

## ***Interactive comment on “Osmium isotope and trace elements reveal melting of Chhota Shigri Glacier, western Himalaya, insensitive to anthropogenic emission residues” by Sarwar Nizam et al.***

**Anonymous Referee #1**

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This manuscript concerns the geochemical characterization of cryoconite from an Himalayan glacier (western Himalaya). The authors applied several techniques to this aim: elemental and isotopic ones. The novelty of this work is the application of Re/Os isotopic systematic in order to evaluate the contribution of anthropogenic atmospheric emissions with respect to cryoconite composition. Combining several pieces of information from major, REE, trace elements and isotopic signatures, they conclude that cryoconite from the Chhota Shigri Glacier has a typical crustal signature, with only secondary inputs from anthropogenic emissions.

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I highlight my lack of competence to judge the methodological side of this work, in particular the one related to isotopic analyses. The authors seem quite confident and I have nothing to report, but I guess that an opinion from an isotopic geochemist would be desirable.

In general the manuscript is well written and easy to follow, but my impression is that this work, in its current form, would be more appropriate for a geochemistry journal. The Cryosphere should publish papers dealing with the diverse aspects of glaciology, including glacial geochemistry. With glacial geochemistry I intend the geochemical processes which are somehow related to glacial environment. In this paper the authors present a detailed geochemical characterization of cryoconite, but they don't really link their findings with glacial (or supra-glacial) processes. For this reason, I believe that this manuscript should be published in a journal more focused on geochemistry, where their detailed geochemical analyses would be more appreciated. Otherwise the authors could deeply revise the manuscript, trying to better link their findings with glacial processes and highlighting the novelty of their method to evaluate the anthropogenic influence on cryoconite composition.

In addition, they should also shorten the side related to geochemistry (and this is a pity since the data are good, but not very suited for this journal), taking into consideration the possibility not to present all their data, which are so many. For example figures 6-7-8 and the associated discussion could be removed, I don't think that their removal would worsen the quality of the paper. Non-geochemists will have great difficulties to follow the paper if the manuscript would be published as it is now. If the authors want to publish their work in The Cryosphere, I suggest to them to select a limited dataset to present here (for example isotopic data and normalized elemental patterns) and focus their attention on the discussion about the anthropogenic influence on cryoconite composition.

The authors should also compare their results concerning elemental analyses with previous results (see for example Owen et al., 2019; Baccolo et al., 2017; Lokas et al.,

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2016; Singh et al., 2013) and better investigate the fact that cryoconite from the Chhota Shigri Glacier seems quite pristine, while other studies focused on Himalayan glaciers and cryoconite showed that pollution is strongly present.

One thing which is not clear to me is the link throughout the entire manuscript of pollution, glacier mass balance, carbonaceous compounds. These are important topics, but this work does not deal with them, so I believe it would be more appropriate to remove them.

Considering the above, I cannot support the publication of this work in The Cryosphere in its current form.

#### More specific comments

Please improve the abstract, now it is the most difficult part of the manuscript to follow. It is not very explicative I guess that you could drastically shorten it. The important things to say are: 1- Himalayan glaciers are rich in supra-glacial debris, also linked with human activities; 2- you have geochemically characterized cryoconite samples from an Himalayan glacier, also applying cutting edge methods (osmium isotopes); 3-your results show that cryoconite on your glacier has a fully crustal signature, regardless the data you consider (major and trace elements, osmium isotopes); 4- provide some information about the scientific significance of such results.

#### Page 1

Line 11-16: please rephrase, these sentences are very difficult to follow and not grammatically perfect.

Line 16: you introduce emission residues and then you suddenly turn to metals. Please better introduce metals as one of the most important anthropogenic species spread in the environment.

Line 20-21: "a benchmark glacier for process understanding in the western Himalaya" what does it mean?

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Line 22: maybe change "composition" with "signature"?

Line 23: change "compositions" with "values"

#### Page 2

Line 8-10: you write "Given that the presence of anthropogenic emission residues on the Himalaya is linked to driving climate change, enhanced glacier melting, and downstream water resources,...". I don't really agree with this passage. The most important process linked to the presence of anthropogenic species on glaciers is the increase of human atmospheric emissions, mostly related to industrial activities and transport. What is the link between climate change and anthropogenic pollution on glaciers? Please reformulate this passage. Also the role of glacier melting and downstream water resources is not clear in driving the presence of anthropogenic species on Himalayan glaciers.

Line 14-19: the authors state that scientific research on anthropogenic species found on Himalayan glaciers mostly focused on carbonaceous compounds and that studies dealing with metals are not common. This is not true! There are tens of papers showing that the concentration of many elements into glacier ice, in particular heavy metals, has increased in the last decades. If the authors look in scholar for the words "ice core asia metals", they will find heaps of interesting papers to cite.

Line 19-22: also this statement is not correct. For example look at Beaudon et al., 2018 (Central Tibetan Plateau atmospheric trace metals contamination: A 500-year record from the Puruogangri ice core), you will find that also for metals there are some works discussing their probable source.

#### Page 3

Line 3-5: "given that Re-Os isotopes are independent to the rate and magnitude of emission, biological or physiochemical fractionation during transport, complex orography and meteorological parameters." I would simplify as follows: "given that the Re-Os

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isotopic signature is strongly conservative. It mostly depends on the emission source of the considered material and for this reason it is adopted in provenance studies (add a ref about this point).

Line 23: "and is therefore an excellent site to study long-distance emission inputs." Why? I don't get the point, please explain better

Line 25: "4050 and 6263"

Line 25-26: "a benchmark glacier for process understanding in the western Himalaya" also this passage is not clear. Why is it considered a benchmark glacier? What processes are you talking about?

Page 4

Line 4: "comprises"

Page 6

Line 15: "sample powder"

Line 26: "sample duplicates"

Page 11

Line18: "are common"

References:

Baccolo et al., 2017. Cryoconite as a temporary sink for anthropogenic species stored in glaciers Beaudon et al., 2018. Central Tibetan Plateau atmospheric trace metals contamination: A 500-year record from the Puruogangri ice core Lokas et al., 2016. Accumulation of atmospheric radionuclides and heavy metals in cryoconite holes on an Arctic glacier Owens et al. 2019. Extreme levels of fallout radionuclides and other contaminants in glacial sediment (cryoconite) and implications for downstream aquatic ecosystems Singh et al. 2013. Atmospheric deposition studies of heavy metals in

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Arctic by comparative analysis of lichens and cryoconite

best regards

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