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Climate of the Past Discussions

Interactive comment on "How to treat climate evolution in the assessment of the long-term safety of disposal facilities for radioactive waste: examples from Belgium" *by* M. Van Geet et al.

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Reply to the interactive comment of M. Thorne

We received comments from 3 referees (e.g., M. Thorne, J. Naslund and D. Paillard) on the paper "How to treat climate evolution in the assessment of the long-term safety disposal facilities for radioactive waste: examples from Belgium" submitted for publication in "Climate of the Past".

Each of the referees stress that Climate of the Past could be a good place to publish this paper as it exposes a problem of interest for its readers. However, two reviewers (e.g., J. Naslund and D. Paillard) propose to modify the content of the paper: to decrease largely the part on the general context of radioactive waste disposal and to expand the

part on the climate; on the contrary, you would like to expand the overall context by describing the main issues in more details. We decided to follow the proposal of D. Paillard and J. Naslund and to focus the paper on the climatic issue and its impact on the radioactive waste disposal instead of presenting the overall methodology followed to assess long-term safety. Moreover, your comments will be treated in the SFC1 that ONDRAF/NIRAS is currently preparing.

An answer to your overall and specific comments is given hereafter:

Overal comments

1. *"It is worth noting that considerable differences exist between different countries in respect of the host rock proposed for a deep geological facility. Although the paper is properly focused on potential facilities in Belgium, it would have been nice to have seen these proposals framed within the context of the wide diversity of host geologies under consideration internationally."*

As we decided to follow the proposal of D. Paillard and J. Naslund and to focus the paper on the climatic issue, we did not include the discussion on the worldwide context.

2. *"... This illustrates that in defining scenarios for assessment, consideration has to be given not only to the relative likelihood of the climate scenarios, but also to their significance for repository safety."*

Indeed, the final objective is to study the effect of the climate evolution on the repository safety. In order to get there, first, some possible future climate scenarios need to be defined. The aim of our presentation at the 'Berger Conference' in May 2008, resulting in the present paper, was to start a discussion with climate experts on 'which future climate scenarios will be relevant for NE-Belgium', or 'which climate scenarios are relevant for our purposes' or 'which climate scenarios should be considered in the safety assessment of disposal facilities for radioactive waste'.

In a next step, the impact of these climate scenarios on the ecosystems, soils and

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landform development will be evaluated, as well as the impact on the hydro(geo)logical system. Finally, all this information will be used to study the impact of the climate changes on the repository safety. This entire study is part of the Safety and Feasibility Case 1 that ONDRAF/NIRAS is preparing.

3. *"... the penetration of permafrost to repository depth ... It is nice to see this brought out in Figure 6 of the paper."*

Because we had to shorten the document, Figure 6 is no longer there. Nevertheless, we included a short discussion on the permafrost issue in the paper.

"It would be interesting to include some comment on whether simulations have been conducted to assess the potential degree of permafrost penetration that could occur under an extended period of periglacial conditions."

Based on some observations, the penetration depth of the permafrost is thougth to be 20-50 m (de Gans, 1981; Eismann, 1981). Simulations by Boulton and Caban (1997) reveal a permafrost penetration depth of 100 m. However, according to Walraevens (1996), the permafrost penetration depth appeared to be more complex to calculate as it is also strongly dependent on the humidity conditions of the soil, which are themselves dependent on the climate conditions. Note, however, that for the reference zone Mol-Dessel, the above mentioned permafrost penetration depths suggest that the top of the Boom Clay has not been subjected to permafrost conditions in the past. Nevertheless, in our safety assessment studies, conditions at which permafrost conditions occur in the top of the Boom Clay will be considered as well. For the references: see the revised version of the document.

4. *"comment on the long interglacial period ..."*

We agree that the underlying reasons for such a long interglacial period are the long residence time of CO2 in the atmosphere (estimated at 200ka in BIOCLIM) associated to the low albedo of the earth at high latitude in absence of ice cap. Unfortunately, the

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current knowledge on the CO2 cycle remains incomplete to define the residence time of CO2 in the atmosphere precisely. Thus, additional work should be performed by the specialists of the topic to permit us to build more realistic and more defensible reference scenario (at least in terms of timing). There is a consensus pointing to the fact that there will be no new glaciation before at least 100 ka (that value being correlated to the most pessimistic point of view).

5. *"comment on the thermal expansion and increasing global sea level"*

Our paper doesn8217;t aim to present the reasons for each processes that could occur in the 'life time' of a radioactive waste repository. But, the impact of sea water flooding on the long term safety of the repositories will be assessed in detail in the fore coming SFC. It is far beyond the scope of the paper to discuss in detail the effect of sea water infiltration on the design. Of course, such a discussion is crucial in a safety case.

6. *"... the authors rely on the results from the BIOCLIM project ... There is, therefore, an argument for revisiting the types of long-term climate projections that were made in BIOCLIM ..."*

Indeed, at this moment, we rely on the results from the BIOCLIM project. More recent long-term climate predictions are not available to our knowledge at the moment for the region of our interest. We agree that it is worth revisiting the types of long-term climate projections that were made in the BIOCLIM project. However, changes in degree, persistence or timing of warmer/cooler periods might occur, but it is very likely that the overall patterns of climate change would be rather similar. Moreover, since a lot of uncertainties will probably remain, we decided to evaluate the impact of extreme climate conditions on the performance of the repository, rather than 8216;exact8217; values on 8216;exact8217; timings (since the latter differ from one scenario to another). It is worthwhile to mention that O/N plans to perform some new calculations on long-term climate changes (some scenarios that were not considered in the BIOCLIM project), in close collaboration with the climate experts of the U.C.L. (the team of A. Berger, which

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was involved in the BIOCLIM project) and the V.U.B. (two Belgian Universities).

7. *"One aspect of the effects of climate change that has been given limited consideration is the significance of a very prolonged interglacial on ecosystems, soils and landform development."*

See the answer to comment 2.

8. *"... disposal in a thick clay formation has substantial advantages that are not fully brought out in the paper..."*

Because we had to shorten the document, we decided not to include the discussion on the advantages of disposal in clay.

Detailed comments

1. Page 466: comment on the safety function R2

We are completely agreeing with the referee comment on the gas problematic. It is why ONDRAF/NIRAS launched several RD studies aiming at determining gas diffusion rates through the Boom Clay and the related pore pressure increases. However, explaining these issues are fare beyond the scope of the present paper. Preliminary results point to the fact that these issue shouldn8217;t be a fatal flaw to the deep geological disposal as designed by ONDRAF/NIRAS with the help of SCK-CEN. This is taken into consideration in the research carried out by ONDRAF/NIRAS and SCK-CEN. This issue is not mentioned in more detail here since it is not the aim of this paper.

2. Page 467: comment on the safety function I

We are agreeing with the comment of the referee on the human intrusion issue. Nevertheless, such a discussion is far beyond the scope of the present paper (aiming at presenting how to deal with the climate issue when envisaging radioactive waste disposal). Moreover, that part has been largely shortened. Indeed, in the preparation of the Safety and Feasibility Case 1, the consequences of possible effects of human

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intrusions and human activities are taken under consideration.

3. Page 468: comment on the safety role D

We are agreeing with the referee comment on the safety role D. But it has been decided not to expand that part of the paper (see previous comments).

4. Page 468: Define the normalised Radiotoxicity index

The definition hasn8217;t been added because the figure has been removed. Nevertheless, the definition is to be found below:

The NRTI is defined as the product of the dose coefficient for ingestion Fj [Sv/Bq] and its activity Aj [Bq] present in the near surface disposal facility at a given time, summed over all 20 critical radionuclides j, and divided by the maximum value of this product:

5. Page 470: comment on the position of the FANC

Even if the comment is relevant, as that part on the overall methodology followed has been removed. We are aware of the new ICRP guidelines. In agreement with the FANC, we will evaluate how to take this into account in future safety assessment evaluations. However, since this part is no longer in the paper (due to reduction of this part), it is no longer relevant here. Of course, such a discussion will be held in preparation of SFC1.

6. Page 472: *"... The approach of safety assessment indicators has similarities with the use of the safety indicators by SKB ...".*

Reference to SKB has been made. For a detailed description of both methodologies, we refer to SKB (2006) and ONDRAF/NIRAS (2009).

7. Page 475: "consider the potential of abrupt climate changes ..."

We developed the most realistic possible reference scenario, on the basis of the current knowledge. On one hand, the kinetics involved in the lifetime of the repository isn't

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judged as primordial as it needs time to reach equilibrium a disposal depth. On the other hand, we are going to assess the impact of severe climatic conditions on the safety statements. If the impact should reveal to be limited, the long term safety could be guaranteed.

Interactive comment on Clim. Past Discuss., 5, 463, 2009.