Comment on the Report on the work of the ad hoc group of experts on effectiveness evaluation

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My scientific research aims to better understand the pathway by which mercury-reduction policies affect emissions, transport, and ultimately human and environmental impacts. My research involves combining global-scale chemical transport modeling (using the GEOS-Chem model) with data analysis and other analytical approaches from natural science, social science and engineering. From that perspective, I welcome the work of the ad hoc group of experts on effectiveness evaluation, and believe that its report draws upon best available information at the state-of-the-art in terms of monitoring and assessment of the global state of mercury pollution. I would like to draw attention to three different issues which might be taken into account in further development of the effectiveness evaluation framework.

1. The effectiveness evaluation framework could better account for the role of present-day emissions in creating future legacy mercury. The effectiveness evaluation report refers (p. 20) to the fact that using monitoring data as indicators of effectiveness evaluation would require a complex determination of causal changes between Convention implementation and monitoring results. Further, it notes that this complexity will increase due to confounding factors that will affect "natural emissions/releases" such as those from permafrost. This statement about complexity is true, and improving understanding of this complex causal pathway will be important in assessing changes in mercury concentrations with time. However, confounding factors are not just a result of natural processes, but are dominated by the influence of legacy mercury, a product of human activities (Amos et al., 2015; Selin, 2018a). Further, on the timescale addressed by the effectiveness evaluation of the Minamata Convention, *legacy mercury emissions are affected not just by past behavior, but also mercury emissions in the present and near future*.

Global biogeochemical cycle models (e.g. Selin, 2014; Amos et al., 2013, Qureshi et al., 2011) can simulate this effect, although many of the underlying processes remain uncertain. Most of the three-dimensional atmospheric models referred to in the committee's report do not take into account this effect in future scenario analysis, due to computational limitations. Selin (2018b) proposed that a simplified global metric based on biogeochemical cycling models, Effective Anthropogenic Mercury Deposition (EAMD), could help inform policy decision-making and effectiveness evaluation, by drawing attention to the impacts of delayed regulation. Further scientific work is also needed to better understand the influence of present-day emissions on future legacy mercury, in order to better target strategies for policy evaluation.

2. Modeling capabilities should be integrated more explicitly into effectiveness evaluation. Our current generation of atmospheric chemical transport models need improvement, and their use can also help guide measurement strategies. The draft effectiveness evaluation committee report notes geographical gaps in Africa, Latin America, the Caribbean, certain parts of Asia and the Pacific, and in Russia. Other major gaps in measurements also exist in the Southern Hemisphere and over the global oceans. Measurements in remote regions can help set a global baseline, inform model evaluation, and (in combination with models) improve scientific understanding of mercury atmospheric processes and global biogeochemical cycling. The report notes that "A global ambient mercury monitoring program should be developed to systematically identify future monitoring sites" (p.2). Such a program could usefully employ model-based evaluations to identify sites that would provide the most relevant constraints on global mercury concentrations and trends.

3. Better intercomparability of atmospheric measurements is required to discern policy signals. The report (p.13) recommends conducting intercomparison studies to ensure that air concentration measurements are comparable across regions and monitoring locations. In this context, it is important to note that *the intercomparability of mercury measurements should be not only evaluated, but also improved* in order to be able to identify and attribute expected changes.

This is a lesson that is well-known from efforts in monitoring, reporting, and verification of other trace species in the atmosphere. One technique that is used to derive emissions estimates from atmospheric concentrations is inverse modeling, which runs models "backwards" to derive emission estimates from observed atmospheric concentrations. The type of results that can be gained from inverse modeling approaches can have a substantial impact on policy and effectiveness evaluation. One recent example comes from the Montreal Protocol, where recent research by Montzka et al. (2018) using inverse modeling identified a previously unknown source of CFC-11 production in contravention of Montreal Protocol requirements. Similar analyses, driven by the scientific community, could be useful for evaluating the progress of the Minamata Convention in the future. However, at present, the intercomparability of mercury measurements do not meet the standard required to conduct similar analyses to those done for chlorofluorocarbons. Our recent effort to conduct a similar analysis for mercury emissions (Song et al., 2015) revealed that measurement intercomparison error was the greatest limitation to quantifying sources. The Minamata Convention would be better informed not only by more atmospheric mercury measurements, but also by more accurate and comparable measurements.

I would be happy to answer any further questions about the comments provided here, provide copies of relevant references, or offer further assistance or feedback to the parties and stakeholders of the Minamata Convention.

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