Policy Brief 5

Enhancing Atmospheric Mercury Monitoring

Mercury (Hg) pollution, particularly in the atmosphere, presents significant environmental and health risks. Effective monitoring of atmospheric mercury species is essential for understanding its impacts and fulfilling the commitments under international frameworks like the Minamata Convention. Recent advancements in Hg measurement techniques and modeling have highlighted both persistent challenges and pathways for improving monitoring accuracy and policy enforcement. The National Science Foundation-sponsored workshop on atmospheric Hg measurements, held at the University of Nevada, Reno, emphasized the need for new methods and addressed limitations in current technologies. Notably, PhD students from the GMOS-Train project, a Marie Sklodowska-Curie Innovative Training Network (ITN), participated in this conference, contributing their insights into the measurement and modeling of atmospheric mercury.

Key Findings:

1. **Measurement limitations:**
   Existing methods for measuring gaseous oxidized mercury (GOM) and particulate-bound mercury (PBM) face significant limitations, including calibration biases and inefficient collection of specific Hg compounds. These challenges hinder accurate data collection required for environmental policy-making. Traditional methods, such as KCl-coated denuders, are biased and fail to capture all forms of GOM, but newer techniques like Cation Exchange Membranes (CEMs) show superior performance in this area.

2. **Advancements in calibration:**
   The GMOS-Train project introduced innovative calibration methods using non-thermal plasma (NTP) technology, improving the accuracy of GOM measurements. This method reduces uncertainty in atmospheric mercury measurements and provides a traceable, reliable standard for environmental monitoring. The development of real-time calibration systems will further enhance the reliability of atmospheric Hg monitoring. There is a need for real-time calibration systems and improved species-specific standards to enhance accuracy and account for environmental variability.

3. **Modeling challenges:**
   Current atmospheric models exhibit significant biases, overestimating Hg deposition near emission hotspots and underestimating it in remote regions. These discrepancies are largely due to insufficient data on emissions speciation and inaccuracies in reactive Hg redox chemistry. Sensitivity simulations have highlighted areas for improvement, particularly in the representation of emissions speciation, dry deposition mechanisms, and photochemical reactions.

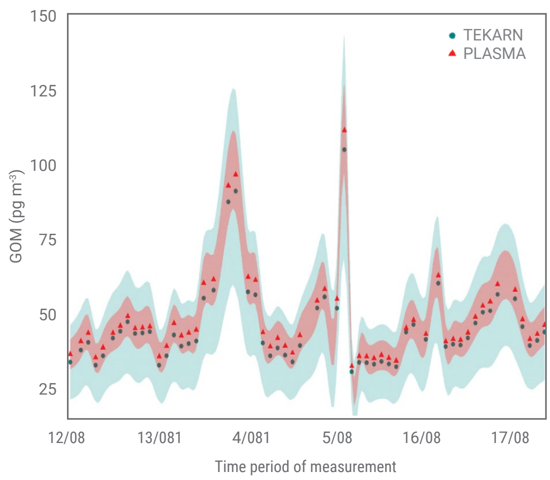

Figure 1: Calibration comparison: NTP vs. traditional calibration: A comparison of measurement uncertainties between traditional calibration methods and the innovative NTP-based method, highlighting the reduced uncertainty and improved accuracy in environmental Hg monitoring. (Nair et al., 2024)

Recommendations:

1. **Improve measurement protocols:**
Adopt CEMs for GOM measurements: These membranes should be integrated into monitoring networks as the preferred method for capturing cationic GOM species. CEMs provide higher retention of GOM over extended sampling periods compared to traditional denuder systems. Establish standardized calibration methods: Promote the adoption of NTP-based calibration methods, ensuring traceability to national standards and improving the reliability of data from Hg monitoring networks.

2. **Support technological innovation in Hg measurement:**
Develop real-time, field-deployable calibration systems: Research and development should focus on making NTP-based systems more practical for continuous Hg monitoring in field conditions. Refine pre-concentration methods: Enhance the stability and selectivity of CEMs in humid and high-pollution environments, focusing on capturing a broader range of GOM compounds.

3. **Enhance atmospheric modeling:**
Correct historical data and improve model inputs: Accurate historical data, corrected for measurement biases, is essential for refining global models. Emission inventories should better capture the speciation of anthropogenic Hg emissions. Improve dry deposition modeling: More research is needed to quantify dry deposition velocities in different environmental conditions to reduce spatial biases and improve model predictions.

4. **Strengthen international collaboration:**
Coordinate global Hg monitoring efforts: Enhanced collaboration under the Minamata Convention will help standardize Hg monitoring, improving the comparability of data and supporting more effective policy implementation.

Conclusion:

Technological advances, such as the adoption of CEMs and NTP calibration, combined with enhanced atmospheric models, offer significant potential to improve global mercury monitoring. These improvements are essential for meeting the objectives of the Minamata Convention and mitigating the risks associated with atmospheric mercury pollution. The GMOS-Train project, through its doctoral students' active participation in conferences and their groundbreaking research on Hg measurement and modeling, continues to contribute valuable insights that shape the future of global mercury monitoring efforts.

References

- Nair, et al., (2024) Application of traceable calibration for gaseous oxidized mercury in air, Analytica Chimica Acta, 1288, 342168, https://doi.org/10.1016/j.aca.2023.342168.
- 1. Gačnik, et al. (2022). Calibration Approach for Gaseous Oxidized Mercury Based on Nonthermal Plasma Oxidation of Elemental Mercury. Analytical Chemistry, 94(23), 8234–8240. https://doi.org/10.1021/acs.analchem.2c00260
- 2. Gustin, M. et al. (2024): 'Measurement of Atmospheric Mercury: Current Limitations and Suggestions for Paths Forward.' Environmental Science & Technology, 58(29), 12853–12864. DOI: 10.1021/acs.est.4c06011.

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This project will receive funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement no. 860497