Gerhard Proehl:

Okay at the end I will try to make some remarks about a comparison of remediation measures applied after the accidents in Chernobyl and in the Fukushima Daiichi Nuclear Power Stations. This presentation is based on the presentation given at IRPA Congress in 2016 in South Africa. I would like to say thank you to the co-authors. And I'm also one of the authors. That is why I felt free to take this as a starting point. We have already seen this picture again. Chernobyl, same levels as Fukushima but the area affected is much larger. When we compare now the affected area in a bit more detail and we don't get the total deposition to terrestrial and freshwater systems in Europe. Then we have 64 PBq of cesium 134, 1 PBq is 10 to the 15 Bq [ph] and 2 to 3 Bq deposited in the mainland Japan. And if you look at the area with levels of more than 100 KBq per square meter, this is 56,000 in Chernobyl but only 3000 in Fukushima. So you see that the seriousness of these two accidents is different and the same is for cesium 134, slightly different numbers. But the point is here that Chernobyl releases affected a much larger area since Fukushima.

When we look at the landscapes affected I mean Chernobyl at the time we had almost collective farming and private farming, agriculture, forests is a big importance of mushroom, berries, because we have many areas with forested and sheep. The land is not very fertile. The use of fertilizer was a very high at this stage. So, the agriculture in general was not very intensive. In Fukushima, I mean we have two main elements. First is the agricultural areas, particularly rice and paddy. But there's also a large area of forested catchments which have been effective with steep slopes, which cannot be used for agriculture. So and then we compare two accidents. I mean, for Chernobyl and both Fukushima they started before or around the start of the growing period. The population density in Chernobyl is low to moderate and there's no real pressure to use the land set [ph] by the intensity of the agriculture or it was relatively low at this time. In Fukushima, it is a bit different. The population density is relatively high.

And there are also some people who want to use or have to use the available parts because there's a lot of mountains and the areas which can be used for agriculture is limited. So the intensity of agriculture is low to medium in Chernobyl and high in Fukushima. The key products here are milk, meat, grain and potatoes in Chernobyl. (0:05:00) Fukushima is rice, fruit, leafy vegetables, root crops, grain, flowers. And the movement of cesium radionuclides in the landscape is low, but high in Fukushima due to the steep slopes. And if you then look at the internal exposure, if we looked at the for example the fraction of soils

with high organic matter, in high organic matter it is one indicator or can be an indicator for enhanced uptake of cesium from soil by plants and Chernobyl is moderate or high and Fukushima is pretty low. Use of potassium fertilizers is very low-to-moderate in Chernobyl, but it was always high in Fukushima due to the intensity of the agriculture.

So, this leads to a moderate to very high availability of radiocesium for root uptake and then low availability to moderate availability in Fukushima Daiichi. Transfer of animal products is moderate to high but low in Fukushima. Intake of local foods in Chernobyl was high and very high because people usage but low in Fukushima. As a lot of food is bought in the supermarket. And the intake of wild food grown in forest mushroom, berries is very popular in the affected areas of Russia, Belarus and Ukraine but not so pronounced in Fukushima. So, this means for the final consequences all these factors interact and have to be evaluated for an evaluation and assessment of the dose.

And so, if you look at it important pathways in Chernobyl internal and external exposure is about half-half, it is about same and one part is also internal dose from wild foods from forests. And this is less in the Fukushima case and I think this brown part here is also looks for me pretty high, I think it could be less. But this is a snapshot from the Kawauchi village in Fukushima Prefecture and has been published. When we look for the goals of recovery, I mean, the goals of decontamination.

Of course, the main goal is to reduce doses on the long term. And in both cases, Fukushima and Chernobyl 1 mSv/y was or is applied in both sides. In the Chernobyl case, it was only put in force from 1991, five years after the accident, but now it's the same. And of course, another goal is to enable residents of contaminated areas to return back to their normal life. However, nevertheless, the priorities in Chernobyl and Fukushima were different.

In Chernobyl more than hundred thousand people were living in areas with more than 1 mSv/y and the priority was given to remediate to reduce their effective dose rate. And the return of people to evacuated areas in Chernobyl was considered difficult because in parts of the Chernobyl exclusion zone, they were also relevant depositions of strontium and in particular plutonium contaminations. And it was considered (0:10:00) as too difficult to, to remediate that. So low priority already was given to return of people. But since this is also something to do with the pressure of people on land and Ukraine is a larger country more land is available, less people.

So, this is ___ the way forward. In Fukushima, I mean, there was the idea to re-establish an acceptable basis of a fully functional societies in all affected areas and also to revitalize these areas because this area also had some economic impact. So a reduction of economic activities and the idea was to revitalize this. And one factor was the also this enormous efforts for the monitoring of rice. I think in one year I would say about millions of rice bags are monitored. Again comparison for the long term dose of Cesium 134 was ___ seeing the action of with agriculture practice and living habits you have the intensity of agriculture, high in Fukushima, low in Chernobyl, use of potassium fertilizer is different, fraction of organic soils with low [ph] nutrients is different. Availability of cesium in soil is different. Intake of local food is different. So by the end of the day, the contribution of ingestion is low in Fukushima but high in Chernobyl. And if we look for the comparison of the radiological criteria, we have seen long term goals is the same.

There were different approaches in the beginning of this accident in the USSR in the Soviet Union. In Fukushima, it was 5 mSv for the first year and then from September 2011, 1 mSv per year was given as an annual dose. If we convert these dose to an ambient dose rates, this means by the beginning remediation measures were introduced for a ambient dose rate of 2.2 µSv/h. Whereas in Fukushima, if we exclude the natural background from this point to 3 µSv/h, it is 0.19 µSv/h. So this is a factor of more than 10. Also, we had in both countries we had a modification of the activities in food standards in both cases. So they declined gradually. In Chernobyl, okay, we have there's a categorization of the land according to the cesium deposition to soil below 37. It's not contaminated, it's considered as not contaminated between 37 and 185 kBq/m2. Remediation is done for so-called sensitive soils, which are soils as wet peat or acid sandy soils, which tend to have higher uptake of cesium by plants. And then the intensity of the remediation activities increased with the contamination level. And above 1480 kBq/m2 there was no first of all (0:15:00) economic activity because this was evacuated or people were relocated.

In Fukushima, if you look at the designation of remediation areas, there were three zones. The green zones is less than 20 mSv/year, yellow zone 20 to 50 mSv/year and red zone more higher than 15 mSv/year. And then outside this area these zones with yellow and all the colored areas this yellow figure remediated or are still under remediation. If you look at the same comparison of the remediation approach we have similarities as both cases, the food restrictions and monitoring was applied to identify high levels of activities. Food

centers [ph] were implemented and there was a decontamination [ph] with priority given to residential areas. In Chernobyl, focus was given to both external and internal dose whereas in Fukushima focus was given to external dose only because to do other measures, internal dose was pretty low. In the areas remediated in Chernobyl are all settlements with average doses above 1 mSv/y. And in Fukushima, in this intensive countermeasure area. The approach was a bit different. In Chernobyl focus on measures was to prioritize measures which have a high effectiveness in dose reduction.

And to find out there was also the application of cost benefit analysis, because the question was, how much money is needed to reduce dose if you have two options and usually the option was taken which was more effective in terms of financial efforts and workforce et cetera. This was not necessarily the case in Fukushima. There was the priority to have a rapid implementation to try to reduce the activities as fast as possible, taking into account also social and cultural factors and anxieties of the people, concerns of the people. This means countermeasures were also applied in areas which were not very much affected. I mean, the reason for that is probably at that time, former Soviet Union had maybe some economic problems whereas Japan is a wealthy society and there were sufficient financial resources available to implement all these factors. So, the cost here nevertheless [ph] in Chernobyl is high but much higher in Fukushima.

And for forest areas in Chernobyl, just some advice was given what to do in the forest and what to collect in the forest. In the case of Fukushima, there was also declination measures were done on the border of the forests, which are close to houses. If you look at the remediation (0:20:00) measures applied in the residential areas they are partly sometimes similar, I mean, decontamination, high pressure water, removal of deposits et cetera. But also there are also some differences.

For example, top soil removal, pairing of fruits, high pressure water, this was more done in Fukushima also reflecting some more intensive use of the land. And if you look at important countermeasures for Chernobyl, in the agricultural area, use of uncontaminated feedstuff before slaughter if possible. Radical improvement of pastures has been deep ploughing, re-sowing, application of lime and potassium fertilizer. Use of Prussian Blue to reduce cesium resorption in the gut of animals and also live monitoring, I mean, the animals they were live monitored with a measurement device so to say, measuring the dose rate on special parts of the animal on – for example, on the hip. And their calibration curves exists which convert

the gamma dose rate measured on the hip of the animal to decontamination of cesium in meat. This was a pretty effective measure and you could determine the ___ in meat without killing the animal.

And Fukushima Daiichi ___ was removal of plants, topsoil removal, drainage of suspended soil from paddies, deep ploughing, use of extra fertilizers. This was main countermeasures in agriculture. And again here comparison of agricultural remediation measures in Chernobyl and Fukushima. Fukushima priority was given to clean feeding, live monitoring and Prussian Blue to animals was not applied. Radical improvement here more soil removal, tillage reversal, treating paddy fields, removal of plants, soil hardening and removal. So there was slightly different spectrum on countermeasures applied in Chernobyl and Fukushima.

And with the forest remediation there were in both cases restrictions for the access, not to enter the forest and also restriction harvesting of food products and collection of firewood. Also, local monitoring, monitor, it's always important to know where is the contamination and what is the time trend. And for forest Chernobyl focus was given to provide information and advice on regarding the spatial variation of contamination, for example, which mushrooms to avoid, where and when to collect wood, where and when to collect wild products and to hunt animals and also to provide tree felling schedules because there's also little seasonal [ph] variation of cesium in wood.

Fukushima, it was remove surface material from 20 m from the border and an action level for the use of wood for mushroom production was implemented. So if you look at the waste generation, in (0:25:00) Chernobyl about thousand settlements with decontamination and the waste was buried nearby. And focus was given to such remediation options which did not generate waste or not too much waste. In Fukushima, I mean, as you know there was a huge generation of waste and also link to high costs. And therefore, we had these bags, these temporary storage sites, which are now – will be removed I think until 2024. Then all these bags will be stored in the interim storage site close to the plant. And finally, I have a summary if you look for the radiological consequences, you can see that the consequences of the accident in Fukushima are much lower than that of Chernobyl. However, the scale of remediation of efforts [ph] implemented is comparable. In both cases for remediation, long term goal was at 1 mSv/y. However, in particular, in the beginning, the radiological criteria for remediation in Japan are lower than those in the USSR.

In Japan, the limits for foods were reduced and therefore, we had also relatively high costs in Japan and in Japan also the decision was made to remediate land that was evacuated. In Chernobyl, the consideration of dose saved and the related cost was an important part of the Fukushima – of the remediation strategy. And for Fukushima the remediation of affected areas regarding radiological and social and cultural consideration is very high priority. Thank you very much.