RESUMED **[11.00 am]**

COMMISSIONER: At 11.00, we'll reconvene on the topic of low and intermediate level waste storage and disposal, and we welcome Mr Dirk Mallants. Counsel?

MR JACOBI: Dr Dirk Mallants is the Senior Principal Research Scientist at CSIRO Land and Water; he's worked in soil and groundwater hydrology for more than 25 years, and is experienced in characterising and modelling water flow and contaminant transport in complex environments.

Dr Mallants was previously the head of Performance Assessments Unit at the Belgian Nuclear Research Centre, SCK-CEN, and in this role he oversaw the safety and assessment studies which were carried out for the Belgian repository for low level radioactive waste.

Dr Mallants is widely published in the area of water related environmental contamination issues, and has delivered IAEA training courses concerning sub-surface characterisation and safety assessments for wastes arising from the nuclear fuel cycle.

For those watching the evidence, the Commission has images and plans which it cannot display at this time, because they are the copyright of SCK-CEN; it will resolve that issue, it hopes, in due course and will publish the images at a later time.

COMMISSIONER: Dr Mallants, thanks very much for joining us. Can I start to try and put this into context? What was the problem in terms of the Belgian repository that you were trying to resolve? What was the driving point for creating this project in the first instance?

DR MALLANTS: The Belgian concept that I will discuss today was designed to accommodate what we call Category A waste, which is low and intermediate level, short-lived waste, which mainly originates from the operation of nuclear power plants, and from the future decommissioning and dismantling of nuclear power plants and other facilities of the nuclear fuel cycle.

Now, Belgium has seven nuclear power plants that provide about 60 per cent of the nation's energy need, so the waste generated from the operation, and as I mentioned, from the dismantling of other nuclear facilities such as nuclear research centres; other facilities include fuel fabrication, we had a MOX plant to produce mixed oxides.

There are, of course, other wastes but they contribute to much more volume. So you have the waste from medical and industrial users, which account in volume for about 7 per cent; approximately 93 per cent of the total volume of Category A waste will be from the operation or dismantling of these nuclear power plants.

That is for a scenario of 40 years of operation of these nuclear power plants, and the estimate is that that will generate about 70,000 cubic metres of Category A waste. Of course if the lifetime of the power plants would be extended, that would generate of course, additional volume. But we're talking about 70,000 cubic metres.

Back to the definition of low and intermediate level - - -

COMMISSIONER: I think we're comfortable with that, we understand that part.

DR MALLANTS: Okay.

COMMISSIONER: Can I then talk about the approach when this was first started? From what I've read, there was a lot of technical emphasis in the first approach. Can you just walk us briefly through how the program started, and perhaps talk about the emphasis that was made at the early phases, where the emphasis was and what happened subsequently to that?

DR MALLANTS: The planning goes back quite a while, to the mid-80s, when the government decided that surface disposal is the final solution to manage Category A waste.

COMMISSIONER: How did they get to that conclusion, that surface - was it a technical - - -

DR MALLANTS: That was mainly a technical, well, a purely technical consideration indeed. I will talk about that later, but the idea was that the repository would be sited in a site without hard rock, so only with unconsolidated sediments, which means that the only viable option would be to have a surface repository.

The selection of the sites was also a pure technical approach; it was a nationwide survey to identify potentially suitable areas, and then within those areas, sites were identified on the basis of pure technical criteria, which included the risk of flooding to be minimal.

There shouldn't be any resources, any mineral resources because that could result in human intrusion later on, potentially. The site should be geo-technically stable, of course with the host such a complex and in the end a very heavy facility, there should be very low say, seismicity, of course. And finally, the hydrogeology, the sub-surface, the groundwater flow, should be sufficiently simple, such that we can quantify it without too much uncertainty so that we have confidence in describing the hydrogeology.

However, when doing this nationwide survey, there hadn't been any community engagement, so as you can imagine, there was then very little support for those sites once they became public. Then the government took a completely different approach, and that is to start consultation, voluntary consultation where the focus would be on those sites where there has been nuclear facilities in the past. Those sites included sites where they had nuclear power plants, research centres or other nuclear industries.

So there were then four potential sites where the community volunteered to join this project, and then so called local partnerships were erected, which went on for almost 10 years. And they supervised the studies of safety assessments, site characterisation - - -

COMMISSIONER: I think counsel assisting will be keen now to unpick those processes. My final question is, how long did it take the government to change its approach to a social engagement approach, from a purely technical approach? Was that a question of a couple of years, or was it a decade? Broadly.

DR MALLANTS: Yes, that was probably about five years, four, five years, yes.

COMMISSIONER: Four or five years?

DR MALLANTS: Yes.

MR JACOBI: I just want to pick up, you referred to there being four volunteer communities.

DR MALLANTS: Correct.

MR JACOBI: How long did the government proceed with dealing with those four independent communities?

DR MALLANTS: Yes, so that was, as I said, almost 10 years, and the engagement still continues with the preferred site, so it's a continuing process. But initially, with those four sites it was about 10 years, and that is, of course, a quite lengthy period.

But that allowed the local partnerships to get full understanding of the various issues associated with radioactivity; with radioactive waste, how do you safely dispose of such waste, how do you demonstrate the long term safety of such a facility, understanding that we often have difficulties to predict weather, let's say, a few days in advance, and now you're going to tell us what the safety is going to be in a few hundreds of years.

So that was a fairly lengthy process, but it was worthwhile, because in the end it was successful.

MR JACOBI: Yes. I understand that ultimately a site was selected from amongst those four communities and I'm just interested, what was the driving factor for the ultimate selection of that particular site amongst the four communities?

DR MALLANTS: First of all, out of those four sites that volunteered, only two got strong support from their partnerships. So the partnerships endorsed the project, and on the basis of that endorsement the local communities then took a decision to support the design and then the Federal government supported those two sites.

So there have been a number of factors that influenced that final decision. Safety was, of course, fundamental, and there's a number of site characterisations or site characteristics that were important as well, although the two sites that had very strong support were in the same setting, the same geological and hydrogeological setting. So there weren't too many differences between those two.

One of the differences was that one of the partnerships requested a modification of the design, a design which put extra effort or emphasis on monitoring, long-term monitoring, of the performance of the concrete vaults in which the various wastes were disposed.

MR JACOBI: I want to come to that in just a minute but I'm just interested at this stage just to pick up about how the proponent engaged with the community during the siting process, and this is in the period up to the period before the ultimate site was selected, about what were the elements of the participatory approach that were used.

DR MALLANTS: Let me just go one step back. So each of the partnerships had a representation, so the members were represented - or representatives of various parts of the communities. There were teachers, there were businessmen, there were farmers, environmentalists. There was even one person from Greenpeace. There were lawyers. There was a broad representation of the community. These were all volunteers. They had four different working groups. So there was a group on safety, so long-term safety; environment and health. There was one on socioeconomic benefits. So that had to do with the compensations that the community receives because it is taking on the burden of the entire country to host the waste. Then there was one working group - the name escapes me.

These different working groups invited technical experts to discuss matters that were of concern to the working group. For instance, the working group on long-term safety would invite technical experts to talk about what is the waste. "What is category A waste? For how long does it need to be disposed until the radioactivity decreases to background levels? What is the type of engineering? What is the type of multi-barrier concept that we need to make sure that the long-term disposal is going to be safe?" So they had many, many of these hearings which they in the end used to develop their own assessment, their own safety case, which was then submitted to the local council which endorsed the approach.

MR JACOBI: How did they organise the activities or topics that they were addressing?

DR MALLANTS: They did that in consultation of course with the waste management organisation. They had a scenario laid out of the different issues that were relevant and that would also be typically tackled within a safety case. So that's where they got their method, so to speak.

MR JACOBI: You referred to them meeting experts. Were they experts from the proponent or from the regulator, or did they have their own independent experts?

DR MALLANTS: Different. So they were experts from the organisations you mentioned, so the implementer NIRAS/ONDRAF, the federal agency for nuclear control, a number of technical support organisations - there were several - independent experts and the partnerships also could engage with experts they preferred. They had fairly substantial financial support to rent an office, to have meeting rooms, to hire a few technical staff but also to do studies themselves and to hire experts to discuss matters of their concern. It was a broad group of experts that came to those meetings.

COMMISSIONER: Dr Mallants, can I just pick up on something you said, you said "a waste management organisation". Was this part of the government? Was it an independent group?

DR MALLANTS: So the NIRAS/ONDRAF, which is the Belgian national waste management organisation, was erected by the Minister for Economy and it was the Minister of Economy that had decided what the mission of NIRAS was.

COMMISSIONER: So was that independent? Did it report to the minister or - - -

DR MALLANTS: It did report to the minister, yes.

COMMISSIONER: So it wasn't independent in that sense.

DR MALLANTS: As independent as possible I suppose.

COMMISSIONER: Within that group were they technical experts, were they economic experts?

DR MALLANTS: As you can imagine, dealing with radioactive waste and the management of radioactive waste and developing a safety case requires a multidisciplinary team. So there were multidisciplinary teams in the different organisations, not just with the waste management organisation but also within the nuclear regulator. You had geologists, you had geochemists, you had hydrologists, engineers, numerical modellers just to make sure that all the different aspects were properly covered. The extra task that NIRAS/ONDRAF had was of course to integrate all these different pieces of knowledge of information in a consistent story and make it sufficiently understandable to a broad audience. So they had integrators but they also had experts in the different fields that are of concern.

COMMISSIONER: Was it their responsibility to provide a recommendation to the minister or was it - - -

DR MALLANTS: Yes.

COMMISSIONER: They were?

DR MALLANTS: Yes.

COMMISSIONER: We've had it suggested to us in previous evidence that - and this may be an Australian characteristic more than anything else - that it's important to have an independent organisation so that one gets over the challenge of politics and the changing nature of politics. Was that a feature within Belgium or because there was already nuclear activities and had been for four or five decades that this bipartisanship was less of an issue?

DR MALLANTS: I suppose that was more the role of the independent referee, if you want. That was the role of the federal agency for nuclear control. So they had to approve the safety case and if they wouldn't have approved it, NIRAS couldn't propose it or endorse it to the minister. So that was the independent party having that overview.

COMMISSIONER: That was the regulator.

DR MALLANTS: That was the nuclear regulator, indeed. That is of course a story of its own how the engagement went about between the federal agency for nuclear control, the technical support organisations and the waste management organisation. It's an interesting process because for all of us that were involved in this process it was a first time that such a repository was going to be built and that we had to demonstrate safety and that a safety case had to be developed. It was a steep learning curve. So it is important then also to take the regulator on a journey from the very first day, get him acquainted with the methodologies that one applies, the tools that you use, the people that are doing these assessments, to build trust from the very beginning but also to make sure that as a technical support organisation and as a management organisation you have another pair of eyes that's looking at the development, who's giving feedback and who's questioning the why and the how of your assessment.

It is very, very important that this is happening from the very beginning in a very staged way. Don't make the mistake to wait until the end, until the safety case is delivered to the regulator, and adopt a report 10,000 pages that have to be reviewed. If there hadn't been this previous engagement process, it would be very difficult to get that approved without major issues. So if there is any issue, detect it up-front, detect it before you develop your final safety case. I think that's a very important lesson learned, to have this very active dialogue with the nuclear regulator.

MR JACOBI: Had an application already been made to the nuclear regulator to enable that dialogue to commence, or how were you able to have the dialogue - - -

DR MALLANTS: Yes, that started as soon as the Federal Agency for Nuclear Control was erected, so that was part of the process to have that independent body erected, and immediately afterwards there was a plan put in place, five or six stages, I believe, with different milestones and milestone reports that had to be peer reviewed by the regulator. Technical support organisations and NIRAS/ONDRAF had to address the comments until the regulator was happy that their concerns were addressed, and in these ways in a step-wise manner you move to the different phases and different difficulties and resolve them such that in the end you have a fairly smooth process of accepting the safety case.

MR JACOBI: Was there a shared expectation from the regulator that it would be approached at these stages - - -

DR MALLANTS: Yes, absolutely.

MR JACOBI: - - - and provided those materials?

DR MALLANTS: It was a very formal agreement, yes.

MR JACOBI: Can I just come back. You mentioned the working groups themselves were funded.

DR MALLANTS: Yes.

MR JACOBI: Who were they funded by?

DR MALLANTS: They were funded by NIRAS/ONDRAF.

MR JACOBI: That is the proponent?

DR MALLANTS: Yes. Of course NIRAS/ONDRAF is made from the Ministry of Economy, but in the end it's the waste producers of course that pays, which is everyone, because we're all using electricity.

MR JACOBI: Did the working groups themselves engage with the community?

DR MALLANTS: Very much so, yes, indeed. There's various ways this happened, first of all, because they elected members from the community from all levels, then they had a number of particular engagement events. There were annual events where it would go out, kind of a market, and show what the progress was. A very low level way of engaging with the community. They had their secretary, so any time the community could ask questions it would be then considered by the partnerships and they would get back with an answer, so there was a very effective dialogue happening with all levels of the community.

COMMISSIONER: Just so I can make sure I get this correctly. The members of the partnership were elected or appointed?

DR MALLANTS: I suppose "appointed" is a better word.

COMMISSIONER: By whom? By the community?

DR MALLANTS: I wasn't there when they did it, but I suppose it's all done where you first appoint a board and there's a call for volunteers, which then on the basis - - -

COMMISSIONER: Were selected.

DR MALLANTS: - - - were obviously selected, yes.

COMMISSIONER: The working groups, were they appointed or elected, or did they come from the partnerships, or did you bring out externals?

DR MALLANTS: No, they were within, they were all members of the partnership. For instance, in one of the partnerships there were about 60 participants, so they had about four working groups of almost 15 each.

COMMISSIONER: The individual members of those partnerships, were they recompensed for their time or was it voluntary?

DR MALLANTS: No, just pure voluntary.

COMMISSIONER: Including the working groups as well?

DR MALLANTS: Yes, but, as I said, the partnerships each have their four partnerships, received, I think, about 250,000 Euros a year to have a secretary to have meeting rooms, and to also allow their participants to visit other sites, existing nuclear repositories, France Centre de l'Aube, El Cabril in Spain, or to attend workshops organised by the European community, for instance (indistinct) and others. Yes, they made sure they were very well informed, and for this of course they had the financial means to do so.

MR JACOBI: You mentioned earlier that the working groups have an effect on the ultimate design of the facility. At the time that the working groups were established, how far along the design process were you and to what extent were they involved in the process of the facility's design and its ultimate development?

DR MALLANTS: Yes, there is, of course, different stages in this whole process, and, as I mentioned, the very first one is kind of an exploratory phase where the whole nation was screened, and there wasn't any involvement at that time.

MR JACOBI: I'm interested in the specific facility itself, that is, the facility concept. I assume it had been decided that it was going to be a surface facility, but I'm just interested to what extent was the working group then able to engage in the ultimate design that was selected.

DR MALLANTS: Yes, so once the working groups had been established the designs, and there were different designs, and maybe we can - - -

MR JACOBI: I think we're going to come to them in a minute.

DR MALLANTS: Okay, that's fine. There were different designs, but I think it was just in one working group that they had a closer look at the design. They had their experts, external experts, and collectively there was then a recommendation to modify the design. The modification had to do with the ability to monitor the performance of the vault, basically, the concrete vaults, to have visual inspection of cracks of corrosion, of any leakage that did occur, and that has led to - well, accepting those requested modifications by the Waste Management Organisation, and that went into the final design, so the final design does have kind of a basement underneath each of the vaults.

The monitoring, I think, will be done by robots, not by humans but by robots, that have cameras and can look at those various aspects I mentioned. Yes, that definitely helped them to accept the entire design.

MR JACOBI: I'm just interest to the extent to which that might be said to represent a substantial modification to the design. Was that something that needed to be engineered in, in a different way that had been conceived originally?

DR MALLANTS: Yes, indeed, because whatever changes were made to the design it cannot jeopardise the long-term safety, so having those caverns, which they are, underneath each of the vaults and then a connection to a central drainage gallery, which by gravity would drain water, in the very unlikely event there would be water in the facility. Having that connection to this drainage gallery has the potential to provide a pathway, so you have to make sure that once the repository is put in its final state that all these pathways are closed, so they have to be properly sealed, they have to be properly backfilled with concrete to avoid any preferential pathway.

Any changes, any modifications to the design can never impact or impair the long-term safety. To accommodate that monitoring ability, there was a need to also then look at what is the best option to backfill it to ensure there wouldn't be any long-term pathways.

MR JACOBI: I think there's some images you've provided us earlier. Is it possible to see where that particular inspection area is?

DR MALLANTS: I could take this picture. What we're seeing here is the vault during filling, and underneath the floor of the vault - - -

MR JACOBI: It looks a bit like a battlement.

DR MALLANTS: Yes, indeed. You have concrete pillars, so these were cylindrical pillars of this size, and in between you have the open space which allows for a robot to look at the state of the - - -

COMMISSIONER: Has construction started yet, Dr Mallants?

DR MALLANTS: No, the construction has not yet started, but there is a number of works that have started. They have to do with, on the one hand, demonstrating that the properties behave as they should behave, so that's more a test for long-term monitoring, so they have a test vault and they also have a test multi-layer cover. This may be important to discuss. There is no need to have all the components of the repository designed once you start constructing. There can be some components where you still continue some research, for instance, the multi-layer cover will only be put in place after all the vaults have been filled, which is 30, 40 years from the start of construction, and during that period you can try and optimise the design.

You can look at different slopes of the different layers, thicknesses of material, types of material, so you have a few options there. You have a scale model, and I think they're looking at a model of 30 by 40 metres and six metres high. It's fully instrumented with all sorts of monitoring devices to understand the long-term behaviour. Then when the time comes that you want to implement it, choose the best option.

MR JACOBI: I think I want to come at this point to those technical aspects in terms of its design and I'm just interested perhaps in first of all understanding the sort of period in which the facility needs to be able to securely isolate and contain the waste. What's the design lifetime of the particular facility?

DR MALLANTS: So that's bringing us back to the nature, the type of waste, so it is low and intermediate level short-lived waste, where short-lived means that the radioactivity, the radionuclide concentrations, are sufficiently low such that during the nuclear regulatory control period they decay to negligible levels, to background levels. What that period is depends of course on the specifics of the inventory, the types of radionuclides where you have some traces of long-lived radionuclides, there’s always going to be some traces of long-lived radionuclides - uranium, thorium and others - but you have to recognise that those radionuclides are ubiquitous in nature, they're everywhere. They're in soil, they're in rock. They're especially in concrete because cement contains a significant amount of naturally occurring long-lived radionuclides.

So depending on the specifics of the inventory and depending on what dose is accepted after release, you can define acceptance criteria. It will say for each of the waste streams how much activity is acceptable. So that then allows you to define what length the nuclear regulatory control period has to be. That also defines what the lifetime of your engineered barriers has to be. For this type of waste we're talking about a control period of two to three hundred years. So that would be the minimum lifetime of your engineered barriers. Although, one has to make a distinction between what we call different safety functions.

The long-term safety is defined by isolation and containment. Containment refers to physical containment and chemical containment. So physical containment really is avoidance of any water coming in contact with the waste. If there's no water, it's very unlikely that any radioactivity is going to escape. Water is a vector for transport for migration of radionuclides. Then there's the chemical containment, which is the immobilisation of radionuclides within cement and concrete. Cement and concrete are probably one of the best materials to immobilise radionuclides and also long-lived radioactive contaminants that are present in those wastes.

So these safety functions have a different lifetime. The physical containment is basically governed by the corrosion of the rebar steel within the concrete and that is defined, for instance, by how much water can infiltrate in the concrete or how much air with CO2 would get in contact with the concrete, which then results in a process that we call carbonation. This results in a decrease of the pH in the concrete. If that happens, the passivation of the steel disappears. When the pH has dropped below a level of let's say 9.5, the passivation of steel gets lost and then corrosion of steel starts, you form corrosion products. They cause microstress, microcracking and when you have cracks of course the ability to keep the water out reduces. That period was estimated to be about a few hundred years, before the ability to lose that capacity eventuates. That’s physical containment.

Chemical containment has to do with the, as I said previously, to immobilise radio-nuclides, and that is really depending on the amount, the volume of concrete you have. And there is, of course, a huge volume of concrete. On the basis of very detailed numerical simulations, but also - - -

MR JACOBI: Yes. I was hoping to come back a bit later to deal with the question - - -

DR MALLANTS: Yes, okay.

MR JACOBI: - - - about the demonstration of the safety case. Can I just pick up at this point, in terms of the broad design, were there different design options that were available? And I’m just interested to understand why the particular design that was selected and why that particular type of surface repository was selected.

DR MALLANTS: If we consider the preliminary project phase, where we had these four different sites, and you have indeed the picture in front of you, there were three different designs that were considered. First of all, the classical vault type surface repository, then there's the silo type repository, which is much more sub-surface, so the majority of the facility is below ground, and the visual impact of that would be much smaller, compared to, let's say the typical vault type.

The silo was designed for a different geology, different sub-surface, where they had fractured rock, where the vault type would probably not be the best option. And then there was also a request or a requirement by the government to evaluate deep disposal, and by deep here I mean a depth of about 230 metres below ground surface, in a plastic clay formation, which was about a hundred metres thick. In the middle of that clay formation, the design was to have different tunnels, and to dispose of waste in those tunnels.

So those were the different designs considered. As I mentioned previously, the silo type wouldn't be a good option for unconsolidated sediments. It is important at any time to keep the water out of the facility, so if you have shallow groundwater, if you have a very permeable aquifer, you need to have something as far away as possible from the groundwater, so you build on the surface. To improve the design, there was even an embankment of about two and a half metres, to have additional buffer, let's say, between the base of the vault and the level of groundwater.

So yes, those were the three designs that were considered in the assessment.

MR JACOBI: I understand you ultimately selected a vault concept, and I'm just wondering whether you can explain the components. I understand there's a concept called a monolith that forms part of the overall structure, and how that fits with the vault and the monolith itself provides some containment and isolation.

DR MALLANTS: Yes, so there's a picture where you have all these components nicely next to each other. And this is really multi-barrier concept. So long term safety by means of robust system with different engineered barriers such as that if one fails, it doesn't jeopardise the long term safety. And the very first element of that, isolation and containment, is the conditioned waste itself.

And as you can see, these are super-compacted drums of solid waste; there's about eight in a 400 litre drum. The voids between the different pancake shape super-compacted drums are back-filled with concrete. So you have there already a very solid element, the 400 litre drum, which is an important element against limiting intrusion and promoting containment.

Then there's four of those drums that fit in a container, in a concrete container, a high performance container which is about two metres by two metres, and 1.4

metres high.

MR JACOBI: Sorry, can you unpack what you mean by high performance? I gather you're talking about the concrete?

DR MALLANTS: I am talking indeed about the concrete, so this is concrete that has been optimised to have this lifetime of at least several hundreds of years, and if I recall well, they should have a lifetime of close to 800 years. So that was an optimisation of the formulation, of the composition of the concrete, the aggregates. The size and the type of the aggregates. The type of cement, there's many types of cements, but you have to select a cement that promotes physical and chemical containment.

For instance, low heat cement was used, special fillers were used to have an as tight as possible concrete, with an as low permeability as possible. Permeability refers to the capacity to transmit water. So those were all optimised, which resulted in a very high performing container, which had also a very high mechanical strength. It may be interesting to refer to drop tests that were done. So the containers were dropped from a level of one metre, on their weakest point, to demonstrate if they could withstand such a drop, and they came out unperturbed, so demonstrating really this was a very solid, robust container.

So yes, those were then filled with four of those 400 litre drums and the spaces, the voids backfilled with concrete, and then there was a concrete lid. So you really have a very durable entity which is the basic unit of disposal. This is a bit different from other concepts, where the drums are put directly in the vault and the voids are backfilled with cement or concrete.

One of the reasons to have this type of monolith was to counter-balance some of the weaknesses of the site. I did mention that the site had groundwater at shallow depth; the site really didn't contribute considerably to containment, so there is then the option to counter-balance that weakness and put more emphasis on some of these engineered barriers.

The overall system, engineered barriers and site, are still safe in the long run, so that has resulted in the selection of monoliths and in improving their long term performance.

MR JACOBI: Can I just pick up also, you mentioned before that there's a multi-barrier system on top of, or proposed, once the site's capped, and I'm just interested, perhaps you can explain, you talked about there being testing of the layering.

DR MALLANTS: Yes, indeed.

MR JACOBI: Could you explain what it is that's proposed to cap the site?

DR MALLANTS: Yes, I think we see that in the same slide. So those, just picking up on the previous element, the monolith, they go in the vault, all the vaults get a roof and then once that system has been demonstrated to be sufficiently safe, and that is why they have this basement, they will close the entire facility, they will isolate it from the environment by a so called multi-layer cover.

Well, there's different purposes of the multi-layer cover. One of the purposes is to provide a stable environment for the concrete. As I mentioned, concrete will degrade to a number of reasons: there's potentially ingress of water that can contain chemicals that are aggressive to cement, so we need to avoid it as much as possible; air contains CO2 so the CO2 again can interact, so we need to keep those away from the concrete as long as is possible.

It's really making sure we have this long term protective environment around the concrete. Another purpose of having the multi-layer cover is isolation, reducing the likelihood of intrusion, human intrusion into the waste after the site has been released from nuclear regulatory control. Because these are, well, four or five metres thick layers with different materials, they provide a physical barrier to intrusion.

And another important function, safety function of the multi-layer cover is, of course, to keep the water out of the facility as much as possible. So at that location, Northern Belgium, there's about 900 millimetres of rain; plants, if you have grass or other trees or shrubs growing on the cover, will transpire about five to 600 millimetres. So there's about 300 millimetres remaining that can potentially infiltrate in the soil and get into contact with the concrete. That's something we have to avoid as much as possible, hence the cover has a number of layers which have a very low permeability, so which have a very low capacity to transmit that water.

One of the best materials is, of course, clay. Very dense clay is very impermeable to water. But again, it's the multi-barrier principle that applies here. So in addition to clay, you would have let's say, geomembranes, a high density polyethylene. So if something would go wrong with the clay, you still have that other barrier to prevent water from infiltrating.

MR JACOBI: I understand that the design, if there's capability to retrieve waste, and I'm just interested where that particular requirement came from, and why that was a requirement that was imposed and then how that was addressed.

DR MALLANTS: Yes, that was a requirement, I think it was the government itself that had that as a requirement, so that of course affected the design. As you can see, still in front of you we're looking at the monolith, in the corners you have this little opening, and there's a steel hook which allows the monolith to be retrieved by means of a crane.

Of course, retrievability is going to be relatively simple in the beginning of, let's say, the filling of the repository when there's no roof yet, but as you start to close, as you gradually start to close and isolate and put in concrete layers and then earth covers, it's going to become gradually more difficult to retrieve the waste. So retrievability is relatively straightforward in the very beginning, so should there be an issue with one of the engineered barriers, a weakness for whatever reason, could have been poor concrete formulation because you had to change supplier, or you had to use aggregate from a different quarry and they didn't meet standards, although there are standards in place, of course.

So if anything went wrong and that would have been detected, there is an ability to retrieve the waste. Or, if future generations decide that there might be another use of these wastes, then there is the ability to retrieve this waste.

MR JACOBI: I want to come to the issue of demonstrating the safety case, and I think before you spoke of the idea of conducting analyses for example on the barrier system that's going to be used to cap the facility, and I'm just interested to understand how, in essence, one can plan to make predictions many hundreds of years into the future and be certain that the safety case is robust.

DR MALLANTS: Yes, so there's elements to that of course. So maybe I can go back to the main components of what a safe system is, so isolation and containment, and we gradually come to the demonstration of that. Isolation as I mentioned, refers to limiting the likelihood of intrusion, and this can be established through various ways, and the most obvious way is, of course, surveillance, active surveillance, before release of the site. Another element of this isolation is restricting which radionuclides go into your facility and that is managed through the waste acceptance criteria that will be defined for each of those 400 litre drums. What is the concentration that we can accept and also what is the overall capacity? What is the overall total activity for – I think it's about 40 critical radionuclides and if a waste drum does not conform to those requirements it simply cannot be disposed in that surface repository, it is likely to go into a deep repository later on. Having those multiple barriers or the multi-layer of cover modules, monoliths, the conditioned wastes, they of course also contribute to avoidance of intrusion and then overall of course a good quality of waste conditioning.

Then there's the other element of the long term safety which is containment and that is indeed to avoid the spreading/release of radionuclides into the environment, the biosphere, and as I already alluded to this depends on long term safety, physical and chemical containment. I think we have discussed the role of the various engineer barriers, the roles of the drums, the vaults, the - - -

MR JACOBI: What I'm keen to come to is how do you demonstrate that and particularly with respect to how in essence can you predict the behaviour for something such as concrete over that sort of time scale?

DR MALLANTS: Yes. Yes, so you can imagine that many different processes will happen and a number of events will happen, will occur during the lifetime of the repository, so those all have to be accounted for in the design and have to be accounted for in the safety assessments, so there's a number of, we could call them, disruptive events that one has to deal with, typically earthquakes because you want a site repository as far as possible from a tectonically active location, but there's probably no site on earth where the likelihood for an earthquake is really zero, so that has to be considered in the design and what is typically done is you increase the amount of rebar in the concrete until it can withstand a very extreme earthquake specific for your site and to give you a number I think there's about 200 kilograms of reinforcement per cubic metres of concrete.

Other events are typhoons, which could affect the earth cover, they could cause erosion of some of the layers, and then there's a number of natural degradation processes which could affect each of these engineered barriers and we have already talked about the impact of aggressive water on concrete, on the rebar corrosion, so a safety assessment has to deal with these various elements and typically you use multiple lines of evidence. You're looking at different types of information that will tell you that these safety functions will perform well in the long run, so if you're looking at multiple lines of evidence, for instance, in regards to concrete there's a number of direct and indirect measurements or assessments one could do. You could measure the permeability of the concrete and this is what will be done every so many monoliths there will be a sample and that will be analysed. You can look at the compressive strength of the concrete which has to abide to certain standards and there's a number of other direct measurements you can make. You can have, let's say, this test cover we talked about where you monitor the behaviour of water flow in the cover, but there's also a test vault where you can equally monitor a number of parameters that are critical to understand the long term behaviour and then there's of course the safety assessments themselves which use very complicated numerical models which incorporate all the physical, chemical and mechanical processes that have an effect on the long term performance of the concrete and those models have been used to look at the long term evolution. Of course the question is then what is the validity? What is the validity of those models recognising that it is often difficult to have a weather prediction right a few days ahead and here we're doing predictions several hundred years or sometimes thousands of years in the future, so with regards to concrete one of the elements that helps build trust in the behaviour is the use of analogues and this can be in terms of concrete archaeological analogues. There are so-called Roman concretes which have been around for almost 2000 years. The composition is of course different from modern concretes. Romans used different hydraulic binders. They used pozzolanic earth, which is kind of a volcanic ash, whereas today we use of course Portland cement, but the final product had a similar large amount of silicates which are a main component of concrete and those concretes are still around and there are some marvellous examples of these intact concretes and I think I have a picture of the Pantheon in Rome which has a concrete dome of more than 40 metres in diameter. It doesn't have any reinforcement at all and it is still in a perfect condition, so I think this is a very nice example demonstrating that concrete has a very long durability both in terms of physical, mechanical and chemical behaviour and it's this kind of information that we can also use in the models and we can try to predict how those evolutions went about and if there is a good correspondence between what the models tell and what these archaeological or geological analogues tell us we have strong evidence that the models are doing what they should be doing.

If I can just talk a bit about the earth cover for instance, so that has a number of soil layers. How are they going to behave in the long run? Well, look for similar sequence of soil layers, monitor them and try to predict the water behaviour, the water redistribution over one, two or a number of years and if you can demonstrate there is a good agreement between them all in the data again you have a very strong argument that the models are right and that you have confidence not only in the models, but also in the ones that are using the models then they know what they're dealing with and you can apply this principle to different elements of the repository.

MR JACOBI: Can I pick up the concept of – we've read in some of the IAEA documentation about the sorts of factors that are relevant considering about siting and I'm just interested in the interplay between site selection and the engineered structure. Is there such a thing as a perfect site or do you need a perfect site?

DR MALLANTS: Yes, that's an interesting question. There is indeed this IAEA safety guide on near surface disposal which recognises the fact that there is no need for a perfect site. As I mentioned already when the site has weaknesses in terms of a limited containment capacity you can compensate for that by putting more emphasis on the engineered barriers such that the entire system, site and engineer barriers, is safe and it allows of course – that flexibility allows for incorporating the social dimension which is so critical in Belgium and in a number of other OECD countries it was pivotal to the success of the whole process. So an ideal site is not necessary at all, so if you have a site where there is community support, but it may not be an ideal site for whatever reasons, do not abandon that site. You have options to improve, to optimise the design until it becomes safe.

Again, an important element of that whole story again is the waste acceptance criteria. You can only go that far with optimising engineered barriers, but in the end, it is the waste acceptance criteria that define what you can put there. So if you say, "I allow only those wastes which will give me, let's say 10 per cent of the background dose, should it be released in the end," well then that tells you exactly what goes in that facility, and all the rest has to go in another type of repository. So you have that control in what goes into the repository.

MR JACOBI: I just want to pick up something you just said then, in terms of the significance of the substantiation that we've just been discussing, to the success. I just wondered perhaps if you could explain how important that was in the community coming to the view that the process, the project could proceed.

DR MALLANTS: You're referring to the multiple - - -

MR JACOBI: No, no, the process of substantiation that is demonstrating through analyses and the safety case - - -

DR MALLANTS: Yes, yes.

MR JACOBI: - - - how important was that to ultimately the project proceeding?

DR MALLANTS: That was, of course, central, for each of the parties involved: partnerships, nuclear regulator, also the NEA, the Nuclear Energy Agency, which conducted the peer review. It was central to them accepting the final design and the site on the basis of the arguments that were provided. So the solid, robust science that underpinned the statement or the claim, "Yes, the facility is safe," that was really central.

MR JACOBI: How long did the development of that safety case, that research, how long did that take?

DR MALLANTS: Well, if you take the start of the community engagement process when the partnerships were erected as the very first starting point, until the final safety case, well that was almost 15 years, I think. An important part of the site characterisation was done in those first eight years, and we still had four different sites, so a lot of site characterisation was done in that phase.

But then of course, once the final site, the preferred site was selected, there was still a need for a number of optimisations. So the initial design that went into that phase had to be updated, so there were a number of iterations. You have your design, then you do your safety assessment, you get your impact, you're looking at a reference scenario where - well, there's a number of scenarios that have been considered, so there's an expected evolution scenario where all the barriers behave as expected and that gives you a minimum impact, and then there's a number of altered evolution scenarios where you account for these disrupting events, they give you an output, they give you an impact. If that is too high, you have to revise your design.

MR JACOBI: When was it in that period of about 15 years that the community, they ultimately voted, or that working group ultimately made a recommendation - - -

DR MALLANTS: (indistinct)

MR JACOBI: When did they make that endorsement in that process, at which point everybody made the decision to go ahead.

DR MALLANTS: Yes, that was at the end, that was at the end of the eight years.

MR JACOBI: Right.

DR MALLANTS: They had their own safety case, so to speak.

COMMISSIONER: Can I go back to the social licence issue, and try and understand the process of discussion and decision about what the community benefits might be, and then what were those benefits? Was this community led or was it state led?

DR MALLANTS: Well, as everything with this process, it was a combination; there was input from all sides. It is important to reiterate that the partnerships were treated as equals among regulators, the waste management organisations, the technical support organisations. As I just explained, they had a formal role they had to endorse, if they wouldn't have endorsed, the local community would not have approved the project.

Also in discussing what the benefits could be, there was very strong engagement with the partnerships and then the waste management organisation, but the specifics of the benefit, it's probably a bit early days. I don't think the fund has already been set up, but the aim is to have a local fund, and the fund would work as kind of a pension fund, as a superannuation fund - - -

COMMISSIONER: Right.

DR MALLANTS: - - - where there would be annual fees by the waste producers, and the returns would then be used by the partnership to support social/economic projects. It could be educational projects, nature conservation, and then a lot of other initiatives. In the decision of what is going to be funded, the partnerships will have a strong role, because there's going to be a board, and I think there's two partnerships which will each have three elected members in that board, and then there's representatives of NIRAS/ONDRAF. So they collectively will decide what it's going to be.

In addition to the local fund, it's maybe also important to say that there will be a visitors' centre, or a communications centre, set up which the partnerships really grab as a unique opportunity to attract as many people as possible to the site, and to demonstrate, well, to demonstrate the project and the uniqueness of the project and the benefits to the society. So the idea is to have permanent exhibitions, science exhibitions on different aspects of life, of course about radioactivity as well.

It's going to be important to demonstrate for instance, that, as I mentioned previously, radioactivity is around us everywhere, at low levels. There's probably very few people that realise it, but life on Earth is possible only owing to the decay of naturally occurring radium, uranium, thorium in the core of the Earth. That decay generates the heat, generates 50 per cent of the heat, to give us the climate we all enjoy. So there's radioactivity everywhere, and that visitors' centre will take the opportunity to explain all these aspects, and they expect several tens of thousands of visitors every year. So they're not afraid to tell everyone that they have this repository, it is being seen as an opportunity.

Yes, there's another number of activities that the partnerships will undertake, so they will not stop, they will continue. They will continue to monitor the evolution of the repository, they will be looking at these test covers, these test vaults, they will continue to have their website where they can interact with the community. So there's a number of activities that they will have and that, in part, will be funded also by the local fund.

COMMISSIONER: Just so that I have this correct, the partnership was signed off on the final agreement to have it on site, without having defined what the local benefit might be?

DR MALLANTS: Correct. I don't think there has been any particular projects selected, because - well, the fund hasn't been erected, but there's a broader- - -

COMMISSIONER: No standing, no quantum established, like, 5 per cent or - - -

DR MALLANTS: You mean it's in dollar or Euro terms?

COMMISSIONER: Yes.

DR MALLANTS: I suppose as an agreement and that, yes, but I don't know the details. But it's significant.

COMMISSIONER: Yes. It's fine.

DR MALLANTS: It's significant.

COMMISSIONER: Yes. Yes, I'm just wondering what a wonderful community to sign off on a project like this without having to define what the quantum might be.

DR MALLANTS: I'm sure there's an agreement on the quantum, but I'm not aware of the details, but, yes, we can find that if that is of interest to you.

COMMISSIONER: It would be indicative. It would be useful to broadly understand what the benefit to the local community would be.

DR MALLANTS: (indistinct) orders of magnitude, it's tens of millions.

COMMISSIONER: Right.

DR MALLANTS: For a long, long period.

COMMISSIONER: Long periods.

DR MALLANTS: Yes.

COMMISSIONER: Dr Mallants, that's been very informative and I thank you for preparation of the material and for appearing with us today. It's been very useful to see how another country's gone about this process and it's very instructive for us. We'll adjourn now until 1330 when we'll have representatives from Finland talk about their waste sites.

DR MALLANTS: Thank you.

ADJOURNED **[12.11 pm]**