Gerhard Proehl:

I will have a series of presentations on the topic which you mentioned what is about assessment of exposures to people after nuclear accidents. And the other is dealing with say assessment of exposures in the post closure period of nuclear waste disposals. I will start with the first which deals with the assessment of exposures to people from nuclear accidents. First of all, I will give an introduction on very general issue which is radioactivity and radiation exposure from natural sources. As you all know, radioactivity is a phenomenon, it is a natural phenomenon.

And it means it is a disintegration of atomic nuclei and simultaneous emission of energetic rotation. I think you all know that elements comprise of atomic nuclei and an element is defined by its number of protons. However, the number of neutrons varies and therefore any element has different isotopes. Non-stable isotopes of an element are called radio isotopes and radioactive atoms in general are called radionuclides. In total, we know now about 118 elements and only 80 of these 118 elements have stable isotopes. In total, there are about more than 1000 radionuclides. Where do these nuclides all come from?

There are three main groups. The first group is pretty much all radionuclides. They exist since the creation of the Earth. Cosmogenic radionuclides are generated due to interaction of cosmic rotation with atoms at very high altitudes in the atmosphere and man-made radionuclides they exist in earth since about 70 years or 80 years. They are generated in nuclear installations as nuclear power plants or research reactors or accelerators.

The decay of any radionuclide is specific. It is specified by a certain radiation type, whether it emits alpha radiation, beta radiation or gamma radiation and also by the energy of the radiation which is emitted. Since energy is measured in units of electron volts. Usually, the emission of alpha and beta radiations is accompanied by the emission of gamma radiation. The alpha radiation these are very relatively heavy particles. They consist of helium nucleus, two neutrons and two protons. So range in air is very short. It's only a few centimeter. The range in water is about a millimeter.

Beta radiation consists of electrons and they are smaller and lighter so the range is a bit longer. This is about some 10 centimeters to some meters in air depending on the energy. The range of water is some millimeters. Gamma radiation this is electromagnetic radiation the range in air depending (0:05:00) on the energy can be up to some hundred meters and the range in water is about 10 centimeters.

X rays are as gamma radiation with energy in the range of 50 to 100 kilo electron volts and the characteristics are similar. Each radionuclide is characterized by its physical half-life. The half-life is a time required until the activity decreases to 50%. Half-lives of radionuclides vary widely, from very small fractions of a second to billions of years.

The activity of radionuclide is measured in becquerel. One becquerel means one decay per second. However, the activity is an important unit, an important quantity. However, by the end of the day, we are interested in the energy which is deposited in tissue, human tissue, organs, bones whatever. And the quantity for this unit for the dose is millisievert. So we have energy emission the transport and then the energy absorption. And the energy absorption is a measure for the dose which is quantified in millisievert.

Why are we interested in doses? Why do you want to know how much energy is absorbed by tissues? The alpha, beta and gamma rotation is also called ionizing radiation. This is because due to the high energy this radiation is able to form free radicals. These free radicals may interact with cells and they may also damage the cell nucleus or damage the DNA. And possible effects are, for example, cell killing or the malignant degeneration this means the formation of a cancer cell and it may also come up with mutations and because of this adverse effects of radiation, we need also radiation protection.

Let me come back to the range of the gamma-radiation and of x-rays. This is important for shielding radiation and the range depends first onto energy of the gamma radiation. This is a range here from 20 keV to 5 MeV and for different materials, for air, for water, for concrete and for lead and as you see the higher the energy the longer the range in a specific material. On the other side, the range of gamma radiation decreases the density of the material. The more dense the material is the lower (0:10:00) is the range.

Since ___ marked in red this is the range between 500 keV and 1 MeV and in between we have the relevant gamma energy for cesium 137 which is 662 keV. And what you see for this gamma radiation emitted by cesium 137. So, range in air is about between 70 and 90-80 meters. It can very well shield it or attenuated by concrete so this means if we have radiation source outside the environment and you stay inside the walls or the structures of the building provides a shielding and an attenuation effect. By the way, the range of x-rays the energy of x-rays is between 50 keV and 100 keV. And you might have already experienced during an x-ray examination. So it is part of the body which are not subject to examination maybe protected by lead tissue by lead shield and you see already lead with the thickness of less than a millimeter will decrease the radiation from x rays already by 50%.

Let's come to the natural radionuclides in the body or is it written or yes, natural radionuclides in the body. In the body, we have about each of us about 10,000 Bq of activity. 4000 of this is due to potassium-40 which is a primordial radionuclide. This means it exists already since the creation of the Earth, so half-life is 1.3 billion years. I think the other main contributors regarding the activity is carbon 14 which half-life of more than 5000 years, which is generated in upper layers of the atmosphere and Tritium which is radioactive hydrogen.

So, potassium-40 is an essential element for all life on Earth, for both, for plants and for animals. So, any food we eat or nearly any food contains some potassium-40. The typical concentration of potassium-40 from milk is about 50 Bq/kg and for meat about 50 to 100 Bq/kg. Vegetables that is more widely depending on the use of fertilizers was 30 to 150 Bq/kg. So potassium intake with food is about 90 Bq per day and as I said the total activity of potassium 40 is 4000 Bq/kg. The dose from potassium-40 together [ph] is about 0.15 mSv per year and the total dose from all natural radionuclides is about 0.3 mSv per year on average.

(0:15:00) Here is a list of radionuclides from primordial radionuclides. There are a lot and all of them have very, very long half-life So this is Zirconium 10 to the 19 years so it's nearly stable. So they exist really from since very, very long time. However, the activities of these radionuclides in the Earth is very low. These are cosmogenic radionuclides. The Tritium is the most important. Beryllium-7 is continuously generated in the upper atmosphere as well as Beryllium 10, Carbon 14, Sodium 22, Silizium, Phosphorus, Argon 39, Krypton 81 and Krypton 85. So radioactivity is always around.

So coming to the exposure from natural radionuclides, terrestrial exposure is from radionuclides rocks, soil, construction material and plants and the activity in this material causes an external radiation external exposure to people and in total, the average is about point 0.4 mSv per year. Then we have the inhalation of radon. Radon is part of the uranium decay chain which is from uranium 238 down to stable lead. And radon is all always around. So radon gas emanates from soil and from some construction materials. The exposure varies widely and it's about 1 to 10 mSv per year. The cosmic radiation depends, in particular, on the height above sea level. The annual dose starts from 0.3 mSv per year at sea level going up to 3.5 mSv for the Mont Blanc. This is the highest mountain in Europe and its altitude is about 4800 meter. So we have here the internal exposure with food. As we said, the internal exposure is 0.3 mSv per year. And if you look at it altogether, all of this together, this is a compilation of the UNSCEAR 2008. UNSCEAR means United Nation Scientific Committee for the Effect of Atomic Radiation.

So, we have here ingestion, inhalation and external exposure. This is a global mean and it’s a range. It's not so full range but typical range. And if you look at that the ingestion varies from 0.2 to 1 mSv per year. Inhalation from 0.2 to 10 mSv per year is about in particular due to inhalation of radon and external exposure 0.6 to 2 mSv per year. And in total the range is about 1 to 13 mSv per year. However, there are areas on the Earth where (0:20:00) the annual dose from natural sources is even higher than this upper range. So, it is vary [ph] slightly.

We have also medical radiation exposure. It is mainly due to diagnostics, applying x-rays and computer tomography. Doses per diagnostic examination varies widely depending the organ or tissue which is examined. For tooth it's quite low, it's 10 mSv. But if you come to a computer tomography which is when the number of x-rays images are done, doses maybe up to 25 mSv depending on the organ and tissue which is examined.

In total, the global average for the medical exposure is about 0.6 mSv per year. However, this has an increasing trend since in particular the application of computer tomography is increasing.

So, a short summary, we have seen that natural exposure varies widely. The global average is about 2.4 mSv per year and if you are going for the lifetime and we assume a lifetime about 80 years, you'll notice may vary, become up to about 200 mSv per life. The global range, the annual dose is 1-13 mSv per year, life time dose is approximately 80 to 1000 mSv.

The level of the natural exposure and its variation is an interesting quantity because maybe you've used this one, but it's not the only one. Yardstick to evaluate the relevance of exposures from other sources. Such comparison should always be taken with some care. However, it is at least one yardstick for the evaluation. Okay, thank you very much so far.