SOURCES AND DISTRIBUTION OF ISOPRENOID AND HYDROXYLATED GLYCEROL DIALKYL GLYCEROL TETRAETHERS IN AN ALPINE LAKE OF CHINA

Jingjing Li, Qian Wang, Xiangdong Yang

Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, China

Introduction

Glycerol dialkyl glycerol tetraethers (GDGTs) are membrane lipids occurring in archaea and some bacteria, and are widespread in marine and lacustrine settings, soils and peat (Schouten et al., 2013). GDGTs consisting of isoprenoid alkyl moieties (isoGDGTs) can be used to trace archaeal biomass in oceans and lakes, for example, crenarchaeol contains a cyclohexane group and is specific to Thaumarchaeota (ammonia oxidizing archaea) in the marine and lake water column or soils (Sinninghe Damsté et al., 2002; De La Torre et al., 2008), whereas isoGDGTs containing one or two cyclopentane moieties are commonly produced by methane oxidizing archaea (i.e., mainly ANME-1) (Pancost et al., 2001). Recently, improvements of analytical methods have gradually revealed a larger structural diversity of GDGTs and their derivatives (De Jonge et al., 2013; Liu et al., 2012). IsoGDGTs with one or two hydroxyl moieties were tentatively identified as OH-GDGT-0, -1, -2 (Liu et al., 2012). OH-GDGTs could originate from both Thaumarchaeota and Euryarchaeota, as demonstrated by the occurrence of OH-GDGTs in the cell membranes of Thaumarchaeota Group I.1a and a strain of thermophilic methanogens (Elling et al., 2014). However, most of these studies have focused on marine settings, OH-GDGTs in lacustrine environments are scarcely explored (Huguet et al., 2013; Kaiser et al., 2016), the relationship between iso- and OH-GDGTs in lacustrine environments is less constrained. In order to better understand the sources and paleoclimatic implications of iso- and OH-GDGTs in lacustrine environments, we investigated the distributions of iso- and OH-GDGTs in settling particulates, surface sediments from different water depths, and the catchment soils of an alpine freshwater lake in Southwest China (Lake Lugu).

Results

The concentration of OH-GDGTs from the soils collected within the catchment area of Lake Lugu is below the detect limitation, however, the isoGDGTs of soils collected within the catchment area are heterogeneous. The average sediment fluxes are 0.35 ± 0.29, 0.45 ± 0.35, 0.41 ± 0.26 and 0.59 ± 0.44 g $m^{-2}\cdot day^{-1}$, for the trap at 10 m, 15 m, 25 m and 35 m, respectively. The bottom sediment trap deployed at 35 m exhibits the highest total mass fluxes, while the top sediment trap deployed at 10 m displays the lowest total mass fluxes. The relative abundance of isoGDGTs in settling material shows distinct patterns of individual isoGDGTs, i.e., isoGDGTs in sediment traps deployed at 10 m and 15 m water depth is dominated by GDGT-0 and followed by crenarchaeol, in contrast to the sediment traps deployed at 25 m and 35 m water depth that dominated by crenarchaeol and followed by GDGT-0.

The distribution pattern of OH-GDGTs is similar in sediment trap material from four different water depths, the OH-GDGT composition is dominated by OH-GDGT-0, which accounts for 38–55% of the total OH-GDGTs, and followed by OH-GDGT-2 and OH-GDGT-1. The strong linear correlation between the fluxes of total isoGDGTs and OH-GDGTs (r^2 = 0.99), has been found in sediment trap material, indicating a similar biological source for isoGDGTs and OH-GDGTs in the water column. Also, the fluxes of GDGT-0 and crenarchaeol are highly correlated with the fluxes of OH-GDGT-1 (r^2 = 0.99; r^2 = 0.99), OH-GDGT-2 (r^2 = 0.99; r^2 = 0.99), and OH-GDGT-3 (r^2 = 0.99; r^2 = 0.99), respectively. The principal component analysis (PCA) based on the distribution pattern of isoGDGT in surface sediments from different water depths indicates that isoGDGTs in the shallow sediments (water depth < 20 m) is dominated by GDGT-0, which constitutes 29–98% of the total isoGDGTs, and then followed by crenarchaeol, while the percentage of crenarchaeol in deep sediments (water depth > 20 m) is higher than GDGT-0.

Conclusions

Both the iso- and OH-GDGT fluxes increase with the water depth, and the higher abundance of iso- and OH-GDGTs observed at deeper water depth may be due to in situ production in the deeper water column. Significant linear correlation between the fluxes of total isoGDGTs and OH-GDGTs in sediment trap material indicates a similar biological source for isoGDGTs and OH-GDGTs in the water column, mostly likely Thaumarchaeota Group I.1a. The high iso- and OH-GDGTs fluxes in Lake Lugu correspond to high wind speed and dissolved oxygen of water column, indicating that the seasonal changes of the water column and temperature-related thermocline can strongly determine the behaviour of producing organisms of iso- and OH-GDGTs in this lake. Further, based on the correlation of the fractional abundance of OH-GDGTs from sediment trap at 10 m water depth and lake water temperature, we have developed a regression model with lower prediction errors that will be a promising way to reconstruct the lake water temperature.

References

De Jonge, C., Hopmans, E.C., Stadnitskaia, A., Rijpstra, W.I.C., Hofland, R., Tegelaar, E. and Damsté, J.S.S. (2013) Identification of novel penta-and hexamethylated branched glycerol dialkyl glycerol tetraethers in peat using HPLC–MS^2, GC–MS and GC–SMB-MS. Organic Geochemistry 54, 78-82.

De La Torre, J.R., Walker, C.B., Ingalls, A.E., Könneke, M. and Stahl, D.A. (2008) Cultivation of a thermophilic ammonia oxidizing archaeon synthesizing crenarchaeol. Environmental Microbiology 10, 810-818.

Elling, F.J., Könneke, M., Lipp, J.S., Becker, K.W., Gagen, E.J. and Hinrichs, K.-U. (2014) Effects of growth phase on the membrane lipid composition of the thaumarchaeon *Nitrosopumilus maritimus* and their implications for archaeal lipid distributions in the marine environment. Geochimica et Cosmochimica Acta 141, 579-597.

Huguet, C., Fietz, S. and Rosell-Mele, A. (2013) Global distribution patterns of hydroxy glycerol dialkyl glycerol tetraethers. Organic Geochemistry 57, 107-118.

Kaiser, J., Ön, B., Arz, H.W. and Akçer-Ön, S. (2016) Sedimentary lipid biomarkers in the magnesium rich and highly alkaline Lake Salda (south-western Anatolia). Journal of Limnology 75, 581-596.

Pancost, R.D., Hopmans, E.C. and Sinninghe Damsté, J.S. (2001) Archaeal lipids in Mediterranean cold seeps: molecular proxies for anaerobic methane oxidation. Geochimica et Cosmochimica Acta 65, 1611-1627.

Schouten, S., Hopmans, E.C. and Sinninghe Damsté, J.S. (2013) The organic geochemistry of glycerol dialkyl glycerol tetraether lipids: A review. Organic Geochemistry 54, 19-61.

Sinninghe Damsté, J.S., Schouten, S., Hopmans, E.C., van Duin, A.C. and Geenevasen, J.A. (2002) Crenarchaeol: the characteristic core glycerol dibiphytanyl glycerol tetraether membrane lipid of cosmopolitan pelagic crenarchaeota. Journal of Lipid Research 43, 1641-1651.