

***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.**

M. Van Geet et al.

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Reply to the interactive comment of D. Paillard

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

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part on the climate; on the contrary, M. Thorne 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, the comments of M. Thorne will be treated in the SFC1 that ONDRAF/NIRAS is currently preparing.

The paper has been revised in accordance with the three referee's comments: the climate part has been amplified and is presented before the general context of radioactive waste which has been largely shortened.

The answers to your specific comments is given hereafter:

1. *"A large part of the manuscript (paragraphs 1 to 4) describes the general context of radioactive waste disposal, in terms of strategy, overall design and safety assessment. A significantly smaller part (paragraphs 5 to 6) discusses the climatic aspects of this problem. These proportions (2/3 versus 1/3) should be reversed."*

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 climate scenarios should be considered in the safety assessment of disposal facilities for radioactive waste. Since most climate experts are probably not familiar with the topic of radioactive waste disposal, we thought that a presentation on the overall context was interesting. For the paper, we agree that the non-climate part is long, compared to the climate part of the manuscript. In the revised version of the manuscript, the non-climate part is significantly reduced.

"Another suggestion would be to start first with geoprospective scenarios, then to discuss how and why they will be used by radioactive waste agencies."

In the revised version of the manuscript, we changed the order of the chapters: 1- Introduction 2- Future climate evolution 3- Long-term safety assessment of radioac-

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tive waste disposal facilities 4- How to treat climate evolution in the long-term safety assessment of radioactive waste disposal 5- Conclusions

2. *"Future climatic scenarios are computed from CO2 scenarios. They are extremely dependent on them and thus there is a strong need to discuss first of all the processes involved.... The natural CO2 cycle processes are not so well understood on such time scales..."*

We agree with this comment. Indeed, future climate scenarios are based on CO2 scenarios. Since the natural CO2 cycle processes are poorly understood, various CO2 scenarios exist. We are aware of the fact that for these scenarios, several values/parameters are chosen, and hence the choice of another value may have a large impact on the resulting CO2 scenario, and hence also on the future climate scenario. This consideration is added to the manuscript.

"It is not a problem of "climate models" stricto sensu, but much more a question of better understanding the climate - érosion - alteration - carbon cycle feedbacks, something that has never been considered yet for future climates. The authors are apparently not aware of these critical assumptions, which are determining most of the long term future evolution of the Earth."

We are aware of these critical assumptions. In fact, because of the poorly understanding of the CO2 cycle on such long time scales, and hence the climate evolution, we decided to evaluate the impact of extreme climate conditions on the performance of the repository, rather than 'exact' values on 'exact' timings (since the latter may differ from one scenario to another). This is explained in chapter 4 of the manuscript.

3. page 479 line 4: Concerning category A (1000-year time scale): *"the present-day climatic conditions can most likely be maintained as representative ... According to current projections, a complete melting of Greenland and West Antarctica is a likely scenario on the millennial time scale, which could raise sea levels by 10 to 20 meters. Such a sea level rise is likely to change considerably the environnement ... in particular*

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in Northern Belgium. ... A recent paper on Antarctica (Naish et al., 2009) clearly highlights the fact that other kinds of "glacial cycles" are likely to appear in a warmer world. If it is true that we are probably not entering a Northern hemisphere glaciation anytime soon (see eg. Paillard, 2006, 2009), it is also quite likely that we are heading towards a "super-deglaciation".

After the submission of this manuscript, we had a discussion on this issue with some climate experts, amongst which Prof. Dr. A. Berger, Dr. M.F. Loutre, Prof. Dr. Ph. Huybrechts (this meeting was planned already a long time ago, but unfortunately it was after the dead line for paper submission). During this meeting, the same comment was made. We are now aware of the fact that a significant sea level rise may occur, and that flooding by the sea of NE-Belgium cannot be excluded within the next 1000 to 10000 years.

What concerns the category A waste and the eventual sea water flooding related to a super deglaciation, such a flooding is not excluded and the impact of sea water intrusion will be evaluated if such an event will be further confirmed by the experts.

4. In the conclusions: *"scenarios are ... conservative. Yes indeed, they should be. It is then very dangerous to extract conclusions from a small subset of possibilities..."*

In our safety assessment studies, the effect of climate changes on the repository safety should be evaluated. We refer to some studies (mainly BIOCLIM) that have been performed in this frame, but we are aware of the fact that these scenarios are only a small subset of possibilities, that a lot of things are poorly understood especially on the long time frames considered, and hence a lot of uncertainties remain.

Therefore, our approach in evaluating climate changes in the assessment of long-term repository safety, is rather to evaluate the impact of global warming and cooling on the performance of the repository system components. We will illustrate the robustness of the disposal system towards the possible results of climate change.

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To this end, the impact of past glacial periods can be used as a guideline for cool periods. However, even more extreme cases, for example an ice cap in NE-Belgium, can be considered. For extreme greenhouse ages, a worldwide de-glaciation can be considered. In this sense, our scenarios will be illustrative and conservative.

In addition, the interaction with climate experts will be continued. With their help, it should be possible to better define the robustness of the used climate models.

"Models on climate evolution helps in narrowing the amount of scenarios to be considered. This is not necessarily the case, as exemplified in BIOCLIM which has broadened the range of possibilities. Models on climate evolution should on the contrary help to better define this range, and help to link hypotheses made on external or unknown parameters (society, economic choices, AND here carbon cycle...) to possible consequences."

Indeed, after the our meeting with the climate experts, we were aware of the fact that we should broaden the range of possibilities. So, in stead of narrowing the amount of possibilities, we will consider even more possible future climate scenarios. Nevertheless, the interaction with climate experts will be continued to better define the range of possibilities.

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