Environmental Science & Technology

VIEWPOINT

pubs.acs.org/est

Underestimation of CH_4 Emission from Freshwater Lakes in China

Hong Yang,[*,†,‡] Ping Xie,[†] Leyi Ni,[†] and Roger J. Flower[§]

[†]Donghu Experimental Station of Lake Ecosystems, State Key Laboratory for Freshwater Ecology and Biotechnology of China, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, PR China

[‡]School of Geography, University of Southampton, University Road, Southampton, SO17 1BJ, U.K.

[§]Environmental Change Research Centre, Department of Geography, University College London, London, WC1E 6BT, U.K.

Methane is an important radiative trace gas, accounting for ca. 18% of anthropogenic greenhouse-gas (GHG) emissions. Although its atmospheric concentration is small compared to other major GHGs such as carbon dioxide (CO_2), it is >70 times more potent as a GHG than CO_2 over a 20-year period. Freshwaters, including lakes, rivers, and reservoirs, are important natural sources of CH_4 emission. However, accurate estimation of CH_4 emission from global freshwaters is limited by the relative paucity of field measurements. Recently, Bastviken et al.[1] constructed a global freshwater CH_4 emission estimate based on 425 waterbodies from 54 publications. They provided persuasive evidence that CH_4 emissions from global freshwaters represent a significant contribution to the global GHG balance. The global average CH_4 diffusive emission from lakes between 24° and 54° latitude is 225.7 ± 626.2 mmol m^{-2} yr^{-1} according to calculations using 53 lakes in Bastviken et al.[1] Only four out of the 53 lakes used are not drawn from North and Southern American or European lakes. No Chinese freshwaters were included implying that CH_4 emission from Chinese lakes was similar to the global average. However, our field data[2] and data from other ISI-listed lakes studies[3−5] indicate much higher diffusive emission fluxes from Chinese lakes. Here we summarize CH_4 emissions from the main Chinese lake regions, we modify global estimates using the available Chinese data, and explain some differences and potential future trends.

There are five lake regions in China: East Plain lakes zone (EPLZ), Tibetan Plateau lakes zone (TPLZ), Inner Mongolia-Xin Jiang lakes zone (IMXJLZ), Northeast China Plain and Mountain lakes zone (NECPMLZ), and Yunan-Guizhou Plateau lakes zone (YNGZPLZ) (Figure 1). EPLZ, TPLZ, and IMXJLZ are three main lake regions, contributing 94.3% to the whole Chinese lake total area of ca. 90 000 km^2. EPLZ lakes represent 23.3% of the total Chinese lake area. Most lakes in this region are very shallow and eutrophic or hypertrophic. Our *in situ* measurements at Donghu Lake, the largest Chinese urban lake, showed CH_4 emission up to 531.5 ± 424.3 mmol m^{-2} yr^{-1}.[2] A study at Taihu Lake, one of the five largest freshwater lakes in China, indicated that the average CH_4 flux was 2106.3 mmol m^{-2} yr^{-1}, with a range of 37.5−6500 mmol m^{-2} yr^{-1}.[3] The average CH_4 emission in EPLZ lakes is 1320 mmol m^{-2} yr^{-1}. TPLZ lakes account for approximately 50% of the Chinese lake area. The Tibetan Plateau is known as "the roof of the world" and "the third pole", due to its high altitude and low temperature. In this region, Huahu Lake, a typical alpine lake with an altitude of 3430 m and average annual temperature of 1.7 °C, showed CH_4 diffusion rates of 22.7 mmol m^{-2} d^{-1} (ranging from −18 to 16200 mmol m^{-2} d^{-1}) in the peak growing season from June to August.[4] Even discounting emissions for the rest of the year, this amounts to 2718 mmol m^{-2}. IMXJLZ lakes represent 21.5% of the Chinese lake area. Most lakes are in arid and semiarid regions and are dominated by macrophytes where eutrophication has caused changes in aquatic macrophyte populations.[5] Measurements at Wuliangsu Lake indicate that CH_4 emissions in aquatic macrophyte zones were 13.1 ± 11.8 mmol m^{-2} d^{-1} during the growing season (from April to October). Considering only the peak growing season this indicates annual emission of not less than 2809 mmol m^{-2}.[5]

Because of limited field data and the great spatial variation in CH_4 flux, caution is needed in estimating CH_4 emission from all lakes. Nevertheless, the available data indicate much higher CH_4 emissions from Chinese lakes than Bastviken et al.'s global average. A preliminary estimate, based on the field measurements presented above from the three main lake regions in China indicates that Chinese lakes could contribute an extra ca. 3.0 Tg yr^{-1} to the global CH_4 budget.

CH_4 emission fluxes in Chinese lakes are much higher than those published for American and European lakes because of their higher nutrient enrichment, higher organic matter input, and shallow lake water depth. According to the OECD classification, 41 of the 53 lakes cited by Bastviken et al. are meso- or oligotrophic, seven are eutrophic or hypertrophic levels, and five are unclear. This indicates that the global average calculated was biased

Published: April 22, 2011

dx.doi.org/10.1021/es2010336 | Environ. Sci. Technol. 2011, 45, 4203–4204

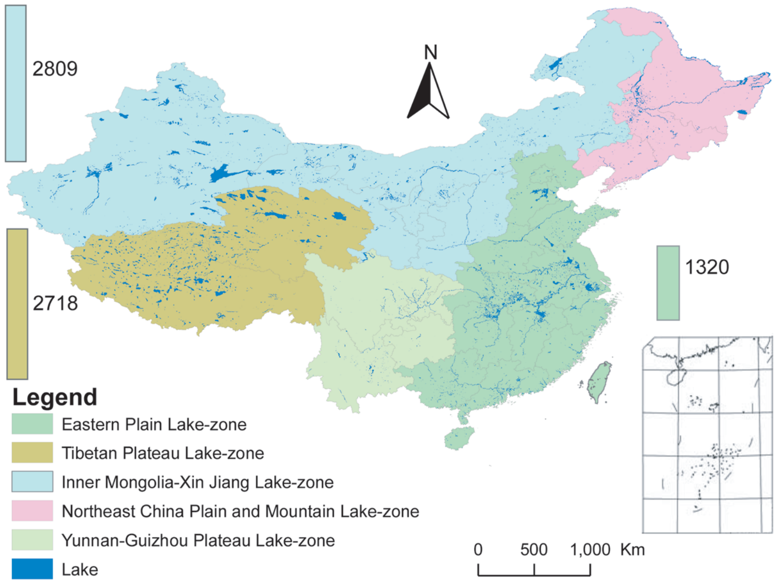

Figure 1. CH_4 diffusive emission (mmol m^{-2} yr^{-1}) from three main Chinese lake regions.

toward lakes with relatively low productivity. In contrast, Chinese lakes, especially most EPLZ lakes (e.g., Donghu Lake and Taihu Lake) and many IMXJLZ lakes (e.g., Wuliangsu Lake), are eutrophic or hypertrophic. A high photosynthetic rate and higher organic productivity increase substrates for methanogenesis. In addition, eutrophication in many IMXJLZ lakes, such as Wuliangsu Lake, and widespread lake-level lowering has caused macrophyte beds to shift from submerged to emergent plants, thereby accelerating CH_4 transport to the atmosphere[5] by changing the gas conduit route. TPLZ lake catchments are peatlands rich in organic carbon and these deliver water with high dissolved organic carbon, providing a rich carbon source for methanogenesis, probably one of the reasons for the very high CH_4 emission in TPLZ lakes.[4] In addition, most lakes in the EPLZ are very shallow (average water depth is ca. 2 m) and this contrasts sharply with the average lake water depth of 14 m calculated from the available data for 41 of the 53 lakes cited by Bastviken et al. The shorter transport distance between the sediment and lake water surface will reduce CH_4 oxidation in the water column.

Chinese lakes are already being affected by increasing water temperature. The further increases in temperature predicted for the next few decades will increase primary production and push aquatic macrophyte populations away from submerged plants toward emergent ones, potentially increasing CH_4 release. However, quantifying the fluxes at the regional scale is not easy using existing data sources. Due to the great spatial variation in CH_4 fluxes and the complex mechanisms influencing CH_4 production, transport, and emission, wider spatial investigations and more intensive year-round, longer term monitoring are urgently needed both to make more accurate estimates of current CH_4 emissions and also to facilitate the modeling of future emissions.

AUTHOR INFORMATION

Corresponding Author

*Phone: +44(0)2380-592253; fax: +44(0)2380-593295; e-mail: hongyanghy@gmail.com.

ACKNOWLEDGMENT

We appreciate comments on early drafts of this paper from Rick Battarbee and Don Monteith. The study was supported by the Knowledge Innovation Projects of CAS (KZCX1-SW-01-07; KZCX1-SW-12). The views expressed do not necessarily represent the views of the supporting funding agency.

REFERENCES

(1) Bastviken, D.; Tranvik, L. J.; Downing, J. A.; Crill, P. M.; Enrich-Prast, A. Freshwater methane emissions offset the continental carbon sink. *Science* **2011**, *331* (6013), 50.

(2) Xing, Y. P.; Xie, P.; Yang, H.; Ni, L. Y.; Wang, Y. S.; Rong, K. W. Methane and carbon dioxide fluxes from a shallow hypereutrophic subtropical Lake in China. *Atmos. Environ.* **2005**, *39* (30), 5532–5540.

(3) Wang, H. J.; Lu, J. W.; Wang, W. D.; Yang, L. Y.; Yin, C. Q. Methane fluxes from the littoral zone of hypereutrophic Taihu Lake, China. *J. Geophys. Res.-Atmos.* **2006**, *111*, D17109.

(4) Chen, H.; Wu, N.; Yao, S. P.; Gao, Y. H.; Zhu, D.; Wang, Y. F.; Xiong, W.; Yuan, X. Z. High methane emissions from a littoral zone on the Qinghai-Tibetan Plateau. *Atmos. Environ.* **2009**, *43* (32), 4995–5000.

(5) Duan, X. N.; Wang, X. K.; Mu, Y. J.; Ouyang, Z. Y. Seasonal and diurnal variations in methane emissions from Wuliangsu Lake in arid regions of China. *Atmos. Environ.* **2005**, *39* (25), 4479–4487.