We thank Anonymous Referee #2 for their review and helpful comments on our manuscript. Below we outline our response to each specific comment in turn (shown in blue text), with the reviewer's original comment in italics.

*The manuscript of Clason et al. deals with interesting for a wide community of scientists topic of contamination of cryospheric systems. Data presented in the manuscript are novel and important in the recognizing concentration and distribution of artificial and natural radionuclides on glaciers and glacier adjacent habitats. The authors focused not only on the nuclides but also on the geochemistry of samples. I appreciate all efforts taken in the design of the study, fieldwork, and the text. However, some parts need reconstruction, better description, and careful discussion. I recommend the manuscript for publication but only after crucial improvements.*

***GENERAL COMMENTS***

*Strong points:*

- *a proper sampling design mirroring environmental gradients,*
- *investigation of the proglacial lake sediments,*
- *first data on the artificial radionuclides content in cryoconite in Scandinavia,*
- *very nice and well-prepared figures,*
- *providing all necessary raw data in the supplementary material.*

*Weak points:*

- *some parts of the text are overstated,*
- *methods require better description,*
- *authors did not show statistical differences between sampling points and types of the material,*
- *in the central forefield, only two samples were collected, making this area weak for any comparison*
- *many statements require appropriate references.*

- We respond to the general comments made here within our response to individual comments below.

***SPECIFIC COMMENTS***

***Title***

*Sounds good, however, in the light of the recent literature about the artificial radionuclide content in the cryoconite environments, authors can not say about hyper-accumulation which is overstated. I suggest rewriting the title and say about the spatial distribution of artificial and natural radionuclides in glacial and glacier adjacent environments. It is something new.*

- The very high activity concentrations of radionuclides detected in Swedish cryoconite complement other recent studies that have also detected high accumulations and the title already mentions downstream distribution. We have, however, removed "hyper" and added "spatial" to the title.

***Abstract***

*Line 10-15: I would be happy to see facts. For example, the first sentence suggests a threat for downstream systems while the results do not really indicate such a phenomenon. Monitoring is very*

*important, and this paper indeed contributes to broadening this knowledge. I suggest rewrite some parts of the text.*

*Moreover, I feel that authors should focus on the rationale of the study, aim, a brief description of methods and results, finally conclusions based on empirical evidence.*

- We feel that the key findings of the paper are included within the abstract, and also feel that it is important to set the results within a wider context. The opening statement has been reworded and set within the context of legacy contaminants more broadly, as have the final two sentences.

***Introduction***

*This part is well written and presents a robust background for the study. I would add only a short section presenting why the concentration of radionuclides is so high in the glacial environments and why glaciers are a good study site for the investigation of FRN.*

- As alluded to at the end of the abstract, the processes governing the accumulation of FRNs in glacial environments remain poorly understood, so there are currently no published studies to reference here that explore in any detail **why** radionuclide concentrations are so high.

*Lines 60-65. Authors overlooked data from Antarctica (Buda et al. 2020, Biotope and biocenosis of cryoconite hole ecosystems on Ecology Glacier in the maritime Antarctic. Science of The Total Environment, 724, 138112.).*

- The authors thank the reviewer for alerting us to this source and the reference added to text.

*Line 75. I feel that knowledge on cryoconite as the efficient accumulator of various contaminants (artificial radionuclides, heavy metals, POPs, etc.) is widely known. In my opinion, authors shouldn't describe this fact as a part of their own findings.*

- We have modified the text to make this clear.

***Study site***

*This part requires special improvements. The authors roughly described the glacier and the surrounding area. Study on the spatial distribution of nuclides in the environment requires a much more careful description of glacier bedrock geology, amount of rain, snow cover, potential sources of contaminants (I believe the study site is great since is located between Novaya Zemlya, Chernobyl, and is far from towns and factories potentially delivered heavy metals), organic matter content. Moreover, cryospheric systems are much more simple than other Arctic systems, like for example fjords, tundra. The simplicity of biological communities, easy way to find sources of microbes and organic matter, stable temperature, and predictable behaviour of the glacier makes it a good study model.*

- While we have added some information here on local geology and climate, the snow cover will change on a regular basis so we have not added any information regarding this. There is also no previous data on organic matter content at this site so any description of this is reserved for discussion of our own results later in the manuscript. As far as heavy metals are concerned, significant atmospheric inputs from the major Russian industrial complexes on the Kola Peninsula have been reported. However, the Tarfala site is some 600 km to the west of these inputs and

relatively low metal atmospheric depositions of metals from the Kola industry have been recorded in northern Norway (Chekushin et al., 1998. Sci Total Environ., 220, 95-114).

***Methods***

*When samples were collected? how many samples have been collected? how they were stored?*

- This information has now been added to the text.

*Provide a range of a.s.l. for the sampling sites.*

- This information has now been added to the text.

*Line 108: what means „sufficient material" ? provide amount/volume/weight?*

- This varies by sample type. Some cryoconite is very "fluffy" while other samples are more granular, such that a full vial will vary in mass.

***Stable isotope analysis***

*How material was collected and stored? It was frozen? It was kept at a low temperature?*

- The material used for this analysis was the same as described in section 3.1. It was not frozen, was dried on site, and stored in individual clean plastic bags for transport to the laboratory in the UK.

*Do authors prepare any replicates in order to get the most accurate analysis of 13C/12C and 15N/14N?*

- The final sentence in section 3.4 now describes the duplicate analyses.

***Results and Discussion***

*Lines 178-79. Be more specific and add the number of collected samples in methods.*

- The number of cryoconite samples has now been stated within the methods section.

*Lines 184-185. Provide appropriate reference.*

- I'm not sure which part this refers to specifically, but we have added a reference about the impacts of $^{137}$Cs for health (Van Oostdam et al., 1999).

*Lines 200-204. Could authors make this long sentence shorter? Split into two?*

- We have shortened this sentence as suggested.

*Line 204. Why only soil organisms? Many recently published papers indicate cryoconite hosts unique, independent from other freshwater and soil habitats microbial communities.*

- This is true, and an important component of cryoconite ecology research. We have changed the text to reflect the wider, diverse microbial community.

*Lines 209-210. Taking into account that only three glaciers were investigated so far, I feel that comparison between hemispheres is too far.*

- We agree, and have modified the text to remove mention of the hemispheres.

*Lines 228-229. I would be happy to see this idea better described.*

- The lines of text to which the reviewer refers have been re-worded to improve the clarity.

*Lines 250-252. This part should be transferred to methods.*

- We appreciate the reviewer's opinion on the position of this statement within the text, however as it explains a new level of analysis we would prefer to keep this section where it is to ease the reader's understanding. The lines immediately preceding describe the outcome of the XRF analyses, that is the sum of the concentrations of the major and trace elemental oxides and as such the information is appropriate to the Results and Discussion.

*Line 254. What is „Canadian sediment guidelines for risk to aquatic life"? please provide a reference.*

- The authors thank the reviewer for drawing attention to this omission. The CCME (1995) reference has been added to the text and the list (line 261). The reference Hűbner et al (2009) is inappropriate and has been removed.

*Lines 269-274. The effect of sunlight seems to be something new. Maybe it is worth discussing the exposure of other glaciers investigated in terms of FRN and see this idea in a wider context.*

- While we agree that this is an interesting and novel finding, we feel that this is outside of the scope of this study, and would require both individual FRN sample data and geolocations of samples from other sites. Future research by our research network will focus on comparison between sites.

*I feel that sunlight influences productivity, then higher chances for accumulation of FRNs by photoautotrophs and other microbial species. The paper of Huang et al. (Accumulation of Atmospheric Mercury in Glacier Cryoconite over Western China. Environmental Science & Technology 53(12)) will be also very helpful for discussion.*

- We thank the reviewer for drawing this paper to our attention.

*Lines 277-285. I think that authors should use more statistical analysis than only PCA. The concentration of FRNs between types of environments and material can be neatly presented.*

- The reviewer does not specifically state which further analyses they would recommend, and we do illustrate the differences in FRNs between environment / material types in figure 5. However, we have now added correlation matrices for each sediment type to aid comparison between environments.

*Line 310. It is one observation only, I suggest being careful in the explanation of this phenomenon.*

- We agree, and have updated the text to urge caution over this interpretation.

*Lines 390-405. I feel that this part is no needed. At this moment it is rather a speculation. In my opinion and according to the results of the authors, FRNs will be too diluted in downstream to be*

*harmful. Nevertheless, monitoring and control of this issue are very important. I suggest remove this part or write it in another way.*

- This section of text does not suggest that FRNs **will** be harmful, but rather states that more research is required to better understand FRN distribution and accumulation in glaciated environments. We do not believe that sufficient research has yet been conducted to confidently state that FRNs in glaciated are not harmful, thus we would like to keep this section in the paper to help foster discussion and future research ideas within the community.

***Conclusions***

*The authors wrote few sentences which are not the effects of their work. I suggest adding proper references in appropriate parts of the text.*

- We have removed text within the conclusion around FRNs across the cryosphere since we only focus on one site here. We would also prefer not to add any references to this concluding section as there is nothing new stated here that is not already covered within the manuscript.