does not mean that just above this because there is enough safety margins which have been kept in the thresholds.

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- ICRP considered it reasonable to set the public dose limit based on a **risk level** which appears to be regularly accepted by the **public in everyday** life, i.e. that of public transport. From a review of the available information, the ICRP considered that a risk in the range of $\mathbf{10^{-6}}$ **to** $\mathbf{10^{-5}}$ per year would be likely to be acceptable to any individual member of the public. Such a risk would imply the restriction of the lifetime dose to an individual to a value corresponding to about **1 mSv/y** per year of lifelong whole body exposure. Excluding the very variable exposures to radon, the annual effective dose from natural resources is about 1 mSv, with values at high altitudes and in some geological areas of at least twice this. On the basis of all these considerations, the ICRP recommends an annual limit of effective dose of **1 mSv**.

Now how did this ICRP set this dose? As I mentioned there is a risk due to radiation. So the normal publicly accepted radiation that is what a public can accept is from accidents in the public transport that is common thing which happens which we have come to accept and this data over many years in the different countries have been taken and it is seen that a risk in the range of 10^{-6} to 10^{-5} per year is an acceptable risk to a member of the public. So we look at that radiation which will have a similar amount of risk so that it is acceptable. For example, the dose, lifetime dose of individual if it is one millisieverts per year then this has a risk of 10^{-6} to 10^{-5} per year is the risk. Now if you look at the natural radiation which is already present, you are getting about one millisieverts so and in some cases double of this. So looking at this ICRP has put annual limit of effective dose of one millisieverts.

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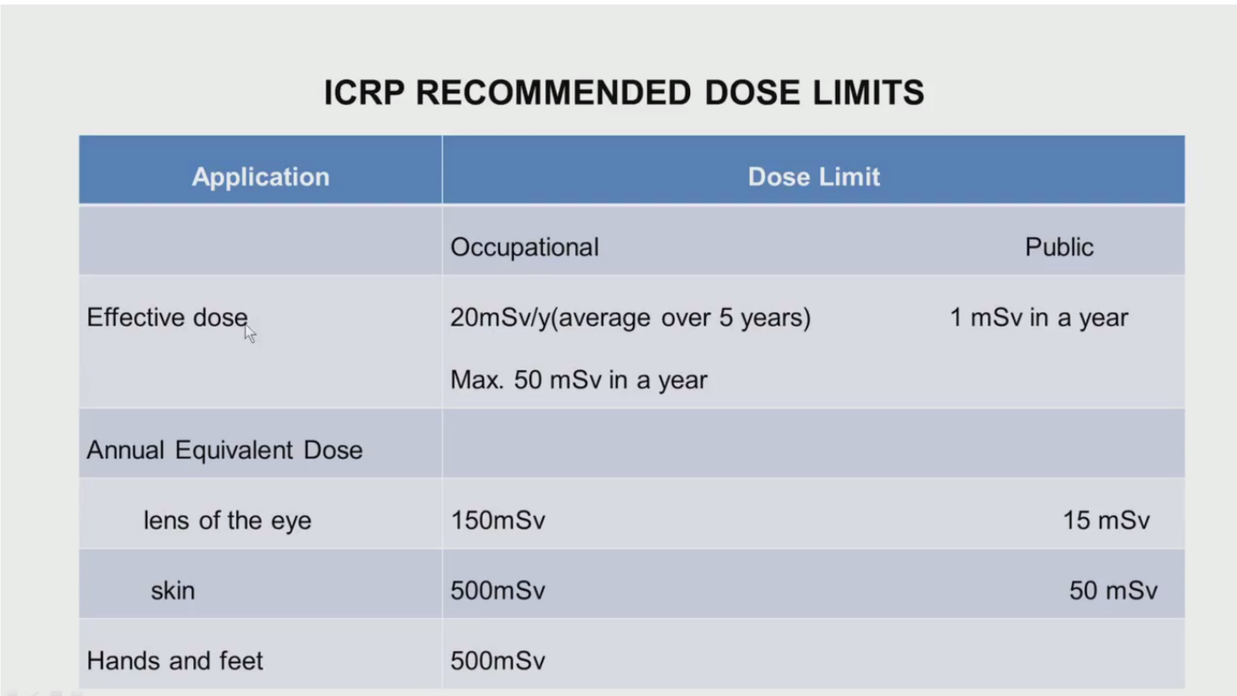

ICRP RECOMMENDED DOSE LIMITS

Application	Dose Limit	
	Occupational	Public
Effective dose	20mSv/y(average over 5 years) Max. 50 mSv in a year	1 mSv in a year
Annual Equivalent Dose		
lens of the eye	150mSv	15 mSv
skin	500mSv	50 mSv
Hands and feet	500mSv	

This then gives a tabulation value. We saw effective dose, occupational workers or the people who are working in the plants, 20 millisieverts per year averaged over five years for public one millisievert per year but on an alternative course maximum should we receive which will be 50 millisieverts. Then they also looked at different parts of the body, lens of the eye 150 millisieverts for the occupational workers. 15 millisieverts for the public. Skin 500 millisieverts and 50 millisieverts hands and feet. So this sort of. So if you look at this then what do this mean to us? What does this mean? Okay 20 millisieverts per year, 50 millisieverts per in a year, what does it mean? Suppose we find a person has received one year let us say 2013-14 he worked we took the exposure he had he got 50 millisieverts or more than 50 millisieverts, we will take him off work in a radiation area and we will observe his health. Not that it is something to be very much get worried about it. It only shows that okay whatever thresholds we had set he has crossed. That does not mean that he is going to immediately get fall sick or something. Now we will try to remove him from there and so that he does not get any further radiation, and observe is health. That's all.

So we have put these limits to ourselves as a discipline and again again I always repeat that statement thanks to the fact that Hiroshima and Nagasaki was came first before the reactors, we are aware that radiation can cause damage and we want to limit the radiation to as lower dose as possible.

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Means of protection against external exposure

- The absorbed dose of a person being the product of the dose rate multiplied by the exposure time, protection against external exposure is generally a combination of three parameters which are: **source distance, shielding** (these two acting against the dose rate) and **exposure time**. Farther the person is from the source, lesser will be the dose received. Shielding around the source would also reduce the dose. Lesser the time a person spends near the source, lesser will be his dose..

Then how to protect? It is very simple. Suppose I have a radiation source at a point. I try to keep away from the source. My exposure will be less because exposure will come down as I move away. It is inverse square law any radiation. So I keep myself away I will get less. Then if I am in the area where radiation is there for a longer time I get more exposure. I get a more dose.

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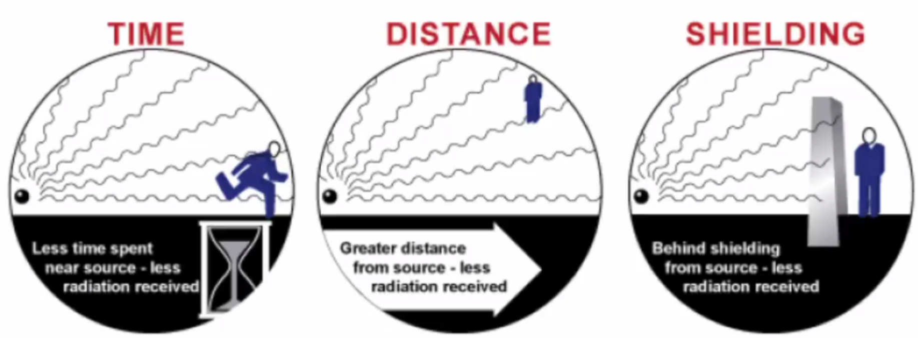
Shielding Principles



I have more energy is deposited on my tissues. Then what is the third one? Okay I in may have to work very close then I need to provide a shielding so that the shielding will protect me, put me in a lesser radiation zone and I would be able to work. So these are the three things by which we can protect. Lesser the time he spends, lesser the dose. Further he is away, lesser the dose and you provide shielding between the source and the human being he gets lesser source.

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Means of protection against external exposure

- The absorbed dose of a person being the product of the dose rate multiplied by the exposure time, protection against external exposure is generally a combination of three parameters which are: **source distance, shielding** (these two acting against the dose rate) and **exposure time**. Farther the person is from the source, lesser will be the dose received. Shielding around the source would also reduce the dose. Lesser the time a person spends near the source, lesser will be his dose..

So these are the three ways by which we implement the radiation protection.

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- Protection is principally obtained by the following means:
- Shielding of sources.
- Physical barriers, set out in such a way as to prevent approaching sources too frequently.
- The use of mobile shielding, adapted to the type of radiation.
- Examples:
- A single material shield is sufficient to block out completely specific types of radiation: Sheet of paper for α radiation, 1 cm thickness of plexi-glass for β radiation, for electromagnetic radiation (X or γ) it is possible to attenuate the radiation and the higher atomic number of the shield material is the best protection.

So shielding of sources is one by which we are able to implement. Then physical barriers. Now where we know that a radiation of a particular strength is there and we know it can cause. We try to cordon off that area. We have got some color codes by which different area red area means person should not enter that area without any clearance from the top people. So they are called then physical barriers by which you cannot go. Then in all cases you may not be able to put a prominent shielding. You can use a mobile shielding and again the shielding which you use should be suitable for the type of radiation as alpha, beta, gamma. For example your single sheet of paper, the thin paper can stop your alpha radiation. If you want to stop the effect of stop I will not say stop, it practically brings you to a very low level. 1 centimeter of Plexi-glass would reduce the effect of the beta radiatio.

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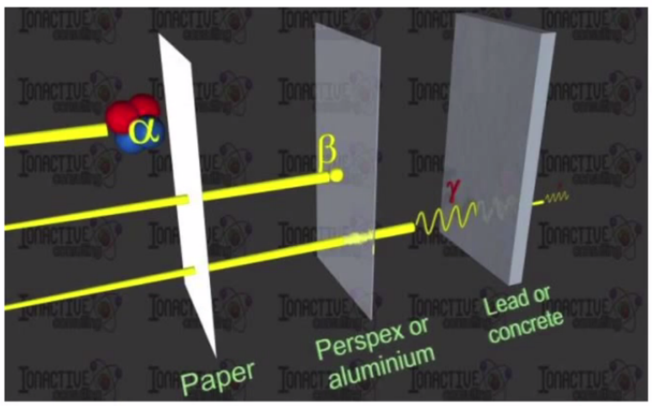
Penetration of Radiation



And for gamma, etcetera. it is possible by if you use high nuclei atomic number nuclei as a shield like lead or concrete. Even water itself is a very good shield.

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Means of protection against external exposure

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Now we talked about the exposures coming external that is from the different sources but as I mentioned there is something within us, how do you reduce that? Suppose you have some radioactive particles in the atmosphere, in the environment where you are working and they go you inhale. How do you do that? Now in the case of inhalation basically first thing is you have to confine the source. You must have ventilation of the areas. Ventilation means there should be a change of air so that the radioactive particles do not get accumulate. There should be a change of the air, air changes. Ventilation is very important. Then you must have filters in this path of the air circulation so that the radioactive particles are filtered. Then another thing is you have airlocks. You might wonder what is an airlock. See it is nothing. Let us take you take our reactor building inside which contains the reactor. Then what we do we do not want the air inside to come out because that air could contain radioactivity.

So we do not want it to come out but we need to go inside the reactor building to do some operation, or some surveillance, or survey what is happening we want to do. We have to go we cannot say no. so what we do we have two doors so that at a time only one door is open. Suppose let us say a person is coming from outside.

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REACTOR PERSONNEL AIR LOCK

He opens the first door. When you open the first door the air inside is not in communication with the air between the two doors. So he comes in then he closes that door. Now he opens the inner door then he can enter the containment. Now only the air within the space between the two doors gets a bit of contamination but this again this air is taken, filtered and so this is called airlock. In reactors we have airlocks we called as personal airlock where humans move and where materials are being taken like fuel bundles, fresh fuel bundles, or the reprocessed fuel bundles which are burnt and taken for reprocessing. They go to a material airlock. So they are all called airlocks.

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Means of protection against internal exposure

- The means at one's disposal to prevent the incorporation of radioactive particles are twofold, physical and legislative.
- **Physical means:** Regarding inhalation, the means at one's disposal are basically related to the confinement of the source. Even if the working areas are well ventilated, with air filters and vacuum air locks between the different zones, this is only to counteract an accident resulting in an atmospheric contamination. Regarding the ingestion of possible contamination, the means at one's disposal include training to suppress automatic reflex gestures such as touching your mouth or nose with hands or fingers when wearing contaminated gloves.

So this is one way of confining the activity to a particular area. Now what are the ways by which we can reduce the ingestion or contamination. One very important rule for any person who is working in a radioactive area is that never use your bare fingers. You always use your gloves and when you are using gloves at that time do not touch any other part of the face or the body. If you are working only work you do and when you are coming out these gloves you throw off. You dispose it when you come out and then only come out. So there is an area in the plant when you come out in fact we not only wear gloves for the hands we do have for the shoes we have a shoe cover again it is a cotton shoe cover. We put the shoe cover and then go. While coming out we remove the shoe cover, put it in a bin which contains all the radiation people coming from in radiation area to the outside area they put that and this contamination gloves are taken separately, laundered, and washed and specifically in a particular manner in our waste management facilities. This is a very very common practice which we follow in all nuclear establishments.

So here what I want to tell you safety, safety, safety, at every stage has been the what you call line behind our nuclear activities.

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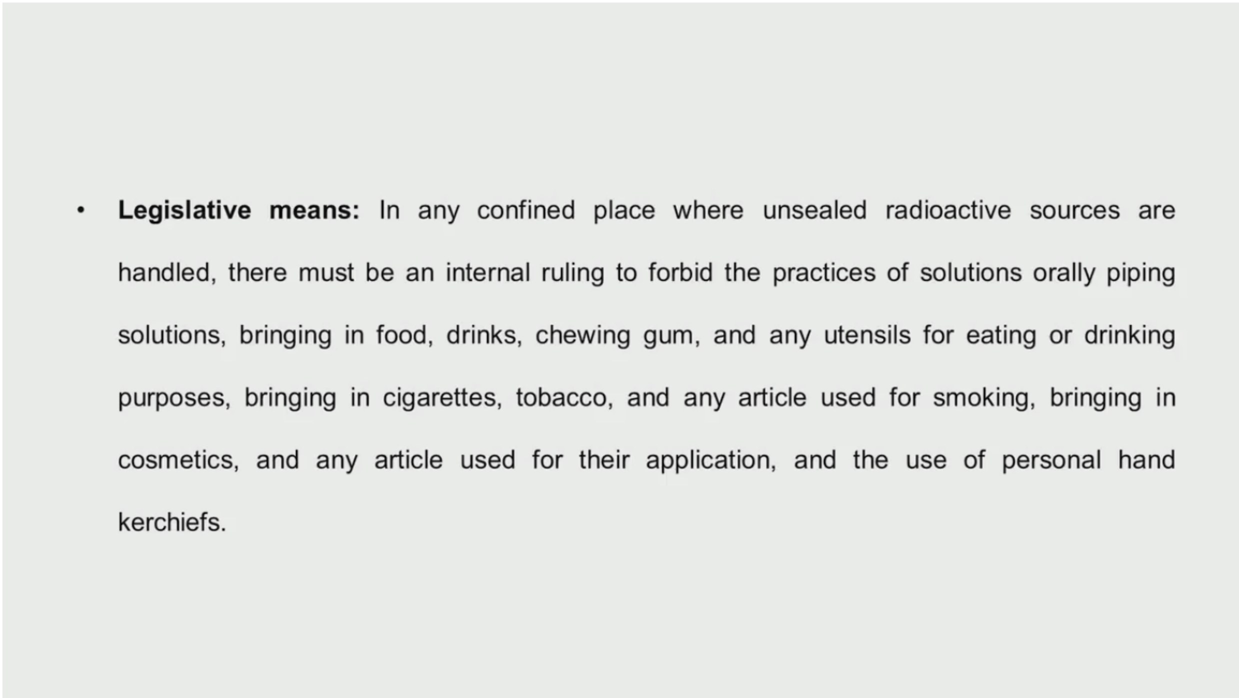

Then other thing is called as the legislative means or also another terminology called as administrative means is okay you put rules for radioactive sources. For example, you have a radioactive solution then you are handling it in a laboratory you are analyzing you must not use some pipes like a [Indiscernible] [00:37:53] so that it does not get into your system. This one. This you must have a person must know and most of us know that whatever is harmful we do not do.

Then other one let us say a worker is there normally there is a practice many of us take our lunch packets to our place of work and we eat there. In normal cases it is okay but if it's a worker working in a radiation area will never allow him to take the food inside. In fact in all our nuclear reactor establishments where intense activity is going on or the reprocessing and all we are not allowed to take any of our carriers, our lunch boxes are kept outside and lunch boxes are not allowed inside and this is checked by administrative means. We have the security personnel who checked not only us whether we are authorized to go inside. They also do this checking that we do not carry anything like lunch boxes, etc. So this is a way of trying to minimize the contamination. So this also requires, for example, individual has to follow these rules without any this thing so that he is safe.

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Means of protection against external body contamination

- The means of protection against external body contamination can be split up into two categories:
- **Direct means**: appropriate protective clothing for the type of work carried out, in particular wearing disposable, specially adapted gloves. Behavioral training to limit glove contamination while working, monitoring the level of contamination whilst working, and knowing how to correctly remove contaminated gloves without risking hand or wrist contamination.

Now we look at the internal contamination and what protection we can do. Then the external body contamination. What we can do? We talked about the shoes, gloves, hand gloves. There is also protective clothing for the workers and as I mentioned disposable gloves and for all this we are giving training before itself and how to do that so that you do not spread contamination. These are all training which are given to the people.

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- **Indirect means**: these include all procedures used to combat surface contamination and possible spreading, such as the confinement and limitation of movement of the sources, respecting rules for working inside the different zones (in particular with regard to protective clothing), careful installation layout, frequent contamination checks, and the use of smooth, waterproof surfaces allowing decontamination with ease in the event of an accident.

Then the other one is how do you have the layout. The layout of the plant should be such that any radiation worker should come out into a non-radioactive thing. He should not get into your non-radioactive again get into a radioactive zone. So in order to avoid spreading and we have to limit the moment of basically the people and even the moment of the sources of radiation. So if we do that then contamination will not take place, last but not the least, we have to do continuous checks and we need to see whether any contamination is happening and in case it has happened we should see how to isolate the what you call person or the clothing and take proper action.

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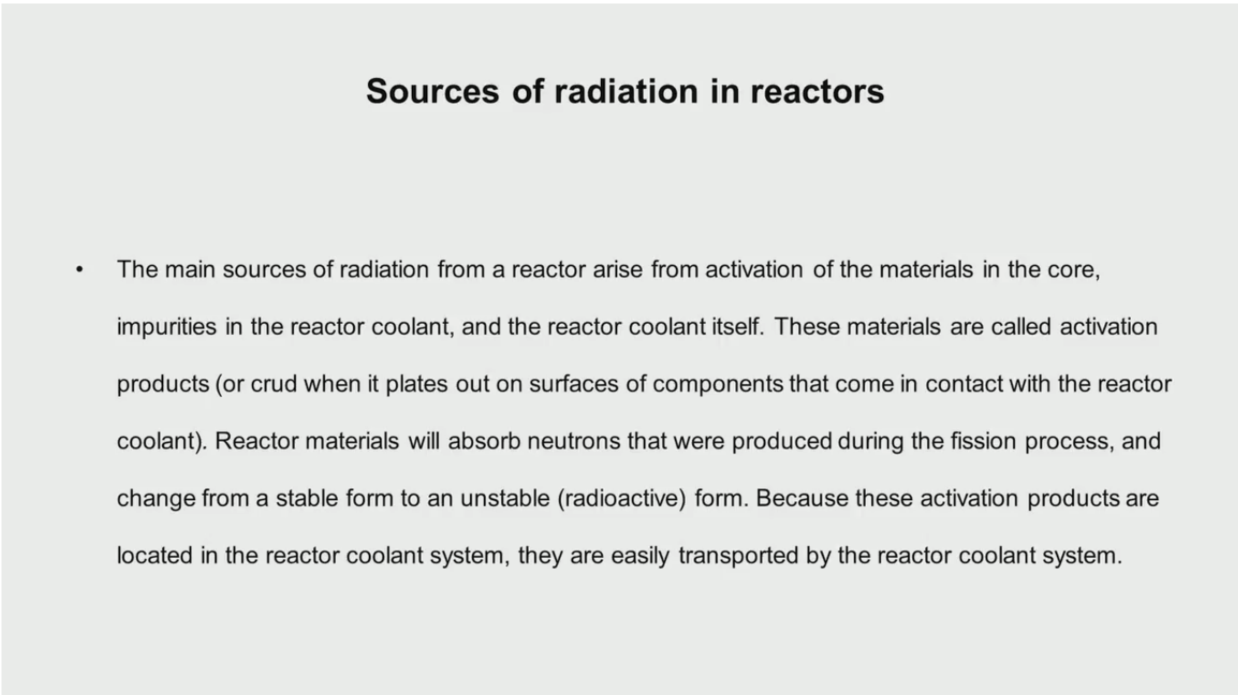

Now coming to the reactors. We look at external and inhalation etcetera? But what are the sources of radiation. In a reactor now in the reactor your coolant flows to the core, the coolant also contains impurities. If you say water, water just contain impurities. The coolant itself will get activated and these impurities also get activated. Then there are fission products which can come in case there is a damage to the fuel clad and they can get activated and these activated products because of the coolant flow can get into the whole coolant system so that could be an activation of the coolant system.

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- Contamination can occur because of a coolant leak. In pressurized water systems, the leak may be directly into the atmosphere, or via a heat exchanger into a secondary system, in which case the radioactive elements would be carried over with the steam into the turbines and then to the atmosphere via the condenser air ejector. A leak in the heat exchanger of a gas-cooled reactor would normally cause steam to leak into the primary system due to the higher secondary pressure.

Now okay it is in the coolant system what is there to worry. The activities within the coolant system the particles or contamination within the coolant system, but in case there is a leak it can come to outside environment. It could be in a pipe or it could be let us say in a heat exchanger failure. The element might come down. And if you take a boiling water reactor we saw that the reactor steam produces a steam and that steam goes to the turbine. So it is an active so that way also it can go to the turbine and then the turbine then let us say it is to go to the condenser and if there is a leak in the condenser it can get into the environment. In a similar way if you have a gas cooled reactor also if the leaks gas leaks it can come out, active thing can come out. So this sort of activity can come to the atmosphere in case of any leak.

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IMPORTANT FISSION & ACTIVATION PRODUCTS FROM REACTOR

MATERIAL	RADIATION	HALF LIFE
Krypton-85	Beta/gamma	10years
Strontium-90	Beta	28 years
Iodine-131	Beta/gamma	8 days
Cesium-137	Beta/gamma	30 years
Carbon-14	beta	5770 years
Zinc-65	Beta/gamma	245 days
Cobalt-60	Beta/gamma	5 years
Iron-59	Beta/gamma	45 days
Tritium	Beta	12 years

Just to keep track what sort of activation products which we can look for and the fission products in a reactor they are Krypton, Strontium, Iodine these are very important but you see their half lives 10 years, 28 years, 8 days for Iodine-131. Then you have got Cesium, 30 years. Carbon-14, 5770 years. In fact carbon-14 is this one thing I forgot to tell you we use in dating the life based on the carbon-14 content because it would have been 5770 years so anything within this period based on the analysis, radioactive carbon analysis we can do. So this has been used even for old sculptures and things we can find out dating of archaeological products. Zinc, Cobalt then Tritium. So these are all the important fission and activation products from the reactors.

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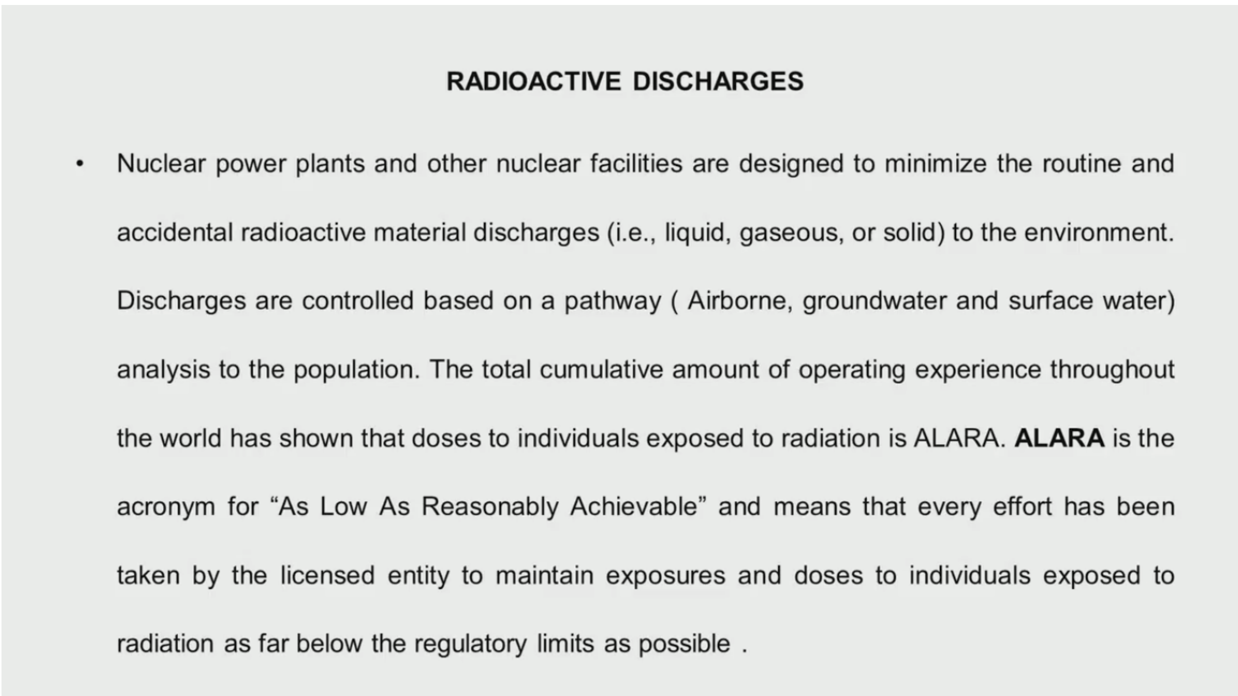

RADIOACTIVE DISCHARGES

- Nuclear power plants and other nuclear facilities are designed to minimize the routine and accidental radioactive material discharges (i.e., liquid, gaseous, or solid) to the environment. Discharges are controlled based on a pathway (Airborne, groundwater and surface water) analysis to the population. The total cumulative amount of operating experience throughout the world has shown that doses to individuals exposed to radiation is ALARA. **ALARA** is the acronym for "As Low As Reasonably Achievable" and means that every effort has been taken by the licensed entity to maintain exposures and doses to individuals exposed to radiation as far below the regulatory limits as possible .

Then what else? Then the discharges. As I said we have ventilation. We have filters and then finally some of the air needs to go out that should not, that also might contain but there is that limit should be maintained. So it could be a gaseous pathway or if you are using the reprocessing plant or it could be a liquid pathway and solids in case there are solids which are activated. Now the total cumulative experience throughout the world has been showing that if we follow we should not only follow the limits set by the ICRP but we should be achieved as low as reasonably achievable. This is called as the ALARA concept. The idea is do not stick to the threshold. You bring it as low as possible and you do every effort to see that the exposures are minimal. In fact, when we look we call for every plant we look at the man REM exposure or man-Sievert exposure. We try to audit that we put limits in such a way that if any plant is having minimal man-Sieverts then we do complement them and give them some added benefits. So at least to know that it is it is not that okay anything above that is with everything is within threshold but within the threshold keep minimum as low as possible. And this is being implemented by the licensing authorities and the regulatory authorities.

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SHIELDING

- A major engineering problem in designing a reactor and associated plant is the provision of adequate shielding to guard personnel and delicate measuring equipment from the ill effects due to the various radiations. α and β particles are more easily stopped than neutrons or γ radiation and any means adopted for shielding against the latter will effectively stop the α and β particles so that these need hardly be considered in designing the shield. Ideally one would require a hydrogen containing material such as water or polythene near the core to slow down the fast neutrons, then a thermal neutron absorbing material such as boron or steel and finally a heavy material such as lead to absorb the γ rays produced in the reactor and also in the thermal shield.

Shielding just as I mentioned alpha and beta particles are stopped easily, but for gamma you require a heavier material like a hydrogen-containing material. So you could go for lead or boron steel basically for neutrons.

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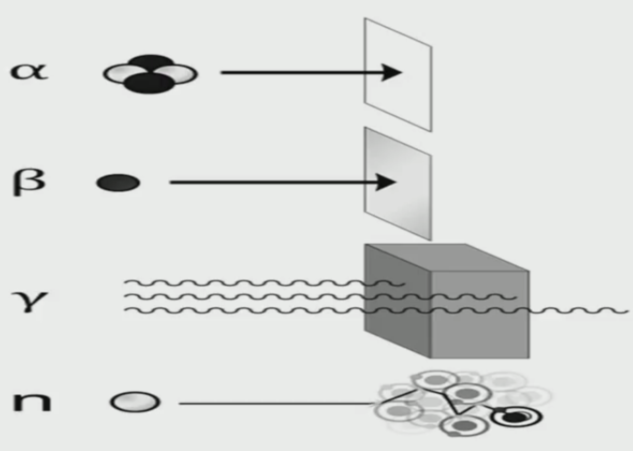

This is just a figurative picture for alpha being stopped by a piece of paper, thin sheet of paper be by a thicker metal, gamma by a solid and neutrons by any other absorption in any other material.

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THERMAL & RADIATION SHIELDS

- For a power producing reactor, a thermal shield of several inches of steel followed by 2 to 3m of special concrete is used. The high percentage of water in the concrete slows down the fast neutrons and by mixing iron, barium ores, steel shot or steel turnings into the aggregate the necessary heavy elements are provided to attenuate the γ rays; these will also absorb the thermal neutrons resulting from the slowing down of the fast neutrons by water. A concrete density of not less than700 kg/m^3 is considered desirable. Particular precautions must be taken to ensure that the shielding is adequate at points where cooling ducts, control mechanisms and other devices necessitate an opening in the shield.

Now there are one is what we call talked about was the radiation shield. Then there is also got a thermal shield because we do not want the heat of the reactor, the temperature reactor to be felt outside within the environment. So we have got thermal shields. So around the reactor we have steel followed by concrete to shield against the different radiation and the water basically in the concrete slows down the fast neutrons and you put barium, iron, etcetera. So to attenuate the effect of the gamma rays and they also absorb these neutrons. So that way concrete mixed with ion elements or boron or they are all used as a very good biological shield. Of course, stainless steel acts like a biological acts as a thermal shield and the density of concrete is something like 700 kg per meter cube but beware concrete is one thing. It cannot stand temperature beyond 80 degree centigrade. 60 is normally the limit. Beyond that we might lose the water which is in the concrete and it might lose its shielding property. So always wherever we use concrete we try to keep the temperature below 60 and if it is getting heated you try to provide cooling in the plant. So even in the shielding you need to provide cooling for the shield to maintain this temperature below in case it is concrete.

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SUMMARY

- This lecture has introduced you to the concept of radiation dose and the units. It has given details of naturally occurring radiation and brought out the fact that what we receive from operation of nuclear facilities is very less. The biological effects of radiation and the conservatism involved in deciding the dose limits have been brought out. The radiation protection approaches adopted and shielding in NPP has been detailed.

So let me just summarize what we have learned in this two lectures, last two lectures. You are introduced to the concept of radiation dose, exposure. Then we looked at the effect of the type of radiation, the effect of the type of tissue. Then what are the naturally occurring radiation effects, how much we get from the cosmic, how much we get we saw. We then look at in this lecture on the biological effects of radiation and how we put conservatism in designing these limits and not only that even though limits are prescribed, we still have achieved, try to achieve as low as reasonably. We want to limit as low as possible and this we have detailed some of the ideas of how shielding can be done whether it is a thermal shield or a radiation shield.

So with these two lectures I am sure you had a – would get a good idea. I am sure that there would be some questions. Please do go through and in the next class we will try to resolve the questions. Thank you.

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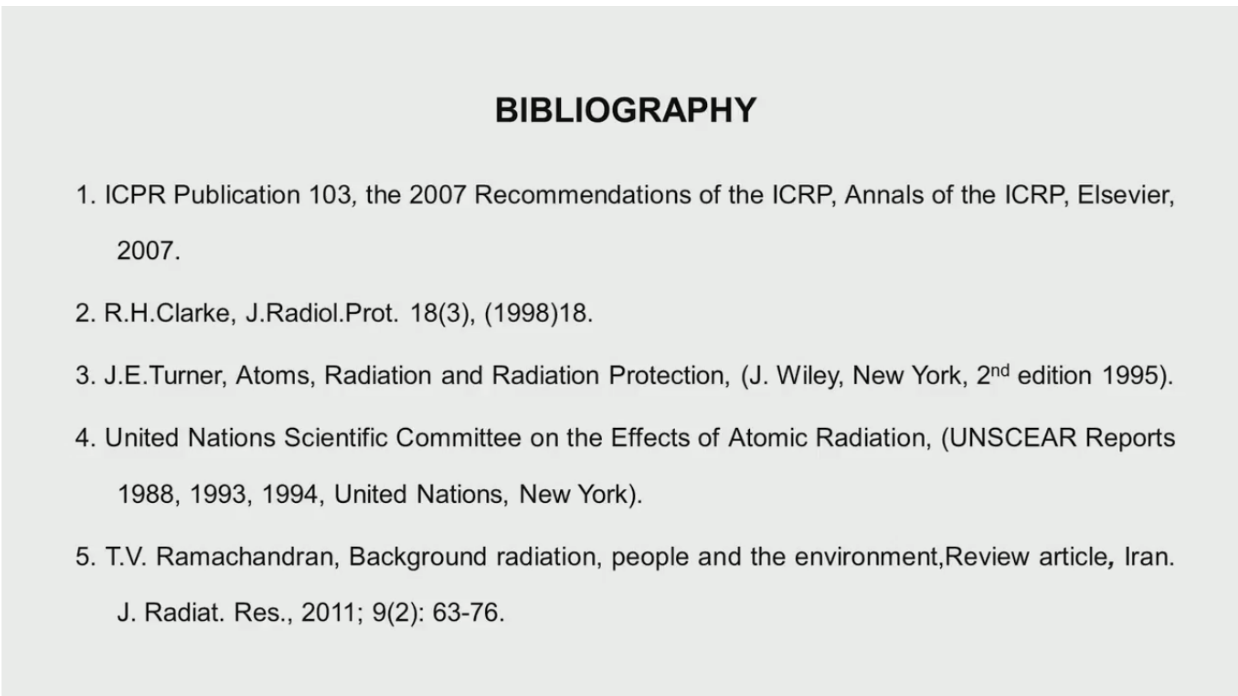

Bibliography as in my earlier talks I have given you some bibliography. You can see the reference by Ramachandran gives the background radiation and people in India. It's a very important paper for basically for India wherein you get a total picture of what is there in India.

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ASSIGNMENTS

- How does radiation cause damage in biological systems?
- Explain the terms absorbed dose and effective dose.
- Describe the sources of natural background radiation and their contribution to the radioactivity in the environment. What are the man made sources of radiation and what are their radioactivity contributions.
- What are the means of radiation protection of occupational workers in a NPP?
- Examine the literature on various combination of shielding materials for the different types of radiations and indicate possible materials for further research

These are some of the assignments which I think you must take to have a complete understanding. Thank you.

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