Overview on radon measurements in Arctic glacier waters

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Answer to the comments of the unknown referee, April 16th.

We thank the reviewer for his comments and suggestions. Here the answer to the review:

Our group was the first to measure radon in glacier melt water. First measurements were made in 2006. Together with 2007 measurements they were presented at an international conference in October 2007, a paper on these measurements was accepted 2009 and published 2011 (Kies A., Nawrot A., Tosheva Z., Jania J., 2011: Natural radioactive isotopes in glacier meltwater studies. Geochemical Journal (GJ); Volume 45, number 6, pages 423-429).

Radon measurements done in glacier melt water were presented in extended abstracts:

Kies A., Surbeck H., Tosheva Z., 2007, Natural radioactive isotopes in glacier studies. The Dynamics and Mass Budget of Arctic Glaciers, Workshop on GLACIODYN (IPY) meeting 2007, Pontresina, IMAU, Utrecht University, pp 57-60.

Kies A., Nawrot A., Surbeck H., Tosheva Z. 2008: Natural radionuclides in glacier meltwater as useful tracers. Workshop on GLACIODYN meeting 2008, Obergurgl, IMAU, Utrecht University edit, pp 65-69.In September 2010 an oral presentation in Prague presented radon measurements from 2006 to 2010. An extended abstract was published in the conference booklet. In the paper of Bhatia the reference to this abstract is given.

At the submission of the present paper the authors were not aware of the paper of Bhatia et al., the paper and findings from this paper will be mentioned in the reviewed version.

Most reported measurements were performed in late winter, in the accumulation period. Our group was the first to measure radon at glacier outflows during the accumulation period. This was done in 5 successive years at the forefront of the same target glacier.

We thank the reviewer for showing the mistake concerning the partition coefficient. Of course the partition coefficient for 0°C is 0.5 (An insight into the given reference reveals this mistake). This mistake is not relevant for the paper as the calibrations have been done based on liquid scintillation measurements in the laboratory. Counts for a given time (normally 30 minutes) are directly converted to radon-in-water volume activity. The partition coefficient has to be known if absolute radon-in-air measurements are converted to radon-in water- contents.

The water samples used for calibration were prepared by a set-up based on a closed circuit putting water in contact with a certified open radium source (from Czech Meteorological Institute). A strength of the present paper is that the radon measurements are expressed in Bq/L and not in impulses per second. Furthermore our equipment allowed continuous measurements over longer time periods.

Our focus was not limited to artesian outflows. The main outflow at the target glacier, easily accessible, was artesian. Therefore it was chosen for continuous measurements. As mentioned by the reviewer artesian outflows have the advantage that radon degassing is often negligible, this degassing is subject to supplementary difficulties in the interpretation of the results as often it is difficult or even impossible to judge the percentage of radon lost before the outflow or between the outflow and the measuring point. The amount of radon lost depends on the flow conditions, laminar or turbulent and also on the flow rate. For an important flowrate the proportion of radon degassing from the water is smaller, i.e. pro liter of water less radon is lost. Much experimental work on in this subject had been performed in our group during the mentioned study on a catchment in Luxembourg. In monitoring radon in a river at some distance from the source, variation in radon content is often more influenced by the flowrate than by a varying radon input into the river at his source. What we wanted to address is that if artesian outflows exist it is preferable to use them. It is worth to make a survey in the glacier forefield for such possibilities. Without artesian outflow one can gather information as presented in the paper of M. P. Bhatia. In the present papers examples of non artesian outflows are also given and discussed. It is important to be aware of degassing and take it into account.

Besides continuous measurements done in artesian outflows, most of the radon measurements performed over a time lapse of 8 years concerned not artesian outflows. In April-May continuous measurements were not possible. Numerous outflows, mostly non artesian, were sampled during this period.

We do not claim that our overview is complete. The title overview refers to the long time span of the measurements done on one target glacier and the fact that it included ablation and accumulation periods.

We do not agree with the conclusion of the reviewer that the paper is not proper for the Journal.

Once more we thank the reviewer for the care he took for analyzing in great detail the paper, for his suggestions and proposed improvements. Some changes will be made in a rvised version.

In the following we give an answer to the different points given by the reviewer.

2. Mistake in abstract: did not appear in the original

3. We think that these lines are relevant for the paper. They explain why we decided to extend the radon measurements to glacier meltwater for testing the hypothesis if there is radon in meltwater and if similar conclusions (Hydrograph separation) can be obtained. Also the reader is informed of the expertise gained in the laboratory that guaranties the quality of the radioactive measurements.

4. Typing error, changed.

5. As mentioned previously the paper of M. Bhatia and their findings will be included in the reviewed version. We claim to be the first to have the idea to use radon for probing glacier meltwaters.

6. In radioactivity studies, ‘half-life’ and ‘period’ indicate both the time span for half of the radionuclides to decay.

7. Maybe repetitive, but as the reader may not be so familiar with radioactivity this small sentence was deliberately included to facilitate the understanding.

8. canalized was replaced by channelized.

9. We propose: *Cold glaciers have no distributed system and meltwaters contain no radon unless water is flowing through a moraine where radon uptake is possible. Increased radon levels in meltwater are a hint that at least part of the glacier has a polythermal regime.*

10. The calibration of the devices was done in the laboratory prior to deployment in the field. Certified radon in water was prepared in laboratory at radon concentrations. International radon-in-water intercomparisons confirmed the quality of the measurements.

11. Some data on natural radionuclides are presented in the present paper, other are listed in Kies A., Nawrot A., Tosheva Z., Jania J., 2011: Natural radioactive isotopes in glacier meltwater studies. Geochemical Journal (GJ); Volume 45, number 6, pages 423-429).

12. The devices to monitor radon continuously are based on Lucas Cells (scintillation cells paired with photomultiplier). The mounting of the device, the electronics and the calibration were part of a work performed by one of the authors (O. Hengesch, 2009, travail de candidature, University of Luxembourg, Ausarbeitung einer autonomen, microcontrollerbasierten Messeinheit zur bestimmung verschiedener parameter im Quell- und Gletscherwasser pp 105). For the calibration the reference radon-in-water set-up was used.

13. The mistake 0.1 instead of 0.5 has been corrected (sorry for the mistake and thanks to the reviewer). As explained before there is no incidence on the outcome of the measurements.

14. Good point. Actually the diffusion of radon through the silicon tube induces a distortion of the results. It is possible by computation to correct for. Given the low sampling rate it showed no noticeable influence on the evolution of radon levels.

15. Total Dissolved gas pressure (TDGP) is a very useful tool in Hydrology. Here we wanted to test its usefulness in combination with radon.

16. The text will be modified to enhance the quality of language.

17. The low concentrations of the radionuclides in water, especially the concentration of radium, prove that the source of radon is not the water but the sediments and rock basement. The concentrations are important as they give an idea of the availability of these radionuclides.

18. In line 17 is mentioned Fig. 4. We propose to change in:

An example is given in Fig.4: a continuous increase in ionic concentration and EC is recorded in outflow A during the freezing process and the original values in the newly formed outflow B; radon is not affected.

19. Attempt will be done to change the text and the figure captions to get more clear.

20. The reference value proposed is the result from 3 weeks measurements each April for 5 consecutive years. The number of samples taken in the forefield, often after breaking the ice cover, is high and allowed a comparison and the establishment of the reference value. From year to year due to the retreating glacier the situation at the forefront changed, nevertheless similar maximum levels in outflows were measured.

21. Slip - has been changed.

22.We agree, these possibilities have been discussed.

23. Sorry for this repetition

24. *'The overdeepening has a kind of buffer ….'* We agree that information on the discharges are missing. Also we recommend that these measures should be combined with the measurements described here. This will be mentioned in the conclusion.

25. Here is some misunderstanding due to the scaling of the x-axes. The numbers are not the days of the month but the days after September 12th.

26. See fig. 9, EC is lowest and starts to rise whereas radon continues to decrease.

27. The first time statement will be modified. But here first time is correct as it is for the first time that measurements were done in both accumulation and ablation periods.