NUCLEAR FUEL CYCLE ROYAL COMMISSION

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TRANSCRIPT OF PROCEEDINGS

ADELAIDE

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COMMISSIONER: Good morning.

DR CALDICOTT: Good morning.

COMMISSIONER: Welcome, Dr Caldicott.

DR CALDICOTT: Thank you.

COMMISSIONER: This morning we're talking the effects and threats of radiation, and as our first witness, we welcome Dr Helen Caldicott. Counsel.

MR JACOBI: Inquiring into the risks associated with potential future nuclear activities, our primary concern is the risks to humans, animals and environmental health posed by radiation. Indeed, that is a risk particular to the engagement in nuclear activities. This issue has been the subject of considerable attention in the submissions received by the Commission from a broad range of groups. Those submissions contain not only strongly held but widely disparate views. This is remarkable because radiation has, for more than a century, been scientifically studied.

The types of radiation and sources, both from the natural environment and human made, are, from a scientific stand, well known and it has since been the subject of considered analysis and study, among other matters, as to its health effects, its utility and treatment, the nature of occupation risk, and the availability of measures to protect humans from exposure in those contexts. It is essential that on this topic, the Commission can identify the areas of broad agreement with respect to risk, the scope of disagreement, and where there are differences in views, the underlying reasons for them.

It is also essential that the Commission is able to describe with accuracy the consequences and risks when facilities operate both as expected and the extent of the risks presented by accident or emergency scenarios. The notable examples to be addressed in the evidence today are the incidents at Chernobyl and again, it having been addressed in the evidence last week by Dr Stephen Solomon, the events at Fukushima Daiichi. For that reason, the focus of this session is on radiation, and the effects and threats of radiation is upon the evidence that is said to support the various claims.

It will, for that reason, be an important theme of this session as it is for the Commission generally that witnesses can identify for the basis of the statements made and be able to explain the rationale for their views and the reasons for any differences of opinion. Without that it's difficult for the Commission to proceed with forming an evidence-based conclusion as to the nature of the risks presented by prospective witnesses.

Dr Helen Caldicott received her medical degree from the University of Adelaide Medical School in 1961 and founded the Cystic Fibrosis Clinic at the Adelaide Children's Hospital, was an instructor in paediatrics at the Harbour Medical School and on the staff of the Children's Hospital Medical Centre in Boston until 1980. In 1978, she was the founding president of Physicians for Social Responsibility, which was awarded the 1985 Nobel Peace Prize. In 1978, she founded the Women's Action for Nuclear Disarmament. She was nominated for the Nobel Peace Prize by Linus Pauling.

In 2002, Dr Caldicott founded the Nuclear Policy Research Institute, NPRI. She is currently the president of the Helen Caldicott Foundation, which arranges forums through which to provide information to the public on the risks of nuclear energy and nuclear weapons. Helen Caldicott has made numerous television and radio appearances and has written nine books and peer-reviewed articles on the health risks of radiation. She is a paediatrician and a fellow of the Royal Australian College of Physicians, a diplomat at the American Board of Paediatrics and a member of the American Thoracic Society, and the Commission calls Dr Helen Caldicott to give evidence today.

DR CALDICOTT: Thank you.

COMMISSIONER: Dr Caldicott, in your submission you tendered evidence about the medical implications of the release of radiation following the Chernobyl and Fukushima accidents, and we want to get to that in some detail.

DR CALDICOTT: Mm-hmm.

COMMISSIONER: But perhaps to start, you might just give us a very brief precis of what you think the medical implications from both those accidents are, and then we'll move into the specifics.

DR CALDICOTT: Thank you for asking me. There are basically four sorts of radiation: x-rays, to which we've all been exposed, that goes straight through your body and you don't become radioactive; then there's gamma radiation given off by many radioactive elements made in nuclear power plants and by uranium and its daughters, and that's like x-rays too. So miners who are mining uranium are exposed to consistent gamma radiation to their whole bodies, including their testicles where the genes and sperm could be mutated. That's dangerous.

Then there's alpha radiation, which is particulate, emitted from an alpha emitter like plutonium or uranium, two protons and two neutrons. You can hold an alpha emitter like plutonium in your hand and the radiation doesn't get through the dead layers of skin. However, if you inhale plutonium, one-millionth of a gram - and I've got a picture here of, like, a little star - in the liver or the lung

kills most of the cells in that area because it's so toxic, but on the periphery, as radiation decreases with the square of the distance, cells remain viable and there's a mutation in the regulatory gene that controls the rate of cell division.

The cell will sit latent and quiet for any time from four to 80 years. That's called the latent period of carcinogenesis, the incubation time for cancer. Then one day, instead of it multiplying by mitosis into two, it goes crazy and produces trillions of cells. That is cancer. A single mutation in a single gene in a single cell can cause cancer, and we usually can't stop the growth of cancer.

Then there's beta radiation which is emitted and that's just an electron from an atom. These alpha and beta emitters, many of which are made in nuclear power plants, need to get inside the body, inside - they're called internal emitters - to damage you, but gamma radiation in x-rays can damage you from the external. Now, we're all exposed to external radiation, natural radiation. It's thought about 30 per cent of cancers we see are caused by that. No radiation is safe. Each dose you get from a dental x-ray, medical x-ray, adds to your risk of getting cancer.

COMMISSIONER: I wonder if we could just move directly on to your evidence about the accidents and what you saw from that. I think we've got the background from - so perhaps going to the Fukushima accident.

DR CALDICOTT: Okay. Fukushima. So do you want me to walk you through the accident and location?

COMMISSIONER: Just briefly and then we'll go into the detail.

DR CALDICOTT: Yes. Okay. So I knew the three GE engineers who designed the Mark 1 GE reactors. They resigned in 1975 because they said these reactors were too dangerous.

COMMISSIONER: I'm really looking for the accident rather than - - -

DR CALDICOTT: Yes. Okay. So they built the reactors at sea level. They dug a cliff and built them at sea level. Big earthquake.

COMMISSIONER: Yes. I understand that.

DR CALDICOTT: Yes, tsunami. So they lost their external electricity supply. They lost the pumps to pump the million gallons of water per minute into each reactor. They had diesel generators underneath, which then drowned from the tsunami. Therefore, within a few hours three reactors melted down. The Japanese government didn't inform the people for three months that that

had happened. In that time, huge amounts of radiation was released, three times the amount of noble gases, argon, krypton and xenon, than at Chernobyl. Three reactors. Large amounts of caesium, about the same as at Chernobyl, and many other isotopes, which I will refer to shortly, not just caesium but many, hundreds, very short-lived ones which are very dangerous because they're very radioactive.

The wind blew from west to east across the Pacific for two days, so people escaped, but it changed and blew across Japan, as you know. People fled into the path of the highest radiation levels. The Japanese government did not inform the people. They knew where it was going. The Americans were monitoring the radiation by planes and the Japanese had a speedy system to monitor. They didn't want to create panic. So the people fled into the highest radiation doses. And it was an horrific accident with four explosions. One at cooling pool 2, I think, experienced an excursion, which probably was a nuclear explosion. The others were hydrogen explosions.

COMMISSIONER: The evidence of which, you say, there was a nuclear explosion?

DR CALDICOTT: Yes. An excursion, that comes from Unni Gundersen, a nuclear engineer who actually testified before my symposium in Europe at the Academy of Medicine last year.

COMMISSIONER: The implications, health implications from that – from those activities.

DR CALDICOTT: Okay. Huge amount of radiation was released and I'd like to go to the fourth slide. These are all the elements in a reactor. Now people only just talk about caesium and tritium and iodine and strontium. Some are very short lived but some are very long lived, hundreds or thousands of years and I want to just walk you through very quickly to see how many radioactive elements there are. The polonium that's an alpha emitter, some are beta, some are alpha, many are gamma. All the way down to tunium, terribly dangerous like plutonium, plutonium many isotopes. (indistinct) and that. So what we are talking about when there is a meltdown, those elements are released in to the air and people only virtually measure the caesium and the radioactive iodine. They don't measure the tritium and they tend not to measure the noble gases. Noble gases are called noble because they don't combine chemically in the body, argon, krypton and xenon. However when you inhale noble gases, xenon, it's absorbed through the lung. It's a very high-energy gamma, like x-rays and it is absorbed by the fatty tissue of the body. We used to use it in medicine to measure fat.

I used to use it for ventilation for fusion scans in my patients and the fatty

deposits tend to be the abdominal fat pad and the upper thighs where the gonads are. And therefore, the testicles and ovaries can be exposed to high-level gamma radiation which won't matter in this generation, nor for many generations hence because mutations are usually recessive, like cystic fibrosis, one in 25 of us carry that gene but the normal gene negates the cystic fibrosis gene. You need two cystic fibrosis genes to have the disease, so it takes a long time for generations, for those two genes to get together. There are 2,600 genetic diseases now described. Almost all mutations cause disease and deleterious effects upon the human population, in not just humans but animals and plants. So that's the noble gases but all the other isotopes which are not being measured and which land on the ground and which concentrate in the food and to which people are exposed, are not measured. What's your next question?

COMMISSIONER: We might go straight on now and examine the evidence in relation to the medical implications after that. Mr Jacobi.

DR CALDICOTT: Yes.

MR JACOBI: I just wonder perhaps, you made a submission to the Commission which is available on the Commission's website and I just wanted to start off by asking – we have seen significant conflicts or diverse views expressed with respect to radiation effects in the submissions that we have received. I am just interested to understand what you regard as the critical sources of information concerning the radiation effects - - -

DR CALDICOTT: Yes.

MR JACOBI: - - - of Chernobyl and Fukushima. What do you say are the critical sources?

DR CALDICOTT: I don't regard the IAEA as credible because it has two missions; one to promote nuclear power and one to regulate it. The IAEA signed an agreement with WHO in 1959 that WHO could not examine any nuclear accident unless the IAEA said it could. Therefore it did not examine on the ground the medical effects of Chernobyl, nor Fukushima so WHO in this context is highly compromised. In other contexts, it's not. UNSCEAR is – much of it is populated with pro-nuclear people or not physicians or people who really understand radiation - - -

MR JACOBI: Sorry, I just - - -

DR CALDICOTT: - - - and let me - - -

MR JACOBI: Sorry. Can I just say for the transcript that you have referred to

UNSCEAR, that is the United Nations.

DR CALDICOTT: Yes, sorry. I missed - - -

MR JACOBI: Scientific Committee - - -

DR CALDICOTT: Yes, on radiation.

MR JACOBI: - - - on the effects of atomic radiation.

DR CALDICOTT: Now let me say that my colleagues, the medical profession, really understand radiation and the biological ramifications of radiation and in fact, we are the biggest irradiators of the public at the moment, let's be frank. CT scans give you a hell of a dose, mammograms and the like, and we are not careful enough with radiation and we should be and there are more and more articles coming out about that. But - - -

MR JACOBI: Sorry. Could I just interrupt, what was your specific criticism of UNSCEAR because - - -

DR CALDICOTT: I am going to read it to you.

MR JACOBI: Okay.

DR CALDICOTT: So here is a critique from IPPMW, the International Physicals for the Prevention of Nuclear War, which I helped to found, criticising the UNSCEAR report. I will read it:

> *Before detailing the multiple inaccuracies of the UNSCEAR report, the doctors list four major points of agreement. First, UNSCEAR improved on the world - - -*

Well I won't go through that. What was - - -

MR JACOBI: Perhaps if you could just give us the reference, that is fine.

DR CALDICOTT: Yes. But I want to read out the rest, because this is very important.

> *The total amount of radiation – radioactivity released by the disaster was under estimated, this is Fukushima, by UNSCEAR, and its estimate was based on disreputable sources of information. It ignored frequent five years of non-stop emissions of radioactive materials that continued unabated and only dealt with releases during the first weeks of the disaster. Fukushima is presently*

releasing huge amounts of radiation in to the air and water in petabecquerels. That is ignored. UNSCEAR relied on a study by the Japanese Atomic Energy Agency which the IPPMW points out was severely criticised by the Fukushima Nuclear Accident Independent Investigate Commission for its collusion with the nuclear industry. The Independent Norwegian Institute for Air Research estimate of caesium was four times higher than UNSCEAR figure, even Tokyo Electric Power itself estimated that iodine 131 releases were over four times higher than UNSCEAR estimate. Internal radiation taken up with food and drink - - -

Which I told you about the internal emitters,

- - - significantly influences the total radiation dose that an individual exposed to, the doctor's note and their critique warns pointedly, UNSCEAR uses as one of – one – as it's one and only source, a still unpublished database of the IAEA and the Food Agricultural Organisation. It therefore has profound conflict of interest. Food sample data from the IAEA should not be relied on as it discredits the assessment of the internal radiation doses; it ignores them and makes the findings vulnerable to claims of manipulation, as with its radiation release estimates. IAEA, UNSCEAR ignored the presence of strontium in food and water which is a major carcinogen. Internal radiation dose estimates made by the Japanese Ministry for Science and Technology were 20, 40 and even 60 times higher than the highest numbers used in IAEA, UNSCEAR reports. To gauge radiation doses endured by over 24,000 workers, and it's more than that; UNSCEAR relied solely on figures from TEPCO, that severely compromised owners of the destroyed reactors.

The UNSCEAR report disregards current scientific fieldwork on actual radiation effects and this is the only scientific work that has been conducted at the moment in Japan on plant and animal populations. Peer reviewed ecological and genetic studies from Chernobyl and Fukushima find evidence that low dose radiation exposures cause, the doctors point out, genetic damage such as increased mutation rates as well as developmental abnormalities, cataracts, tumours, smaller brain sizes in birds and mammals and further injuries to population. The special vulnerability – the embryo and foetus to radiation was completely discounted by UNSCEAR, the physicians note. The doses to the foetus or breastfed infants would have been similar to those of other age groups which goes against basic principles of neonatal physiology and understanding. Because the foetus is by hundreds – the orders

of magnitude more sensitive to radiation than others and they ignored that. And also in utero exposure can be teratogenic which can produce damages such as this. Damages the foetus in the first three months of intrauterine life, killing a cell that's going to form the right arm, or the left part of the brain.

And here are some other shocking pictures which I currently have lost of women who were exposed to caesium in an area in the Ukraine where they harvest their own food and they've got very high body levels of caesium. They have conjoined twins, Siamese twins and encephalopathy, babies born with no brains, spina bifida, microcephaly, microphthalmia and the like. Non-cancerous diseases associated with radiation doses, and this is very important, because UNSCEAR only looks at cancer, such as cardiovascular diseases because seizing concentrates in cardiac muscle and the thyroid and endocrine glands and there are a lot of sudden heart attacks in the Ukraine and the like from Chernobyl, especially in children. Endocrinology because there's a lot of diabetes because seizing concentrates in the pancreas where insulin is formed, infertility, genetic mutations in offsprings and miscarriages.

This has been documented in peer reviewed medical journals but are totally dismissed by UNSCEAR. The physicians remind us that large epidemiological studies have shown undeniable associations of low-dose radiation to noncancer health effects and have not been scientifically challenged. The report plays down the health impact of low-dose radiation by misleadingly comparing radioactive fallout to natural background exposure. IPPNW scolds UNSCEAR saying it's not scientific to argue that natural background radiation is safe, which it's not, and that excess radiation from nuclear fallout that stays within the dose range of natural background radiation is harmless, and that's what UNSCEAR proposes. In particular, ingested or inhaled radioactive materials deliver their dose directly and continuously to the surrounding tissue, bone, thyroid, muscles, et cetera, and therefore pose a much higher danger to internal organs, and they ignore that.

Their measurements of food stuffs were totally inaccurate and they only took a few measurements of foodstuffs.

COMMISSIONER: Perhaps we could - - -

DR CALDICOTT: I'm sorry, it's long but it's terribly important.

COMMISSIONER: I guess we want to question some of that evidence.

DR CALDICOTT: Why?

MR JACOBI: Why do we want to question it? Because we're trying to get to understand it.

DR CALDICOTT: But this is all sourced from peer reviewed articles in the medical literature by a group of very highly qualified physicians.

MR JACOBI: Can I just ask you for it, Ms Caldicott. Who is the author of what you're currently reading from?

DR CALDICOTT: This is a summary from UNSCEAR document written by John LaFarge but he took out the main points of the IPPNW document but I didn't have time to print the main IPPNW document, which you can certainly access on the Internet.

COMMISSIONER: We'll do that.

DR CALDICOTT: And I would suggest that you do that, and I apologise for not having the original IPPNW document, which is imperative. The other thing I do want to say - - -

MR JACOBI: Can I also ask you, what's been the response in terms of the criticism that's been made, that's just been made there? When was that particular criticism made? That was made in 2014. Is that right?

DR CALDICOTT: Yes.

MR JACOBI: What was the response of the organisations to that?

DR CALDICOTT: The report was - actually UNSCEAR was 13 and this report by IPPNW - I'm sorry, I don't have the date that it was - 2014.

MR JACOBI: Perhaps if I - - -

DR CALDICOTT: The response is very little because not very many people either read the UNSCEAR documents or the IPPNW documents. They're not available to the public and there are not many people on television or radio promoting or talking about the results of this. I want to say one other thing: the only cancer that's being studied now in Japan is thyroid cancer. Thyroid cancer is caused by radiation, but all cancers - all cancers - are caused by radiation, and leukemia and the other abnormalities or pathologies I've

described.

They examined about 400,000 children under the age of 18 at the time of the accident by ultrasound, by fine needle biopsy and by removing the nodules. At this time - and they've still got more to go - 127 children have been diagnosed with thyroid cancer.

MR JACOBI: You suggested that the only cancer that's being studied is thyroid cancer.

DR CALDICOTT: In Japan.

MR JACOBI: What's your source for that particular statement?

DR CALDICOTT: God. The source - well, I'll have to send it to you.

MR JACOBI: If you don't know right now, that's fine. But I'd appreciate - - -

DR CALDICOTT: I need to take a note.

MR JACOBI: - - - if you could send it to us because these are - - -

DR CALDICOTT: Anyone got a pen?

MR JACOBI: Yes, I can make a note and provide it to you there after.

DR CALDICOTT: No, that's your pen. I cannot - where's my pen? Sorry, I don't have the source but it's not one source, it's many sources and I just want to finish that by saying the normal incidence of thyroid cancer in a population of children under the age of 18 is one to two per million and we've now got 127. These cancers appeared two to three years later. The cancers of thyroid in Chernobyl appeared four years later, although they didn't start looking for thyroid cancers until four years afterwards because the Soviet government denied what was going on in Chernobyl. There's been a huge number of thyroid cancers post-Chernobyl. I've got references to that in my books.

So thyroid is the first to appear but leukemia will start appearing at five years. So the latent period for thyroid cancer is about two to four years. Leukaemia is five to 15 years. We get that from the Hiroshima and Nagasaki data. Solid cancers start appearing about 25 years later. Their latent period of carcinogenesis is any time from 25 to 80 years, and no cancer denotes its origin. So you have to do big epidemiological studies - many of which have been done.

COMMISSIONER: Let's move on to some of the specifics of your

submission.

MR JACOBI: Can I just - in fact it's come up in something that I think you've already said, which is that you've expressed a view in your submission that no dose of radiation is safe and in fact that's something that you said today about your submission at page 3. I just wonder whether you want to offer a reference to support the conclusion.

DR CALDICOTT: Yes, I can.

MR JACOBI: I think you've otherwise expressed it in terms that even background radiation will give rise to a risk of cancer.

DR CALDICOTT: Yes.

MR JACOBI: I'm just interested in what is the source for that particular proposition.

DR CALDICOTT: BEIR VII report, the biological effects of radiation by the National Academy of Sciences. BEIR VII, biological effects of ionising radiation. They - - -

MR JACOBI: I'm interested particularly at low or very low doses; that is - - -

DR CALDICOTT: Yes, right down to zero. In fact a new study has been reported where about 400,000 nuclear workers have been studied and they've been studied by Public Health Department of England, the Institute of Radiation and Protection in France, the Centre for Research of an Epidemiological in Spain, et cetera, et cetera. It's an international study and it shows that the risk of cancer to nuclear workers - excluding neutrons, which are very carcinogenic - was double what they thought it was originally in their estimates and the doses go down to .1 rem per year, or .1 millisievert per year.

MR JACOBI: I think that's slightly different than my question. My question was directed at the idea of - I think the proposition was advanced that even background radiation can be demonstrated to cause cancer.

DR CALDICOTT: Yes.

MR JACOBI: I'm just interested in the evidence that supports that particular proposition.

DR CALDICOTT: That's just generally known in the medical literature. I didn't bring the medical literature with me but I'm sure it's written in the BEIR report for biological effects of ionising radiation. We accept that, and I'll

tell you why - - -

MR JACOBI: But can I just raise that we've at least seen some contention in submissions about - - -

DR CALDICOTT: I know.

MR JACOBI: - - - the LNT hypothesis and its - - -

DR CALDICOTT: It's not a hypothesis; it's proven. It's proven by this extraordinary study of all these nuclear workers were right down to zero there's an excess incidence of cancer, right down to zero. This is a peer reviewed study done by international Centres for Disease Control, National Institute for Occupational Safety, Department of Health and Human Services. This is all done by international organisations and they all agree and it was published in I think The Lancet. So there's no disagreement.

Now, let me just go back for a second. It's background radiation when the earth was much radiologically hotter that induced mutations that caused fish to develop lungs, birds to develop wings and eventually this wonderfully species of us developed with opposing thumbs and huge brains. However, most mutations are deleterious and cause disease and they cause cancer, and they cause abnormalities like mutations and - which I'll show you with the swallows and the like. So background radiation is a cause of mutation. Mutations in a regulatory gene in a cell can cause cancer. Mutations in other genes can cause genetic disease. Therefore background radiation is responsible for I think about 30 per cent of the cancers we already see.

MR JACOBI: I was going to ask you about that as well.

DR CALDICOTT: Even the mummies in Egypt had cancers. So that's why cancer is more common in older people, because we live longer and are exposed to more background radiation and x-rays, and also the 80,000 chemicals that are in common use now, many of which are carcinogenic. So there's a synergism between radiation and chemicals in the environment.

MR JACOBI: Can I also ask you - I'm interested actually to go back to the 30 per cent. Do you have a source for that particular division between cancers that are said to be induced from background and otherwise the 70 per cent, which I assume is from other intermediate or anthropogenic sources?

DR CALDICOTT: Yes, I do. I think it's in my book here, but I'll have to look it up for you, okay, and I - - -

MR JACOBI: That's all right. Perhaps we can write you an email after this

and ask you - - -

DR CALDICOTT: Why don't you write me an email? I'll send you the reference.

MR JACOBI: We'll do that. That would be terrific.

DR CALDICOTT: Yes. Sorry, I can't - - -

MR JACOBI: That's all right.

DR CALDICOTT: I couldn't come with all references in hand.

COMMISSIONER: No, that's fine. Well, it's not a quiz in that sense. So we haven't - - -

DR CALDICOTT: Well, it kind of is, but I have to have everything in my hand. Background. Here we are. 40, 44. I don't know if it says it. Radiation, health.

> *It's thought that about 80 per cent of cancers we see are caused by environmental factors, whereas only 20 per cent are inherited. Cancer has plagued the human race. It is generally accepted that many cancers in the past and the present have been and are caused by background radiation.*

And then I said because aging exposes people to increased levels it's a disease of old age. But I can certainly send you the reference to that.

MR JACOBI: Can I just ask you, in your submission under a heading - this is page 4 at fact number 3 - you refer to acute radiation sickness.

DR CALDICOTT: Yes.

MR JACOBI: And then there's a statement following it that, "Reports of such illnesses, particularly in children, appeared within the first few months after the Fukushima accident." I'm interested in the source of that particular statement.

DR CALDICOTT: Okay. Acute radiation sickness is - I was actually wrong with that. Acute radiation sickness is when you get a hell of a dose of radiation and it was newly described by - we'd never seen this before until Hiroshima happened, and one of our journalists - and I can't remember his name - got in past the American military and looked at the disease in the hospitals and doctors were scratching their heads. People were dying with their hair falling out, blood under their skin, vomiting, and bleeding to death, and what we

realised was that very high levels of radiation kill the actively dividing cells of the body, which is hair, gut and blood cells.

And that man, Litvinenko. Do you remember the Russian man who took tea in Claridge's and someone dropped some polonium in his tea, and he died within two weeks of acute radiation illness, hair dropping out and the like? Actually patients we give high radiation doses to with cancer trying to cure them and get - - -

COMMISSIONER: We're trying to understand your evidence in relation to Fukushima.

DR CALDICOTT: Yes. That's right. So there's a report, and they're anecdotal. They're not collected by physicians, because physicians aren't collecting on the ground this sort of data. Anecdotal reports of lots of children developing nose bleeds, meaning they were low in platelets. And I do have some physicians' reports from Tokyo where the fallout was very high, and there are a lot of infectious diseases. So when radiation damages the white blood cells, you're much more predisposed to infection than normal people, particularly children.

MR JACOBI: Yes. UNSCEAR - and though I understand your views you've expressed about UNSCEAR - have expressed a view in its report, and this is at page 11, paragraph 38, that, "No radiation-related deaths or acute diseases have been observed amongst the workers or general public exposed to radiation from the accident."

DR CALDICOTT: Well, that's because they haven't been studied by doctors, or analysed and written up in the literature. So they're winging it, because they don't know. There's no data and the data I have comes from my colleagues who are treating patients in Tokyo and high radiation areas and it's anecdotal and I'll send you that, but please send me an email.

COMMISSIONER: Yes, we will. The UNSCEAR report we had the other day had doctors involved - - -

DR CALDICOTT: What sort of doctors? Medical doctors?

COMMISSIONER: Medical doctors, yes. Well, that was the evidence we were given.

DR CALDICOTT: Well, I'd like to see their credentials, please.

COMMISSIONER: Okay. Well, I'm just trying to understand the differences of view.

DR CALDICOTT: Yes. I understand from your perspective as a lay person who it's very hard to understand this. It's very complex, but if you ask any of my colleagues - what I'm saying is - - -

COMMISSIONER: What is complex is that you say that there are no medical doctors in that and the people responsible for the UNSCEAR report say there is.

DR CALDICOTT: All right. Well, I need to see them.

COMMISSIONER: Okay.

DR CALDICOTT: Yes, and their affiliations.

MR JACOBI: Your submission says that, as I understand it, that Fukushima will cause an epidemic of cancer as people inhale or ingest radioactive elements, I think expressed in terms of eating or drinking, and as I understand it, that's an argument that is based on biological accumulation. Is that right?

DR CALDICOTT: Well, too, their initial exposure by very high levels of gamma radiation from the short-lives isotopes as they fled into plumes of radiation, and also with what's being discharged daily from the Fukushima reactor, and into the water, three to 400 tonnes per day since the accident of very highly polluted radiation water into the Pacific per day, three to 400 tonnes, and the oceanographers are examining this. It's now starting to be found on the west coast of America and Canada.

Tuna are being caught in California with caesium emanating from Fukushima. We could be catching fish now that swim south instead of west to east with radiation in them from Fukushima. And it's going to get worse, because there's no way they can stop that flow of water into the Pacific. It's very, very serious.

MR JACOBI: Again, though I understand what you said about WHO and UNSCEAR, WHO, in their report in 2013, expressed the view that - and I'm quoting here - "Outside the geographic areas most affected by radiation, even in locations within Fukushima, the predicted risks remain low and no observable increases in cancer above natural variation in baselines are anticipated."

DR CALDICOTT: How the hell do they predict that? No one measured the doses that people received. No one has put the people in whole-body counters to find out how much caesium, et cetera, they have in their bodies. No one knows how much radioactive iodine they inhaled or ate in their food or drank in their milk, because radioactive iodine only lasts for 120 days and then it

decays to zero. The measurements haven't been done. In fact, the only scientist in Fukushima and Chernobyl actually getting data is Tim Mousseau, an evolutionary biologist who's looking at the birds. Can we go back to the slide, please, Lucy, of the swallows?

Yes. Okay. He's examining the barn swallows both in Chernobyl and Fukushima. The little white patches are albinism. Their mutations producing white feathers, and under the beak there's albinism. That's a beak deformity, number F, caused by a mutation. That's their air sacs, abnormal air sacs, number G. These are abnormal tail feathers caused by mutation, and I don't have one with cataracts actually. That's a normal one in A, but many of the birds have cataracts. 40 per cent of the male birds are sterile. Their brains are smaller than normal. Their populations are decreasing. What happens to birds happens to humans.

Look at me Chad. We test our drugs on animals to make sure they'll be safe for humans. That's how we practice medicine. Animals have the same biological systems as us. So you can extrapolate from the barn swallows and other animals, they've been - and they've written several hundred papers in peer-reviewed literature. This is only actual data collection that is going on in Japan right now. So it is for WHO and UNSCEAR to extrapolate with no data, no dose. They're just guessing. They guess the measurements, and that's not science.

This is science, and this man will win the Nobel Prize, I think, because he's changing our attitude towards radiation by doing basic research which no one else is doing. He can't even get funding for the research, because the nuclear industry is so powerful, it influences government so he can't get funding to do this basic biological research.

MR JACOBI: You've expressed that in terms of exposure, and as I understand it the UNSCEAR report, and your submission refers to the fact that people were exposed to high levels of whole-body gamma radiation.

DR CALDICOTT: Yes.

MR JACOBI: And the UNSCEAR report on that topic states that for adults the effective dose - and that's expressed in millisieverts - estimated to have been received before and during the evacuation was on average less than 10 millisieverts and about half that level for those evacuated on 12 March 2011.

DR CALDICOTT: It's an estimate. They didn't measure. No one measured it. It's an absolute estimate. That's what they did about Chernobyl, the Chernobyl report. They estimated. They don't get on the ground and actually

measure the food, measure people with whole-body counters. They don't, like these doctors in Russia - this is the only document that actually looks at diseases in people in the Ukraine and Belarus and around the area. I may say that there's a war going on in the Ukraine at the moment. There are 15 reactors the same size as Chernobyl. Any bomb dropping on a reactor could cause a meltdown. This is the most extraordinary document. I'm a paediatrician and highly trained, if I may say so. It's the most extraordinary medical document I've ever read. Now, it's not very carefully peer reviewed. Therefore the New York Academy of Sciences, they published it but after a few years they disclaimed it because there were quite a few pro-nuclear people on the academy and they said, "Well, it's not peer reviewed." It's the only document that's been done. The only medical data on the ground to look at patients.

MR JACOBI: On that topic, perhaps we'll come to Chernobyl. I know about the - the document you're referring to is Yablokov document, as I understand it.

DR CALDICOTT: Yes, Alexey Yablokov and Nesterenko.

MR JACOBI: Prior to that time there was the Chernobyl Forum. This was a - - -

DR CALDICOTT: Who organised that? WHO and IAEA.

MR JACOBI: It was UNSCEAR, the World Bank, WHO, the IAEA.

DR CALDICOTT: The World Bank? What are they doing - - -

MR JACOBI: And the governments of Belarus, the Russian Federation and Ukraine. They expressed the view - - -

DR CALDICOTT: What year was that?

MR JACOBI: That was between 2003 and 2005 and I understand they produced a report for 2006. The Yablokov document you've just taken us to, as I understand it, has been criticised by the Australia of the UNSCEAR work in 2008.

DR CALDICOTT: Of course. But the UNSCEAR people did not go to the doctors, to the clinics, to look at the children, to look at the leukaemia, to look at the diabetes, to look at the premature aging in children, to look at the micro carefully. In Sweden where they got a high fallout there's a very good report to show that babies in utero at the time of the accident had lower IQs than normal. That's because the developing embryonic brain is very sensitive to radiation. There's another study I want you to know about, the KiKK study. Germany - and you know they're very meticulous with their data - looked at children under

the age of five who lived within five K of nuclear power plants all over Germany. They found that the incidence of leukaemia in children under the age of five is double normal and the incidence of solid cancers is high. That study was repeated in England and France.

If you live near a nuclear reactor with its normal emissions every day - tritium, carbon-14 and all the rest - it's dangerous and children are 10 to 20 times more radiosensitive than adults. Little girls are twice as sensitive as little boys and foetuses hundreds of times more so. But the nuclear industry takes a normal 70-kilogram white 20-year-old male as a standard to apply radiation doses.

COMMISSIONER: Can you go back and answer that question again please, so that we get an answer on it.

MR JACOBI: The question I asked was with respect to - I was interested to understand why you prefer the work that was done by Yablokov - that is, the document which you've just come to - over either the Chernobyl Forum work, which was the joint work, or the UNSCEAR 2008 report.

DR CALDICOTT: Because all their data was gleaned by calculations and guesswork. They didn't go on the ground to take actual measurements of food, actual measurements of radioactive elements in people by whole body counters, go to the clinics to see the long-term effects. You know, Chernobyl was 86. What's this now? It's about 30 years since Chernobyl. We're still waiting for more cancers to develop. The Hiroshima data showed cancers are still arising amongst the hibakusha many years since that bomb dropped. You've got to understand how cryptogenic and latent cancer, and silent cancer, is post-radiation. You can't rely on guesses by nuclear engineers and calculations. That's not science. Science is knowing what - if I guessed about my patients without actually doing the tests, I'd be deregistered.

COMMISSIONER: We'll explore those comments with the authors of the report.

DR CALDICOTT: Well, they will deny it. There's a lot of emotion in this issue, Commissioner.

COMMISSIONER: I do appreciate there is a lot of emotion. Can we proceed.

DR CALDICOTT: Especially as I've treated dying patients with cystic fibrosis - I mean children. Yes, I'm emotional. I took the Hippocratic Oath. I'm here to save lives, not to help to induce epidemics of cancer, leukaemia and genetic disease in all future generations from nuclear power.

COMMISSIONER: I doubt whether the UNSCEAR experts would say they

were either.

DR CALDICOTT: Really?

COMMISSIONER: Yes.

DR CALDICOTT: Then they're denying data. I just want to say one other thing, and it's anecdotal. I gave Grand Rounds - I don't know if you know that. It's a weekly medical meeting that Royal Adelaide Hospital has to discuss diabetes or neurosurgery. I did Grand Rounds at the Children's Hospital Medical Centre at Harvard recently where I worked. The top paediatricians in the world. I walked them through the whole nuclear fuel chain and the medical implications. They were stunned. They turned ashen-faced and one of them said, "What are we going to do about this?" Now, these are the top paediatricians in the world. They did not question my data. It's self-evident. We all know what I talked about. It's medicine.

COMMISSIONER: I guess it needs to be proven. That's what we're here to do.

DR CALDICOTT: It is proven because we've got the documents. Well, as far as we can go. I mean, you know, there's a lot more work to be done obviously.

COMMISSIONER: Indeed. Indeed.

MR JACOBI: I think coming back to Yablokov's work, I think your submission cites that work in support of the statement that over 1 million people have already perished as a direct result of the catastrophe, and the catastrophe referred to was that of Chernobyl.

DR CALDICOTT: Yes.

MR JACOBI: And I'm just interested to understand whether you could explain how that million people has been arrived at.

DR CALDICOTT: Okay. So let's go back to the first slide. This is the fallout from Chernobyl and I don't know what - it was 2000. I guess I will go - can I go up to the slide?

COMMISSIONER: Sure. June 2002.

DR CALDICOTT: So here's Chernobyl, right. This is the Ukraine where there's a war going on, and Belarus. Now, the very dark areas got a huge amount of fallout and people - these are exclusion zones. They can't live there any more. The lighter ones are also extremely high fallout. You can see how it

spread throughout Europe, Austria. What they don't have here is Turkey. Turkey got a very high fallout and the Turks were so annoyed they picked all their radioactive tea and sent it to the Russians because they were so annoyed with them. But Turkey is still - don't buy Turkish dried apricots or Turkish food because Turkey is still very radioactive and it will last for hundreds or thousands of years.

Finland, Sweden - so the accident was first picked up in Sweden and the Swedes said, "What's going on?" Gorbachev denied it, until he had to admit it. Norway - there are farms in the United Kingdom now, in Cumbria, over 300 farms farming lambs and the lambs are so full of caesium the government went to the farmers and said, "You've got to shut your farms down." They said, "What? For how long?" and they said, "Oh, about a hundred years." It's not. It's 300 years. That's how long caesium lasts because the caesium lands on the ground, concentrates by orders of magnitude in the grass and in the lands.

There are wild boar running around Germany at the moment so radioactive they almost glow in the dark, and it's ongoing. As plutonium-241 decays to americium-241, as all these elements decay, americium-241 is much more dangerous than plutonium-241 which is all over the place. It's because it's a very high gamma emitter. So these areas will become more and more radioactive over time.

MR JACOBI: Can I just take you back to the question that I asked, which was about the 1 million figure.

DR CALDICOTT: Yes.

MR JACOBI: Is that calculated by multiplying an LNT prediction against a large population set? Is that how the million is arrived at or how was the million arrived at?

DR CALDICOTT: Would you please send me that question and I will give it to you in the reference.

MR JACOBI: I just want to just raise something with you, which is that again going back to UNSCEAR, it's 2008 report - and this is at page 64 and 65 of its report, states that there were a total of 28 deaths of plant staff with 134 diagnosed with ARS and there were 6000 thyroid cancers observed, of which 15 proved fatal. Their conclusion at paragraph 100 is that the vast majority of the population should not live in fear of serious health consequences.

DR CALDICOTT: So they said 39 people died, the liquidators?

MR JACOBI: No, sorry, I'll start again. A total of 28 deaths - - -

DR CALDICOTT: 28?

MR JACOBI: - - - of plant staff with 134 diagnosed with ARS. 6000 thyroid cancers observed, of which 15 proved fatal. Then I'm interpolating from another paragraph that the vast majority of the population should not live in fear of serious health consequences. I'm just interested in the difference between the million and - - -

DR CALDICOTT: It's extraordinary. I can't understand what they're talking about because the data shows that it's been collected by the Russians that over half the - there were 600,000 liquidators. They were farmers, soldiers, people brought from all over Russia and they were handling spent fuel rods in their bare hands, over half have been seriously ill but I can't – I will have to send you the exact figures of how many have died. I've got them in this book; I'd need to look it up, if you want me to.

COMMISSIONER: Well, you can send us the data.

DR CALDICOTT: Please send me the email and I'll send it to you. An enormous number have died from cancers, leukaemias, their babies many are being born deformed, so I don't know where UNSCEAR thinks it gets its figures from. It's guess work. Twenty-eight people died.

MR JACOBI: I need to qualify what has been said. As I have said, they said the - - -

DR CALDICOTT: Makes me tear my hair out, I'll tell you. As a doctor it's just – they're lying.

MR JACOBI: Well, I'm - - -

DR CALDICOTT: You can't lie about human health. If I lied in medicine, I'd be dismembered – I mean deregistered.

MR JACOBI: I am endeavouring to quote from paragraph 99, which I have read, which says that:

> *The observed health effects currently attributable to radiation exposure is as follows, 134 plant staff and emergency workers received high doses of radiation that resulted in ARS. The high radiation doses proved fatal for 28 of those people, while 19 (indistinct) survived and died up to 2006.*

DR CALDICOTT: And what year was that?

MR JACOBI:

- - - *(indistinct) various reasons.*

This is a 2008 - - -

DR CALDICOTT: But when did they take that data from? From what year was that data gleaned?

MR JACOBI: I can't give you an answer.

DR CALDICOTT: Well, then that's very important because since the accident it has been horrendous for the liquidators.

MR JACOBI: Well – and my understanding is that from the following - - -

DR CALDICOTT: And it's wrong. It's absolutely wrong.

COMMISSIONER: Just finish - - -

MR JACOBI: Sorry - - -

DR CALDICOTT: Okay.

MR JACOBI: - - - just to answer your question Ms Caldicott, the – paragraph 100 suggests that that annexe is based on 20 years of studies and from the previous UNSCEAR reports.

DR CALDICOTT: Twenty years of studies of what? The Chernobyl liquidators, or 20 years of studies of what?

MR JACOBI: As I understand it, the complete body of scientific material that was available at the time.

DR CALDICOTT: There was no body of scientific material except that gleaned from Russia and the clinics treating these patients. Where did they get that scientific material from? What's their source please?

MR JACOBI: Well, that's indeed the question that I'm asking you with respect - - -

DR CALDICOTT: Well, that's a question I'm asking.

MR JACOBI: - - - (indistinct) indeed, that is the reason why we (indistinct) understand it.

DR CALDICOTT: Well, I can certainly source you the correct information for that. Certainly.

MR JACOBI: Right.

DR CALDICOTT: There has been a lot of work done on this and it continues as these people still die with horrendous stories from their relatives.

MR JACOBI: Now - - -

DR CALDICOTT: See what staggers me is that – I mean I know you're a lawyer and I know you're a (indistinct) man but these people have no understanding of what they're talking about and – but they sound very formal and they're a UN body and the like but they haven't got the data on the ground. It's like me trying to guess what I do with a patient without reading the literature and knowing absolutely what I'm doing.

COMMISSIONER: We'll certainly quiz them about where they get their data.

DR CALDICOTT: Well, I'm sure you will but whether you'll get honest replies, I don't know. I'll tell you where I get my data and it's valid.

COMMISSIONER: Well, okay that's certainly what we need to - - -

DR CALDICOTT: Yes.

COMMISSIONER: - - - complete our investigations.

DR CALDICOTT: And thank you for having me, if I may say.

COMMISSIONER: Pleasure. Are there any other - - -

MR JACOBI: Yes. There was just one matter that I just want to just - - -

DR CALDICOTT: Yes.

MR JACOBI: - - - deal with, and that is you have referred, I think by reference to the map, to areas in which there are – there is existing contamination and I think you referred to increasing risks. Again, as against the UNSCEAR report, and the UNSCEAR report refers to the areas that are contaminated and perhaps particularly with respect to caesium, because its decay rates are in fact shrinking.

DR CALDICOTT: Yes.

MR JACOBI: And I'm just interested to understand what the basis of your view is in contrast to that, which I think suggests that it was in fact increasing risks as opposed to decreasing risks.

DR CALDICOTT: But remember that I showed you the chart of all the radioactive elements.

MR JACOBI: Mm'hm.

DR CALDICOTT: Why have they just picked out caesium?

MR JACOBI: Well, they haven't. I have picked out caesium and asked them about that.

DR CALDICOTT: Well, what else have they picked up?

MR JACOBI: Well - - -

DR CALDICOTT: Please?

MR JACOBI: - - - they include at page 52, a chart which shows the total activity of radionuclides by petabecquerels.

DR CALDICOTT: Yes, but what - - -

MR JACOBI: And deals with caesium, plutonium, americium, caesium - - -

DR CALDICOTT: Americium.

MR JACOBI: Americium and both of the plutoniums, 239, 240 and 241.

DR CALDICOTT: Yes. So let me read you this, if I can find it, and I'm sorry I have to look, I know exactly where it is on the page but - - -

MR JACOBI: That's all right.

DR CALDICOTT: You know, these Russians looked a chromosome elaborations in cells, hugely important scientific investigation. Sorry about this, and I'm wasting time.

MR JACOBI: That's all right.

DR CALDICOTT: It's not really – very specific. Yes, the territory contaminated by plutonium today where the level of alpha radiation which I explained, is usually low, will again become dangerous as a result of the future disintegration of plutonium 241 to americium 241, and I referred to that, in the ensuing tens and even hundreds of years. An additional danger of americium 241 is its higher solubility and consequent mobility in to ecosystems and food compared with plutonium. It's very complex. All these isotopes, many of which have never been examined from the biological perspective, we don't know where they go in the body, we don't know what isotopes – I mean for instance, caesium is a potassium analogue, it's like potassium, so it goes to muscles and to brain where it induces tumours and cancers and rhabdomyosarcomas and heart attacks, strontium is a calcium analogue, it goes for bone but there are very few isotopes studied by the Health Physics Association of America and I read all their – I wrote an article for the New England Journal of Medicine about all of this and spent a year researching it at the Harvard Library. Very few of the isotopes have actually been studied about their biological consequences and I showed you the number of them. It's quite extraordinary. So they are sort of skimming on the surface, just looking at caesium and strontium and maybe tritium but not really and maybe americium but the others are ignored. This is very serious because they all got out when you have a meltdown.

COMMISSIONER: Dr Caldicott, than you very much for your evidence this morning. Thank you for coming across to - - -

DR CALDICOTT: Thank you.

COMMISSIONER: - - - give us your views. We will follow up with some - - -

DR CALDICOTT: Yes.

COMMISSIONER: - - - questions about - - -

DR CALDICOTT: Yes. And I will send you more references, so you know what I'm talking about.

MR JACOBI: Perhaps we can indicate that we will publish the letter and the response.

DR CALDICOTT: That would be good (indistinct)

MR JACOBI: But we will deal with it by reference to - - -

DR CALDICOTT: And I appreciate you inviting me.

MR JACOBI: - - - specific sources.

DR CALDICOTT: As I have spent my life trying to work on this subject. I started when I read *On The Beach* when I was 15 and then I did medicine in 56 and learnt about radiation and genetics, so I've been on to this always.

COMMISSIONER: Thanks Dr Caldicott. We will adjourn until 13.00 when we will have Dr Carl-Magnus Larsson, the Australian Radiation Protection and Nuclear Safety Agency.

ADJOURNED **[11.57 am]**

RESUMED **[1.03 pm]**

COMMISSIONER: We resume, and I welcome Dr Carl-Magnus Larsson. Counsel.

MR JACOBI: The Australian Radiation Protection and Nuclear Safety Agency, ARPANSA, is the Commonwealth government's primary authority on radiation protection and nuclear safety. Its functions are multifaceted and include regulation, research and promotion of radiation protection standards that are consistent across Australian jurisdictions and in line with the international standards. Dr Carl-Magnus Larsson commenced as the chief executive officer of ARPANSA in 2010, and prior to that, Dr Larsson worked in senior positions at the Swedish Radiation Safety Authority.

He has coordinated multinational European commission- supported research projects, Facet and Erica, both on environmental assessment and protection, and has been a member of the OECD, NEA, Radioactive Waste Management Committee, RWMC, and the chair of the RWMC regulators' forum. He is the Australian representative to the United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, and was the chair of that committee between 2012 and 2015, and the Commission calls Dr Carl-Magnus Larsson.

COMMISSIONER: Dr Larsson, thank you very much for joining us. Before we start with the evidence, I want to trace some of the evidence that we were given earlier today in relation to UNSCEAR, and I'm particularly interested to understand how information as collected, what sort of information was collected, and perhaps you could start with explaining broadly how that happened, over what period.

DR LARSSON: I assume that we are talking about the Fukushima assessment here.

COMMISSIONER: Yes. Fukushima.

DR LARSSON: Because obviously UNSCEAR's work expands over many, many different areas. The assessment was based on available information, scientific information that was being generated in Japan and by international organisations, and was published, and we had extensive access to extensive datasets gathered by all these organisations, including also a number of non-governmental organisations that we can also use to benchmark our databases against. UNSCEAR is not an organisation. That's something that we probably need to point out. It's a scientific committee which is set up by 27 United Nations member states and it reports directly to the United Nations General Assembly.

So it's not an organisation that has its own staff and own laboratories. It collects scientific information, analyses the information and provides information to the General Assembly on sources and effects of radiation. That's the way it works.

COMMISSIONER: So within that group that did the Fukushima accident, could you just give me an explanation of the sorts of scientific staff that were associated with that particular investigation?

DR LARSSON: Well, there was a team of about 80 international experts.

COMMISSIONER: 80?

DR LARSSON: Yes, around about 80, and they were all nominated by the member states of UNSCEAR, but also from a number of other United Nations member states. But my personal estimate would be that probably the total number of scientists that were involved in the study was maybe three times larger, because all of these individuals would have also worked with people back in their own laboratories and their own institutions. So I would estimate that around about 200 people would have been involved in this, as we did at ARPANSA, although I'm the representative and we had a number of other members of our staff that were also members of the group. We interacted with other people that we had back home in our organisation.

So that's basically a very big international effort involving 80 scientists that were directly nominated, but also a number of other - - -

COMMISSIONER: And what sort of qualifications would those 80 (indistinct)

DR LARSSON: They were generally scientists or have a scientific background and be used to this kind of work in the particular specialised fields. The project was divided into different work packages, so to speak. You were

last week discussing these matters with Dr Solomon of ARPANSA who was in charge of the dose estimates to the public and also dose estimates in the environment.

COMMISSIONER: Were there doctors engaged with this group?

DR LARSSON: Are you referring to medical doctors or scientific doctors?

COMMISSIONER: Medical doctors. Yes.

DR LARSSON: Yes. Some of them, some of their representatives and some of the experts that participate in the deliberations of UNSCEAR. They have expertise in medical fields. Some of them are practising doctors.

MR JACOBI: Can I just ask as well, was information collected from physicians working within Japan in terms of health effects or information collected from organisations such as hospitals or other organisations providing treatment?

DR LARSSON: Well, over the years that the report was prepared, there has been a lot of interaction with the medical profession in Japan, in particular the Fukushima Medical University which also of course is responsible for running the Fukushima Health Management Survey. So, yes, there has been a lot of interaction.

COMMISSIONER: In terms of understanding the impact of radiation on foliage and crops, did the organisation have access to that information?

DR LARSSON: The organisation - as I said, it's not an organisation. It's a committee.

COMMISSIONER: Sorry, the study group.

DR LARSSON: Yes. So we don't have the staff that can go out and do the sampling or do the experimental work and the laboratory work themselves. However, a number of the members of the study team, they went to Japan for specific purposes, for specific questions, and in particular, the group that was set up to work on the radiation exposure workers went to Japan to on site get in-depth information on the methodology, the equipment and so forth, that was used in order to get information on the exposure of the workers.

COMMISSIONER: Thinking about that exposure, did the group examine cancers beyond thyroid cancer?

DR LARSSON: Well, absolutely. Thyroid cancer was one subset of the

investigation, obviously a very important one. We know from the experience from Chernobyl of course that this is something that we need to give due attention, but the Committee examined all cancers.

COMMISSIONER: All cancers.

DR LARSSON: All solid cancers as one group, and also special cases of thyroid cancer obviously, breast cancer, and outside of solid cancer, also leukaemia.

COMMISSIONER: Okay. In terms of - and if you don't have the background for that, that's fine - in terms of - in terms of the investigation and Chernobyl, was it a similar size body with the same principles?

DR LARSSON: It worked basically on the same principles. It was obviously 1986. It was pre-Internet time, pre the enormous flow of information that we have seen since, and it had to rely on a lot of information that was being provided and was also very generously provided by the Soviet Union, as it was at the time. But of course the premises for the whole study was different, because it was 25 - more than that - years ago, almost 30 years ago.

COMMISSIONER: Did you collect in the Fukushima activity evidence about caesium and iodine?

DR LARSSON: Well, UNSCEAR didn't for the reasons that I just stated, hasn't collected those data but data has been made available by various sources and also from going through the open scientific literature. And it's not only caesium and iodine. It's obviously all radioactive substances that would be of interest in an assessment like this. So the UNSCEAR assessment considered all relevant elements, but in the early phase obviously iodine is a very significant portion of the exposure, and also because of the specific exposure pathways that potentially could end up with radiation exposure are children, it's something that needs to be considered.

In the long run, the caesium-137, in particular caesium-137 and 134, at least in about a 1:1 ratio, caesium-134 has a half-life of two years, so it disappears relatively quickly, but caesium-137, obviously a half-life of 30 years, and in the long run that becomes the dose dominant radionuclide, but UNSCEAR also considered other radionuclides and in particular in the early phases also the very short-lived radionuclides. So they have all been considered, but focus is, as you mentioned, on iodine and caesium for the reasons that I just gave.

COMMISSIONER: And finally, it's been put to us that UNSCEAR is a pro-nuclear body and therefore there should be some question about the findings.

DR LARSSON: Well, all the 80% participants in the study signed forms where they had to indicate whether there was any particular interest, declaration of interest, and to my knowledge, there was none of them where we concluded that there was a conflict of interest. UNSCEAR is not pro-nuclear or anti-nuclear. It was set up in 1955 to report on sources and effects of radiation to the General Assembly, and that was obviously at a time when there was still ongoing atmospheric weapons testing, and there were 15 counties that were invited by the Secretary General at that point in time, Australia was one of them.

It's now grown to 27 countries and all these countries nominate a national representative, and I have the honour of being the Australian representative at some point in time. And the countries can also nominate alternates and expert advisors to these representatives. It doesn't have any coupling to the nuclear industry or to the anti-nuclear movement. It's a scientific committee that works on science purely.

COMMISSIONER: Thank you.

MR JACOBI: Perhaps if we can start with some of the issues that we want to discuss with you today, perhaps at the level of some fundamentals.

DR LARSSON: Yes.

MR JACOBI: I'm just wondering about whether you could offer a brief explanation of the distinction between dose absorbed and effective dose. The document is going to be significant for some of the issues we're going to cover.

DR LARSSON: Yes. Well, the basic physical quantity when we talk about the radiation dose is the absorbed dose, and the absorbed dose is the amount of energy that is being deposited in the receiving matter, in the body, for instance. So it is essentially energy deposited per kilo of that matter. That's the basic physical unit. Now, in order to transform this into something that can be used for radiation - - -

MR JACOBI: And that's measured in gray? Is that right?

DR LARSSON: That's measured in gray, yes. That's measured in gray. And in order to be able to use that information in radiation protection, for instance, we need to convert it to something where we can start to understand what is the relationship between those and the effect that it can have. And we have a number of other quantities that we are discussing then, and that may sometimes be confusing. We can multiply the absorbed dose with a quality factor which is dependent on what type of radiation that you're receiving, whether it's alpha,

beta, gamma and so forth, and that gives an indication of the biological effect that it would have, which is higher for alpha radiation, for instance, than it is for beta and gamma.

We can also go to the next step where we include the different sensitivities of different tissues in the body, and we weigh that together and we get something which is called the effective dose, and normally when we're talking about exposure, as you probably are going to discuss here a little bit later, we are talking affecting dose. The effective dose is a quantity that is used for radiation protection purposes, but it is risk related. It is not possible to convert it so that you can say that it's exactly a risk per unit effective dose, but it is risk related, and therefore it becomes useful also in radiation protection. And the equivalent dose and the effective dose is measured in unit sievert.

MR JACOBI: As I understand, it's sometimes in a thousandth or a millionth. Is that right?

DR LARSSON: Well, what we are supposed to hear during a year when we are doing work like this is in the order of a few millisievert.

MR JACOBI: Now, again as just a basic question, fundamentals, in terms of the sources of radiation, could you offer just a very briefly outline about what the sources of radiation are to which we are exposed?

DR LARSSON: Yes. We can move to that pie chart, which is a completion of the information that we have. Now, this is obviously information that is lumped together for what we call here the average Australian. So it can vary dependent on where you live, what are you doing, whether you are actually exposed to medical examinations or undergoing medical examinations or even medical treatment. But for the average Australian, if we lump all that information together you will see that you have a large portion there which is to the left, which is the exposure to the average Australian from medical examinations, and you will see that this is actually more than half of the exposure.

Of course if you don't go through any medical examinations you won't have that, but a lot of people will also have much more than that. The other contributors are mainly what we refer to as natural background radiation. You've got cosmic radiation, which is coming from outer space. You've got a terrestrial source, which is radiation from bedrock and so forth. Radon and progeny is - we are fortunate in Australia. It's a relatively small problem in Australia compared to many other countries. There is a contributor.

Potassium 40 is a primordial element. It was there when this planet was created and it contributes to some internal exposure as well, and we've got

uranium and thorium in the bedrock and their decayed chains that also contribute some of it. Atmospheric weapons testing is now something which is down to a very low level, and so with the exception for atmospheric weapons testing, we can call all the others background radiation. The background radiation in Australia is about - for the average Australian, once again - round about 1.5 millisievert in a year, and then you have an extra component there which is about the same, which comes from medical diagnostic tools of radiation and medicine.

MR JACOBI: Yes, and perhaps we should just unpack. What is the average Australian, for the purposes of this?

DR LARSSON: The average Australian is just looking at all the sources, pulling that together for the whole Australian population, and dividing it like this for the average individual and for one year.

MR JACOBI: And given our focus on source, I notice that on the bottom it's referred to as a publication put out by ARPANSA itself.

DR LARSSON: Correct.

MR JACOBI: How is that calculated and who calculates that?

DR LARSSON: Well, ARPANSA has over the year done a lot of measurements. There's radon mapping. We know the geology of the country of course. The cosmic radiation can be measured. What can be difficult to get really precise information around is of course the use of radiation in medicine, although we know roughly how many procedures that are being used in Australia in a year. There is also a little bit of difference in that they could be different kinds of procedures, there can be different doses from different procedures. You have brand new equipment versus equipment that is one or two years old and so on but the best information that we – the best information that we can get, or by using the best method that we can use we have compiled the data and that indicates that the medical exposure would be in the order of 1.7.

COMMISSIONER: Is that a conservative assessment?

DR LARSSON: No, that’s a relatively realistic, I would say - - -

COMMISSIONER: Realistic.

DR LARSSON: All of this would be realistic but I would also emphasise again that the - - -

MR JACOBI: It's an average.

DR LARSSON: - - - average Australian doesn't really exist, we – none of us is really average but if you lump everything (indistinct)

MR JACOBI: It invites the question, I guess perhaps if I can deal with just the – what you might describe as radiation from natural sources as opposed to the anthropogenic ones about what the variability is. I think you mentioned it is different elsewhere. Are you able to give an idea about the sorts of ranges that are involved?

DR LARSSON: For - - -

MR JACOBI: For natural radiation sources.

DR LARSSON: Yes. Well, globally, if you look globally that would range widely and UNSCEAR has estimated that the range is between one and 10 millisievert, actually between one and 13 millisievert. But also stated that there are very significant population groups that would be exposed to a much higher level than that, we are talking about tens or hundreds, or thousands of people that would be above that. So it varies, as I said, a lot between different countries. Some of the contributors to that variability are radium, some of the northern countries for instance where I come from, the radium country (indistinct) substantially higher than what it is here in Australia. And the contribution from medical, that's not (indistinct) sorry, that's not natural cause but if we look at that as well, that will also be dependent on the level of health care in different countries and it is certainly higher in countries like Japan and US than it is here, but in some of the European countries it is also lower.

COMMISSIONER: I understand from some of my readings that it can be up around 30 and 40 in places - - -

DR LARSSON: There are such places. There are - - -

COMMISSIONER: Yes.

DR LARSSON: - - - such places, yes.

MR JACOBI: If I can come just to deal with the average for the anthropogenic medical, I am just wondering whether you can give some context in terms of what dose in millisieverts a person would expect to get if, for example, they undertook a CT scan or something like that?

DR LARSSON: That could be up to in the order of 10, so – and if you have multiple of course that would be just accumulate. There is a drive to get those

doses down and we are probably going to talk a little bit later about that. So we can see some positive progression here of the exposure. But it's also the use of CT; it's also something that is increasing. Obviously it's increasing for good reasons because it is in the interest of the patient that it is in the interest of health care. One of the issues that we are looking at is whether it's always necessary to use a CT, or whether alternative procedures are at hand that would not lead to this exposure. And this is something that has to do with how we look at radiation protection of the patient in the long run.

MR JACOBI: Perhaps we can move on from the fundamental - - -

DR LARSSON: Sure.

MR JACOBI: - - - and I just wanted to deal with a question of methodology and that is that we have read a lot in submissions about the attribution of health effects to radiation. And I am just interested to understand whether there is an agreed approach to how one approaches that, if one is doing a retrospective as opposed to a prospective analysis?

DR LARSSON: Yes. No, going back and I am not sure that we are deviating from the fundamental (indistinct)

MR JACOBI: Right.

DR LARSSON: But fundamentals as we were just discussing but yet again, if we go to UNSCEAR's work and in this particular case, this particular figure comes from the 2012 report to the General Assembly to the Scientific annexe A after that report, which is specifically about attribution of health effects and inferring risks. What this slide tries to illustrate is that you can look at radiation effects, you can – in some cases, you can detect radiation effects in individuals. These are individuals that have received a very high level of exposure and you can take what is called tissue reactions or deterministic effects and that can be safely attributed to radiation in – by a suitably qualified medical practitioner, usually, by eliminating other potential sources and looking at the diagnosis as such and how these injuries present themselves.

MR JACOBI: Are we in the area of ARS or acute radiation sickness at this point?

DR LARSSON: We are approaching that. We are approaching that, it doesn't necessarily lead to acute radiation sickness because some of these effects can be localised. For instance if – in the case of radiation therapy where you have a very localised beam, which is to treat a localised cancer, but there are occurrences of course where localisation is not correct and you can have these kind of effects presenting themselves. They are rare but they do occur. In that

case, you have an effect which you can – with certain attributes to radiation. When you have – when you look at the population and look at what we call stochastic effects and stochastic effects are not – are statistical effects in a population. The higher the exposure is of that population, the more of these cases you will get. You will not get more severe cases but you will get more of these cases. Whereas with deterministic of tissue reaction effects it is actually the exposure of the individual and the more you expose the individual, the more severe is the effect. You can with – if the population is exposed to relatively high levels of – or moderate and high levels of radiation, you can with statistical certainty detect an increase in the number of so-called stochastic effects. And what we are talking about here is mainly cancer.

That is being – that kind of research is being carried out within the scientific field of epidemiology. There are a number of such studies that have been carried out over the years and the most well known is probably the so-called life span study which was started in 1950 in Japan with the survivors of the atomic bombings in Hiroshima and Nagasaki and that has obviously now been running for a good 65 years. The most recent report on cases up to, I believe it was 2003, so 53 years follow up, 58 years or 60 years since the event. But there are a number of other studies as well. We have seen recently published a fairly big study on nuclear workers called In Works, that just released its data, so we have got plenty of information there. The problem with this of course is that you run in to situations where the statistics does not allow a resolution of any effects when you come down in the low dose region. We will move to another slide that could illustrate that a little bit more graphically. Well, we can do that already now. This is again coming from the UNSCEAR 2012 report annexe A and what it tries to illustrate here is both what you can see and what you cannot see. Or what you cannot see when we look at the probability of a health effect versus the dose. The red curve that is to the right there is actually those tissue reactions or - - -

MR JACOBI: That - - -

DR LARSSON: - - - (indistinct) effect.

MR JACOBI: What I think was box A in the last slide?

DR LARSSON: Yes. Exactly. And there you can see that after you have reached certain threshold, you will see these effects becoming manifest and when you go up to sufficiently high doses, you will have that manifesting 100 per cent of the population and you will – at those levels also go through what you referred to before as the acute radiation syndrome and so on, and different levels of those, and it may certainly lead to death. It's a little bit more difficult with the stochastic effects and let's talk about cancer and what the sloping blue field there tries to illustrate is that at radiation doses which go

above 100 millisievert or 100 milligray there is clear evidence that there is an increase of cancer in the population. That's been demonstrated in many cases. Certainly the life span study shows that very well.

The problem here is when we go down below a hundred millisievert and very low doses because even though we know with certainty let's say at about a hundred millisievert we have this effect, we don't know - we can't detect when we go down to just a few tenths of millisievert. That is just because the baseline variability and the frequency of occurrence - there's statistical noise if you like. But you also enter into some which is indicated by the grey slope to the left there where there are uncertainties about the exposure because you come very close to the natural background and the natural background variable, as we have already seen.

So unfortunately that also means that most of the exposure that most of us - for instance, when we are sitting like we are doing here are encountering over there down in the bottom left corner where we have got the statistical difference which is caused by the variations in the background and the statistical noise, which is about the baseline frequency of disease occurring. So in that area it's almost impossible statistically to be able to demonstrate any occurrence of cancer.

We can deduce from other studies that it's suddenly - and certainly we cannot think we have evidence above a hundred millisievert and when we go to 99 millisievert it doesn't just disappear of course. We can with certainty think about that we also have an increased risk when we go below that. But we don't know what the dose response curve looks like in that particular area and I think there is the next one - - -

MR JACOBI: Can we come there in just a moment. I just wonder whether we might go back because I'm just concerned we don't move on from the last graph. So I think we dealt with the retrospective aspects. I'm very interested to deal with the issue of predicting because we've heard quite a lot about predictions. I'm just wondering whether you can explain what that shows with respect to prospective prediction.

DR LARSSON: We can do prediction in some cases when we actually have clearly established from the retrospective analysis that we are certain that we have a cause and effect linkage here. We can look at predictions (indistinct) predicted with regard to some of the workers, predicted that they were increased risk of cancer. The numbers would probably be low was also what was concluded but there was an increased risk of cancer. In that area that I was just talking about where we do have the statistical uncertainties, we don't know for certain that there is a risk. We don't know how big that risk is. What we are doing then is that we infer on the basis of a hypothesis, which may be a

very sound hypothesis but not proven, what the risks might be. That means that in the terminology that we're using here, we are only attributing effects if we can actually see them. So it's a retrospective exercise.

Whereas when we look prospectively we can do some predictions if the exposures have been sufficiently high. The rest are inferences, and those inferences are very, very uncertain. In particular, when we come down to very, very low doses within the variation range of the natural background, those inferences become extremely uncertain.

MR JACOBI: I think that might actually bring us to what was the next slide in terms of - I'm just wondering whether you might explain what the alternative hypotheses are. We've heard a lot about the LNT hypotheses in the submissions that we've received and I just wonder whether you might explain what those hypotheses are and what the evidence is that might be said to underpin any of them.

DR LARSSON: I mean at the end of the day what we need to rely on when we talk about affects on the human population is epidemiology and the radiation biology should contribute and explain epidemiology. It's very difficult to start with radiation biology and extrapolate what's going to happen in the human population because a lot of the experiments that we have, they are relatively short-term, whereas a cancer may take years or decades to develop and we don't know exactly what happens in that window in between. But there are various proposals for dose response curves in the low-dose range, which this is showing. So the data points that you've got there are the ones that we would obtain probably at a hundred millisievert and above.

There are various proposals for dose response curves in the no-dose range which this is showing. So the data points that you have got there are the ones that we would obtain probably at 100 millisievert and above. The LNT hypothesis is the linear no-threshold hypothesis, postulates that you can just extrapolate down to zero so that any additional dose will also lead to small but still an additional risk.

And that is what underpins radiation protection. Radiation protection doesn't talk about a linear no-threshold hypothesis but an assumption. It's a linear no-threshold assumption and that assumption underpins radiation protection. So we assume for radiation protection purposes that there is a linear relationship.

MR JACOBI: What's the reason for making that assumption?

DR LARSSON: Well, it's supported by some evidence and you - - -

MR JACOBI: No, sorry. I was interested in it from the perspective of why would you use that hypothesis for the purpose of radiation protection?

DR LARSSON: Well, it is considered that it is a prudent approach. We are extrapolating into an area where we actually don't have evidence, but we think it's a prudent approach to assume that we can extrapolate the curve that we have for the higher exposures down to zero which effectively means, as I said, that any additional exposure is also associated with a small but still additional risk. So that's for radiation protection purposes. We don't have epidemiological evidence to actually support it.

MR JACOBI: Am I right in understanding that because it's used for radiation protection, it underpins the frameworks, the guidelines and the standards that are developed?

DR LARSSON: Correct, and we do consider that that would be a conservative approach that adds an element of extra protection to the protection framework.

MR JACOBI: And is that the framework that's used in Australia at present?

DR LARSSON: Absolutely, but as I was just alluding to, there are other possible ways by which you can look at and hypothesise around the response curve in that dose range, and there are various models here and each of those models can actually be supported by some biological reasoning. You can look into the biological mechanism and you can develop a sequence of events that would potentially lead to that kind of dose response curve. One of the most put forward dose response curve would be that we will actually have a threshold. You see curve D there which is a threshold. You see that there is nothing happening and you increase the dose and then all of a sudden it happens.

There are some biological reasoning that could support that, like stimulation of the immune response would increase the detection of transformed cells and eliminate those as the exposure increases. The E curve is a so-called hermetic curve which actually indicates that - and could be supported by a biological reason that an exposure to radiation would actually trigger the response mechanism in the body and make the body less susceptible to radiation, and then of course you reach an exposure level where it would start to increase again.

Curve A would potentially be suggestive of radiation at low doses being more detrimental in terms of a health effect and then it would be - when we come up to the higher doses there are some biological models that can support that as well. There have been demonstrations of effects where it's not the cell itself that is being hit by radiation that is responding, but also adjacent cells, which

seems to indicate that there is some sort of communication mechanism between the cells, the cell that was hit and other cells and so on.

What we also in the radiation protection community think about curve A here is that if the radiation risk at low exposures had been seriously underestimated we would have seen it in the epidemiology. So we don't believe that it's seriously underestimated. But we do have a situation where we have those different models. We don't have the epidemiological data. We do have data from radiation biology, but they are very, very difficult to use in terms of predicting what the outcome is going to be in an exposed population.

MR JACOBI: Yes. I think that evidence was given this morning; I think it was expressed in terms that no dose of radiation is safe.

DR LARSSON: But that's radiation protection assumption, that's – from the use of radiation protection. It doesn't translate in to risk assessment or epidemiology because we just don't have that data but we use that approach on radiation protection.

MR JACOBI: Now I think I just want to ask another question in terms of making predictions about – sorry, forming a view with respect to causation - - -

DR LARSSON: Yes.

MR JACOBI: - - - of illness or cancer as a result of radiation. I am just interested to understand the extent to which it is appropriate to reason from that LNT, I understand it's used for radiation protection purposes - - -

DR LARSSON: Yes.

MR JACOBI: Is it appropriate to use it for predictive or causation base purpose of those lower doses?

DR LARSSON: No.

MR JACOBI: Why not?

DR LARSSON: Well, you can do it if you want but in that case you have to do the calculation, when you can do the calculation but you will also have to communicate very clearly what are the assumptions that you have made. This figure that we got here illustrates different assumptions that can be made. And the other factor is the uncertainty and the uncertainty – the relative uncertainty when you come down to these exposure levels, increases dramatically. So you will have a situation where you have made your calculation but you have assumptions that are uncertain and you have the uncertainty which is caused by

the statistical variation and so on. All of that contribute to what you have calculated in terms of a data appoint here. May have very, very little informational value and it might even be misleading. We can still do it and it is still being done in some cases, if you do massive screen studies, or if you do – want to make – take decisions with regard to how to fit out your health care system in order to deal with different diseases, you can still do it but what you will come up with is a number that might be indicative to you that there is no need to make any particular action in the health care system but it has very, very little informational value in terms of actual protections.

MR JACOBI: Perhaps if I can apply that to a specific example. I think in some of the submissions we have seen, we have seen risk factors from low doses - - -

DR LARSSON: Yes.

MR JACOBI: - - - multiplied against large population - - -

DR LARSSON: Yes.

MR JACOBI: - - - cohorts to predict risks. Is there any value in that, or does that face the same difficulty?

DR LARSSON: That is what UNSCEAR in the 2012 report recommends against, for exactly the reasons that I was giving. You can do the calculation but in that case, be honest and communicate what assumptions that you have involved in doing that calculation and what are the uncertainties and give that range of uncertainty. But that is rarely done, it's often done as a precise number and that precise number carries large – very large uncertainties.

MR JACOBI: I am just wondering whether we can translate some of the discussion in terms of low, very low, in to some numerical terms so that we get some numbers around that. I think the next slide might pick - - -

DR LARSSON: Yes.

MR JACOBI: - - - that up.

MR JACOBI: Just wondering whether you might explain why we have come to classify some things as very low or low and then come – then come to the question about the effects - - -

DR LARSSON: Yes.

MR JACOBI: - - - are likely to be?

DR LARSSON: Well recorded very low and low and so on, that is of course a little bit – just a question of nomenclature. I think that the exposure that we are receiving in every day life should be very low and then we have – we go up to the higher exposure levels here. Now this is a compilation of information which doesn't take in to account for instance that some of the exposures may be acute and some may be over a long time but it is just helpful to discuss those ranges that we are talking about. So - - -

COMMISSIONER: This is per year I take it?

DR LARSSON: This is per year, yes. That is correct. So let's say - yes, well it doesn't have to be per year, it can also be acute but let's say that the one to 10, which is very low here, is really what most of us would experience within that range, would experience within a year. The average Australian that we were talking about before, would experience around about 3.2 but if you have a couple of medical examinations you might get to 10 but it's nothing really there that deviates from normal life. It is part of life and we are within the one to 10 millisievert range. Based on the models that we have, we might infer that there are risks associated with that exposure as well but models will also tell us that those risk are extremely small. And we don't know exactly, based on what we were talking about previously, whether there are any risks at all. But if there are risks, they would be very, very small.

If we go up to the next range, which I have indicated here, which is 10 to 100, well if you have a series of CT scans or if you have an unusual work situation, you might come up to a few tens of millisieverts. Yet again, there are studies there that suggest to us that the risk while still low might have increased and it is also supported by some observations, for instance some studies that have been done recently of children and exposure to CT, John Matthews in Australia for instance had done a major study on children and exposure to CT and there are certainly observations that would support that there is an increased risk in that dose range. If we go to the hundreds and one thousand, well here we have – for instance there were 174 workers in Fukushima that experienced more than 100 millisievert. There were many, many thousands of them in Chernobyl. The liquidators in Chernobyl that experienced such doses and if you come up to the high range there which is 1,000 that is where we start to see the tissue reactions and the symptoms of radiation sickness if there is whole body exposure. If you go to higher than 1,000 then the deterministic effects would be all the tissue reactions would be certain and if you go up to a few thousand, you will – and it's a whole body exposure that will result in death.

Now these are – these radiation doses are fortunately very, very rare. They might happen during accidents but most of the cases where we have doses like that is of course in radiation therapy and the radiation therapy is intended to kill

cells, that is the whole purpose for it. It is being administered in a way that would also spare the surrounding tissue.

MR JACOBI: Now I don't know whether the next slide adds to anything that we have just discussed?

DR LARSSON: Now I think that this is really wraps up what we have been talking about so far, so it really lumps all the information together that we have mentioned. When you go to the lower end there, the effects are not well known and there is a very high uncertainty, but if we go to the other end of course the cancer and hereditary effects where we see those risks increase and we get very high doses to harmful tissue reactions. Whilst I indicated there that we've got hereditary effects, hereditable disease has not been diagnosed or has not been – there has not been demonstrated in the human population, not even after the atomic bombings. But there is ample evidence from animal studies and so on that that can certainly occur and there is no reason to believe that it can't occur in the human population and actually even though it hasn't been demonstrated, it is also part of the radiation protection system where we also protect against hereditable disease, even though it hasn't been demonstrated.

COMMISSIONER: It hasn't been demonstrated even Chernobyl?

DR LARSSON: No.

MR JACOBI: Can I come to issues of radiation protection and I am just interested to understand, we have already picked up that we make an LNT assumption for the purposes of that. I am just interested to understand what are the broad principles or underlying rationales that inform decision making with respect to radiation protection? (indistinct) insight to that?

DR LARSSON: Well, there are three basic principles and the first principle is justification, justification for a practice that involves radiation and in simple terms, justification is do more good than harm and that can be a relatively simple consideration if you look at medical application for instance. Diagnosis through diagnostic imaging procedures, you do that in the interest of the patient, in the interest of the patient's health. You do it because it does good. You might do some harm, but the harm is clearly outweighed by the good.

In other areas where we talk about industry using radiation and so forth, the justification is not based solely on radiation protection and health considerations. There's a whole raft of different other considerations that come into play (indistinct) but nevertheless, justification is one of the cornerstones here. The other is optimisation and optimisation essentially means that you optimise the protection as much as you can. You take all reasonably

achievable steps in order to reduce the exposure, that is, the exposure of individuals, the exposure of a whole population, and also reduce to the extent possible the probability of accidents. So that's driving the exposures down.

The third principle is then the principle of dose limitation, because you can theoretically think that you have a situation where you optimise, but that also leads to an acceptable exposure of certain individuals, and in order to protect those individuals you also have dose limits.

MR JACOBI: Now, I'm just interested in understanding, perhaps you can explain what, as they currently stand in Australia, the dose limits are, and then what you understand to be the proper interpretation of those dose limits.

DR LARSSON: Well, the dose limits from all sources for members of the public is 1 millisievert. So it's well within the background range that we were discussing here before. And of course for those practices that can actually generate exposures in the environment, the driver driving them down should also be optimisation. For people that are exposed in their work life to those limits it's 20 millisievert, and so that's obviously 20 times higher, but there is here of course also a knowledge about what you are doing. There is monitoring of the exposures. There is a very active optimisation that goes on within the workplaces where you're occupationally exposed and that drives the doses down. So in reality, in most of those areas we are down to exposures of the occupationally exposed population which is in the order of those limits for the public.

In other areas it's more difficult to control the doses, because they are mainly resulting from sources that cannot be controlled, cosmic radiation being, for instance, something where we are discussing with airlines about the radiation protection of aircrew and also frequent fliers and so on. It's hardly a controllable dose, but you can still control the exposure of the individuals to radiation that they are also well within the occupational dose limits.

MR JACOBI: So they're well within the 20. Is that right?

DR LARSSON: Well within, well within, round about 3, 4, 5, maybe up to 6 millisieverts.

MR JACOBI: Now, I'm just interested to understand, the Commission has heard about, again in the submissions, the ALARA principle, and I'm just wondering whether you could explain its practice application.

DR LARSSON: Well, that's optimisation as low as reasonably achievable, and that becomes simply the acronym ALARA. Essentially what you do is that you take all reasonable steps that you can to reduce the exposure. We reduce

the exposure of individuals, the number of individuals exposed, and also the probability of accidents, and you do that on the basis of doing cost effective implementation or implementation measures that are cost effective so that you actually get some result for the money that you invest, and that can be a complex analysis in some cases and a very simple analysis in other cases.

MR JACOBI: And is ALARA a legal requirement in Australia?

DR LARSSON: Optimisation is part of the legal requirements. We don't call it ALARA but we call it optimisation.

MR JACOBI: I think we'll just skip over a slide and come to monitoring.

DR LARSSON: Yes.

MR JACOBI: And I think we've got some figures for uranium industry workers, and I'm just interested whether you can, first, offer an interpretation of the information that's contained there.

DR LARSSON: Well, what this illustrates is - the sort of blue, violet, purple curve at the bottom there is the average individual dose to uranium industry workers, and we got this data because a while back we set up what we call a dose register and that's a centralised repository for uranium mining workers, and we have got data from all the active uranium mines and also from the mine (indistinct)

MR JACOBI: Are they obliged to provide that information?

DR LARSSON: They are obliged to provide that information and they do that here in South Australia, for instance, as part of licence conditions, and they provide that information to us as a repository for this information. And it allows us of course to look at drains with time, and the conventional wisdom is of course that often what you measure you will also probably achieve. If you monitor something you will automatically strive for improvement, and what we can see here in terms of the individual doses over the years that we have collected for here, some of the data are actually old and predates the dose register, but anyway have been submitted by the uranium mining industry.

There is a decrease. You can also see the orange line there which is the maximum exposure of a single worker over the years, and you see a decrease there as well. It's probably a little bit pessimistic here, because those data normally don't take into account the use of protective equipment. So the data will be representative of not using protective equipment, whereas the real data would then probably be lower than that. It's just a demonstration of the evolution of the exposures in one occupationally exposed category.

MR JACOBI: Just so I understand, that part of the answer about the distinction between what's measured and what the person is in fact exposed to, is that because measuring the tags or other things, the measurements are made at a point that doesn't use - there's not such protective equipment or - - -

DR LARSSON: No. If the protective equipment is used, then the actual dose would be lower than the one that is estimated, and this is something that we have no ongoing dialogue with the industry and also with other regulators in Australia in order to get the best available data, because if you want to use this data in the future for whatever purposes - there are the international pool studies and so on - then you'll want to know exactly what it measures. The point I'm making here is that there is a decreasing trend and to monitor the exposures is not a bad way of actually making that happen.

MR JACOBI: And the blue dotted line?

DR LARSSON: The blue dotted line is just the number of workers that have been included in the dose rate study.

MR JACOBI: I'm just interested to understand, what's the protective equipment that you're referring to in uranium mining?

DR LARSSON: That would be protective equipment for inhalation mainly.

MR JACOBI: And why would that change the result?

DR LARSSON: Because the monitoring data is based on measurements. There can be measurements that are carried by the individual workers, but of course there would be monitors and so on, and they wouldn't know, they wouldn't take into account, the protective effect.

MR JACOBI: And the inhalation equipment, I gather, would exclude the dust?

DR LARSSON: Yes, that's right. That's right.

MR JACOBI: Is it effective on radon or not, or is that - - -

DR LARSSON: Radon is a gas, but it's also often attached - or the radon progeny also attach to the dust, so definitely there would be an effect.

MR JACOBI: Now, I think, beyond the question of uranium industry works, we've got some outputs for diagnostic exposures. There's one on that slide.

DR LARSSON: Yes, that's right, and this is also a slide and it's a complicated one. It's the so-called national diagnostics reference level database which is something that has been assembled yet again by ARPANSA on the basis of surveys that we have done with the clinics. These have a different computer tomography, CT procedures, and you see it's part of his chest, head, lumbar spine and so on. The diagnostic reference level is based on the information that we have got and it establishes a reference level above which we have about 30 per cent of the data and below which we have about 70 per cent of the data.

The idea with this is to explain to say that, well, there's 70 per cent here that can do it at a dose which is lower, so maybe you can as well, and that drives down the exposures. That's one element of it, but there are also other elements that contribute here, the equipment, modern equipment can use the exposure more efficiently and there is also some changes in procedures and so on, but what you can see for all these procedures is that they are actually going down. That's not all because we have a diagnostic reference level, but I think it's a contributor and yet again its an illustration of the point that if you actually monitor it you may see how you're tracking and that in itself is an incentive for implementing new actions.

After three or five years or so you can make another survey and you get another diagnostic reference level, it would presumably be lower and we will then drive down the exposures without losing, of course, the quality of the medical imaging and the diagnostic relevance of it.

MR JACOBI: Just so I'm clear on the interpretation, we have changed here from effective dose to absorbed dose. Is that right?

DR LARSSON: This is absorbed dose, yes, and normally if you look at organs you would prefer it to work with the absorbed dose.

MR JACOBI: The black cross, is that an average of all treatments that have been provided in that year in that part of the body? Is that right?

DR LARSSON: Well, on the basis of data that we have been able to collect, yes, and that is because we have an ongoing collection of data and we have covered now two-tenths of the clinics but there are more data coming on all the time and we see this happening.

MR JACOBI: So the datasets are supplied by hospitals. Is that right?

DR LARSSON: Yes. Clinics that are using these kind of procedures.

COMMISSIONER: That's not mandatory.

DR LARSSON: Sorry?

COMMISSIONER: That isn't mandatory, the reporting.

DR LARSSON: Well, it's actually part of - this is actually something that comes out of radiation protection series number 14 which is the code, the medical code, as we call it, which has got also three separate guidance to it, one on diagnostic imaging, and that is being implemented through the health authorities in the different jurisdictions. All of this is an outcome of the work that is being done between ARPANSA and states and territories in Australia, it goes through what is called a radiation health committee which brings together all the radiation regulators in all jurisdictions in Australia and develop the codes and agree on the codes, and then they become implemented in the states and territories.

MR JACOBI: I'm sorry to take you out of sequence. This slide has reminded me of something that's in evidence that was given this morning. Perhaps we can come back to the slide on LNT, that one there. I'm just interested, we were told in evidence this morning that - perhaps I can put it this way to you, are you aware of a statement that it's known that about 30 per cent of cancers are induced by background radiation, and the other 70 per cent are induced by anthropogenic sources? Are you aware of there being such a statement?

DR LARSSON: No. The percentage of radiogenic cancer or induced by radiation are significantly lower.

MR JACOBI: I think that the division wasn't between radiogenically caused cancers and all cancers, this was the idea that of radiogenically caused cancers, 30 per cent were induced by natural background sources, and the other 70 per cent were induced by anthropogenic sources.

DR LARSSON: Well, yes, that's another way of raising it and I misunderstood your question there, but if you go back to the pie chart, if we look at the distribution of sources or the sources of radiation exposure yet again on the average Australian here, then of course what you see here is that the anthropogenic sources, they are dominating, and that's the medical use of radiation. Now, the medical use of radiation is in the interests of the patient, because it's actually to improve the health outcome of the patient. Of course, if some of these procedures are not justified because there are alternatives that we can use instead of maybe it wasn't justified in the first place, then that exposure is unnecessary, but this is the best picture we can give you on the sources of exposure.

MR JACOBI: Are you aware of the 30/70 per cent division? It's not something that I can say I've read in the submissions.

DR LARSSON: No, I think that would be an extremely uncertain statement for all the reasons that we have been discussing, in particular, in the first part of this session.

MR JACOBI: I am just wondering, and perhaps we could come back, we have dealt with information that ARPANSA has collected from diagnostic purposes, I am just interested to deal with the reporting of radiation incidents. Perhaps if we can first deal with what the obligation is to report radiation incidents in Australia.

DR LARSSON: Yet again it's mandatory and it's set out in what is called the national directory for radiation protection which yet again is uniformly applied across all Australian jurisdiction and there is a particular schedule in that publication, schedule 13, which details the incidents that should be reported to the Australian Radiation Incidents Register. For 2014, from memory now, there were in the order of 300 such incidents and the incidents are of various kinds and, for instance, medical use of medicine that could be that the radiation dose in a diagnostic procedure deviated a certain number of per cent from the one that it should be, therapy the same, that you have a deviation a certain number of per cent from what it should be. It could also be mistaken identity and so on, or the wrong tissue being subject to the diagnostic examination.

So there are a variety, in a nuclear field that could be a criticality which is, of course, something that is extremely rare, but a number for 2014 that have been reported to us is in the order of 300. If we look at the number of procedures in the year, in particular in the medical field, only CT, that's several million, maybe 3 million, in the order of that, so even though if we considered that most of these incidents are in the medical field, it's a very small number in relation to the use of radiation in medicine.

The pie chart to the right is a breakdown in what are the causes, to the extent they have been reported and can be assessed, which is not surprising, human error is the largest contributor here and some of them aren't clear. In some cases it might be that a patient that was undergoing examination using diagnostic procedures, a female patient didn't know she was pregnant, it turned out later that she was pregnant, and there are some procedures that may be unusually uncomplicated, unexpectedly complicated and so on, and all of this contributes to these incidents.

MR JACOBI: Can you give me an example of what's a non-medical, that would be shown in the purple? This is on the left-hand side back to the pie chart.

DR LARSSON: Yes, well, it could be things like for instance using a

radiation source and overriding the so-called interlock system, the passive safety systems, where you cannot access the facility when the radiation source is - or when you're able to be exposed by the radiation source, and other kind of deviations from the protocols.

MR JACOBI: These are radiation sources used in industry in sensors and so on. Is that right?

DR LARSSON: Yes, by industry and research and so on.

MR JACOBI: Now, I think you've also collected data on what was required to be done as a response. Can you offer an interpretation of that?

DR LARSSON: Yes, that's right, and has to be treated with some caution, because obviously if we are looking at some two or 300 accidents, it's difficult to be completely sure about the distribution of preventive measures between different kind of measures, but training and education is always something that is used; reinforcement, by simply reinforcing the rules and procedures; changing the procedures; changing the equipment; and other types of improvements, and we also have about 20 per cent there where actually the information that we have received, we haven't got any information by the user of what preventive measure they implemented after these incidents.

Yet again, I think this is something that is important, that you're vigilant and you monitor, and if you have a system where you can monitor the radiation incidents, if you have a reporting system that actually goes to the root causes, you can evaluate that information and you can provide advice, your requirement or what have you, to the industry that is using the radiation sources for other activities on how to improve the safety.

MR JACOBI: I might at this point change and perhaps focus on regulatory aspects given that's a significant part of ARPANSA's role. I'm just wondering whether we can perhaps skip over a slide and come immediately to dealing with the source of the content of Australia's current radiation protection obligations. I'm just wondering perhaps whether you can offer some explanation of the source of that content.

DR LARSSON: Yes. This outlines, in an idealised fashion, if you like, the transfer of information through different international bodies which eventually end up with the national regulation, but if we start from the end with the national regulation, what we have in Australia is very well aligned with international best practice and very well aligned with the international framework that has been developed over many years for radiation safety. And we already spoke about UNSCEAR, and UNSCEAR's role since 1995 is to report on sources and effects and risks to the United Nations General

Assembly, and periodically collect that information into the scientific annexes and they are being used and widely respected as state-of-the-art knowledge of the sources and the effects of radiation.

That doesn't mean that you don't have individuals or organisations that would criticise the information, and we spoke about that earlier. And that's fine. That's the way it should be. There should be a robust scientific debate otherwise you won't have the momentum in the scientific development if you don't have that robust debate. And I should mention here also the World Health Organisation which perhaps doesn't appear here in the way that it should be done, but also the World Health Organisation obviously collects a lot of information on radiation effects and radiation risks and translates that into advice.

COMMISSIONER: Is that work that WHO does independent of the IAEA?

DR LARSSON: Yes.

COMMISSIONER: Is this is a mandate that they have collect - - -

DR LARSSON: Well, the matter for the World Health Organisation is to provide advice in health issues in general, but when it come to radiation, for instance, in relation to radiation accidents as we had in Fukushima, the World Health Organisation produced two reports. One was a first initial dose assessment, which is called a preliminary dose assessment, and they followed up with a health risk assessment. That is their role, because they are advising health authorities and the UN member states.

COMMISSIONER: We just had evidence to suggest that they weren't allowed to look in this particular area without approval from the IAEA.

DR LARSSON: Well, I've heard comments being made many times. I think that the best way of looking at that is to go to the preliminary dose assessment and to the health risk assessment that WHO produced and that, I think, gives evidence for the high quality and the independence by which they have produced this report.

COMMISSIONER: Okay.

DR LARSSON: The next block there is the International Commission on Radiological Protection, which is a different organisation in many respects. It's a small organisation. It's an NGO. It's a non-governmental organisation. It's actually constituted as a charity, located in England because it's governed by the laws in England. I can't remember. It's not UK. It's England and probably some other area of UK as well. So its operations are governed by the law that

governs the operation of charities, and it was established already in 1928 actually. It was then established as the International X-Ray and Radium Protection Commission, changed its name to the International Commission n Radiological Protection around about 1950.

It is an NGO that works on a small budget but with a lot of contributions in kind from - and the total number of experts working within the ICRP is in the order of 200, 250, depending on how many task groups are working on different recommendations at one point in time. There is a main Commission with 13 members and then there are five standing committees that work on various aspects. They work on radiation effects on symmetry, medical use of radiation on application and on environmental protection, and they issue on the basis of scientific - on the supporting scientific evidence issue recommendations on radiation protection.

So they translate, if you like, scientific information into recommendations on radiation protection. So it forms a link between the pure science and the pure application, and currently it has issued about 130 such publications over the years. The radiation protection framework that has been developed by the ICRP is actually being implemented by the IEA and their safety guides. The IEA produce safety standards that are developed into specific hierarchy. You start with the safety fundamentals which is about the principles that are going to be applied.

Then you have a set of safety requirements and the safety requirements are written in "shall" formats, "You shall do this and you shall do that." And underneath there you have the guides, and the guides are such that they inform the user how they can work in that particular area in order to comply with the safety requirements. The safety requirements are not mandatory for all countries. They are mandatory for all the countries that in one way or the other are receiving support from the IAEA, and they are also mandatory for IAEA itself because IEA carries out a lot of activity itself, not mandatory for a country like Australia, but we see it as international best practice, and the State and Territory regulators, we have agreed that we shall, to the extent possible in the Australian context and relevant in the Australian context, make use of this framework, and that goes then into what you see right there, which is national regulation. What that results in is that regulatory framework that we operate here in Australia is very well aligned with the international framework.

COMMISSIONER: Can I just understand, does the ICRP peer review UNSCEAR's reports?

DR LARSSON: No.

COMMISSIONER: So they are taking the outcomes and turning it in to

regulation?

DR LARSSON: Yes, they do but they also do scientific evaluations of its own because there might not be for a particular radiation protection purpose, a relevant or up to date report from UNSCEAR and it is being done by ICRP then. So the ICRP is about the advancement of radiation protection science for the public good and the public good comes out from the recommendations that be issued by the ICRP.

MR JACOBI: Perhaps if we can move on to what is the last (indistinct) and I think on the next slide it deals with the idea about ARPANSA implement those - - -

DR LARSSON: Yes.

MR JACOBI: - - - particular fundamentals and guides in Australian law.

DR LARSSON: Yes, that's right. And yet again, I come back to the Radiation Health Committee which is a statutory committee set up by the ARPANSA Act and with members from all the states and territories and the regulators from – radiation regulators from all the states and territories and jointly we develop the framework that is then being applied across all the Australian jurisdictions. And we do have a fundamentals document that was released just one or two years ago which is a protection against ionising radiation. We are working on one for non-ionising radiation as well. Underneath there we have the codes and standards and the codes and standards are being implemented through various means in the states and territories. That could be by inclusion in the regulation, specific regulations or licence conditions and so on. Of course also, in this particular case we produce the guides and the recommendations that can be applied by the user and which guides the user, so that the user is able to comply with the codes and standards which are yet again, in the "must" or "shall" language.

MR JACOBI: Now could I come actually to one, because I'm reminded we have skipped over it and that is to deal with RPS SG1 with respect to environmental effects? We have dealt with the effects on humans.

DR LARSSON: Yes.

MR JACOBI: And if we could perhaps come back to slide eight. I am just wondering whether perhaps you could explain the – when one is not dealing with effects on humans, when one is seeking to make an assessment on the environment, what the hierarchy is and what the approach is to making such - - -

DR LARSSON: Mm.

MR JACOBI: - - - an assessment.

DR LARSSON: Yes. The approach to environmental protection is slightly different than it is when we talk about radiation protection on people because I explained to you before, the principles of justification, optimisation and those limits that we apply when we talk about radiation protection of people. Those limits is nothing that applies so far in protection of the environment and it would be impractical probably to set a dose limit because we know that the human population is very variable but that is of course nothing if you compare it to the variability of what you have in nature. Instead, we have – this is still a draft but I'm going to put it to the Radiation Health Committee very soon, if you look at the right part of the curve here, the left part essentially just elaborates on that, but the right part of the curve is that you can in many situations do a simplified assessment of the exposure scenario that you have. You can do that simplified assessment against so-called screening level. The screening level is something that we have to find what dose rate in the environment should be. What is a reasonable screening level? If you are on your simplified assessment, below that screening level then there is ample evidence to support the conclusion that you can carry on with this activity without the environment being at any significant risk.

If you are above the screening value, well then that is an indication to you that you should stop and pause and think and maybe do a renewed assessment but with less – that is less simplified and more specific and take in to account the specifics of that environment that you are working in. You might then end up with a much lower value than what you had in your initial conservative screening and you can still draw the conclusion that this is fine.

MR JACOBI: You have referred to a screening value and I notice that it is expressed in terms of ten micrograys per hour.

DR LARSSON: Correct.

MR JACOBI: Could you explain the significance of that particular figure? Why that is a relevant threshold for screening?

DR LARSSON: That is based on an enormous amount of analysis done of laboratory experiments, ecological information and aggregating that and drawing conclusions as to under relatively conservative – with relatively conservative assumptions would be a level that we would call safe for environmental purposes. There is a huge amount of science that has gone in to that so it's underpinned – that is also why I say that if you, through a simplified assessment, can conclude that your underneath – under that screening level,

there is a huge amount of scientific information that would support your conclusion that the activity that you are looking at is safe.

MR JACOBI: When dealing with human exposure with a later – one microsievert per year to activities that humans are engaged in - - -

DR LARSSON: Yes.

MR JACOBI: - - - are you able to relate the 10 micrograys per hour to some - - -

DR LARSSON: That would – as you say, we have got the background level which is indicated with a broad band there which is indicative of the fact that the background radiation for those (indistinct) are going to be highly variable and dependent on - - -

MR JACOBI: Yes, well I mean there's - - -

DR LARSSON: This would probably in most cases be about that background value but it is at the level where we don't anticipate you will see any effects in the natural environment.

MR JACOBI: And just with respect to such an assessment, what is it that we are seeking to avoid in terms of conducting such an assessment? What sort of outcomes are we seeking to (indistinct)

DR LARSSON: The protective – aim for environmental protection would be avoid any effects that could have – or could be detrimental to biological diversity or to the conservation of species and in other ways the health and integrity of ecosystems.

MR JACOBI: Now can I come – just come back just very quickly to one of the inferences to which I think we have already had reference with the NDRP and I am just wondering if you could explain the significant of that, you were at slide 16.

DR LARSSON: Yes, that's right. And this was something that goes back to the establishment of the ARPANSA Act and the discussions within COAG and so on on a national uniform framework and you could say that the National Director for Radiation Protection first published in – a few years back but then gradually revised with time, is a collection of the agreements that have been made between different jurisdictions, the Commonwealth and the state and territories in Australia. So it is a repository for the uniform approach to radiation protection in Australia and all the requirements. So there are other requirements on the authorities in the different jurisdictions, what they should

do, what is being considered in licensing , what should be considered in protection and there are a variety of schedules there. And I was talking before about schedule 13 which is part of the national directory, which is about incident reporting and so forth. So it is a central – plays a central role in the radiation protection series but then we have all the specific and more specialised codes and standards and also guidance, which is also part of the radiation protection series but this, if you like, is the central repository of agreed requirements.

MR JACOBI: Moving off these topics to deal with one of the issues that the Commission needs to consider, which is prospective regulation - - -

DR LARSSON: Yes.

MR JACOBI: - - - just – and we have discussed international framework as it relates to activities that Australia's currently engaged in. I am just interested to understand the extent to which there is international guidance available should a government be minded to implement. This a safety guidance available, where a government might implement nuclear energy.

DR LARSSON: Yes.

MR JACOBI: And I think we have got a slide that might pick that up, which is the next one. I just wonder whether you could - - -

DR LARSSON: Yes, true.

MR JACOBI: - - - explain?

DR LARSSON: And of course the source for a lot of guidance n this particular is the International Atomic Energy Agency and in particular there are some guidelines and I have quoted here one of the, which is the specific safety guide number 16, which is establishing the safety, infrastructure for a nuclear power program. It essentially outlines a series of 200 steps that one should go through in order to successfully establish a nuclear power program should that at all be the preferred option of Australia at some point in time.

Obviously this is something that requires to be rolled out over a number of years and the first slide here indicates maybe the initial phase where you establish an infrastructure to launch a nuclear power program and then Australia can make a decision whether to go forward with it or not. If it does not go forward then obviously nothing more happens. But then a lot of development of work is required in the regulatory area in order to create safety and security - a safeguard infrastructure really for governing this program and to construct an NPP.

The indicative time this may take is some three to seven years, according to the IAEA. Build up a safety infrastructure and implementation of the first power plant extends into seven to 10 years. Then start the operations, and the operations of course is going to continue for a very long time. Currently we are talking about 60 years of operation, maybe extending beyond that. Then the post-operational phase is another perhaps - even a century, where we are talking about the decommissioning, the waste management. Depending on what waste management solution that is being preferred, disposal of spent fuel and so on. Which meant that if we talk about a nuclear power program we are talking about a commitment that lasts for maybe one or two centuries.

So the more thinking that is done in the beginning of that phase and get it right, that is of course important for the subsequent years. There is a lot of specific guidance that has been developed by the IAEA in relation to this and one of the sources is there at T16 that I've quoted here. There are also guidance and also other review service missions that the IAEA provide in order to monitor the development of this infrastructure in the country.

MR JACOBI: I want to come to those review service missions just at the end. I'm just interested to understand Australia's experience in actually having undertaken these review missions or participated in an invitation to the IAEA for such a mission.

DR LARSSON: Yes, there was a review mission - yes, you've got here the integrated regulatory review service, which is only one example of the different review service missions but maybe in the regulatory area, the flagships so to speak. It was something that the IAEA started back in 2006 and over the years. I've got another slide on that that we can look at later if you want and see that 70 such missions have been carried out. Australia was actually one of the first countries. The first country, if I'm correct, to invite one of these missions and it was with ARPANSA. So in 2007 my predecessor, Dr Loy, invited one of these missions and when I came to ARPANSA in 2010 I invited a follow-up mission that we then had in 2011.

I'm now looking at inviting a new mission for the year 2018. It's good international practice that has been established by these missions maybe every 10 years or so. It's actually mandated in the European Nuclear Safety Directive and also in the West Safety Directive to have these kind of missions every 10 years. What has been done here is not only that you have a review mission that comes to your country and your organisation for a period of two weeks, it's actually very significant preparatory work that starts one and a half to two years before that. You go through a self-assessment according to a prescribed format and that is being supplied by the IAEA. That's usually a six to nine-month exercise to go through the self-assessment. You develop a

preliminary action plan on the basis of that and you collate the high-level information into something which is called the advance reference material, which you submit.

The IAEA will then take the responsibility to organise a review mission and we assemble an international team and, depending on whether you have a large program or a small program, that team can be anything between 10 and 25, and even more than that, international experts that the IAEA seek from all different countries. The review team will have access to all this material that has been assembled: the advanced reference material, the self-assessment, the draft action plan. We will review that material and we'll then spend normally around about two weeks in the country and in the organisation verifying the information, and eventually we'll issue a report that lists a number of suggestions where there is room for improvement but there is no real deviation against the IAEA safety requirements.

We also issue recommendations where there is a deviation in the host country relative to the IAEA safety requirements. It will also, for the benefit of everyone, identify good practices that they have detected in the host country. You will then amend, on the basis of the review report, the action plan. Good practice is to put the action plan on the web as well as the review report, and as far as I have been informed all countries that have had these kind of review missions have actually done that. Then of course you implement the action plan and you take the actions that you have planned.

Within two to four years you should invite a follow-up mission and a follow-up mission would obviously go through all the recommendations and suggestions and monitor progress against them, and we'll consider that some of them are being closed, some of them are perhaps being closed on the basis of confidence in what's happening but it takes time, and also leave some of them still open and still for the host country to consider.

MR JACOBI: I think the next item might just pick up your (indistinct) with respect to total numbers that are involved.

DR LARSSON: I think if you add all these up you will come to a number which is slightly higher than 70 and this is a major activity and it's also a major consequence of this also, that you establish a very homogenous view globally on nuclear safety and radiation safety because obviously we will send members of ARPANSA staff to some of these missions. I have had the honour to lead missions myself to the United Arab Emirates, both the original mission and the follow-up mission, and more recently to Indonesia. I will go in January and be the deputy team leader for the mission that goes to Japan. That is obviously going to be a very interesting following in the post-Fukushima area time and with regard to the new regulatory agency, the Nuclear Regulation Authority in

Japan.

COMMISSIONER: Dr Larsson, thank you very much for your very clear evidence.

DR LARSSON: Thank you very much.

COMMISSIONER: We will reconvene at 1600, when we will have from the United Kingdom Prof Thomas from the Imperial College London.

ADJOURNED [2.39 pm]

RESUMED [4.00 pm]

COMMISSIONER: We reconvene on topic 11, Effects and Threats of Nuclear Radiation and we welcome from Berlin, Professor Geraldine Thomas from the Imperial College, London. Thank you very much for joining us professor.

PROFESSOR THOMAS: Pleasure.

MR JACOBI: Professor Geraldine Thomas is a Professor of Molecular Pathology at the Imperial College, London. She received her degree in pharmacology from the University of Bath in 1982 and completed a PhD at the University of Wales College of Medicine in 1988. Professor Thomas established the Chernobyl Tissue Bank which we will come to in evidence, which provides infrastructural support for thyroid cancer diagnosis and research in to the molecular mechanisms that underpin the increases in thyroid cancer seen after the Chernobyl accident. She has published extensively on the molecular pathology of thyroid cancer and is the author of a number of reviews of the health effects of radiation exposure following nuclear accidents. She was invited to speak at expert meetings on the health effects of radiation following Fukushima in September 2011 and was invited by the UK Chief Scientist Office to join the UK/Japan dialogue on nuclear energy in 2012. The Commission calls Professor Geraldine Thomas.

COMMISSIONER: Professor, if I might start, who do you consider the credible – what are the credible sources of information concerning the radiation effects from both Chernobyl and Fukushima and perhaps you might want to deal with them separately?

PROFESSOR THOMAS: Yes. I think that major organisations like UNSCEAR and WHO when they set up reports, they get people literally from around the world who are experts in their field to give their opinion. I have served on some of their committees and it is very much more opinion, you're

not expected to toe a party line. We draw all of the evidence from the scientific media, so from journals and things like that. And you have to remember, when you read scientific journals, that not all journals are equal, there are some that are much more reputable, therefore much more difficult. They require scientists to put an awful lot more input and facts and consider the options when they're writing the papers and their discussion. So those are the places that we really go for scientific results. We look at the scientific design, our rate of control and things like that. So it is quite a detailed dissection of what's been put in in the scientific publications, by a number of people with different disciplines. So you get an all round approach to the subject. So I would say probably UNSCEAR and WHO are the major sources of the real scientific (indistinct) that's gone in to this.

COMMISSIONER: It's been put to us that those organisations are populated with pro-nuclear individuals, clearly - - -

PROFESSOR THOMAS: Yes.

COMMISSIONER: - - - you have a different perspective?

PROFESSOR THOMAS: I don't think that's true. I think unfortunately the problem that you have is – I mean I'll be quite honest, I was anti-nuclear until I started working on Chernobyl and I was forced to look at the results coming out of the Chernobyl (indistinct) and actually say, you know this is not what we really thought. Everybody thought we were going to see far more cancers and things like that arising from Chernobyl and it – you have to start questioning where you get that information from and were you right to have thought that way. So I would say actually it's likely that most of the people around those tables started off as being broadly anti-nuclear but they've had to look at the scientific facts and say, our assumptions weren't right. Our hypothesis aren't right, and that's what a scientist does. You have a hypothesis, you look at the facts and then you question the hypothesis again and say, does that hypothesis fit the facts. And if it doesn't, you have to change your viewpoint. So I would not say that they were predominantly pro-nuclear or anti-nuclear, they're just scientists doing their job.

COMMISSIONER: All right. We might unpick some of that then.

MR JACOBI: Can I just ask, in terms of your involvement and participation in the constitution of those sorts of committees and special projects undertaken by UNSCEAR, were they constituted of people that also include people with medical science experience as well?

PROFESSOR THOMAS: Yes. I mean you get a broad range of physicists, people who are experts in medical radiation and things like that, so a really

broad field of people.

MR JACOBI: And in terms of the information gathering, in terms of the data collection, did you also interact with people that had medical science or particular medical qualifications within hospitals or other institutions?

PROFESSOR THOMAS: Absolutely. I mean you have to remember, actually the doses that comes from medical radiation are quite a lot higher than the environmental doses and often you will find doctors are even more cautious than the environmental based scientists simply because they've been taught all the way through their careers that radiation is quite dangerous and you have to be careful how you use it. So yes, I mean there were – there are epidemiologists but there were also medical doctors on those panels.

MR JACOBI: Perhaps if we can just come to some just very basic fundamentals and we will hopefully move through this quite quickly. I am just interested to understand whether or not there are particular radioisotopes that we need to be particularly alert to. We have heard much about caesium and iodine with respect to - - -

PROFESSOR THOMAS: Yes.

MR JACOBI: - - - their consequences for human health?

PROFESSOR THOMAS: Yes. Isotopes are different, you know you can't sort of use a broad brush and describe them. The effects on health really depend on whether they have a long difficult half-life and depend on whether they are taken up in to the body and bound so can release the radiation while they are inside your body. What you have to remember is we tend to think our bodies stay the same the whole time but they don't, we are continually losing stuff from it and taking stuff in, that's why we eat. And so the balance of the biological half-life, i.e., how long that particular dose of isotope you've taken in, stays in your body before it's replaced by the more widely available stable isotopes, because all of these things exist as (indistinct) radioactive isotope phase. So the actual – the health effects depends on the balance between the biological effect and the physical half-life.

So use iodine and caesium as an example, iodine 131 which is the one that we talk about in terms of health effects from Chernobyl for example, has a short half-life of about eight days, physical half-life. But your thyroid needs iodine to make its hormones. If you don't make thyroid hormones you have all sorts of problems with brain function and it generally control the whole of your metabolism. So that hormone is very important. Iodine is normally very scarce in the environment, so the thyroid over our evolution has developed a way of taking up the iodine in to the thyroid and binding it to make the

hormones. Now that means that it (indistinct) in your body is much longer than it would be if it just went in and came out again. So because it's got a short physical half-life and the long biological half-life of about 100 days in most people, that means it's got a chance to release all of its radiation while it's inside you. Whereas caesium is the opposite way around. Caesium doesn't concentrate in any particular tissue. There's no mechanism that we have that makes caesium stay particularly long in any of our tissues in our body. And it has a long physical half-life of about 30 years and a relatively short physical half-life, like 70 days. So it comes in and goes out and very little radiation is released. The dose from caesium is an awful lot less than the dose from iodine.

It's a complicated thing, which is not surprising why a lot of people find it really difficult to get their heads around because you have to understand the physics, the chemistry and the biology. So it makes it really difficult.

MR JACOBI: The Commission has also heard something about strontium and I know we've concentrated on iodine and caesium, could you address strontium in the same way that you've just addressed those last two?

PROFESSOR THOMAS: A few things to remember is things are different weights, so you have heavy elements like strontium and you have the volatile isotopes like iodine and caesium. Because they're volatile, when you have an accident, they get – go in to the atmosphere and they'll drift around on the air circulation round the planet. Whereas, things like strontium because they're quite heavy actually don't go very far form the site at which they're released. So you do get some strontium release. If you look at the atomic bombs for example, because these were above ground tests, they were dispersed – strontium was dispersed a bit more than it would have been if that explosion had occurred on the ground because it's a much heavier thing than the caesium and the iodine. So it does depend on the weight of the isotopes, their atomic mass, as to where they're likely to end up and whether they're volatile or as in strontium's case, not volatile that much. So you will get a small amount of strontium but it is relatively much, much smaller amounts of strontium from something like a nuclear plant having a problem. And the other thing is we do tend to equate atomic bombs with nuclear power plants and they're not the same things at all. They release different things and the kinetic (indistinct) released into the environment is very, very different, because it depends on whether it's an aboveground explosion or whether it's an explosion based on the ground as to where those things get distributed.

MR JACOBI: I'll come back to those differences later, because I think we might work our way through each of the three different - the Hiroshima, Nagasaki circumstances, Fukushima and Chernobyl. But I just wanted to come to another fundamental, and that is the issue of background radiation and I just wonder whether you could give us some insight into your views as to the

averages or the average ordinary exposure that humans receive to radiation. I think we might have a slide that picks this up. Do you have that available to you?

PROFESSOR THOMAS: Yes. Yes, it varies around the world, so it really depends on which country and even which region you're in. A lot of the background comes from radon that seeps up from the ground. So places like Cornwall, for example, in the UK have much more granite, and Edinburgh, have much more granite and therefore have a slightly higher radon dose. So that's affected the background radiation that you have. And there are areas of the world, like the (indistinct) which has thorium in the towns where they have a much higher dose of background radiation because the rocks are quite different. So it's the geology that really affects the background radiation.

And also in places in America actually, it's much higher. It's 6 millisievert compared with around about 2 in the UK. So it does vary. And also different societies obviously use medical radiation differently. So that has a slight effect on the dose. So if you're in somewhere that doesn't use CT scanning, of course your dose is going to be slightly lower on average than somewhere else where they use an awful lot of medical intervention and things like that. There are lots of things that affect the background dose.

And some of us will get more dose than other people because some of us fly a lot. Every time I go to Tokyo on a return flight I get 0.14 millisieverts of radiation from cosmic radiation. So your habits as a human also can affect that. And of course there's radiation in food, things like potassium-40. Bananas are really good source of potassium, very good for you, but also contain a bit more radiation than other things because they have a lot of potassium-40 in them because they take it up from the soil as the plants are growing.

MR JACOBI: Just coming to the pie chart that's there, for which particular population group is that? Is that the UK?

PROFESSOR THOMAS: That's the UK, yes, but I mean, that's actually fairly average for most people. So, you know, in some areas you might get a bit more radon from background rocks, but in most places that's about average. There's probably about the same in Australia as well.

MR JACOBI: Yes. We've just seen a chart from Australia that shows a greater proportion for artificial sources, about 1.7 millisieverts for CT and medical uses. So I think it's a bit more than 50 per cent.

PROFESSOR THOMAS: Yes. I mean, it might well be that, you know, in Australia you're going to use that an awful lot more than, say, in the middle of

Africa, for example.

MR JACOBI: Yes. Now, I just wanted to deal with the issue of LNT. We received in the submissions significant amounts of information about views about the LNT hypothesis or assumption, and I'm wondering perhaps, first of all, whether you could offer some insight into that particular discussion or debate and where there's consensus or not consensus with respect to that issue.

PROFESSOR THOMAS: Yes. LNT is a good example of, as a scientist, you could never have a hypothesis that you can't really test, and that's the problem we have with the LNT. We've got lots of information about radiation effects at high doses. The trouble is, as we've just been talking about, we're all exposed to radiation. So if I said that there was an average dose of 2 millisieverts, which is probably a bit on the low side, per year for each human life year spent on the planet and you die at 70, you're exposed to 140 millisieverts over your lifetime.

So when you get down to the really low doses you have a problem in being able to design the study to decide whether it's due to the radiation because you have that background effect, and so when you get below about 100 millisieverts we know the effect is very small. There's quite a steep slope on that line. We know the effect is very, very small, and it becomes incredibly difficult to actually show an effect because of all the other things that affect our health. So if you like- and the noise - it's like looking for the needle in the haystack when you get down to those low levels that you find what is due to the radiation are not due to everything else that affects our lives, which of course is complicated because over a lifetime, how we live changes markedly. I mean, we didn't have the Internet and things when I was young child.

Everything changes in life, so you're eating habits or (indistinct) so trying to define over a lifetime the effect of a very low dose of radiation, it gets lost in everything else that affects our health, and that's why there's so much argument about the lower dose range. We don't have many studies in that area because we can't do the study. We don't routinely expose people to a little bit extra radiation. It's quite difficult to get that data, and it's just sort of a noisy area when you're looking at it to define things statistically, and that's our issue with it, though some people believe that if you have a little dose of radiation it will actually pep up your DNA repair which is what keeps our bodies going.

MR JACOBI: Is that the so-called hormiotic view or - - -

PROFESSOR THOMAS: It is hormiosis. Yes, hormesis, sorry. Hormesis.

MR JACOBI: Yes.

PROFESSOR THOMAS: I mean, a lot of people like sitting in spas, for example. Interestingly, the German and Japanese are probably the two countries that really go in for spa treatment. You're actually exposing yourself to a little bit more radiation in those places and people think it's healthy. They don't think about the radiation. They just think it's healthy. But some people have taken that and think, well, you know, a bit of radiation does you good, whereas other people believe that we're far more sensitive to low doses of radiation.

I think that's more difficult to say that's correct because if a little bit of radiation was even more dangerous, we'd be seeing so many more effects from things like atomic bomb exposure and atomic bomb testing that we did in the 1960s where the doses around the world literally spread most - I think they didn't quite reach Australia, but they were virtually over the northern hemisphere where we had actually quite a bit more radiation around in the atmosphere than what would be normally from background, but we don't see huge increases of cancer. The increase in cancer we see because we're living too long, so people are getting cancer as a natural thing of aging which we can't really stop.

MR JACOBI: I'm just interested in your view as to the appropriate uses that can be put to the linear threshold. We've heard some evidence that it's appropriate to place store in it for the purposes of radiation protection. Is that your view?

PROFESSOR THOMAS: I find it really difficult because again, we will never ever have the evidence to say we shouldn't do it. So as a scientist, you tend to err on the side of caution and say, well, if I can't find the evidence, I have to assume the hypothesis was correct. I think we're actually getting to a stage now where all the other things that affect our health are becoming more important than very low doses of radiation. So to give you an example, there's a good piece of work done by the BEIR VII report which tries to put some of this into context. So they used American statistics and the Americans do have an awful lot of data on health outcomes, something called the (indistinct) database.

They're a good source of good, hard scientific data, and they reckon that if you exposed 100 Americans, given all of the normal health patterns that we would see in America, to 100 millisieverts, at that low level which we start to have problems defining what the effect is, one of those would get cancer due to the exposure at 100 millisieverts, 42 others will get cancers from other causes. Now, to me, that really put it into sort of context and (indistinct) well, actually I'm a bit more worried about the other 42 cases than the one case and the radiation at that level.

And you can never remove all risk from life. It's impossible. So when you start making one risk really decide things where actually it pales into insignificance compared with the other risk, I think we have a problem getting our heads round what's safe and unsafe when you get to that sort of level. And we could be making other things more risky by trying to protect ourselves from radiation at low levels, for example, and you see that and the psychological effects of Chernobyl and Fukushima. We're too worried about the radiation and it starts to actually have health effects. The worrying has health effects more than the radiation itself (indistinct)

MR JACOBI: Yes. I'm just interested in understanding with respect to LNT its utility in reaching conclusions about the causation of radiation-induced cancer, and that is, I'm just interested in your view as to whether it's appropriate to multiply these predictions from very low doses by large population cohorts to predict outcomes.

PROFESSOR THOMAS: Absolutely not. That does not help at all. To give you another way of trying to look at that, it's a bit like saying that as a man you wet shave and if you cut yourself you're going to lose a small amount of blood. So if lots of men wet shave and lose a small amount of blood, if you add the blood up, that means somebody is going to die from blood loss. That doesn't make sense. That doesn't help you protect men from cutting themselves shaving at all to suggest that it's so dangerous that if you multiply it up by the number of people who wet shave, somebody somewhere is going to die because they've lost so much blood.

MR JACOBI: Perhaps we can move away from LNT and I think we can just - we've got a slide that I think picks up some of the discussion that we've just had in terms of the relationship between dose and effect. I think this is headed Dose and Effect. Do you have that in front of you?

PROFESSOR THOMAS: No, I don't. Hang on a second. Yes, I've got them.

MR JACOBI: Whilst we've talked very low and low dose, are you able to speak to the issues of moderate dose and high dose, just so that we can round out the viewing of that table.

PROFESSOR THOMAS: At moderate dosage you're getting to the area where you - you mean the sort of upper half of the table?

MR JACOBI: Yes.

PROFESSOR THOMAS: A moderate dose is you're getting to the levels of more than a hundred millisieverts, so you're likely to see an effect in a very small number of people but you will see the effects specifically in

epidemiological studies. At high dose you're actually getting to the areas where you start to see direct tissue effects. So if you expose somebody to high doses of radiation for cancer treatment, for example, often the skin will go red, they'll start to feel sick and those are what we call sort of the direct effect of radiation, where you actually get tissue injury. Now, you only need to expose a very small number of people to those high doses to see those direct effects.

When you come down the dose range and you get to the medium dose levels, you're then starting to see fewer people affected. So to get a statistical answer you need to expose many more people but you will see an effect at those doses but the population needs to be significantly larger than at the very high dose.

MR JACOBI: We've seen similar information today expressed in terms of effective dose in terms of millisieverts and I notice that this particular tab was expressed in terms of absorbed dose or grays.

PROFESSOR THOMAS: Yes.

MR JACOBI: I'm just wondering what the relevant translation is here, just so that we're clear on that.

PROFESSOR THOMAS: It depends on the type of radiation. So things like an alpha particle are a bit like a juggernaut running into your DNA. It's very heavy, a helium nucleus. So it's physically going to do an awful lot more damage. So we apply weighting factors for gamma radiation. It isn't a direct translation but for most beta radiation it is a direct translation. You can translate grays into millisieverts. This is part of the problem that we have with radiation, is it's complicated. It's not a straightforward thing. It's not like taking a chemical that you can say, "This dose causes this effect." You have to take into account the type of radiation that's involved as well.

So to be correct, when you talk about doses to tissue, you should give effect in gray. It's much easier when you're looking at different types of radiation and most of it is exposed to multiple different types of radiation. So in order to sum those individual doses together, you have to take account of those weighting effects. We tend to refer to it as sieverts to give us one figure.

MR JACOBI: Just to pick up on some evidence that was given this morning, I just don't know whether you're - are you aware of a statement to the effect - and I hope I've got this right - that about 30 per cent of cancers are produced from natural background radiation and that a further 70 per cent are produced from anthropogenic cause? Are you aware of any such statement to that effect within the medical or scientific literature?

PROFESSOR THOMAS: Yes, it's basically very difficult to be certain.

Again, you've got the problem of so many things cause and effect, like cancer, that it's actually very difficult to tease out which effect is causing what percentage of cases. It depends on the study you read what people will say but it's very difficult to get hard scientific facts. I would suspect actually smoking obesity - sitting here as somebody who should not be the size she is - is probably far more deleterious to your health than exposure to background radiation. You can't avoid that exposure but you can avoid doing some of the things that we know are much more dangerous to health, like smoking and being overweight.

MR JACOBI: Earlier in your evidence we began to refer to some of the distinctions in the kinds of radiation exposure you got in particular events. I indicated that we'd come back and deal with each of the particular significant population radiation exposure events in sequence.

PROFESSOR THOMAS: Yes.

MR JACOBI: I'm happy to first come to the circumstances of the atomic bombs that were detonated over Hiroshima and Nagasaki and I'm just interested - perhaps we will deal with sources as well as we go - but I'm just interested, first of all, to understand what's the consensus of scientific evidence about what are the radiation-related effects associated with the Hiroshima and Nagasaki detonations.

PROFESSOR THOMAS: Yes, there's no doubt about it, the higher the dose the more likely you are to have had cancer as a result of exposure. People tend to think that there was an awful lot of people affected by radiation. Yes, there was. But actually most of the deaths that occurred - and there are about 140,000 casualties in those two atomic bombings, short-term casualties - about 120,000 of that was actually caused by blast injury. I mean this was a massive heat release and that basically caused blasts and it caused a heat surge which killed the majority of the population. About 20,000 of the people who survived that and lived in the very, very centre of the explosion died subsequently, as in a few months, from radiation poisoning, which is the top end of that table I showed you. So those are the very high doses that give you direct tissue effects.

MR JACOBI: This was acute radiation sickness, as I understand it's called.

PROFESSOR THOMAS: Yes. You see the effects immediately. People who have radiotherapy, they will know that a large dose of radiation that we use to cure many cancers, which is targeted to the cancer, does cause some systemic effects as well. So that gives you an idea of what that really is. But then you come down to the people who did not die from the immediate effects but were exposed to fairly large doses, around about - they give it in weighted colon

dose. It's the way it is referred to by the Radiation Effects Research Foundation. So some of them have large doses: four gray, three gray. Then you start coming down into the milligray. For most of the population it's a five. Those exposures had lower-end doses. So there was quite a lot of low dose exposure. But it was exposure to gamma radiation predominantly, not to the particulate radiation of iodine-131. There was some but not as much. It was mainly gamma exposure.

It was quite different to a scenario than an accident in a nuclear plant, for example. There is a clear dose response, in that the high doses result in more cancers. The low doses, there's a slight inflection of the curve at the bottom suggesting that the low doses are not quite as bad, according to the LNT, as you might expect. But it's actually very difficult because once you get down to that hundred millisievert level you're looking at a very small increase in cancer over the background rate. I mean they did very large studies. 86,000 people were in the studies that they looked at and they followed them over their lifetime. Many of those people are now in their 70s and 80s.

We know there's an effect on - if you were much younger at exposure, the effect might even be greater. So you're more sensitive to the lower doses than if you're an older person, for example.

MR JACOBI: I was going to come to the sources of the information upon which you relied for the answers that you've just given in terms of effects.

PROFESSOR THOMAS: Yes.

MR JACOBI: You referred to a number of 86,000 people studied. What's the source of that study and what's the nature of that study?

PROFESSOR THOMAS: That's the lifespan study and that was a very big cohort study that was set up as quickly as they could, given the effects of war in that area, to look at the effects long-term on the population that was exposed. That was run from the Radiation Effects Research Foundation in Japan. It was a very major undertaking to follow that number of people throughout their lifetime and it's a good source of well-collected data that's been collected in a regimented fashion. So you know that the data is not changing over time because of the way you're looking at the data, for example, and collecting that data. Those sort of studies need to be set up from the word go and set up very strictly to make sure that you don't introduce bias into them. So it's a well-conducted scientific study with appropriate controls.

MR JACOBI: Has that study itself been the subject of peer review and analysis?

PROFESSOR THOMAS: God, yes. You don't get any of that published without it going through peer review. People will tear papers apart. Peer review is not an easy process. People tend to think it is, but real peer review and the journals that that sort of information is published in are really rigorous journals. So that's been subject to great peer review. I know there's a lot of people who think it's easy. It's not if conducted properly. But I'm afraid it is pretty rigorous in the way it's been conducted and those are the facts and I'm sorry, but that's what the facts are.

MR JACOBI: You drew a distinction in your evidence earlier between the nature of the radiation exposure from an atomic weapons detonation and the consequences of a nuclear power plant accident. I wonder whether you might expand on what you see is the key distinctions.

PROFESSOR THOMAS: I mean for a start off the atomic bombs are exploded above ground, okay, so the atmospheric conditions are quite different and the way the material is distributed is quite different. What is released is quite different. Yes, you do get T3 and iodine released as well. For example, the iodine will stay up in the atmosphere for longer before it comes down to the ground in rain. So because it's got a short half-life there's going to be less of it than what was actually released by the time it hits the ground and we get exposed to it. It's interesting actually that people tend to think that - sorry, I've lost my train of thought.

MR JACOBI: We're drawing a distinction between what follows from atomic weapons testing and from nuclear power plants.

PROFESSOR THOMAS: People tend to think that there's been more exposure from a nuclear power plant accident but if you actually look at the figures for what was released from the atomic bomb tests - not the bombs themselves but the tests that carried on in the 1960s in America and Kazakhstan and places like that. We actually released far more caesium and iodine into our atmosphere and stratium as a result of those tests than at - - -

MR JACOBI: I think we've got a slide that picks that up and it contains a table.

PROFESSOR THOMAS: Yes. I was quite surprised when I saw that.

MR JACOBI: It would be helpful I think to the Commission if you might unpack the information that's contained there. It uses a particular - as I understand, it's a petabecquerel and I'm just wondering whether you can explain what a petabecquerel is.

PROFESSOR THOMAS: A becquerel is a measure of radioactivity, so it's the

amount of radiation. It's the radioactivity. A petabecquerel is 10 to the 15 becquerel. An individual becquerel is very, very small. It's disintegration per second. So if you're looking at very, very large releases then in actual fact it's nearly tenfold what came from the above-ground tests in the 1960s compared with something like Chernobyl. So it was 85 I think it is petabecquerels from Chernobyl and there's nearly 10 times that much from the above-ground tests.

So we worry about nuclear accidents but far more was released in the 1960s. There's a lovely graph where you get the original raw data from the (indistinct) web sites is you can actually plot the amount of strontium and caesium in milk in the UK from the above-ground tests and in the 1960s that was substantially higher than from the Chernobyl accident. There was virtually no strontium in our milk from the Chernobyl accident in the 1980s but you could caesium in that. So it's interesting, we tend to forget about the above-ground tests and concentrate on the two nuclear accidents, but actually more radiation was released in those tests than either of the two nuclear accidents that we've had more recently.

MR JACOBI: Again I understand that the source of this information is one of the UNSCEAR reports. Is that right?

PROFESSOR THOMAS: Yes, there's two reports. There's the UNSCEAR report from Chernobyl which references that table, and then the Fukushima data comes from the latest Fukushima - - -

MR JACOBI: All right.

PROFESSOR THOMAS: They're all public documents, so it's perfectly - anybody can look at these online if they want to.

MR JACOBI: Perhaps with that point, if we can come to the particular circumstances of the Chernobyl accident and I'm just wondering whether there's anything particular about the circumstances of that incident that has had a particular consequence in terms of the release of the radiation from that particular accident that distinguishes it from Fukushima.

PROFESSOR THOMAS: I mean the plant for that was quite a different design and now when we build nuclear power plants we always put containment facility around the core, which means that if something happens to the core and there's a release of radiation there's another shield, like a firewall around your computer. There's another shield so that you don't get it released straight into the atmosphere. It gives you time to do things like move the population away or get them to close their windows and doors and things like that. So it gives you a bit more time to deal with the situation and keep that

radiation inside the plant rather than releasing it to the atmosphere.

Chernobyl didn't have that. The power station there, what they believe happened was this was an incident where they were doing a safety demonstration and they were trying an experiment with the reactor. I've been told and I think it's probably true, that the train from Moscow - because you have to remember this was Soviet Russia at the time - was late and there was a crew that went off duty who had been trained how to do this specific procedure and then a naive crew came on, and you didn't do those things in Soviet days without the people from Moscow coming to watch you and it was basically human error that caused the accident. What happened was, they removed the rod that would normally moderate the reactor, the safety features were disabled. It went out of control. They couldn't do anything to save it and there was a massive steam explosion, not a nuclear explosion. People confuse the two. This was a steam explosion which basically blew the roof off the building and ejected part of the core. It was a very big explosion.

But in Fukushima it was very, very different. I know the whole world saw an explosion but actually that was the outer containment breaching. That wasn't the reactor core going up. So the amount that was released in the two accidents are very different because the core was exposed following Chernobyl. So much, much more was released in the Chernobyl accident than was released in Fukushima because all the safety systems kicked in in Fukushima, where there weren't any safety systems working at Chernobyl; they'd turned them off to do the experiment.

MR JACOBI: I'm just interested to understand with respect to the exposure of the core at Chernobyl, did that have a particular consequence in terms of the radioisotopes to which Soviet Russia and the remainder of Europe were exposed?

PROFESSOR THOMAS: Yes. I mean the problem you have when a nuclear power plant explodes is you get releases of volatile isotopes. Things like strontium, because they're heavier, don't get ejected as far so they stay in the vicinity of the reactor. So when you have an explosion like that, the iodine and the caesium go up into the atmosphere and get driven around circulation of the wind. That's exactly what we saw. If you map where that contamination went, you can tell which way the winds were blowing. Originally the winds went north. There was also a fire in the reactor as well and that burned for seven days. It took them seven days to extinguish that, which is the pictures that some of us remember of seeing helicopters flying over and dropping things down; it was trying to turn that fire off. But that took about seven days.

So for seven days it was leaking radiation into the atmosphere. It was quite different from the scenario of Fukushima where it was under control fairly

quickly. There it burnt for some time. It carried on releasing radiation. In fact, we didn't know anything about it in Europe because we didn't have all the fancy satellites and things that we have now. We didn't know anything until an alarm went off at a power station in Sweden and the Swedes thought they had a release and got really worried, but in actual fact that was the air travelling across, carrying the radiation from Soviet Russia and it hit the detectors at the Swedish power station. That was the first inkling we had that something was wrong, and that was a week later.

So it took a whole week for that cloud to pass across Soviet Russia and hit the Swedish border. Of course during that week half of the radiation from the iodine would have gone because its physical half-life was so short. It was pretty obvious we were detecting something that was a major release in that area of Russia. If the wind had been going the other way, we may never have known about it because of course the wind would have taken it to the east and over Russian territory.

MR JACOBI: I'm just interested to understand - we'll come in a minute I think to - I want to address what you understand the key health effects have been following the exposure at Chernobyl, but I'm just interested in understanding about the evidence collection and to the extent to which there was evidence collection associated with affects on human health and what's been undertaken in terms of those studies.

PROFESSOR THOMAS: There were a number of large studies set up fairly quickly. The Japanese actually were the first to really respond with that and they set up large-scale screening for – they literally sent vans, that were able to screen children, to Russia and went around the local community. So there was a lot of evidence gathering within that. That was probably in the early nineties and we have to remember that when it happened in 1986 it really was Soviet Russia, it was not easy to get in to that country. But there were people who were allowed in fairly soon after the accident. So you have some people from EU for example were allowed in to just see what was happening to gather some evidence and actually, to put together packages to actually help recovery. So from the very early times, there were people evidence gathering in there, but the real major studies of the effects on health, because we know the effects on health are going to be slightly longer term, didn’t really get going until the early nineties.

But the Japanese (indistinct) foundation started running large screening programmes, the Americans started putting a lot of money in to cohorts, similar to the lifespan cohort but really intended not to be probably as long as the lifespan cohort. But those are still ongoing. They’re still obtaining data and what they do there is they collect people who have got thyroid cancer, have had a diagnosis of thyroid cancer and pair them up with people who have a similar

exposure and live in a similar area and then follow them through the rest of their life to see what the effects are. So there were – it would have been nicer to have had much more data, not many people have direct thyroid measurements for example, but there were some. And not many people undertook detailed questionnaires and it's important to know what people were doing, were they inside at the time of the accident? What foods they were eating? Were they eating lots of milk containing food for example, which we know gets more heavily contaminated in the iodine fallout? So it would've been nice to have more data but actually we got quite a lot of data that tells us the doses that individual people have. And if you're going to relate cause and effect, you need those (indistinct)

So there is a lot of data and it's well constructed, that had been conducted – it's the protocols that most scientists would accept are the best that we could do at the time.

MR JACOBI: Now I think you've indicated that there were a number of studies and I'm just interested to understand, we're aware that there was a major report produced by UNSCEAR, this is in the decade after the nineties, so this is, as I understand it - - -

PROFESSOR THOMAS: Yes.

MR JACOBI: - - - a major report released in 2008. I'm just interested to understand, are you aware of the sort - - -

PROFESSOR THOMAS: There was one before from about 2000 as well, so there's been two major UNSCEAR reports.

MR JACOBI: Yes.

PROFESSOR THOMAS: The most recent one was 2008 which actually wasn't released publicly until 2011, just before Fukushima. But it was 2000 was the first report and that really – we were still actually getting data at that point. So that was a sort of preliminary report and with the 2008 we got far more data, so we have been able to assess the health and consequences much, much better with the longer period of follow up.

MR JACOBI: Did those reports include information concerning these medical data sets from these cohort studies? Did it consider those studies?

PROFESSOR THOMAS: Yes. They were starting to give early results at that stage, so yes they were included. More importantly, was understanding the doses and the amounts of release and trying to get that right because actually you're reconstructing doses because people weren't physically there measuring

things at the time. So that was important to get right as well. But yes, you were starting to see some – certainly some of the cases of thyroid cancer were definitely a problem in 1992. There was no two ways about it, this was not detection (indistinct) screening, this was definitely arising in childhood thyroid cancer, and only childhood thyroid cancer. So you had about eight years worth of data form those screenings in to that first report in 2000 but obviously you'd have more in 2008.

MR JACOBI: And I know this may seem obvious but did that involve people that were medically trained?

PROFESSOR THOMAS: Yes, absolutely. Absolutely. I mean that was one of the reasons that I got interested in this, my boss at the time was probably the most (indistinct) pathologist and he and a gentleman who's (indistinct) both went out in 1992 and actually sat in clinics with the medics in Belarus, seeing these patients as they came in through the door. So no, these were people who were really at the top of their game, experts in their field who went out to conduct these surveys.

MR JACOBI: Okay. Now I just want to turn, we mentioned in introducing you, the concept of the Chernobyl Tissue Bank and I'm just wondering whether you might explain what the Chernobyl Tissue Bank is and what its purpose is?

PROFESSOR THOMAS: Yes. It became fairly obvious, in about the mid-1990's that the people in Ukraine and Belarus were very keen to understand what was happening. They wanted to be involved in a lot of the science and they had a tendency to be giving researcher's material from the same patients, which means when you come to do the meta analysis, you're actually looking at the same patients and you don't know it. So we thought a better way of helping them to do this and a better way of giving research scientists good material to work on was to actually develop a tissue bank where we collated all of the information about the pathology and about the types of tumours that were coming and collected biological specimens so we could try and understand whether there was something different about the way radiation induces cancer or are we looking actually at the same cancers but just more of them. Because if there's something different about the way the cancer's been developed, we might need to change the way we're treating people.

So it was really to try and understand how radiation affects the molecular biology and how it induces these cancers. But it was to do it in a programmed way, so that all researchers around the world could get access to this material, so the best science could be done on the material, to make sure it was collected ethically because the rules in Ukraine and Belarus are not quite – at the time, they've strengthened since, but at the time were not quite what we would

accept in the west. So it was to encourage them to do this in a proper way, in a standardised way and in a way that we could follow over time. A bit like setting up the cohort study but this time with tissue because we wanted to know what radiation actually does to the tissue which causes these cancers?

MR JACOBI: Did that involve cancers other than thyroid cancers?

PROFESSOR THOMAS: There weren't any. That was the problem. I mean people keep thinking we're going to find other cancers other than thyroid cancer. There has been no increase in any other cancer in the populations at large. I'm not talking about the cohort with the liquidators; I'm talking about the population at large. There has been no other increase in any form of cancer, other than thyroid cancer. And there's a really good reason for that. The reason is there was an awful lot of iodine released; this is the first time we've ever exposed 10 million children to iodine. We don't see effects on the adult population; we only see it on the children. So this increase in thyroid cancer is restricted to only those who were young children at the time of the accident and the reason for that is that is a) they probably drank more milk than their parents, so their dose was higher because the milk was contaminated. But also, the thyroid in the child continues to grow, it has to reach adult size and that added growth increases the ability to – for the cells to become cancerous.

So it was important that we collected that and of course it's a particularly sensitive group when you deal with children, it's sensitive where – whichever country you're in. And people expected there to be other cancers. I thought there might be breast cancer for example because the breast has an iodine (indistinct) but it doesn't keep the iodine within the tissue. So it takes it up, especially when you're lactating but then it releases it again very quickly. So the actual dose to the tissue is much smaller than it would be to the thyroid where it takes it up, hangs on to it, and it releases its iodine while it's inside. And it really brought it home to me, when I actually saw the figures from the epidemiologist about doses of caesium. Now the caesium, some of it was skimmed, they took the (indistinct) off and disposed of it but a lot of it stayed on the ground and that mass that we were talking about at the beginning shows you where that caesium deposition was. And of course (indistinct) this is a rural economy where people grow their own food and they eat their own food.

So people were exposed to caesium and I was expecting to see something from that because that's the way we always thought about radiation, low doses can be very, very dangerous. But when you work out how much the dose is to people, just carrying on their normal lives, eating the crop they grow in the garden, over 20 years about nine million people – sorry, six million people got the equivalent of nine millisieverts each. That's the equivalent of one CT scan, whole body CT scan for example.

MR JACOBI: Now could I just - - -

PROFESSOR THOMAS: Because caesiums long lived physically, short lived biologically, the dose is much lower than you would expect. So all of a sudden you start to realise, well hang on, that's why we don't get any other cancers because the two principle isotopes, the iodine yes does cause thyroid cancer but the caesium dose that you get from that is so small that we just don't see the cancers because we wouldn't be able to pick them out from the noise of the (indistinct) cancer in that particular area.

MR JACOBI: Can I just go back through that answer and I'm just interested in the question of sources of the information that we've just discussed. And that is, I think we started with a statement about there not being cancers other than the thyroid cancers.

PROFESSOR THOMAS: Yes.

MR JACOBI: What studies you rely on to express that particular conclusion?

PROFESSOR THOMAS: Those are the large epidemiology studies that have been. I mean, if you're looking for something that - you want to look at the mechanism for how something is caused, first of all, you have to see that there is something causing it. So you can't do studies on the molecular biology unless you can see an increase in that cancer and then look at the excess rate. So you can only study an increase in cancer if you do proper cohort epidemiological studies, and all the cohort studies have shown us that thyroid cancer is the only one that has increased.

There is lots of noise in the scientific - not quite so reputable ranks - that give you anecdotal things of, "Somebody has got this cancer from that," but there's actually no studies that show that is the case, and you have to do this in a scientific way because cancer is caused by so many other things. So unless you do the right design studies, you're going to end up picking up cancer from other causes and think it's due to the radiation. You have to design very carefully in order to find out exactly what is causing it.

MR JACOBI: Can I just come to the thyroid cancers, and you expressed a view about the increased risk, particularly with respect to children, but not in the adult population and their exposure.

PROFESSOR THOMAS: Yes.

MR JACOBI: Again, what are the studies? What's the source of the information that you refer to with respect to those conclusions?

PROFESSOR THOMAS: Again, it's the epidemiology. So there has been less done in the adult population because thyroid cancer becomes so much more common in the old population, so you'd have to do massive studies in order to look at that. Childhood thyroid cancer is very, very rare, so you can see an increase very quickly, and this is a large increase. There's 100-fold increases in some places. As you move into adulthood, thyroid cancer becomes a lot more common even though it's still a rare cancer in terms of cancer terms.

But in order to see an increase with the population that you've got, you'd have to do very large studies and because we knew children were more sensitive, we did concentrate more on the children, because we knew that's what we could see, and of course you have to remember we had to get somebody to do these studies as well. So you have to come up with a proper design that everybody is going to believe the result, otherwise nobody is going to fund the study too. So there has been more concentration on the younger people because we knew they were much more at risk and we could define the population.

The adult population has not been so well studied, but there have been some studies in that population as well, and we just can't see an increase. And the simple way to do this is just to plot cancer rate over time and you can see that there's a cohort effect, so the youngest ones carry that risk with them. So there's no doubt about it. It is the youngest who are most at risk from this with all the studies that have been done.

COMMISSIONER: Professor, there has been evidence also this morning about genetic disease caused by the Chernobyl accident. Is there any evidence - - -

PROFESSOR THOMAS: Absolutely none. You have to remember that to have genetic disease you have to get a radiation dose to the germ cells. Your germ cells are pretty well protected. So to get a large dose to the germ cells is actually quite difficult. The studies that were carried out after the atomic bombs, where the doses were much larger you would've expected to see much more effect, and still have shown absolutely nothing in the next generation. So there's no generational effect at all from the atomic bombs because the individual doses - not the collective dose, which is the totally wrong way to look at it - the individual doses are so much lower.

It would’ve been amazing to see that, because you would then assume that anybody you had put under a CT scan, would it affect their children in the future. It just doesn't work scientifically to even suggest that at those doses. A lot of people did have abortions because they were scared, and we saw that after Fukushima as well. Some of the people were so scared that their children would be affected they had abortions, but the doses - there was just no

scientific evidence to suggest that they would be at risk.

But people are scared and they do react in different ways, and it's very easy to blame something like radiation (indistinct) why something isn't right in your life, and I've seen that with people I know should know better. It's still an automatic response to try and find something to blame if you have a problem with your health or your children's health, but there's no scientific evidence for it whatsoever.

MR JACOBI: Coming back again to the answer from earlier, you expressed, I think, a generalised statement or an average with respect to an average exposure in terms of about 9 millisieverts for the general population that was other than the localised emergency workers at Chernobyl, and I'm just interested to see what's the basis for that estimate, how that was calculated, and where does one go to find that as a piece of material?

PROFESSOR THOMAS: Yes. That's using data from the map that we've been discussing first so we know what the - - -

MR JACOBI: Actually we'll pull that map up if we've got it. We don't. Sorry.

PROFESSOR THOMAS: Yes, so that you'll know what the pool contamination is, you can take questionnaire data to work out how much people were eating during the time, and you can also use whole-body scanning. They are doing that in Japan at the moment. People are being whole-body scanned to look at the caesium burden they have and in most cases they can't find any caesium at all in them. But there's a variety of different ways you can look at it, but most of them will use sort of environmental measurements and give you an estimation of the dose, because it's actually quite difficult to go and scan that number of people in an area like Belarus and Ukraine so you can work out from all of that data what the estimated dose would be.

MR JACOBI: I just want to then come to the question of outcomes, and that is in terms of deaths and other reported losses. Perhaps we can deal first with the localised workers, that is, as a result of the Chernobyl accident. What's your view of the state of the evidence with respect to the number of people who were in fact killed by radiation exposure from the Chernobyl accident?

PROFESSOR THOMAS: Yes. I mean, there are three people who were killed as a result of the explosion, nothing to do with the radiation, just got hit by flying debris and things like that. There are 28 firemen - and these were the guys who were hovering over the reactor core and were exposed to very large doses of radiation. 28 of those have died within a few months as a result of acute radiation sickness. There were a total of 134 people who actually have

acute radiation sickness. They had very large doses and 28 of those have died. 14 of them went on within, I think, about five years of the accident to have children who were perfectly okay. So even those who had high doses, their children were perfectly okay.

There have been around about - again, you have to keep taking account (indistinct) lifetime. So what was reported in a 2008 report from UNSCEAR was 6,000 cases of thyroid cancer. They're going up by about a few hundred each year. Now, of those we know of 90 who have actually died from their disease. Okay? So these were people who unfortunately came to the clinics late and had metastatic disease and we were unable to treat effectively, and over about 50 years, so up to about 20, 25, we would expect, based on the data that we have at the moment, we'll probably have about 16,000 thyroid cancer cases as a result of the radiation. Okay? So more than we would have with normal incident of thyroid cancer.

Thyroid cancer is one of those things that we can cure very effectively, ironically by giving very high doses or radio iodine because the thyroid themselves take up the iodine and they get a large dose of radiation and that kills them. But even so, we would expect about 1 per cent of the people who get thyroid cancer to eventually die of their disease, and that could be many years after they have their first primary cancer. So that would be 160 deaths, for example. About 30 per cent of them we would expect to come back with thyroid cancer deposited elsewhere in their body, but again, most of those we would treat very effectively with radio iodine.

So if you sum all that up, you've got 28 who definitely died from acute radiation syndrome, very high doses, their bone marrow packed up; you've got 160 predicted deaths. That gives you something like just under 200. Then you've got (indistinct) in a fudge factor because until you have a complete dataset you will never know the exact figure, but two to 300 probably maximum. The assumption that they're in paper (indistinct) with a card (indistinct) which reviewed all this on the 20th anniversary of the accident suggested there might be about 25,000 other cancers, but the evidence doesn't seem to say that that's necessarily going to be correct, because the doses to elsewhere in the body were so low because they come from caesium.

We base that data on what we would predict if we use the models that were used for the atomic bombs on that population. That may not be the correct model to be using. So at the moment there are estimates, but what we do know is about 19 of the children who have thyroid cancer have died from their thyroid cancer and 28 workers have died from acute radiation syndrome. The others, although they have acute radiation syndrome, they have sort of lesser forms of it, are still alive and well, apart from the few who died from smoking-related illnesses, alcoholism and (indistinct) which you really can't put down to

the radiation because of course as our population ages they're going to die. We can't avoid death, unfortunately. Well, not yet. That population will die but it won't necessarily die of anything to do with radiation.

MR JACOBI: You gave a number from I think an analysis that had been done. I think the surname was Cardis.

PROFESOR THOMAS: Yes.

MR JACOBI: Of 25,000. Was that 25,000 cancers or fatalities?

PROFESOR THOMAS: Cancers. Interestingly, as we get better at treating cancer of course they may not result in deaths from cancer because in medicine if you cure somebody, it just means they die from something else, not from the cure.

MR JACOBI: I just wonder, based on your involvement and work, whether you think that there are any particular key lessons that have emerged from our understanding now of the Chernobyl accident in terms of the cancer risks.

PROFESOR THOMAS: Yes, I think if you'd asked me when it happened I think everybody was scared there was going to be lots of leukaemia and different sorts of cancer. Now the evidence - and it is very good, hard evidence, and that's part of the reason I think people did not speak out quite as - particularly don't speak out without data. We don't like giving false information. So now we have the data and we can see that actually the major cancer was - in fact the only cancer was thyroid cancer, which we would not have predicted from the beginning. But interestingly, if you go back with hindsight and you look at the animal models, the animal models predicted exactly that: it would be young children who would be most at risk and they would get thyroid cancer and nothing else. Even we treat with radioiodine, very high doses of radioiodine, that does get elsewhere in the body - that's why we're giving it, to get rid of the thyroid cancer - you do find you get a small number of secondary malignances as a result of that radiation exposure but at much higher level.

So my guess is that thyroid cancer will remain the only thing that we actually can prove was due to the radiation. It's very difficult to disprove that anything else went up because of all the other effects that give us cancer. That's partly part of the scientific conundrum we find ourselves in: you can't disprove something but you can prove it; and you can't disprove there was ever any other type of cancer, if we're totally honest scientifically. But the chances are that the vast majority of all the other cancers in that population were not caused by the radiation at all; were caused by alcohol, smoking, all the other common factors that we know about. But pinning the exact amount down to radiation in

our population, as I've said before, at low doses is very difficult and I would say almost impossible. But we keep trying to do it, and that's part of the reason that people are still worried about radiation, is we can't give them a definitive answer, if we're really brutally honest.

But what I can say is, I would be more worried about living with somebody who smoked than being exposed even as a liquidator - to the lower dose liquidators to the radiation from Chernobyl. Smoking is far more dangerous. In fact, smoking also has radiation in it because you have polonium-210, which is now thrown into - so a smoker who smokes on average one pack of cigarettes a day over a year will get the same dose as if they had a CT scan.

MR JACOBI: That's additional?

PROFESOR THOMAS: That's additional.

MR JACOBI: Can I move to Fukushima. I think we've already dealt in part with the differences in causation and I'm just interested in terms of the key isotopes we need to be concerned about in terms of emission from the Fukushima incident and then move on to dealing with the health effects from that.

PROFESOR THOMAS: I mean it's the same two isotopes. It's iodine-131 and caesium-137, the longer lived version of caesium. Those are the two isotopes that we're concerned about. Those are the ones that were released at highest quantities and dropped into the general population rather than just being in the reactor plant itself. So those are the ones that are cause the health effects, if any, on the population.

MR JACOBI: Perhaps if we can deal with - because we've dealt with iodine and thyroid cancer with respect to Chernobyl, are there relevant difference with respect to the Fukushima incident?

PROFESOR THOMAS: I mean the doses at Fukushima were much, much lower. They were about a hundredfold lower, even to those who were evacuated. There are reasons for that: (a) there was much less release; (b) the Japanese did exactly what they should have done, which was to move the population away. The Japanese don't drink much milk and things like that. It was cold, it was snowing. The cows were inside so they weren't eating contaminated grass for those who do have milk in their diet. So there's lots of reasons why their iodine intake would be lower. Also, the Japanese eat a lot of iodine-containing seaweed and things like that. So your thyroid is a bit like a sponge. If you put a dry sponge into water, it soaks up the water and once it's got all of the water contained in the sponge, it can't take up any more. The thyroid is like that.

If you've got lots of stable iodine around, you're actually going to have all of your iodine being sucked in by the thyroid will be taken up by stable iodine. So the radioactive ones don't go in. There are lots of reasons why that dosage was lower but primarily it's a lot less was released and the Japanese authorities did the right things in terms of moving the population away and cutting the food chain. There's no doubt about it that the food chain and what you consume is the most important component of the dose. So you will inhale some iodine if you're standing outside but cutting that food chain restricts the dose of iodine and caesium very, very effectively.

In Japan they can do that. They can call in food from other areas of Japan. In Belarus you can. In Russia, because it's ruled economy, you really couldn't do that. So if they said, "Don't eat the food," if the people had actually done what they were told - and people notoriously don't do what they're told - you know, they had problems feeding the people who lived in that area as well. So the two accidents are quite different, both in terms of the amount released and in terms of response by the authorities (indistinct)

MR JACOBI: You expressed the exposure as being a hundredfold less. Is that capable of being expressed in terms of either grays or middle sieverts?

PROFESOR THOMAS: Millisieverts. So the average exposure to evacuees and (indistinct) was to the thyroid about 500 milligrays. Because it's a beta emitter, you can equate that to the 500 millisieverts. The exposure to the thyroid for the people that were actually physically measured - there's no assumption in the dose; this was actually measured in the thyroid - from Fukushima was about 4.2 milligray millisievert. So we now the doses were that much lower. In the original reports that came out from WHO there were an awful lot of assumptions about how people would behave, so those assumptions went into the dose estimates. So those estimates at about 80 millisieverts, for example. When they actually measured the doses, the doses were an awful lot lower because people had been moved away, they'd shut their windows and doors, they'd not eaten contaminated food. So it's pretty obvious that the measures were pretty effect in reducing the dose, which is the most important thing. No dose, no effect; it's that simple.

MR JACOBI: I'm interested in understanding the extent to which there's been health monitoring of both the general population and those particularly in the Fukushima prefecture following the incident.

PROFESOR THOMAS: There's a huge study going on where they are monitoring the health of the population. That might actually not be helping the population because if you're having your health monitored you immediately think, "I'm going to be ill, that's why they're looking at me," which actually

psychologically doesn't help them that much. But there's a massive health survey that's going on looking at different aspects. There's a big ultrasound study that's looking at the 360,000 children who were exposed under the age of 18. That is actually a survey. So all of these kids will be invited to participate in having their thyroids screened by ultrasound, which is an extremely sensitive technique, every two years until they're 20. I think it then goes to every five years after that. Just the long-term effects on the thyroid.

But there are also other studies looking at women's health, looking at pregnant women's health, looking at the psychological effects as well. So there's massive amounts of data being gathered about that. That's actually got a problem because if you release that data without explaining where the data has come from, you can actually worry the population far more. So interpretation of that data for the public, who aren't experts in whatever health field we're looking at, actually requires quite a lot of skill and quite a bit of interpretation. Otherwise you just get facts which don't mean anything to anybody.

MR JACOBI: I think we've referred to an analysis of caesium and iodine. Is there analysis of other particular radionuclides and their release and their health effects on the population?

PROFESSOR THOMAS: There are huge amounts of people monitoring the environment around there, loads of studies being done. There's some people wandering around with caesium detectors just to see what the levels are on the ground because you get very patchy fall out and of course if you're inside a house you're not going to get contamination unless you walk through a contaminated patch and bring contamination in with you. So there's huge differences in exposure levels depending on where people are at the time and where it rained for example, so – and on to the soil that (indistinct) There were lots of studies going on about that but really and truly, we know that the isotopes they're going to cause a problem not the caesium and the (indistinct) because they're released in to the environment whereas most of the (indistinct) are very, very close to the power plant themselves. It's the volatile isotopes that cause the problem for general health. So there's massive amounts of data that are coming out of those studies as well.

MR JACOBI: Are you aware – and we have heard some evidence that suggested that there were some reports of illnesses consistent with some forms of radiation sickness following the - - -

PROFESSOR THOMAS: No.

MR JACOBI: - - - Fukushima incident?

PROFESSOR THOMAS: No, not true at all. I mean you can feel sick for a

number of reasons and that's one of the first signs of radiation sickness but it doesn't mean you've been exposed to radiation. The doses at the plant were very much lower than the doses at Chernobyl; nobody got a dose of a sievert, which is the sort of (indistinct) acute radiation syndrome as 1,000 millisieverts. So the doses were much, much lower, even within the plant and that's down to really good radiation protection and making sure that you monitor your workers effectively as well. And that was very important. That's why so many people were involved because they were changing the workforce to make sure that individual's levels were kept as low as they possibly could, but to give them (indistinct) they were working in.

MR JACOBI: We have also heard some evidence that suggested that there would be an epidemic of cancers that would be created as a result of the Fukushima accident. Do you have a view with respect to that?

PROFESSOR THOMAS: Absolutely not. I mean I worked on the recent IAEA report and we went through every piece of evidence and we were able to talk to the Japanese, really drill down in to what was known, what was unknown and the levels of radiation that were – that came out of the plant and the doses to which the population were exposed, there will be absolutely no discernible risk in cancer increase. I have to say something though, there was a recent report about a gentleman who had leukaemia who'd been working at the plant, the problem is the law is not our friend here. The law says that if you cannot disprove that it was due to an industrial cause then you pay compensation. So because they were unable to prove that it wasn't due to the radiation because we just can't do that. We can't prove a negative, he was given compensation but I'm really worried about that because if you look at the dose he had, he had AML which is reasonably common in his age group. If you look at the figures from what we have from the atomic bomb studies, actually 30 to 40 year olds and this gentleman was I think 40, that section of the population is actually more resistant than younger people and older people to leukaemia development from radiation. His dose was, I think, 15 millisievert or 19 millisieverts, certainly under 20 millisieverts but his lifetime dose from other radiation sources throughout his life and background would've been 80 millisieverts by the time he was 40.

So why – to me, he's much more likely to have had the leukaemia from things other than radiation and unfortunately people in that age group do get AML and that's a fact of like. I see people like that all the time in the hospitals who have got AML around about that age group, doesn't mean they're exposed to radiation. But unfortunately as soon as you pay compensation it becomes fixed in the public's mind and the media's mind that it was caused by the radiation. That is something totally different and there's certainly not enough evidence to say that. But unfortunately that's the way the compensation rules work in terms of industrial exposure to things that might damage your health. And

also, I should also say that smoking causes 17 per cent of AML and if you've been to Japan, the majority of Japanese men smoke.

COMMISSIONER: Professor, thank you very much. That was very useful for us and - - -

PROFESSOR THOMAS: Thank you.

COMMISSIONER: - - - I thank you for spending some time with us on that evidence. We'll now - - -

PROFESSOR THOMAS: Thank you very much.

COMMISSIONER: - - - adjourn.

MATTER ADJOURNED AT 5.15 PM ACCORDINGLY