

Formaldehyde sources within a shipping channel in China: Estimating their relative emission intensities

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Formaldehyde is a volatile organic compound which is commonly found in indoor environments, but it is also present in the atmosphere from off-gassing or combustion¹. Since river channels are frequently used as a shipping route for cargo ships the annual average of formaldehyde in the channel is 2.5 times higher than the nearby campus atmosphere. To ensure the formaldehyde concentrations were correctly explained under different meteorological conditions, the tracer-pair of CO and O_x (NO₂+O₃) were used on the clustered air masses. The clustered air masses were divided into three categories depending on the direction of which the air cluster originated from in relation to the Long-Path Differential Optical Absorption Spectrophotometer (LP-DOAS).

Previous studies on formaldehyde in the atmosphere have only used satellite imagery or numerical simulations. In contrast, this study uses real-time data which can give a better understanding of actual formaldehyde concentrations. Formaldehyde is a reactive intermediate, one of the most abundant gas-phase carbonyl compounds in the atmosphere, its global levels are contributed by long-lived volatile organic compounds (VOCs) such as methane, it is readily soluble in water and is capable of being absorbed by the human body.² For these reasons it is considered one of the most important outdoor air carcinogens among the 187 hazardous air pollutants identified by the U.S. Environmental Protection Agency (EPA).³ Shipping emissions are also a popular topic in the media, especially sulfur content in fuels.⁴ The papers' objective was to determine the formaldehyde concentrations within the shipping channel, while also

using the knowledge of N₂O emission levels to provide data support for the establishment of emission factors.

The authors used the LP-DOAS to measure the formaldehyde concentrations within the channel from January 1 to December 31, 2019. Measurements were conducted at the Wusong Wharf (WSW) as the experimental site and Jiangwan campus of Fudan University (FDU) as the control site, both located in Shanghai China. There were also three air masses identified based on the direction they originate from. Air mass 1 blows from the north of the channel offshore, air mass 2 blows from southwest Sea of Shanghai and passes through a large urban part of the city, air mass 3 blows from the surface of the East China Sea. Proper identification of air masses before analysis is important due to each mass containing different humidities, temperatures and sources of contaminants.

The mean HCHO levels in the channel (7.32 ± 4.03 ppbv) were much higher compared to the control site (3.02 ± 1.81 ppbv). The largest mean formaldehyde concentration was observed in May which correlates to busy ship activity in the channel and high sunlight conditions. The most noticeable difference in diel concentrations was during daylight hours. During the summer months the WSW and FDU sites recorded a sharp increase in formaldehyde concentration from 8:00 AM to 4:00 PM. This increase in concentration was attributed to photolysis reactions occurring within the atmosphere involving formaldehyde. The separate air masses also displayed varying concentrations of formaldehyde. Air mass 2 displayed the frequent highest concentration of formaldehyde. This was attributed to the air mass traveling through a large urban area of the city before reaching the LP-DOAS detector, potentially carrying contaminants not originating from the shipping channel. The air masses 1 and 3 displayed lower and similar

concentrations of formaldehyde, which were determined to be more representative of the shipping channel environment.²

In conclusion, the concentrations of formaldehyde in the shipping channel environment were 2.5 times higher than the nearby university environment. The concentrations displayed large seasonal and diel variation. These variations were contributed to sunlight conditions leading to photolysis reactions in the atmosphere, and busier shipping seasons at the shipping channel ports.

One major limitation of the LP-DOAS in this study is that formaldehyde concentrations are only being measured at one specific point in the channel at the same elevation. Formaldehyde also has a short atmospheric lifetime and does not remain in the atmosphere for more than four hours at midday.⁵ The experimental design is also very weather dependent. There were issues with weather condition during certain months of the year regarding measurements taken using the LP-DOAS. Daily concentrations can also vary greatly depending on amount of sunlight present.

Future work includes the support of Automatic identification systems (AIS) such as satellite imagery coupled with LP-DOAS to better represent the channel environment. This would also be combined with detailed meteorological information to determine direction of air masses and determine better conditions to measure concentrations. Autosamplers could also be installed directly on selected ships to compare formaldehyde concentrations in the exhaust compared to the atmosphere above. It is also recommended to include more sample sites as this will display a more representative sample of the shipping channel environment.

References

- ¹Government of Canada. *Formaldehyde in your home*. <https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/air-quality/formaldehyde-indoor-air-environment-workplace-health.html> (accessed 2024-10-07)
- ²Liu, J.; Wang, S.; Zhang, Y.; Yan, Y.; Zhu, J.; Zhang, S.; Wang T.; Tan, Y.; Zhou, B. Investigation of formaldehyde sources and its relative emission intensity in shipping channel environment. *J. Environ. Sci.* **2024**, *142*, 142-154. <https://doi-org.ezproxy.tru.ca/10.1016/j.ies.2023.06.020>
- ³United States Environmental Protection Agency. *Risk evaluation for formaldehyde*. 2024. <https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-evaluation-formaldehyde> (accessed 2024-10-07)
- ⁴Turner, B. Cutting pollution from the shipping industry accidentally increased global warming, study suggests. <https://www.livescience.com/planet-earth/climate-change/cutting-pollution-from-the-shipping-industry-accidentally-increased-global-warming-study-suggests> (accessed 2024-10-07)
- ⁵Lui, K.; Ho, S.; Louie, P.; Chan, C.; Lee, D.; Hu, D.; Chan, P.; Lee, J.; Ho, K.; Seasonal behavior of carbonyls and source characterization of formaldehyde in ambient air. *Atmospheric Environment*. **2017**. *152*, 51-60. <https://doi.org/10.1016/j.atmosenv.2016.12.004>