Key shaping factors of anammox bacterial geographical distribution and function in riverine ecosystems

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The anaerobic ammonium oxidation (anammox) process converts ammonium to dinitrogen gas (N₂) using nitrite as an electron acceptor under anaerobic conditions, which plays an important role in global nitrogen cycle. Anammox has been extensively investigated at different spatial scales. However, most previous studies have focused on the impacts of environmental factors on anammox bacterial community composition, whereas the influence of spatial factors, such as geographical distance, remains unclear. Here, we took sediment and water samples from two large-scale river in China: the Yangtze River. High-throughput biomolecule analysis was performed to explore the spatial patterns of anammox bacterial community and their response to environmental factors, spatial factors, community interchange and anammox bacterial traits. Additionally, ¹⁵N tracer analyses has been performed to estimated anammox activity and its contribution to N₂ production (ra), and factors shaping its occurrence. Main conclusions are draw as follows:

(1) The Three Gorges Dam (TGD) induced sediment coarsening could enhance anammox role as an important N-sink and decrease anammox bacterial alpha diversity. Anammox is ubiquitous in sediment of the Yangtze River, with high bacterial abundance (1.0×10⁵ to 2.90×10⁸ copies g⁻¹ dry sediment), and activity (0.003-6.67 nmol N g⁻¹ h⁻¹), accounting for 3.5-82.8% of total N₂ production (ra). Our results showed that the ra at the post-dam site was steeper than that before the dam, whereas the alpha diversity of anammox bacteria showing an opposite trend. Further analysis showed that hydraulic erosion leads to sediment coarsening and loss of organic matter downstream of the dam, which ultimately leads to the enhancement of the ra and the decrease of anammox bacterial alpha diversity. TGD induced sediment coarsening would extend downstream nearly to the river mouth in the coming decades, which would inevitably enhance the importance of anammox in nitrogen loss and alter anammox bacterial community in the Yangtze River for a long time.

(2) A significant distance-decay relationship was observed for anammox bacterial community similarity in the Yangtze River, which was significantly influenced by geographical distance rather than local environmental factors. This implied that niche-independent dispersal limitation plays an important role in shaping anammox community assembly. Furthermore, the slope of the distance-decay curve was much higher than previously reported for whole bacteria, which indicating the species turnover rate of anammox bacteria (z-value = 0.35) was significantly higher than that of the whole bacteria (approximately 0.008-0.05). Anammox bacteria harbor stronger adsorption ability
and film-forming ability than other bacteria. As such, anammox bacterial harbor lower dispersal potential, and ultimately exhibited a higher species turnover rate than whole bacteria.

This study investigated the geographical patterns and the driving mechanisms of anammox bacterial community in large-scale riverine ecosystems, and estimated the key shaping factors of anammox activity and its contribution to total N2 production. The results or conclusions of this study are of scientific significance for further revealing the community assembly and geographical patterns of anammox bacteria on a global scale, as well as the theoretical system of nitrogen cycle.