

Comment on bg-2021-117

Lena Wohlgemuth (Referee)

Referee comment on "Mercury accumulation in leaves of different plant types – the significance of tissue age and specific leaf area" by Håkan Pleijel et al., Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-117-RC2>, 2021

This manuscript will be of interest for researchers aiming to constrain the amount of mercury accumulation in global vegetation, since Hg data from tropical montane forests are underrepresented in literature compared to temperate forests. Furthermore, the role of leaf structure in foliar Hg uptake between and within broad leaves and coniferous needles has not been conclusively resolved, though there is solid evidence that Hg uptake per gram dry weight is larger for broad leaves than for coniferous needles of the same age. However, the authors draw far-reaching conclusions on the relation of foliar Hg uptake and specific leaf area (SLA), which cannot be easily generalized based on the regression model and their data. I approve publication of this manuscript, if the authors adequately address and critically discuss the following issues in their data analysis:

- In Sect. 3.4, Fig. 7b the authors portray regression results of $[\text{Hg}]_M$ to SLA values. The regression fit improves according to Fig. 7a, where $([\text{Hg}]_M/\text{SLA})$ is regressed to SLA. However, I am concerned, that regressing a ratio to the denominator of this ratio might mathematically result in the nonlinear regression and the improvement of fit (R^2), that the authors display in Figure 7a, without there existing an actual relation of this kind. The authors should consider, that the chosen nonlinear regression model of $y/x \sim x$ (Fig. 7b) is sensitive to small needle SLA values. SLA data for *Cryptomeria* has to be excluded from the analysis, since needle area values of *Cryptomeria* were not measured in a comparable way to the other coniferous species (Line 165) and this might have an impact on the regression of Fig. 7. Furthermore, the data displayed in Fig. 7b looks heteroscedastic to me and p values might not be valid. The authors should also evaluate and show regression of $[\text{Hg}]_M$ and SLA separately for needles (excluding *Cryptomeria*) and leaves before concluding that needle $[\text{Hg}]_A$ strongly depends on SLA (Line 286), since this is not obvious from a visual inspection of the data (Fig. 7b).
- The authors state that "SLA as a leaf trait is a strong predictor of Hg accumulation" (Line 397) and that coniferous needles take up more Hg via their surface area than broad leaves (Lines 281/282; 285/286; 410/411). While this might be true from the data presented here, I think this statement should not be generalized easily without further discussion. The authors explain in the introduction that foliar Hg accumulation is dominated by stomatal uptake during leaf diffusive gas exchange. However, stomatal

conductance for leaf gas exchange is higher for broad leaves than for coniferous needles over the growing season (see abundant literature, e.g. Lin et al. 2015), which should result in higher Hg uptake via surface area of leaves compared to needles. The authors should discuss this contradiction. Furthermore, the authors should consider, that the comparison of needle versus leaf $[Hg]_A$ is sensitive to the ratio of $SLA_{leaves}/SLA_{needles}$ in association with the ratio $[Hg]_{M,needles}/[Hg]_{M,leaves}$. From Figure 7, I estimate (please ensure accessibility to raw data) a medium SLA_{needle} value of $\sim 0.003 \text{ m}^2 \text{ g}^{-1}$, which is low in comparison to literature values (see e.g. Poorter et al. 2009 or Goude et al. 2019), thus $SLA_{leaves}/SLA_{needles}$ of this study is relatively high (approximately $0.013/0.003 = 4.3$). The ratio $[Hg]_{M,needles}/[Hg]_{M,leaves}$ (derived from Fig. 7) equals approximately 0.6 and roughly agrees with published literature (see e.g. Zhou et al. 2021) or is higher than values from literature (see e.g. Wohlgemuth et al. 2020). Consequently, the ratio of $[Hg]_{A,needles}$ to $[Hg]_{A,leaves}$ is roughly $4.3 \times 0.6 = 2.6$, meaning that in this study Hg area uptake by needles exceeds Hg area uptake by leaves by a factor of 2.6 on average. However, different and equally realistic ratios (e.g. $SLA_{leaves}/SLA_{needles} = 125/43 = 2.9$; $[Hg]_{M,needles}/[Hg]_{M,leaves} = 0.4$) would result in comparable uptake $[Hg]_{A,needles}$ to $[Hg]_{A,leaves}$ (e.g. $[Hg]_{A,needles}/[Hg]_{A,leaves} = 2.9 \times 0.4 = 1.2$). Therefore, please frame generalizations on the efficiency of needle vs. leaf Hg surface uptake more carefully and clearly mention caveats of the data analysis.

- In line with 2.), please include QA of measurements of projected needle areas (Lines 159 - 165) and exclude area values for *Cryptomeria* as they are not comparable to area values of the other species (Line 165). Please discuss the representativeness of September values of leaf $[Hg]_A$ uptake for the whole growing season. SLA increases before leaf abscission towards the end of the growing season (see Reich et al. 1991 and Epron et al. 1996), and this effect might start as early as September at the latitude of this study. The unusual hot and dry summer of 2018 might have had an effect on leaf Hg concentrations. $[Hg]_A$ of needles C + 3 might not represent needle $[Hg]_A$ uptake over one growing season due to a decrease of SLA with needle age (see e.g. Xiao et al. 2006). Furthermore, C + 3 needles took up Hg(0) over the course of four growing seasons, therefore concentrations of C + 3 needles should be divided by four and not three.

Specific line comments:

Line 21: C + 3 represents three-year old needles.

Line 23: approximately how much older is foliage from Rwanda compared to foliage from Gothenburg in this study?

Line 25 – 29: please be careful about possible correlations of $[Hg]_A$ with SLA (see general comment above)

Line 41 – 44: measuring litterfall Hg is time-intensive but not particularly challenging. Rather just describe all Hg dry deposition pathways.

Lines 63 – 64: please be more specific, which processes you mean. Do you refer to biochemistry inside the leaf or to litterfall deposition? Agnan et al. 2016 might not be the most fitting publication here.

Lines 66 – 71: this paragraph is a bit lengthy. It would be enough to cite abundant literature, that root Hg uptake is small compared to foliar Hg uptake from the air.

Line 81: please reason, why $[Hg]_A$ is more relevant than $[Hg]_M$.

Line 84: please add citation

Line 91: please add citation

Line 90 – 92: please be more clear, that you are referring to deciduous and coniferous forests with the same LAI

Line 94 – 96: please elaborate on this in more detail, since it might not be clear for every reader, why SLA is needed for biogeochemical cycling.

Line 116 – 119: the Gothenburg area has a cool maritime climate, however, was this true for the unusually hot and dry European summer 2018? It would be beneficial to give actual weather data of this particular year here.

Line 125: consider moving Table 1 to SI

Line 132 – 139: you could shorten/move to SI the description of Nyungwe forest and instead give some details about tree physiology of interest at this forest (e.g. how old is foliage there on average?)

Line 159: I think you can move your results on the effect of drying temperature on Hg concentrations from the Discussion (Line 452 – 456) to Sect. 2.2, to make these results more accessible to the readership. Consider moving Figure 1 to SI to shorten the paper.
Line 200 – 203: I challenge the representativeness of $[Hg]_A$ September values for the whole growing season (see general comment above)

Line 220 – 221: please exclude *Cryptomeria* $[Hg]_A$ from the study. Significant differences of $[Hg]_A$ between *Cryptomeria* and *Abies* are unsurprising given that surface area measurements of *Cryptomeria* cannot be compared to the other species.

Line 242 – 244: however, slope in Figure 4b is < 1 , thus there seems to be a slight decrease of Hg uptake with needle age

Line 255 – 256: what exactly is significantly different between the mentioned species? The slope of $[Hg]$ with time (June to September)?

Line 260: Typo (Agee, Fig. 5a)

Line 267: please be more specific. What is this genetic variation and why does it affect foliar Hg uptake?

L278: C+3 needles should be divided by the factor of 4 to be comparable with broad leaves, as they were accumulating Hg over 4 consecutive growing seasons.

Line 307: please be more precise about statistical significance. Which regression model did you use and which regression parameter was significant?

Line 308: was there a significant regression coefficient of $[Hg]_M$ to SLA for broad leaf values from Gothenburg? You indicate that there should be a correlation, but this is not clear to me.

Line 328: please elaborate on this further. By how much time was the period of gas exchange shortened?

Line 336: in case length is a problem, please shorten this section and avoid redundancy.

Line 352 – 355: as an additional factor litterfall could have lost organic carbon as well, therefore concentrating Hg (see e.g. Pokharel and Obrist, 2011)

Line 359 – 361: I disagree, needle litterfall flux is determined as Hg per unit ground area

and it does not matter how old litterfall needles are, thus there is no overestimation. Which values do you compare to needle litterfall flux here, please elaborate.

Line 385 - 386: I do not fully agree with this statement, fluxes are normalized over time, cancelling out high [Hg] in older foliage when we are preferentially interested in fluxes over the course of one growing season. Please also consider that the mass of younger foliage at trees is usually higher compared to older foliage. Therefore, uptake into younger foliage is more important for the overall flux and for this reason younger foliage should arguably be monitored preferentially when we aim to assess fluxes.

Line 397 - 398: I challenge this statement of SLA being a strong predictor from the regression presented in Fig. 7 (see general comment above)

Line 404: ...the same projected leaf area over unit ground area

Line 407: Please add a reference here to back up the statement. When does gas exchange of needles typically end in the Gothenburg area? Please keep in mind that bud break is typically later of needles than leaves.

Line 412: please include stomatal conductance values

Line 433 - 465: please shorten this part and avoid repetition

Line 464: please be more precise, which had been assumed earlier?

Line 469: 3 years old

Line 472 - 473: I disagree, see comment for line 385 - 386

Line 476 - 480: I challenge this (see general comment above)

References

Epron et al. 1996: Effects of elevated CO₂ concentration on leaf characteristics and photosynthetic capacity of beech (*Fagus sylvatica*) during the growing season. *Tree Physiology*

Goude et al. 2019: Comparing direct and indirect leaf area measurements for Scots pine and Norway spruce plantations in Sweden. *European Journal of Forest Research*

Lin et al. 2015: Optimal stomatal behavior around the world. *Nature Climate Change*

Pokharel and Obrist 2011: Fate of mercury in tree litter during decomposition. *Biogeosciences*

Poorter et al. 2009: Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. *New Phytologist*

Reich et al. 1991: Leaf age and season influence the relationships between leaf nitrogen, leaf mass per area and photosynthesis in maple and oak trees. *Plant, Cell & Environment*

Wohlgemuth et al. 2020: A bottom-up quantification of foliar mercury uptake fluxes across Europe. *Biogeosciences*

Xiao et al. 2006: Variation of specific leaf area and upscaling to leaf area index in mature Scots pine. *Trees*

Zhou et al. 2021: Vegetation uptake of mercury and impacts on global cycling. *Nature Reviews Earth & Environment*