

Sources and distribution of polycyclic aromatic hydrocarbons of different glaciers over the Tibetan Plateau

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Twenty snow samples were collected from the Qiyi glacier in Qilian Mountains, the Yuzhufeng glacier in eastern Kunlun Mountains, the Xiaodongkemadi glacier in Tanggula Mountains, and the Gurenhekou glacier in Nyainqêntanglha Range over the Tibetan Plateau. The concentration and distribution features of sixteen priority Polycyclic Aromatic Hydrocarbons (PAHs) were determined by gas chromatography equipped with a mass spectrometry detector (GC-MS). The sources of these PAHs were explored as well. Our results indicated that the average concentrations of PAHs in snow were in the range of 20.45–60.57 ng/L. Maximum PAHs levels were found in the YZF glacier and minimum in the XDKMD glacier. However, no apparent regional distribution pattern of PAHs was found in the glaciers over the Tibetan Plateau. Moreover, the 2–4 ring low molecular weight PAHs predominated in snow samples and the concentrations of phenanthrene was the highest. Integrated factor analysis and isomer pair ratios suggested that PAHs of glaciers over the Tibetan Plateau were derived from low temperature combustion of coal and biomass, and partially from the exhaust gas of locomotives. Air mass back trajectory indicated that organic compounds detected in snowpit of these four glaciers, in the period of time they represented, mainly came from Central Asia and the arid area of Northwest China by westerly wind circulation.

Tibetan Plateau, snow, polycyclic aromatic hydrocarbon, substance origin

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Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that consist of two or more fused benzene rings. They are ubiquitous in the environment as persistent organic pollutants (POPs) with strong carcinogenic, teratogenic, and mutagenic effects [1]. The U.S. Environmental Protection Agency has listed 16 PAHs as prior pollutants in toxic organic pollutants [2, 3]. There are two main sources of PAHs [4, 5]: natural and anthropogenic sources. PAHs in natural sources include natural fires of forest, vegetation and bush, volcanic eruptions, syntheses by higher plants and microor-

ganisms, as well as the diagenesis of organic matters. PAHs in anthropogenic sources include incomplete combustion of fossil fuels (coal and petroleum) and bio-fuels, vehicle exhaust emissions, and leakages and emissions through petroleum exploration, transportation, and petrochemical processes. Compared with the natural sources, the anthropogenic sources are the major sources of PAHs [6]. Given their poly-benzene conjugation system, PAHs are highly stable and difficult to degrade. Therefore, PAHs are considered good indicators of human activity [7]. The levels of PAHs are well correlated to regional energy consumption and the level of industrialization and urbanization [8]. Due to the strong stability and mobility, such pollutants can be

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transferred between different media in various modes, and migrate within regions or even worldwide by atmospheric transportation [9].

Many studies have been done on the composition, distribution, sources, and deposition mechanisms of PAHs in aerosols [10], sediments of rivers and lakes [11, 12], vegetation [13], soil [14] and other media, which all could reflect the concentration changes of PAHs in atmosphere. Studies have shown that snow can effectively remove gaseous and particulate PAHs from atmosphere [15]. Therefore, glacier is important matrix to record PAHs in atmosphere. The glacier melt water with organic pollutants runs directly into rivers, lakes and other surface water bodies, and has potential influences on human drinking water sources and farm water supplies. Therefore, the study on organic pollutants in glaciers is of great significance to evaluate the effects of such pollutants on human and animal health as well as other ecosystem damages [16]. At present, the studies on PAHs in glaciers have been done mainly in the Alps [17] and the polar regions [18, 19], little research has been done on the glaciers over the Tibetan Plateau. Furthermore, the studies of PAHs in snow mainly focused on seasonal changes instead of regional comparisons. In order to fully understand the concentration of organic pollutants and their distribution characteristics in glacier over the Tibetan Plateau, we collected snow samples from the Qiyi glacier (QY) in Qilian Mts., the Yuzhufeng glacier (YZF) in east Kunlun Mts., the Xiaodongkemadi glacier (XDKMD) in Tanggula Mts, and the Gurenhekou glacier (GRHK) in Nyainqêntanglha Range at Yangbajing area. Quantitative analysis of PAHs was performed on these samples to study their composition and spatial distribution within these glaciers. Based on the composition and characteristic parameters of these PAHs over the Tibetan Plateau glaciers, their sources are discussed here.

1 Experiments

1.1 Sampling sites

PAHs in snow samples of the GRHK glacier, the XDKMD glacier, the YZF glacier and the QY glacier from the south to north over the Tibetan Plateau were studied. These four glaciers covered different climate and vegetation areas and the climate changed gradually from a warm and moist one in its southeast region to a cold and dry one in its northwest region, and correspondingly, the vegetation coverage decreased gradually from the southeast to the northwest over the Tibetan Plateau. For instance, the QY glacier (39°14'19"N, 097°45'43"E) is located at the central Qilian Mountains in the northeast margin of the Tibetan Plateau. Because there are forests, bushes, meadows and steppes in the middle and east section of Qilian Mountains, the QY glacier shows typical characteristics of "wet island" in arid and desert regions. The YZF glacier (35°39'37"N,

094°14'28"E) is located in the eastern Kunlun Mountains at the northern margin of the plateau, where the forest coverage is low due to the high altitude and the cold and arid climate. Especially, the high mountains in the eastern section of Kunlun Mountains are surrounded by a small quantity of ferns, forests and some bushes. The ferns found in these areas are all terrestrial plants, and no epiphyte and aquatic plants have ever been found there, while the XDKMD glacier (33°4'18"N, 94°14'01.2"E) on the northern slope of the Tanggula Pass in the central region of the Tibetan Plateau has a cold steppe landscape. In addition, the GRHK glacier (30°03'54"N, 090°29'34"E) in the Yangbajing region at the foot of Nyainqêntanglha Range receives much more precipitation.

1.2 Sample collection

The snow samples were collected from 40-cm-deep snowpit in the YZF glacier of eastern Kunlun Mountains (5610 m a.s.l.), the XDKMD glacier of Tanggula Mountains (5670 m a.s.l.), and the GRHK glacier in Nyainqêntanglha Range (4520 m a.s.l.) on May 18 and 26, and June 1, 2008, respectively. The organic analysis has been conducted on five snow samples at each sampling site taken at a depth interval of 8 cm. Particularly, these four snow samples of the QY glacier were collected from a 17.5 cm-deep snowpit at 4800 m a.s.l. based on the stratigraphy, while the fifth sample was taken on the surface at 4473 m a.s.l. on June 21, 2008. All snow samples at each site were collected only once. The sample melt water volume ranged from 7.6 to 17.9 L. The locations of sampling sites are shown in Figure 1.

1.3 Reagents and materials

The snow samples were collected using a clean stainless steel shovel. Each samples were divided into four equal parts and stored in pre-cleaned 12 L stainless steel reservoirs or pre-cleaned enamelware. All utensils had been thoroughly cleaned before use by repeatedly washing with chromic acid lotion and Milli-Q water in the laboratory. The mixture of G.D.X-102 and G.D.X-105 chemical reagents were extracted by methanol and dichloromethane for 96 h, respectively, and preserved in methanol before use. The filter paper and absorbent cotton were cleaned with methanol and dichloromethane for 48 h using a soxhlet apparatus, respectively, then dried in vacuum, finally, stored in a clear glass bottle. The silica gel and alumina were activated at 180°C and 250°C for 5 h, respectively, and cooled in desiccators. To dry the extracted materials, Na₂SO₄ was activated at 450°C for 24 h. All solvents (*n*-hexane, dichloromethane and methanol) were all pesticide grade purchased from Merck (GFR), Germany. Sixteen U.S. priority polycyclic aromatic hydrocarbons contained naphthalene (Nap), dihydroacenaphthylene (Any), acenaphthene (Ane), fluorine (Fle), phenanthrene (Phe), anthracene (Ant), fluoranthene

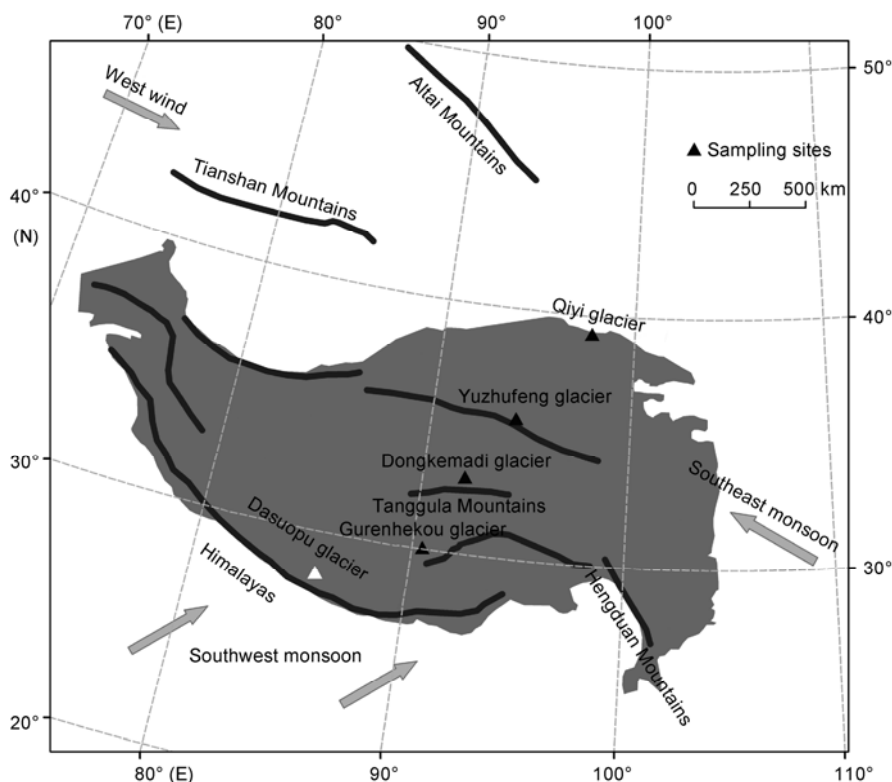


Figure 1 Location of the sampling sites.

(Fla), pyrene (Pyr), benzo[a]anthracene (BaA), chrysene (Chry), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), dibenzo[a,h]anthracene (DaA), indeno[1,2,3-cd]pyrene (INP) and benzo [ghi] perylene (BghiP), were used as standard reagents purchased from Supelco Company (USA).

1.4 Sample pretreatment process

All snow and ice samples naturally melted during a period about 1–2 days in pre-cleaned enamelware or stainless steel reservoir. Concentrated HCl was added to adjust the pH value of the samples to 2. The trace organic compounds in the melt water were then enriched *in situ* using a pre-purified mixture of GDX-102 and GDX-105 resin. Specifically, the mixture of methanol and resins was first transferred into layer columns. The columns were then washed several times using dichloromethane, methanol, and ultrapure water. The packed resin height was about 8–9 cm, and both ends of the columns were sealed by absorbent cotton. After the organic compound enriching, the whole columns were sealed, wrapped in the aluminum foil, and frozen before the transport. Finally, the columns were stored at the low temperature before analysis.

The organic compounds absorbed in the resin was slowly extracted by 30 mL CH_2Cl_2 three times in an ultra-clean laboratory, then the organic extract was dried by the mixture of anhydrous Na_2SO_4 and separated using silica gel and

alumina layer column chromatography. The PAHs were eluted with 30 mL mixture of n-hexane and dichloromethane, and evaporated in dryness under a stream of N_2 , then reconstituted with 2 mL CH_2Cl_2 . To determine whether there was contamination during the sample collection, transportation and storage processes, Milli-Q water was carried to field as blanks at each sampling site and underwent the same processes as the snow samples. The chromatogram analysis of the field blanks detected no contamination. Field blank test to check contamination throughout the procedures showed that there were mainly phthalic acid esters. However, their amounts are so low that their presence does not affect the analytical results.

1.5 Instrument analytical condition

GC-MS analysis was conducted in the Institute of Tibetan Plateau Research, Chinese Academy of Sciences. The PAHs in all samples were analyzed using a gas chromatograph (GC) equipped with autosampler and combined with an ion-trap mass spectrometer (MS) (Finnigan Trace GC/PolarisQ). The separation and quantification were achieved on a DB-5 column (30 m×0.25 mm i.d., 0.25 μm film thickness). The column temperature program was set as follows: the initial temperature (50°C) was held for 2 min, after which the temperature was raised to 180°C at 20°C/min, then further raised to 250°C at 4°C/min, the final temperature was raised to 310°C at 10°C/min and held 5

min. The MS was operated in a selected ion monitoring (SIM) scan mode with 70eV electron impact (EI) source. Sixteen U.S. priority polycyclic aromatic hydrocarbons were adopted as the calibration standards in this study.

2 Results and discussion

2.1 Content and distribution characteristics of PAHs in snow and ice from different glaciers

Figure 2 shows the average concentration of sixteen priority PAHs in snow collected in the QY glacier, the YZF glacier, the XDKMD glacier, and the GRHK glacier. The highest concentration of these PAHs was 60.57 ng/L found in the YZF glacier, the second highest concentration was 31.19 ng/L in the QY glacier, the third was 24.59 ng/L in the GRHK glacier and the lowest was 20.45 ng/L in the XDKMD glacier. Previous research showed that the total concentration of 3–7 ring PAHs within the snow from European high mountain areas was about 5.6–81 ng/L [17], which was comparable to what we obtained from these four glaciers, but higher than the trace amount of PAHs (10 ng/L) found in the east Antarctic ice sheet [18]. This contrast may be explained by the distance discrepancy between the polar regions and the high mountains areas to the sources of PAHs [20]. The total concentrations of PAHs (dihydroacene-naphthylene, anthracene, phenanthrene, fluoranthene and pyrene) in the ice core of the Dasuopu glacier over the Tibetan Plateau was 8.9–97 ng/L and 26 ng/L in average [21], while the corresponding value for the East Rongbuk glacier ice core was lower than 100 ng/L [22]. Since these two glaciers are in the southern highlands of the Tibetan Plateau, PAHs may come from India according to air mass back trajectory, which reflects variable global emissions of PAHs and the modes of their usage in different regions. The overall concentration of PAHs found in glaciers over the Tibetan Plateau was below those of the soil (168–595 ng/g), Rouzi (*Thylacospermum rupifragum* Schrenk) (12.8–92.5 ng/g), and Jidou (*Oxytropis glacialis* Benth. ex Bge) (49.4–14.6 ng/g) of the Mount Everest by several orders of magnitude [23], due to the facile adsorption of the PAHs by the lipids

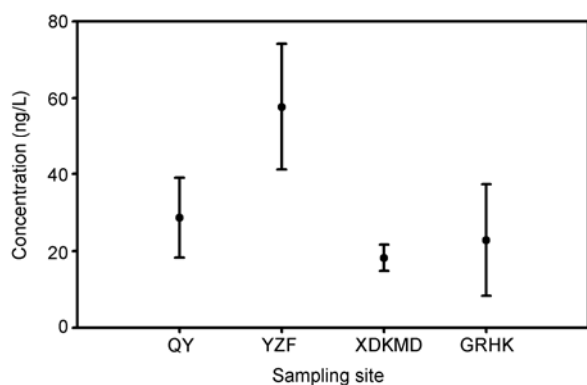


Figure 2 Concentration of PAHs at different sampling sites.

of vegetation and organic matters in the soil.

There was no dibenzoanthracene detected from these four glaciers (Figure 3). Although the compositions of PAHs in glaciers were different, phenanthrene was the most abundant component in all of them. Dihydroacene-naphthylene was the second most abundant component in the samples from the GRHK glacier and the XDKMD glacier, whereas fluoranthene was the second abundant component in snow samples of the YZF glacier and the QY glacier. The concentration of fluoranthene within the samples from the YZF glacier was higher than that of the other three glaciers. As shown in Figure 4, the ratio of the average concentration of 2–3 ring PAHs to the average concentration of total PAHs in snow collected from the QY glacier, the YZF glacier, the XDKMD glacier, and the GRHK glacier was 88%, 98.75%, 94.34% and 95.95%, respectively. Compared to the dominant 2–3 ring PAHs found on the East Rongbuk glacier and Dasuopu glacier, this result indicated that the PAHs detected from snow and ice over the Tibetan Plateau glacier were mainly low molecular weight compounds. This distribution characteristic was similar to the brown snow of the Canadian Arctic [24] and the Greenland ice sheet [25, 26]. However, in aerosols [27] and sediments [28], fluoranthene and pyrene-based high molecular weight compounds ac-

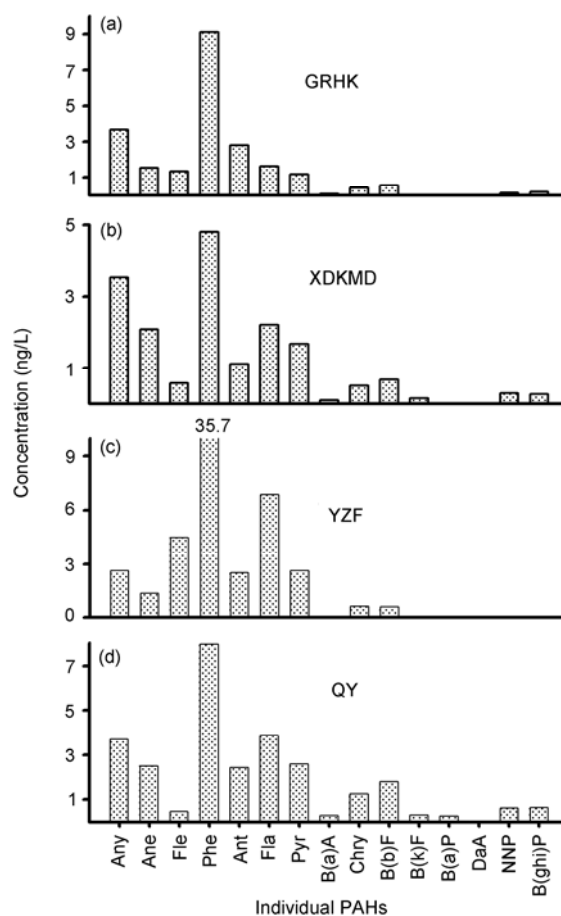


Figure 3 Average concentration of individual PAHs in different glaciers.

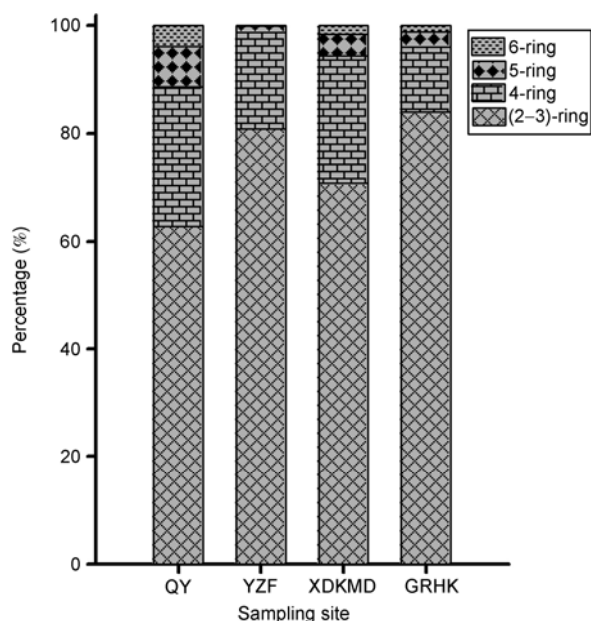


Figure 4 Percentage of different ring PAHs in glacier over the Tibetan Plateau. The 3-ring PAHs include Any, Ane, Fle, Phe, and Ant. The 4-ring PAHs include Fla, Pyr, B[a]A and Chry. The 5-ring PAHs include B[b]F, B[k]F, B[a]P, and DB[a,h]A. The 6-ring PAHs include INP and B[g,h,i]P.

counted for a large proportion of PAHs.

Long-range atmospheric transportation and dry-wet deposition have been as the main modes for POPs to enter the high-altitude areas [29]. PAHs are semi-volatile organic pollutants and exist in gaseous and particulate forms in atmosphere. The low molecular weight PAHs (<202) exist mainly in gaseous form, while the high molecular weight PAHs (>202) tend to form particulates [30]. Daly and Wania [31] have shown that the distribution characteristics of semi-volatile organic compounds depend on their physical and chemical properties, as well as local environmental and climatic conditions. Similar to those in remote areas, PAHs found in glacier over the Tibetan Plateau were dominantly low molecular weight compounds due to the long distance of the glaciers from the PAHs source regions. However, the discrepancy among the PAHs found in glaciers, aerosols, and sediments was mainly caused by the fractionation of light and heavy components in the transmission process, because different molecular weight PAHs have the greater differences in physical and chemical properties as well as transport mechanisms (i.e., atmospheric vapor pressure).

As PAHs spread in atmosphere, the differentiation of their composition occurs. The more volatile low molecular weight PAHs move farther and are more likely to enter and accumulate in the high latitude regions. When temperature drop, they condense quickly or are absorbed by small dust. Then, they are trapped into the glacier. High molecular weight PAHs, such as 5–6 ring benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[a,h] anthr-

acene, benzo[g,h,i]perylene, and indeno[1,2,3-c,d]-pyrene, tend to be adsorbed on atmospheric particles during their migration. Before reaching the high altitude regions, they deposit preferentially [32, 33]. Once deposited from the atmosphere, they are often stored in the soil-water-plant systems [34], rather than transplanted to higher altitude. In addition, the relative percentage of light and heavy components may also vary according to the climate, circulation features, altitude, dust content and their source, and many other factors of the sampling sites.

2.2 Source identification of polycyclic aromatic hydrocarbons

2.2.1 The use of PAHs ratios to infer source

The anthropogenic PAHs and their derivatives are mainly from fossil fuels (coal and petroleum), motor vehicle exhaust emissions, as well as incomplete combustion or thermal decomposition of wood and plastic in reducing atmosphere. Many researchers employed the ratio of PAHs with the same molecular weight and similar structure as indicators to identify the pollution sources. Phenanthrene/anthracene (Ph/An) and Fluoranthene/pyrene (Fl/Py) were commonly used to distinguish between combustion and petroleum source. Guinan et al. [35] reported that the ratios of Ph/An<10 and Fl/Py>1 indicated that PAHs originated from pyrogenic sources, while Ph/An>10 and Fl/Py<1 indicated that PAHs originated from petroleum sources. Accordingly, an Fl/Py ratio of over 1.4 and approximately 1 indicated that the PAH originated from the combustion of coal and wood, respectively [36]. Similarly, Yunker et al. [37] also reported that the Fl/(Py+Fl) ratio was below 0.4 for most crude petroleum pollution and above 0.5 for the combustion of wood and coal, and the ratio was between 0.4 and 0.5 for the combustion of petroleum and its refining products. The An/(Ph+An) ratio was below 0.1 usually was taken as an indication of petroleum, while the ratio over 0.1 indicated a dominance of combustion. In most of the snow samples from the YZF glacier, as well as several snow samples from the XDKMD glacier, the Ph/An ratio was found greater than 10, the An/(Ph+An) ratio was less than 0.1 (Figure 5). These results indicated the YZF glacier could have been polluted by petroleum, the CPI value (approximated to 1) of *n*-alkane in snow samples from the YZF glacier also confirmed this result [38]. In other snow samples, the Ph/An ratio ranged from 0.73 to 12.87, and the average ratio was less than 10, the Fl/Py ratio ranged from 0.87 to 1.75, and the average ratio was greater than 1. An/(Ph+An) was in the range of 0.07–0.58, and the average ratio was greater than 0.1. Fl/(Py+Fl) was in the range of 0.47–0.64, and the average ratio was greater than 0.4. From these ratios, we can preliminarily determine that except YZF glacier polluted by petroleum, the PAHs found on the other three glaciers were mainly from incomplete combustion of fossil fuels.

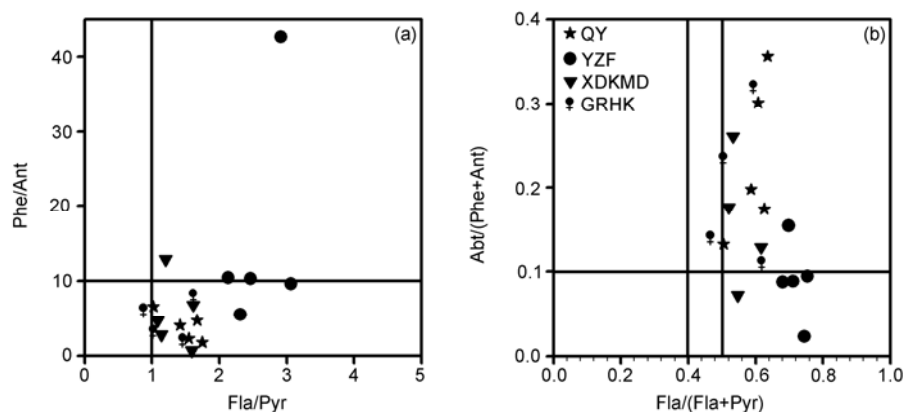


Figure 5 Cross-plots of the values of Phe/Ant against the values of the Fla/Pyr and the values of Ant/(Ant+Phe) against the values of the Fla/(Fla+Pyr).

2.2.2 Factor analysis

Because the concentration of dibenzo[a]anthracene was below the detection limit of our instruments, we performed factor analysis on the other 15 sorts of PAHs from the other three glaciers. According to the rule of eigenvalue greater than 1, two main factors were extracted to account for 50.82% and 17.25% of whole variance, and orthogonal rotation of factors was performed by varimax criterion (Figure 6). The diagram shows that the 15 variables can be divided into three groups. The lower right corner is a group variables with high load factors on fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene and benzo[g,h,i]perylene, etc., which are all PAHs of high molecular weight. Among them, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene and benzo[g,h,i]perylene, etc. have been confirmed by many researches as the characteristic markers of motor vehicle exhaust emissions [39]. Fluoranthene and pyrene are mainly from the combustion of coal and petroleum [40]. Therefore, we believe that factor 1 represents the mix sources of combustion of coal and petroleum as well as motor vehicle exhaust emissions. The top group consists of phenanthrene, fluorene, and anthracene, which are all 3 ring PAHs. Among them, the load factor of phenanthrene is the highest, followed by fluorene and anthracene. Phenanthrene and fluorene are considered mainly from the low temperature combustion of biomass and coal [41]. Mastoral [42] has shown that fluorene has the highest concentration among the PAHs emission under different combustion conditions of coal. Khalili et al. [43] also experimentally confirmed that fluorene and other light components are dominant PAHs within the Chicago coke-oven emissions. Simcik [44] also considered fluorene and anthracene, etc. as characteristic indicators of coke combustion. Thus, factor 2 essentially represents the emission characteristics of PAHs from low temperature combustion of biomass and coal. The bottom left group exhibits high load factors on dihydroacenaphthylene, naphthalene, and acenaphthene with high vapor pressure. They exist as va-

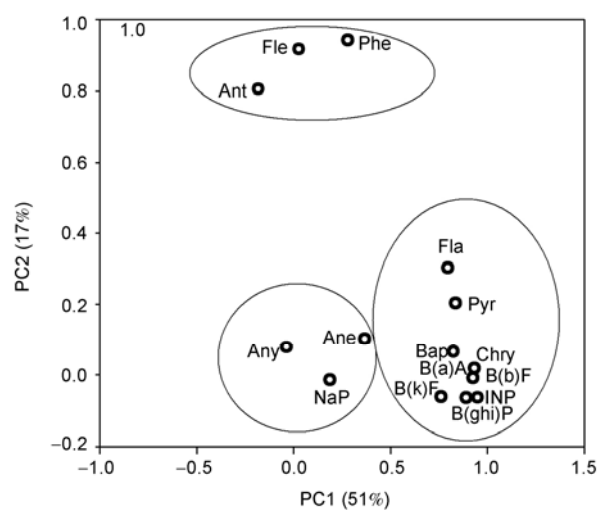
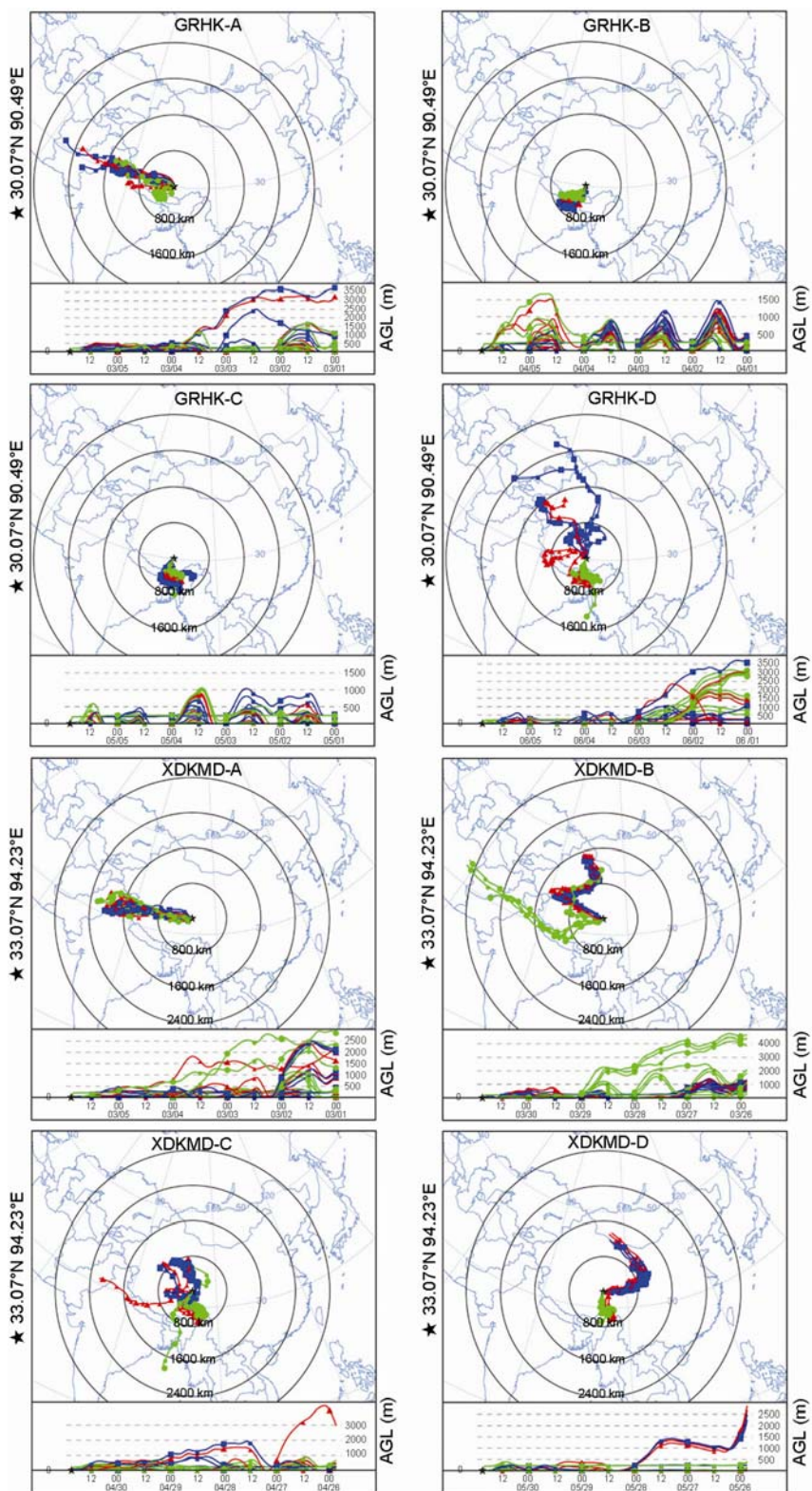


Figure 6 Principal component analysis for all PAHs in glacier over the Tibetan Plateau.

pors in atmosphere, and are transported to glaciers in dissolved phase mainly via the exchange at air-snow interface. Therefore, exchange at air-snow interface may largely contribute to dihydroacenaphthylene, naphthalene, and acenaphthene pollution on glaciers. Dihydroacenaphthylene and acenaphthene are also considered characteristic compounds from motor vehicle emissions directly.

Integrated isomer pair ratios and factor analysis have proven that PAHs pollutions in glaciers over the Tibetan Plateau were mainly from low-temperature combustion of coal and fossil fuels. As the world's highest and largest plateau in low latitude, the Tibetan Plateau with an average altitude over 4000 m suffers the impact of the monsoon and long-distance transportation of air masses from Mediterranean, the Indian Ocean, and the Bengal Bay industrial zone besides China. China relies heavily on coal as the main energy resource particularly in Northern China, coal is the major source of PAHs pollutions in atmosphere. In addition, the dramatic growth of the population and motor vehicles



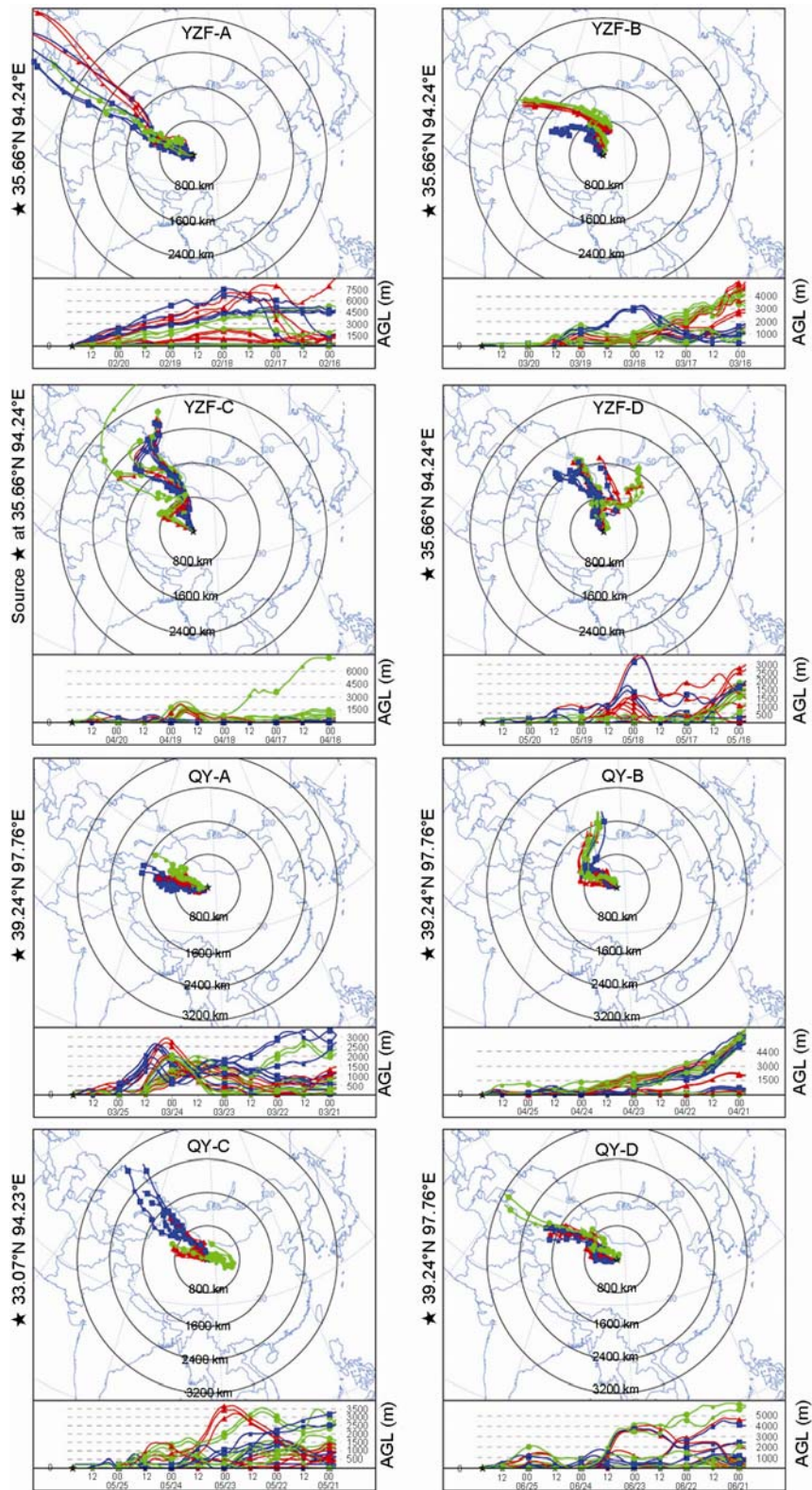


Figure 7 Diagram of back trajectory. GRHK (A–D) were 1–5 March 2008, 1–5 April 2008, 1–5 May 2008, 1–5 June 2008, respectively. XDKMD (A–D) were 1–5 March 2008, 26–30 March 2008, 26–30 April 2008, 26–30 May 2008, respectively. YZF (A–D) were 16–20 February 2008, 16–20 March 2008, 16–20 April 2008, 16–20 May 2008, respectively. QY (A–D) were 21–25 March 2008, 21–25 April 2008, 21–25 May 2008, 21–25 June 2008, respectively.

will also lead to the increase of PAHs, which are emitted into the air and transported along with the monsoon to arrive at the Tibetan Plateau.

3 Backward air trajectories

In order to assess the origin of air masses arriving at the sampling sites, backward air trajectories for the period of time of these four glaciers snowpits represented were calculated using the HYSPLIT4 back trajectory model provided by the U.S. NOAA and the FNL meteorological database (<http://www.arl.noaa.gov/ready/open/hysplit4.html>). Figure 7 sequentially show air mass back trajectory of the GRHK glacier, the XDKMD glacier, the YZF glacier, and the QY glacier from the first to fourth lines. The GRHK glacier was impacted by dusts carried primarily by the westerly circulation from Central Asia and the arid area of Northwest China in June and March, while in April and May, it is mainly impacted by atmospheric pollutants carried by the South Asian monsoon circulation from the Indian subcontinent. Tian et al. [45] have indicated that the different nature of the air masses at the north and south sides of the Tanggula Mts. causes different sources of water vapor. The water vapor of the north side of Tanggula Mts. is derived mainly from the continent, whereas the water vapor of south side is from the ocean. Since the GRHK glacier is located in the mid-south of the Tibetan Plateau, and its snow samples were collected in June of 2008, we can infer that the pollutants detected were from Central Asia and the arid area of Northwest China. XDKMD (A–D) (Figure 7) shows that the XDKMD glacier was impacted by the water vapor not only from the inland area but also by a small number of maritime air masses carried by the southwest monsoon. Therefore, in the periods of time that the snowpit samples represented, the pollutants detected in snow from the XDKMD glacier were from Central Asia and the arid area of Northwest China. The YZF glacier and the QY glacier are located in the Northeast Tibetan Plateau. Due to the high altitude and the low ambient temperature of the YZF glacier in winter and spring, the pollutants tend not to spread but accumulate *in situ*. The water vapor sources in the QY glacier are mainly from Northwestern China, probably including the evaporation in the nearby inland or rapid evaporation from relatively warm water-body on the path of dry westerly airflow, and only a very small amount carried by the monsoon. As shown by YZF (A–D) and QY (A–D) (Figure 7), in the periods of time that the snowpits represented, the pollutants in the YZF glacier and the QY glacier were also from Central Asia and the arid area of Northwestern China. In short, although the XDKMD glacier and the GRHK glacier are impacted by the maritime water vapor sources, they are similar to the YZF glacier and the QY glacier. The organic pollutants in snow collected from these four glaciers in the periods of time that the snowpits represented are mainly from

Central Asia and the arid region of Northwestern China by westerly wind circulation.

4 Conclusions

Sixteen U.S. EPA priority controlled PAHs in typical glaciers over the Tibetan Plateau were analyzed in this study. The result indicated that the average concentration of PAHs was found to be maximum in the YZF glacier and minimum in the XDKMD glacier. The 2–4 ring low molecular weight PAHs predominated in snow samples and the concentrations of phenanthrene was the highest. Finally, Factor analysis and isomer pair ratios suggested that PAHs of glaciers over the Tibetan Plateau were derived from low temperature combustion of coal and biomass, and partially from the exhaust gas of locomotives. Air mass back trajectory indicated that organic compounds detected in snowpits of these four glaciers, in the period of time they represented, mainly came from Central Asia and the arid area of Northwest China by westerly wind circulation. Contents of PAHs in different glaciers over the Tibetan Plateau indicated that we must make timely, necessary prevention measures to PAHs, which have brought or will bring about environmental pollution. In the meantime, we can also realize the pollution trace in snow caused by human activities so as to explore the relationship among organic pollutants in snow, environmental, ecological, as well as climatic change as well as human activities.

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