Review Comments

This study investigated the impacts of anthropogenic and natural emission sources on atmospheric mercury before, during, and after the COVID-19 lockdown based on data measured at a rural site in eastern China. Correlation analysis, an explainable machine learning model, and the PMF model were applied to quantify the impacts of the key factors reflecting anthropogenic and natural sources. The manuscript tried to depict the change of atmospheric mercury behavior caused by the COVID-19 lockdown in China. However, my major concern is that the authors seemed to be a bit arbitrary in drawing conclusions. More solid evidences are required. Moreover, the reliability of the machine learning model and the PMF model needs more rigorous illustration. The novelty of this study also needs to be better addressed. The compensation effect of natural mercury emission when the GEM concentration is reduced has been reported before, and the results from this study could not confirm this effect. In addition, the discussion part in the manuscript needs significant improvement. Therefore, in my opinion, this manuscript is not acceptable for publication on Atmospheric Chemistry and Physics in its current version.

Here are some specific comments:

1. Lines 20–23: The conclusion that the decrease of GEM was not as significant as other air pollutants is not convincing.
2. Lines 46–58: It is not quite appropriate to use the past tense in these sentences. More updated literatures could be used, e.g., Streets et al. (2019) and Steenhuisen and Wilson (2019) for global anthropogenic Hg emissions, Liu et al. (2019) for anthropogenic Hg emissions in China, and Pirrone et al. (2010) and Outridge et al. (2018) for global natural Hg emissions.
3. Section 2.2: The size of the input dataset should be given. The results from model verification should be introduced in detail.
4. Section 2.4: Which factors were considered in the PMF model? How were they determined?

5. Lines 199–200: The case after the “lockdown” could not be called a “rebound”. There were just two small GEM pollution episodes. They could also occur during the “lockdown”. In fact, the lockdown continued for about six months. It was just that the extent of lockdown was gradually weakening.
6. Lines 230–231: This statement is a bit arbitrary. The lower reduction rate of GEM could be due to the discrepancy in key sources for different air pollutants.
7. Lines 233–237: This statement is too vague. What kind of fossil fuel combustion? Coal combustion or vehicle emissions? Is biomass burning an important source in Shanghai?
8. Lines 238–239: It is not appropriate to regard BC as a proxy for anthropogenic emissions. What kind of anthropogenic emissions?
9. Lines 242–243: Using only the R value or the ratio of GEM/BC to indicate the contribution of anthropogenic sources is not robust. Also, the ratio of GEM/BC should be compared with previous studies.
10. Lines 262–266: The increase of the R value didn’t necessarily imply the enhanced role of natural sources. It could be that other meteorological factors took the lead in affecting GEM concentration before and during the lockdown.
11. Lines 266–277: It could also be that different meteorological factors dominate the influence on GEM concentration before, during and after the lockdown.
12. Line 278: These were very weak evidences. The word “confirmed” is too strong.
13. Section 3.3: There should be a training dataset and a test dataset to check if the model is overfitting.
14. Figure 4(d-k): The influencing patterns of each factor should be discussed.
15. Lines 334–338: Does the SHAP value reflect the absolute impact of the factor or the relative contribution of it? If latter, the statement is incorrect. If former, the statement is not necessarily correct either.
16. Section 3.4: The uncertainty of the PMF results should be evaluated. For example, factor rotation could lead to very different outcome.

References:

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Pirrone, N., Cinnirella, S., Feng, X., Finkelman, R. B., Friedli, H. R., Leaner, J., Mason, R., Mukherjee, A. B., Stracher, G. B., Streets, D. G., and Telmer, K.: Global mercury emissions to the atmosphere from anthropogenic and natural sources, Atmos. Chem. Phys., 10(13), 5951–5964, 2010.

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