Gerhard Proehl:

Okay. So, let me talk a little bit about safety standards for the management of radioactive waste. IAEA, International Atomic Energy Agency, is a UN organization which was found in 1957, and one of tasks is to establish or to ensure safety of nuclear applications. And this is already set in the statute, to establish standards of safety for protection of health and for the application of the standards. So, the IAEA, they have developed a number of safety standards which have a hierarchical structure. On top of this hierarchy, there is so called fundamentals, these are only 10 main objectives to ensure safety and protection of people from nuclear applications. Of course, we have a wide range of nuclear applications and so, for any specific application or for a group of applications at least, there are so called safety requirements, which means what to do in general to ensure safety, for example, in the field of predisposal management of waste.

This is still a high-level document, which covers more general issues and topics to be addressed to ensure safe management of waste. And to give more guidance, there are so called safety guides, which give more detailed guidance what to do for the application of the specific activity, and it is related to best practice on experienced in member states and to meet the requirements, how to do, what requirements request. For example, one standard is disposal of radioactive waste, and there are more but general safety of facilities and activities, and then they address the different aspects of management of waste. Predisposal management means any activity which occurs before the waste is disposed and then the disposal, then during disposal. Also with the commissioning of facilities, there is a lot of waste will be generated.

Waste disposal covers wide spectrum of activities. Waste management covers a wide spectrum of activities. These are all administrative and operational activities which are involved in handling, pretreatment, treatment, conditioning of waste, transport, storage, and finally also the disposal of radioactive waste. So, the disposal is the last and very important activity of a long list of activities in-between. So, why do we need disposal? Of course, it is quite simple. The alternative could be storage, and storage can always be only a temporary solution.

Radioactive waste contains probably very long-lived radionuclides, which live much longer than (0:05:00) 100 or 1000 years, and this means storage is not sustainable in the long

term because it requires active control for safety and security, and there are ongoing responsibilities and costs, and this would mean that also future generation would have to be responsible and would have to spend resources on the waste that is produced and generated in present.

As you see there are events and developments, which could have an impact on safety and storage. First of all, wars and terrorism where everything gets out of control but also urban growth, natural events like storms, floods, earthquakes, or volcanic eruptions. So, disposal is really a need. Therefore, disposal facilities is also a key topic of the IAEA, within the IAEA safety standards. This specific safety guide gives an overview of the geological disposal and its implementation, about legal and organizational infrastructure, about the safety case and safety assessment, and also it illustrates a stepwise approach to the development of a geological disposal facility. Stepwise approach is needed because usually such setup of disposal facility takes very long time, and so different steps are defined to go forward.

Another point I would like to explain is the safety case, may be you have not heard so far. The safety case is a comprehensive evaluation of the safety assessment and in particular evaluates the findings of the safety assessment and provides statement of the confidence of these findings. It will also address weak points of the safety assessment and how to overcome those weak points. So, the safety case and safety assessment go hand in hand. The safety case, so to say, comprehensive, holistic view on the safety of disposal facility.

Coming back to the stepwise approach, here you have a timeline, we have several periods, preoperational period, the operational period, and the post-closure period. This shows the different activities, for example, preconstruction activities, construction activities, to operation, closing, and then post-closing activities. And post-closing activities also includes, at least for a limited time, some institutional control. On the long term, disposal facility has to be designed as such that no institutional control is needed. And to give you an idea about this timeline, can I mention that before – so preconstruction activities is about at least 10 years, construction may be another 10 years, operation is usually something like 50, maybe to 100 years, it depends on the host rock and also specific design but at least some decades. Closure will be done probably a bit faster and by the end of the day, post closure is something for eternity but here no longer institutional interventions are needed. (0:10:00)

So, the requirements for safe disposal. First of all, there is a site characterization, and this is to support a general understanding of the characteristics of the site and because we have to look at long timeframes, also how the site will evolve over time. There are several possibilities depending on the site. For example, the Swedish site will be constructed on an area, which is undergoing an uplift since the last Ice Age. So, whole area is lifted by 6 mm per year. The implications of such developments have to be addressed and have to be studied in the site characterization.

The next one is design and, of course, the facility shall be designed in such a way to provide operational and post-closure safety. This is what disposal is about. The construction of this facility has to be such that this objective is fulfilled under any circumstances. The operation, I mean the disposal facility during operation is a normal nuclear facility, and so it has to be operated in accordance with the IAEA safety standards or with relevant national regulations. And the closure, I mean the facility shall be closed to provide the safety function shown in the safety case, which are important for safety over long period of time.

So, to demonstrate long-term safety requires a safety assessment, and safety assessment is a key activity of the IAEA to provide guidance, to ensure safety for wide range of facilities, and disposal is one of them. And within the safety assessment, this requires the evaluation of the overall performance of a disposal system, and this disposal system comprises of the host rock, the area where the waste is stored, the overlaying rock, and then the biosphere. And the safety assessment requires a systematic assessment of all radiation hazards and also to quantify radiological impact both in operation and post closure.

This is a scheme of such a disposal system. This is confinement of the waste and the waste is usually packed in some additional matrix overpack, then they are sealed. So the idea is to isolate the waste for a long time from the biosphere. Nevertheless, in all safety assessments, fancy ideas or scenarios are considered, which might cause in the far future, a migration of radionuclides from the confinement area to the biosphere. Based on this data, on this prediction, what activity could appear in the biosphere, an assessment of doses to people is made who live in this area, which could be affected in the far future. (0:15:00)

The safety assessment is a complex document, and this is just an idea what all is necessary, what all has to be considered and addressed in the safety assessment. So, is the management system internal, whether the company who is responsible for the waste does a

good job, and we have some non-environmental impact, we have operational safety, and the site and engineering and to estimate post-closure radiologic impact, the scenarios, models, and calculations have to be described in detail.

Within our problem, what we have within the inner problem, we are not looking in detail to all these effects and phenomenon which occur in the underground, we focus more on the biosphere part and on the assessment of potential doses to people who live in this area. So, some guidance for this problem is also given in this safety standard. Regarding radiation protection objective in the post-closure period, the following and the safety objective is that the site, design, and construct, operate, and close the disposal facility. So, protection is always ensured, and it has also been demonstrated that doses and risks in the long term will not exceed the dose constraints and risk constraints which are used as a design criteria.

Coming to the criteria for members of the public, for any facility which is planned, the dose limit is 1 mSv per year, and also this criteria should not be exceeded in the future. This 1 mSv per year is the exposure from all nuclear facilities in an area. It might well be that in an area, there are two facilities or three but by the end of the day, each individual should not receive more than 1 mSv per year. Therefore, a dose constraint is introduced, which is the dose limit for specific installation rather than for all nuclear installations on a specific site. At this point, 1 mSv per year, according to the risk factors published by the ICRP, that's International Commission on Radiological Protection, this is a risk of 10^{-5} per year.

Let us look for some criteria in national disposal facility project for Sweden, which is currently undergoing licensing. There is a risk constraint of 10^{-6} per year, and this is approximately equivalent to an annual dose of 20 μSv. For comparison, the exposure from natural background is about 2.4 mSv per year. So, it is about 1% of the natural exposure. Finland has different criteria. The doses to the most exposed people should be below 0.1 mSv per year and for those who are not most exposed, the dose should be very, very low, insignificantly low. (0:20:00). And for the timeframe, that is required to look for the assessment for several thousand years and then Finland said there are no longer detailed dose assessment is necessary, but they give a constraint on the radioactive release to the environment and these releases because these are very long-term processes could be averaged over 1000 years.

Coming back to Sweden, with regard to the timeframe considered for the first year, a quantitative assessment is required and for times longer than 1000 years, a sequence of possible developments should be considered, and these assessments should be as long as 12-year function of the disposal is required, but it should be at least 10,000 years. You see all these radiologic criteria remain below 1 mSv per year, but the details differ from country to country. France says the risk constraint is equivalent to a dose of 0.25 mSv per year, and 10,000 years should be looked at for safety demonstration. In Germany, the dose criteria is still under discussion, so far the criteria for high level waste disposal facility is 10 μSv per year, which is even lower than Sweden and the timeframe of disclosure is also under discussion, that for 10,000 years detailed assessment should be made and then for a million years, a more stylized, a more simplified assessment can be done to demonstrate this long-term safety.

So, this is SSG-14 recordings of post-closure safety assessment. It is said that radiation exposure is a major safety issue, and it has to be developed, and also confidence in the modeling has to be provided. And confidence is often provided if all assumptions are very conservative, it means very pessimistic. However, another requirement here is that the conservatism should be reasonable, shouldn't be overly conservative, so as to have some degree of realism. It is also said that any approach to make an acceptance easier because we look at long timeframes and to look over long periods of time to complex systems is very difficult. That's why it is suggested to try to look for simple approaches. Serial approach is, of course, someone which benefits simplicity, conservatism and realism. This is considered as the best starting point, this is also kind of a best wish.

For looking for the dose assessment, looking for compliance with safety objectives and criteria, it is assumed that in estimating doses to individuals in the future due to a disposal facility, people will be present locally, even if it is (0:25:00) in the middle of a desert but people have to be around, otherwise, there is no dose. And it should also be assumed that people make some use of the local resources that may contain radionuclides originating from the waste of the disposal facility. So, there is requirement to look specifically to those scenarios which could cause the migration of radionuclides from the disposal area to the biosphere. However, since it is not possible to predict behavior of people in the future with any certainty, it is suggested that assessment models need to be stylized, simplified.

There was an IAEA project, which was called BIOMASS in the 2000 years, and the BIOMASS project discusses in detail the rationale and possible approaches to modeling the biosphere and the estimation of doses arising from waste disposal facilities. And this BIOMASS methodology, they have different flowchart with different steps. First of all, it deals with assessment context, where is the disposal site and what kind of waste will be disposed off there. It provides a detailed description of disposal system, develop scenarios, adjusted scenarios for the assessment of exposures to people, develop appropriate assessment models, do calculations and analysis of the doses, and then the question is does this model address appropriately the site, if yes, then comparison with the criteria and, if no, do it again. Details about this methodology will be given in one of the next presentations. The report has been prepared of the BIOMASS project on the development of reference biosphere for solid radioactive waste disposal.

So, finally, I have some conclusions. We have seen that the IAEA has developed safety standards on the disposal of radioactive waste. The safety assessment for waste disposal facility has to cover all components and aspects of a facility, including the host rock, waste packages and confinement, geology and hydrology and exposures to people and the biosphere. So, radiological criteria in the post closure period are well below 1 mSv, and the timeframes to be considered are up to 1 million years, and this depends on the country. The IAEA has developed methodology to set up assessment models for exposures in the far future.

Thank you very much.