Compound-specific carbon isotope compositions of individual long-chain n-alkanes in severe Asian dust episodes in the North China coast in 2002

GUO Zhigang1, LI Juyuan2, FENG Jialiang3, FANG Ming2 & YANG Zuosheng1

1. College of Marine Geosciences, Ocean University of China, Qingdao 266003, China; 2. Institute of Geology, Shengli Oil-field Company, Petrochemical Corporation of China, Dongying 257015, China; 3. Institute for Environment and Sustainable Development, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China

Correspondence should be addressed to Guo Zhigang (email: guozgg@ouc.edu.cn)

Received August 17, 2005; accepted September 27, 2005

Abstract  The molecular compositions and compound-specific carbon isotope compositions of individual long-chain n-alkanes of atmospheric aerosols collected during two severe Asian dust episodes in Qingdao in spring of 2002 were analyzed using gas chromatography/mass spectrometry (GC/MS) and gas chromatography/isotope ratio mass spectrometry (GC/IRMS). Typical plant wax n-alkanes (C29 and C31) had lower δ13C values than those from anthropogenic (engine exhaust) sources (C21—C23). The average δ13C value of plant wax n-alkane C29 in non-dust episode periods was −30.5‰ (−30.3‰−−31.9‰), while −31.3‰ (−31.1‰−−31.5‰) in dust episode periods; for C31, it was −31.4‰ (−31.1‰−−33.0‰) in non-dust episode periods, and −31.7‰ (−31.3‰−−32.6‰) in dust episode periods. Plant wax in the dust episode samples was mainly from herbaceous plants via long-range transport, while local plant wax was mainly from deciduous plants and woody plants. In North China coast, 83.3% of the plant wax in the severe dust episode samples was from C3 plants while 80.0% for the non-dust samples, indicating that plant wax transported to the northwestern Pacific Ocean by airborne dust from East Asia was mainly from C3 plants. The results suggest that the molecular and molecular-isotopic compositions of individual long-chain n-alkanes can, as an effective indicator, identify the terrestrial organic components in the dust from East Asia and sediments in the northwest Pacific Ocean.

Keywords: Asian dust storm, plant wax, compound-specific carbon isotope composition of individual n-alkanes, C3 plants, North China coast.

Asian dust storms originating from the arid regions of central and eastern Asia and from the Loess Plateau in China frequently occur in spring1,2. Driven by the East Asian monsoon, Asian dust can be transported to northern Pacific Ocean2–8. Asian dust is detected in March to May nearly every year at the West Coast of the US9. It has been indicated that Asian dust has great impact on the formation of the Arctic haze band10. Asian dust has a significant effect on global climate, air quality, and biogeochemical processes of nutrients in coastal seas and oceans11–12. Thus, great effort has been made to understand the composition, size distribution, sources, transportation and flux to the ocean of Asian dust in recent years12–17.

There is a layer of wax comprising long carbon-chain organic compounds in higher plant epidermal leaves18,19. This leaf wax can be airborne due to wind-induced mechanical shear and rubbing of the leaves and is a very important component in atmospheric aerosols especially in the dust samples14,20,21. Plant wax is ubiquitous even in aerosols in remote areas and sediments in ocean19,20,22,23. Terrestrial plants use two principal carbon fixation pathways, the C3 and C4 cycles, during photosynthesis. C3 plants prefer more humid conditions while C4 plants prefer hot weather with intensive solar radiation. Thus, the relative abundance of C3 and C4 plants is mainly controlled by the climate22–24. The average C3 plant δ13C is −27‰ (−22‰−−33‰) while it is −13‰ (−9‰−−16‰) for C4 plant δ13C23,24. The molecular-isotopic difference of C3 and C4 plants is pronounced and sensitive to the climate environments22–24. Meanwhile, plant wax is stable in transport, deposition and burial processes, therefore, the variation in δ13C value of plant wax in sediments can quantitatively reveal the distribution of C3 and C4 plants in historical period and reconstruct the regional paleoclimate and paleoenvironment at the molecular-isotope level22–24. Thus, the study of the composition of plant wax in aerosols is significant not only to the global carbon cycling, but also to the past...
global change. In recent years, the compound-specific carbon isotope compositions of leaf wax in aerosols and dust over Africa and Atlantic Ocean have been reported. The compounds studied are mainly long-chain \( n \)-alkanes\[^{25,26} \], alkanoic acids\[^{19,25} \] and alkanols\[^{25} \]. Stable carbon isotopic data of individual \( n \)-alkanes of aerosols in China are scarce\[^{27} \]. To our best knowledge, no data on compound-specific carbon isotope composition of plant wax in Asian dust episodes have been reported.

Qingdao is a coastal city situated in the southern tip of the Shandong Peninsula in northern China (35°35'N and 119°30'E) and is located at the down wind of the origin of the Asian dust storms in spring when northwesterly winds prevail. Qingdao is therefore in the transport path of the storms to the Pacific. According to meteorological and Air Pollution Index (API) reported for Qingdao (www.qingdao.org.cn), two dust episodes associated with high north and northwesterly winds were observed on 20 March (API = 398), and 7–8 April of 2002 (API = 500). The usual API for spring is 40–100 and seldom exceeds 120. The episode on March 20–22 was reported to be the strongest ever recorded in Beijing, with a loading of total suspended particles (TSP) as high as 10.09 mg m\(^{-3} \). It was 54 times higher than that of the national air quality standard\[^{28} \]. The corresponding TSP loading at 0.731 mg m\(^{-3} \) in Qingdao was also the strongest in the last 10 years\[^{29} \]. In this study, the compound-specific carbon isotope compositions of individual long-chain \( n \)-alkanes in the two dust episodes were analyzed and studied, and compared to those of non-dust episode samples collected from November 2001 to March 2002 in Qingdao in order to understand the compositional characteristics and source of long-chain \( n \)-alkanes in severe Asian dust episodes in the North China coast.

1 Experimental

1.1 Sampling

The sampling site is on the rooftop of a three-storeyed meteorological station on top of Baguan Hill in the campus of the Ocean University of China (Fig. 1). The elevation of Baguan Hill is 70 m and is about 500 m from the Yellow Sea. TSP samples were collected on quartz fiber filters (Whatman, QM-A 20.3 cm ×