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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comment on "Global risk of radioactive fallout after major nuclear reactor accidents" by J. Lelieveld et al. (2012)" *by* J. Lelieveld et al.

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We thank Dr. Kleinknecht for his comment and are happy to clarify some aspects of our original publication and our comment which have been misunderstood.

Although the use of the Chernobyl emissions in our study has been clarified in Q1,2,3, some new information has become available since the time of its original publication. However, we do not judge this information as contradicting our approach, rather as providing further information on the degree of uncertainty which the community needs to overcome in future targeted studies.

Table 1 of our original publication lists estimates of 137Cs emissions by Fukushima based on two publications, i.e., 12 and 37 PBq by Chino et al. (2011) and Stohl et al. (2012), respectively. As announced in our original publication, we have performed model simulations of the Fukushima accident and adopted this source range into a high-resolution version of our model (T255) (Christoudias and Lelieveld, 2012); the comparison between model results and observations supports the 37 PBq of Stohl et al. (2012). Since Chernobyl released 85 PBq 137Cs, the difference is therefore not a factor of 20, but only a factor of 2.3. Since Fukushima released this amount by three reactors, the difference per reactor is about a factor of 7. As indicated by Q4, other factors are expected to have made our deposition risk assessment a conservative estimate, so that the overall difference due to these opposing effects will be smaller, as also discussed in Sec. 8 of our original publication. Furthermore, the total release of 137Cs to the environment by Fukushima is larger than the 37 PBq estimated by Stohl et al. (2012) since the damaged reactors were flushed with seawater, which directly delivered radioactivity to the ocean (Yoshida and Kanda, 2012). The discussion about the total release is ongoing.

The statement by Kleinknecht that “radioactivity released to the atmosphere was at the percent level compared to Chernobyl” is therefore in conflict with the studies published thus far.

We object to the formulation “One particular manipulation in the paper..”, which is an unfounded allegation. We have explained explicitly in the manuscript that this particular simulation was not intended to simulate any particular event (e.g., Fukushima or Chernobyl), but rather to address the question raised by the referees and public comments whether it is viable to apply a continuous release to examine the mean deposition patterns from a short-term release, which we show is clearly the case. In the following, we do not address this allegation further, and restrict our response to the specific substance-orientated points raised.

To reiterate, Sect. 6 of our original publication (Sensitivity to short-term and annual emissions), in which the source strength of Fukushima was the same as in Cher-

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nobyl, was added to the manuscript based on discussions with the reviewers. Sect. 6 presents these calculations for the relevant though exemplary locations of Chernobyl and Fukushima, and compares the results from applying annual continuous emissions to those with weekly emissions. The reason for this is explained in the first two paragraphs of this section of the manuscript.

We also reemphasize that we do not generally question the risk assessment by the US nuclear regulatory commission. We compare the risk of a core melt by the frequency of such events in the past decades and find that our estimate differs from theirs by only a factor of 2, which is small considering the uncertainties (Q7). However, some additional assumptions were introduced by the regulatory commission about the probability of containment and the role of weather conditions, reducing the risk of a major accident by a factor of 10,000, which has not been borne out historically (Q8).

Kleinknecht indicates that the risk assessment by the regulatory commission has been experimentally verified. It is unclear what is meant by such a verification, since experiments at the scale required to usefully verify the estimated probability of reactor meltdowns would involve enormous risks. It would be interesting to learn more about how such experiments could be reconciled with the event in Fukushima, which has been declared a "profoundly man-made disaster" by the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission.

Kleinknecht refers to a "News in Focus" publication by Nature and a yet unpublished report of the WHO. The publication mentions that "the general public was largely protected by being promptly evacuated". He cites that the measured doses received by most people were below 10 mSv. This conflicts with the officially published integrated doses to which the public has been exposed, which are partly much higher (e.g., in villages and towns in Soma county, Date county, Futaba county, Monamisoma city, reaching up to 485 mSv (http://radioactivity.mext.go.jp).

Kleinknecht also indicates that "the emission of radioactive material was largely

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avoided, the risk for the population was minimal". This is quite contrary to the fact that approximately 50,000 households were displaced after the Fukushima accident, which certainly would not be justified if no radioactivity were released, or if there were no danger presented by the radioactivity release. We therefore do not understand this statement, and would be interested in a justification of this conclusion based on the evidence at hand.

Regardless of these factual discrepancies, our study did not address doses received by the public after Fukushima, but rather the deposition risk from all reactors worldwide, independent of evacuation success or failure. Our Fig. 9, as explained above and in the manuscript, is not a representation of the Fukushima accident but rather a sensitivity simulation of weekly compared to annual emissions, taking as an example the two locations that have yet been involved in an INES 7 event.

Thus, based on the arguments above, the newly-available information about the Fukushima accident does not motivate a correction of our modeling results and does not influence our conclusions.

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