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Elemental and isotopic compositions in blank filters collecting atmospheric particulates

Jiyeong Lee[1,2], Jong-Sik Ryu[1,2*], Seok Jeong[1,2], Jeonghoon Kim[1,2], Hyeryeong Jeong[3,4], Kongtae Ra[3,4], Minjune Yang[1,2] and Hye Jung Chang[5*]

Abstract

Background: The atmospheric particulates can be harmful to human health due to toxic substances sorbed onto particulates. Although the atmospheric particulates have been collected using different types of filters, few studies have reported background contents of major and trace element, and isotopic compositions in the blank filters used for collecting the particulates yet. Here, we first report background contents of major and trace elements, and isotopic compositions (Zn and Pb isotopes) in the blank filters. Then, we evaluate the best type of filter for elemental and isotope analyses in the particulates.

Findings: The contents of major elements are the lowest in the PTFE filter and become higher in the order of the Nylon, NC, and GF filters, indicating that either PTFE and/or Nylon filters are the most suitable for major element analysis in the atmospheric particulates. Likewise, the contents of trace elements are the lowest in the PTFE filter and become much higher in the order of the Nylon, NC, and GF filters, indicating that PTFE filter is the most suitable for trace element analysis in the atmospheric particulates. Otherwise, background elemental contents result in overestimating their concentrations in the atmospheric particulates. All $\delta^{66}Zn_{JMC\text{-}Lyon}$ values in two GF filters are within those from samples of the Chinese deserts and of the Chinese Loess Plateau. Likewise, their $^{206}Pb/^{204}Pb$ ratios are similar with those of samples from Xi'an and Beijing, indicating that the GF filter is not suitable for Zn and Pb isotope study in the atmospheric particulates.

Conclusions: This study suggests that the PTFE filter is the most suitable for elemental and isotope study in the atmospheric particulates and that the GF filter cannot be used for source identification in the atmospheric particulates using Zn and Pb isotopes.

Keywords: Atmospheric particulate, Blank filter, Major and trace elements, Zn isotopes, Pb isotopes

Introduction

Particulates in the atmosphere emitted from natural and anthropogenic sources can be harmful to human health, widely ranging from respiratory illnesses (NO_x, SO_2, $PM_{2.5}$, and O_3), to diminished delivery of oxygen to vital organs (CO), and to impaired cognitive and neurological capabilities (trace elements; e.g., Cd, As, and Pb) (WHO 2013; Guarnieri and Balmes 2014; Mason et al. 2014; Karri et al. 2016; Khaniabadi et al. 2017; Huang et al. 2018; Song et al. 2018; Santana et al. 2020). It has been known that any particulates finer than 10 μm, particularly those from finer than 2.5 μm ($PM_{2.5}$), are potentially harmful because they are difficult to expel from lungs, and thus, they can accumulate in alveoli (Pope III et al. 2002; Laden et al. 2005; Downs et al. 2008; IARC 2012; WHO 2013). Especially, trace elements (e.g., Cd,

* Correspondence: jongsikryu@pknu.ac.kr; almacore@kist.re.kr
[1]Division of Earth Environmental System Sciences, Pukyong National University, Busan 48513, South Korea
[5]Advanced Analysis Center, Korea Institute of Science and Technology, Seoul 02792, South Korea
Full list of author information is available at the end of the article

Cr, and Ni) and metalloids (e.g., As and Sb) are often sorbed onto particulates, increasing the toxicity of the particulate (Csavina et al. 2012).

Traditionally, four types of filter material to collect the atmospheric particulate have been used, which are Teflon, quartz/glass fiber, mixed fiber, and membrane filter types, depending on variables such as metal content, artifact formation, and affinity for moisture (US EPA 1999). For example, quartz- and glass-fiber filters have been used for determining mass loading, cellulose filters for gas-absorbing compounds, and PTFE filters for trace elements and isotopes (Chow and Watson 2012; Ali 2016). Then, the filters are treated using various extraction methods in order to determine the contents of inorganic constituents and therefore to assess pollution status and metal impact on the environment. However, if the content of particulate is low and therefore contents of heavy metals are low, the contribution of heavy metals in the blank filter to those sorbed onto the particulates would be critical because background contents of trace elements result in overestimating their concentrations in the particulates. In spite of the importance of background elemental contents in the blank filter, there are only a few studies reporting them (Yang et al. 2002; Karthikeyan et al. 2006; Ali 2016). For example, Zn content in Zefluor^{TM} filter is 261 mg/cm^2 (Karthikeyan et al. 2006) and Cr content in quartz filter is 2538 mg/cm^2 (Karthikeyan et al. 2006).

Furthermore, although elemental concentrations in the atmospheric particulates have been mainly used, variations in their isotope ratios are more powerful to determine the origin of atmospheric contaminants and to understand the transport pathways because stable isotopic compositions in the particulate generally reflect those in the sources. Recently, Zn and Pb isotopes have been used to identify each pollution source and estimate its contribution in the particulates (Dong et al. 2017; Souto-Oliveira et al. 2018, 2019). Likewise, it is also critical to evaluate stable isotopic compositions in the blank filters to prevent misunderstanding the source and overestimating the contribution of each source. Nonetheless, there is no study on isotopic compositions in the blank filter.

Here, we first report elemental and isotopic compositions (Zn and Pb isotopes) in blank filters commonly used for collecting the particulates in South Korea, and evaluate the best type of filter for elemental and isotope analyses in the particulates.

Materials and methods

Sample preparation

Detailed information on filters used in this study is given in Table 1. In short, we used both disk and square type filters because the former has been commonly used in high-volume sampling (~ 1700 L/min), while the latter has been used in low-volume sampling (16.7 L/min). Three polytetrafluoroethylenes (PTFEs; Nos. 17-19) and two Glass Fibers (GFs; Nos. 20-21) filters were square, while eleven nitrocellulose (NC), one Nylon, and four PTFE filters are disk type. All samples were stored in the desiccator maintaining 30 ± 5% of humidity and T = 25 °C for 24 h before the experiment. Although previous studies have used various extraction methods (e.g., a mixture of ultrapure acids; Yang et al. 2002; Karthikeyan et al. 2006; Ali 2016), we used 22% ultrapure aqua regia following the US EPA method (US EPA 1999). For the square type filters, we cut them into ~ 25 × 200 mm using ceramic scissors, placed in a 60 ml Teflon screw-cap vessel (Savillex Corp., USA), and reacted with 10 mL ultrapure 22% aqua regia on a hotplate at T = 180 °C for 24 h. Then, the supernatant was filtered through a 0.45-μm Nylon syringe filters (25 mm diameter, Whatman, USA), evaporated at T = 180 °C, and diluted to 10 mL ultrapure 2% HNO_3. In case of the disk filters, whole filter was used and treated as the same way above. All samples were treated as triplicates.

Elemental analyses

Concentrations of elements were measured using a PerkinElmer Optima 7700DV ICP-AES at the Pukyong National University and an Agilent 7700 ICP-MS at the Korea Institute of Ocean Science & Technology (KIOST), respectively. Repeated analyses of a certified reference material (Trace Metals in Drinking Water; TMDW) yielded analytical uncertainties for most major and trace elements of within ± 10%, except Zn (27%) that is overestimated. (Table S1).

Isotope analyses

Information on element separation and isotope measurements is reported in Jeong et al. (2021). In short, pure Zn and Pb were separated using a Bio-Rad AG-MP1 resin (100–200 mesh, chloride form) and an Eichrom Pb-resin (100–200 mesh), respectively. All isotope ratios of Zn and Pb were measured using a Thermo Scientific Neptune Plus MC-ICP-MS at the KIOST. During the measurements, mass bias was corrected using a standard–sample bracketing (SSB) method where IRMM-3702 for Zn and NIST SRM 981 for Pb were used as isotopic standards. Zinc isotopic compositions are reported in delta notation relative to IRMM-3702, where $\delta^{66}Zn = [(^{66}Zn/^{64}Zn)_{sample}/(^{66}Zn/^{64}Zn)_{IRMM\text{-}3702}-1] \times 1000$. The reproducibilities of Zn isotope measurements are better than ±0.02‰ for IRMM-3702 (n = 24, 2σ). The repeated analyses of NBS 981 (US National Bureau of Stands) yielded mean $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ ratios of 16.935 ± 0.004 (2σ, n = 7), 15.485 ± 0.004 (2σ,

Table 1 Mean major and trace elemental concentrations in the filters

Sample	Manufacturer[1]	Diameter (mm)	Pore size (μm)	Na (mg/cm^2)	1σ	K	1σ	Fe	1σ	Mg	1σ	Ca	1σ	P	1σ	Al	1σ	Ti	1σ
Nitrocellulose filter (NC)																			
NC-1	[1]	25	0.22	133	9	4.39	0.22	0.68	0.56	4.89	2.35	26.6	1.0	0.18	0.08	0.87	0.17	0.04	0.03
NC-2	[1]	25	0.45	179	18	3.99	0.30	N.D.		7.75	3.42	27.9	0.9	21.7	0.9	0.61	0.08	0.06	0.02
NC-3	[1]	25	0.8	167	2	4.23	0.27	1.30	0.61	13.6	11.4	27.1	1.4	167	2	0.83	0.18	0.22	0.00
NC-4	[1]	37	0.45	154	5	2.46	0.14	1.02	0.51	1.88	0.14	15.2	0.7	50.8	0.8	0.29	0.02	0.09	0.02
NC-5	[1]	37	0.8	75.7	4.9	1.83	0.04	1.42	0.67	1.41	0.30	12.1	0.2	74.1	4.1	0.28	0.05	0.09	0.00
NC-6	[1]	47	0.22	41.9	0.6	1.48	0.03	0.28	0.04	0.77	0.04	6.90	0.12	0.07	0.00	0.22	0.03	0.02	0.01
NC-7	[1]	47	0.45	41.2	0.3	1.36	0.05	0.56	0.44	1.18	0.02	12.9	0.3	0.11	0.00	0.21	0.14	0.01	0.00
NC-8	[1]	47	0.8	46.5	0.6	1.17	0.04	0.19	0.12	1.08	0.37	8.01	0.23	44.9	0.2	0.05	0.04	0.06	0.01
NC-9	[1]	90	0.22	5.49	0.19	0.32	0.00	0.10	0.00	0.21	0.00	2.14	0.01	0.42	0.07	0.08	0.01	0.01	0.00
NC-10	[1]	90	0.45	11.1	0.2	0.35	0.01	0.11	0.00	0.22	0.00	2.18	0.01	3.32	0.05	0.08	0.01	0.01	0.00
NC-11	[1]	90	0.8	6.17	0.28	0.34	0.01	0.11	0.00	0.21	0.00	2.14	0.01	11.6	0.1	0.08	0.02	0.01	0.00
Nylon filter																			
Nylon-12	[1]	47	1	0.62	0.04	0.12	0.01	N.D.		0.42	0.10	0.15	0.01	0.47	0.01	0.19	0.03	11.3	1.2
Polytetrafluoroethylene filter (PTFE)																			
PTFE-13	[1]	46	2	1.43	0.16	0.04	0.01	0.17	0.02	0.25	0.03	0.95	0.13	0.14	0.03	2.00	0.28	0.02	0.00
PTFE-14	[1]	47	0.5	0.15	0.03	0.03	0.02	0.06	0.00	0.31	0.10	0.04	0.02	0.13	0.02	0.16	0.06	0.01	0.00
PTFE-15	[1]	47	2	0.20	0.05	0.01	0.01	0.05	0.04	0.16	0.09	0.33	0.20	0.23	0.11	0.24	0.16	0.05	0.02
PTFE-16	[2]	47	2	0.05	0.04	0.02	0.00	0.06	0.01	0.07	0.01	0.94	0.13	0.09	0.08	0.08	0.04	0.01	0.00
PTFE-17	[1]	200 × 200	0.22	0.02	0.01	N.D.		N.D.		0.10	0.03	0.01	0.01	0.03	0.01	0.09	0.03	N.D.	
PTFE-18	[1]	200 × 200	0.45	N.D.		N.D.		N.D.		0.14	0.04	0.02	0.00	0.05	0.01	0.14	0.04	0.01	0.00
PTFE-19	[1]	200 × 200	1	0.06	0.03	0.01	0.01	0.03	0.01	0.01	0.01	0.06	0.06	0.47	0.36	0.07	0.08	0.01	0.01
Glass fiber filter (GF)																			
GF-20	[1]	203 × 254	1.6	1158	16	450	3	15.4	0.2	47.8	1.0	186	3	3.24	0.06	514	5	2.67	0.07
GF-21	[1]	203 × 254	1.2	1056	40	434	18	15.1	0.5	38.6	1.2	169	7	3.46	0.16	487	19	2.42	0.04

1σ, 1 standard deviation (n = 3); *N.D* not detected
[1][1] Pall corporation (USA); [2] GVS filter technology (USA)

Table 1 Mean major and trace elemental concentrations in the filters *(Continued)*

Sample	Cr (μg/cm^2)	1σ	Mn	1σ	Cu	1σ	Zn	1σ	As	1σ	Cd	1σ	Pb	1σ	Sb	1σ	Sr	1σ
Nitrocellulose filter (NC)																		
NC-1	1816	409	52.7	6.5	211	48	115	46	1.54	1.03	0.27	0.12	N.D.		2.09	0.51	79.6	3.5
NC-2	1641	235	39.4	1.0	304	17	617	317	N.D.		1.08	0.51	N.D.		1.04	0.70	89.5	2.3
NC-3	1820	292	45.8	1.7	557	47	210	138	1.87	2.26	0.05	0.04	2.17	1.03	2.11	0.59	100	5
NC-4	675	60	24.5	1.4	330	16	121	14.5	0.43	0.44	0.02	0.01	4.60	2.33	0.61	0.26	54.7	1.6
NC-5	792	69	25.9	3.9	274	36	50.0	13.5	0.07	0.05	0.01	0.00	1.90	0.84	1.04	0.18	45.9	0.6
NC-6	566	71	18.7	1.2	139	41	30.4	20.9	0.27	0.07	0.03	0.01	0.86	0.64	0.22	0.11	24.3	1.3
NC-7	422	99	33.6	3.3	71.6	1.7	5.40	1.43	0.14	0.10	0.01	0.00	N.D.		0.09	0.10	43.0	1.8
NC-8	549	36	17.4	0.9	189	7	67.8	18.9	0.12	0.02	0.01	0.01	N.D.		0.41	0.11	33.1	1.0
NC-9	94.1	17.8	73.0	9.7	21.1	2.2	10.9	1.9	0.03	0.01	0.01	0.01	0.34	0.09	0.03	0.00	5.37	0.36
NC-10	116	10	69.9	6.9	30.2	3.3	17.1	2.1	N.D.		N.D.		0.92	0.19	0.06	0.01	5.31	0.29
NC-11	123	5	70.0	5.8	31.6	1.3	9.60	0.78	N.D.		0.02	0.01	0.67	0.04	0.09	0.02	4.89	0.13
Nylon filter																		
Nylon-12	323	21	114	31	24.2	7.0	67.3	39.1	ND		0.10	0.03	2.62	1.24	2693	151	2.81	0.78
Polytetrafluoroethylene filter (PTFE)																		
PTFE-13	94.7	9.5	57.4	6.6	5.90	1.95	11.8	4.9	N.D.		N.D.		N.D.		0.37	0.03	1.06	0.41
PTFE-14	32.0	3.4	23.1	3.4	4.13	1.35	4.99	2.32	N.D.		N.D.		N.D.		0.31	0.11	0.02	0.01
PTFE-15	32.4	2.4	14.8	12.3	17.6	10.8	29.7	19.2	N.D.		N.D.		4.95	4.25	0.42	0.15	0.28	0.15
PTFE-16	21.6	2.8	18.9	4.0	57.1	64	183	210	N.D.		N.D.		N.D.		0.17	0.04	0.47	0.27
PTFE-17	7.95	0.79	2.36	1.04	1.32	0.73	4.02	2.20	0.05	0.01	0.01	0.00	0.03	0.01	0.05	0.01	0.08	0.05
PTFE-18	13.2	1.3	2.82	0.96	0.83	0.28	1.96	1.06	0.09	0.01	0.01	0.00	0.42	0.20	0.08	0.01	0.05	0.05
PTFE-19	20.8	8.4	7.98	6.39	1.67	1.95	4.12	4.46	0.16	0.01	0.02	0.02	0.02	0.01	0.13	0.04	0.07	0.10
Glass fiber filter (GF)																		
GF-20	55.5	5.8	5728	228	156540	2698	534894	5670	6.32	2.20	64.5	2.4	452	12	8.11	0.25	6710	162
GF-21	54.9	2.2	5894	189	152530	5920	517844	19717	9.13	0.93	82.3	2.1	488	16	7.74	0.30	6740	206

n = 7), and 36.681 ± 0.001 (2σ, n = 7), respectively, in agreement with reported values (Todt et al. 1996).

Results and discussion

Major elements

All concentrations of major elements are reported in Table 1 and Fig. 1. Concentrations of major elements in the NC filters are quite variable, ranging from 0.01 mg/cm^2 for Ti to 179 mg/cm^2 for Na. Among major elements, Na is the most abundant with one order of magnitude higher than other elements. Interestingly, major element concentrations decrease as a diameter increases. For example, the mean Na concentration in a diameter 25 mm filter of 159 mg/cm^2 decreases to 8 mg/cm^2 in a diameter 90 mm filter. This is because the units in concentrations are mass per unit area. However, major element concentrations did not show any correlation with pore size. Although two previous studies reported major element

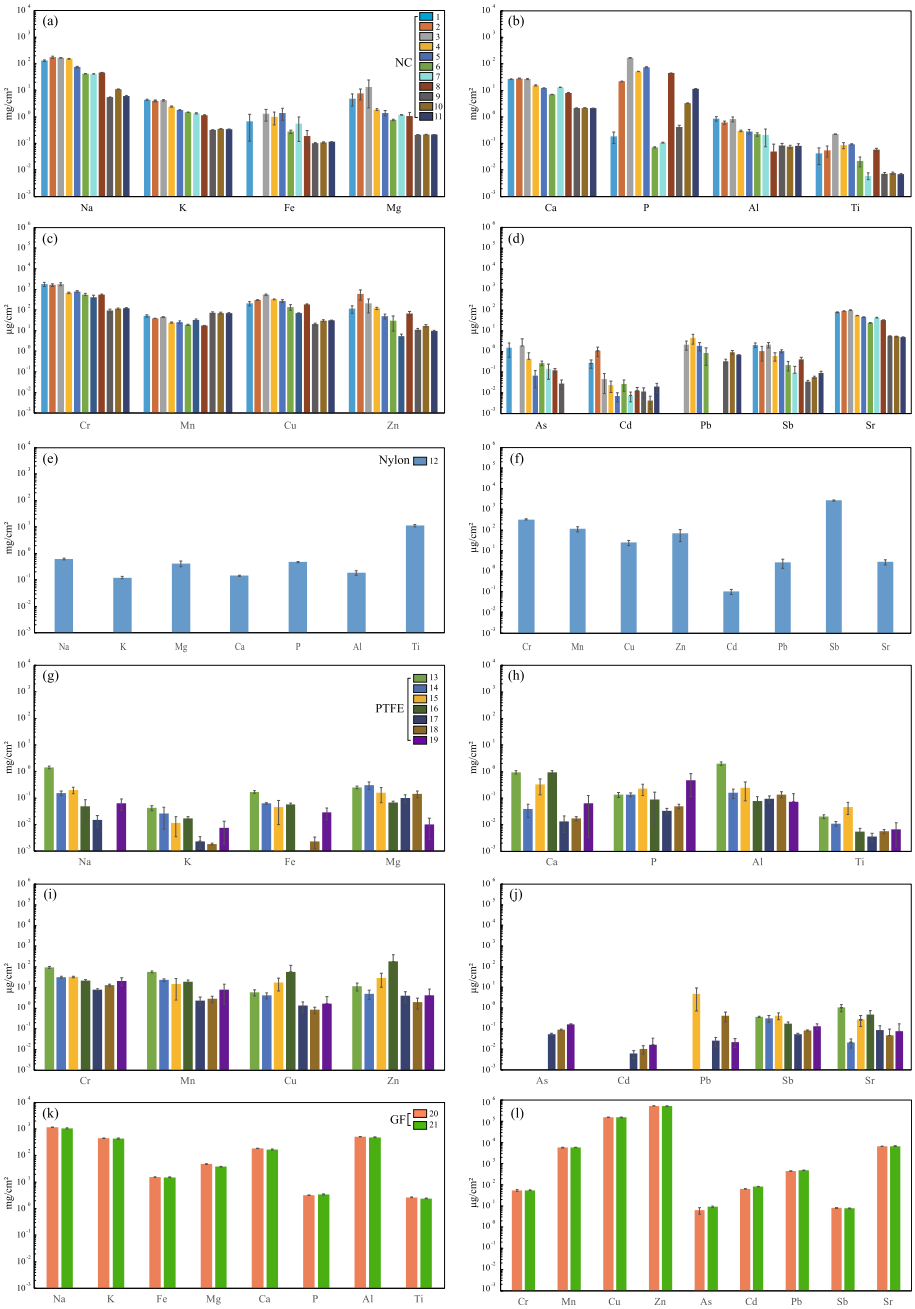

Fig. 1 Concentrations of major and trace elements in the blank filters. **a**–**d** Concentrations in the NC filters. **e**–**f** Concentrations in the Nylon filter. **g**–**j** Concentrations in the PTFE filters. **k**–**l** Concentrations in the GF filters

concentrations in the cellulose filters are much variable than those in this study, it could be due to the different digestion methods that used a mixture of HNO_3 + H_2O_2 + HF + H_3BO_3, and HNO_3 + HF, respectively (Yang et al. 2002; Morton et al. 2013), instead of diluted aqua regia. For example, the former reported Fe content of 0.06 mg/cm^2 and the latter Fe content of 18.87 mg/cm^2, while this study yielded a mean Fe content of 0.58 mg/cm^2. That is, large amounts of elements from the filter are attributed to both strong acidity and reactivity of acids.

Concentrations of major elements in the Nylon filter are also variable, ranging from 123 μg/cm^2 for K to 11.3 mg/cm^2 for Ti. Compared to the NC filter, all major element concentrations are quite low. Although it is difficult to compare the Nylon filter to the NC filters due to a limited number of the Nylon filter, the results indicate that the Nylon filter contains much lower concentration than the NC filter with respect to the same diameter (i.e., 47 mm).

Concentrations of major elements in the PTFE filters are also variable depending on the type (i.e., disk vs. square types). The former displays concentrations ranging from 20.9 μg/cm^2 for Ti to 620 μg/cm^2 for Al, while the latter ranges from 8 μg/cm^2 for K to 186 μg/cm^2 for P. Compared to three different filters with a diameter 47 mm, the PTFE filter contains the lowest content of major elements than both the NC and Nylon filters. Although previous study reported the Teflon and Zefluor^{TM} PTFE filters contained Fe contents of 12.1 and 499 mg/cm^2, respectively (Karthikeyan et al. 2006), Fe content in this study is two orders of magnitude lower than them. It could be due to the difference in reagents used in two studies that Karthikeyan et al. (2006) used a mixture of ultrapure acids (HNO_3 + H_2O_2 + HF) but this study used 22% aqua regia. That is, the discrepancy in both acidity and reactivity of acids causes a big difference in background elemental concentrations.

On the contrary, major element concentrations in the GF filters are much higher than those in the other filters, ranging from 2.5 mg/cm^2 for Ti to 1107 mg/cm^2 for Na, which are higher than one order of magnitude. Although previous study showed Fe content in a quartz filter is 1702 mg/cm^2 (Karthikeyan et al. 2006), this study yielded that Fe content is about 100 times low (15.2 mg/cm^2). Much high concentrations of Na, K, Ca, and Al in the GF filters could be attributed to the fact that the GF filters are manufactured from 100% borosilicate glass created by combining and melting boric oxide (B_2O_3), silica sand (SiO_2), soda ash (Na_2CO_3), and alumina (US EPA 1979; Khan et al. 2015; Jones 2019).

In short, the contents of major elements are the lowest in the PTFE filter and become higher in the order of the Nylon, NC, and GF filters, indicating that either PTFE and/or Nylon filters are the most suitable for major element analysis in the atmospheric particulates. Otherwise, background contents of major elements result in overestimating their concentrations in the atmospheric particulates.

Trace elements

As shown in major elements, trace element concentrations in the NC filters are quite variable, ranging from 0.2 μg/cm^2 for Cd to 783 μg/cm^2 for Cr. Interestingly, among nine trace elements, three elements (Cr, Cu, and Zn) are much more concentrated than the other elements, which is consistent with a previous study that those three elements are much more enriched (Yang et al. 2002). Furthermore, trace element concentrations decrease with the increase in a diameter as shown in major elements. However, trace element concentrations did not show any correlation with pore size. The results indicate that the NC filter is not suitable for determining Cr, Cu, and Zn in the atmospheric particulates.

Likewise, concentrations of trace elements in the Nylon filter are also variable, ranging from < 0.1 μg/cm^2 for As to 2693 μg/cm^2 for Sb. Compared to the NC filter, although most of trace elements yield lower concentrations, concentrations of two elements (Mn and Sb) are much higher, indicating that the Nylon filter is not suitable for determining Mn and Sb in the atmospheric particulates.

On the contrary, concentrations of trace elements in the PTFE filters are much lower than both the NC and Nylon filters even concentrations are also variable, ranging from 0.01 μg/cm^2 for Cd to 34 μg/cm^2 for Zn. Among nine elements, only four elements (Zn, Cr, Mn, and Cu) are more concentrated with up to three order of magnitude high. Trace element concentrations also depend on the type (i.e., disk vs. square types). For four elements above, the former yields much higher concentrations, ranging from 21 μg/cm^2 for Cu to 57 μg/cm^2 for Zn, while the latter ranges from 1.3 μg/cm^2 for Cu to 14 μg/cm^2 for Cr. Compared to previous study for the Teflon and Zefluor^{TM} PTFE filters (Karthikeyan et al. 2006), this study yields much lower concentrations in all elements which is probably due to the difference in acidity and reactivity of acids (a mixture of ultrapure acids versus diluted aqua regia).

The GF filters contain the highest concentrations relative to the other filters, ranging from 7.7 μg/cm^2 for As to 526 mg/cm^2 for Zn, which are higher than up to three order of magnitude for Zn. Higher concentrations of Zn, Cu, and Mn could be attributed to the impurities in either borosilicate glass and/or silica because previous study also reported the quartz filter digested with a mixture of HNO_3 + H_2O_2 + HF contains high amounts of

Table 2 Zinc and Pb isotopic compositions of the GF filters

Sample	$\delta^{66}Zn_{IRMM3702}$	2σ (*n* = 12)	$^{206}Pb/^{204}Pb$	2σ (*n* = 3)	$^{207}Pb/^{204}Pb$	2σ (*n* = 3)	$^{208}Pb/^{204}Pb$	2σ (*n* = 3)
GF-20	− 0.10	0.02	18.044	0.008	15.594	0.007	37.999	0.018
GF-21	− 0.12	0.02	18.044	0.003	15.595	0.003	38.001	0.005

trace elements, ranging from 111 mg/cm^2 for As to 1213 mg/cm^2 for Zn (Karthikeyan et al. 2006).

In summary, the contents of trace elements are the lowest in the PTFE filter, and become higher in the order of the Nylon, NC, and GF filters, indicating that PTFE filter is the most suitable for trace element analysis in the atmospheric particulates. Otherwise, background contents of trace elements result in overestimating their concentrations in the atmospheric particulates.

Isotopes

Recently, multi-isotope (Zn and Pb isotopes) studies have been initiated to determine the origin of contamination source in aerosols and to evaluate the individual contribution of these pollution sources (Araújo et al. 2019; Souto-Oliveira et al. 2018, 2019; Schleicher et al. 2020). Although multi-isotope approach allows us to shed light on the origin and contribution of potential anthropogenic sources in the atmospheric particulates, there is a limitation to apply them due to little isotope data for potential anthropogenic sources.

Because three types of filters (NC, Nylon and PTFE) contain very low contents of Zn and Pb for isotope measurements, only GF filters were analyzed. The $\delta^{66}Zn_{IRMM-3702}$ values of two GF filters (Nos. 20 and 21) are − 0.10 ± 0.02‰ (2σ, n = 12) and − 0.12 ± 0.02‰ (2σ, n = 12), respectively, indicating that two filters are identical in terms of Zn isotopes (Table 2). As converting δ-values relative to the Lyon standard ($\delta^{66}Zn_{JMC\text{-}Lyon}$) using an equation of $\delta^{66}Zn_{JMC\text{-}Lyon} = \delta^{66}Zn_{IRMM\text{-}3702} + 0.29‰$ (Schleicher et al. 2020), two GF filters yield $\delta^{66}Zn_{JMC\text{-}Lyon}$ values of + 0.19 ± 0.02‰ (2σ, *n* = 12) and + 0.17 ± 0.02‰ (2σ, *n* = 12), respectively. Because the $\delta^{66}Zn_{JMC\text{-}Lyon}$ values in the blank GF filters are within those from samples of the Chinese deserts ranging from + 0.07 to + 0.33‰, and of the Chinese Loess Plateau ranging from + 0.22 to + 0.49‰ (Schleicher et al. 2020), it should be cautious to use the GF filters for Zn isotope study.

Likewise, the $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ ratios of two GF filters are identical within errors (Table 2). Because the $^{206}Pb/^{204}Pb$ ratios of the Chinese Deserts range from 18.542 to 18.888, and in the Chinese Loess Plateau from 18.731 to 18.832 (Schleicher et al. 2020), it seems that the GF filter ($^{206}Pb/^{204}Pb$ ratio of 18.044) can be used for Pb isotope study. However, the fact that the particulates collected from Xi'an and Beijing yielded the $^{206}Pb/^{204}Pb$ ratios of 18.031 and 18.129 (Schleicher et al. 2020) confirms the GF filter is not suitable for Pb isotope study in Korea.

Conclusions

Major and trace elements and Zn and Pb isotopes in four different types of blank filters collecting atmospheric particulates commonly used in South Korea were investigated in order to evaluate the best type of filter for elemental and isotope analyses in the atmospheric particulates. Concentrations of major elements are the lowest in the PTFE filter and increase in the order of the Nylon, NC, and GF filters. Likewise, trace element concentrations in the blank filters are the same order as shown in major elements. All results indicate that the PTFE filter is the most suitable for elemental and isotope analyses in the atmospheric particulates; otherwise, background contents result in overestimating their concentrations in the atmospheric particulates. Furthermore, Zinc and Pb isotope data measured in the GF filters indicate that the GF filter is not suitable for Zn and Pb isotope study in the atmospheric particulates.

Abbreviations

ICP-AES: Inductively coupled plasma atomic emission spectroscopy; ICP-MS: Inductively coupled plasma mass spectrometry; MC-ICP-MS: Multicollector inductively coupled plasma mass spectrometry

Supplementary Information

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Additional file 1: Table S1. Concentrations of major and trace elements of reference material, TMDW.

Authors' contributions

J.-S.R. and H.J.C designed the study and led the writing of the manuscript. J.L wrote the first draft and conducted sample preparation and chemical analyses. S.J and J.K conducted sample preparation. H.J and K.R conducted isotope analyses. All authors contributed equally to the data interpretation. The authors read and approved the final manuscript.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding authors (J.-S. Ryu, jongsikryu@pknu.ac.kr; Hye Jung Chang, almacore@kist.re.kr).

Declarations

Competing interests

All authors declare no competing financial and/or nonfinancial interests in relation to the work described.

Author details

[1]Division of Earth Environmental System Sciences, Pukyong National University, Busan 48513, South Korea. [2]Department of Earth and Environmental Sciences, Pukyong National University, Busan 48513, South Korea. [3]Marine Environmental Research Center, Korea Institute of Ocean Science and Technology (KIOST), Busan 49111, South Korea. [4]Department of Ocean Science (Oceanography), KIOST School, University of Science and Technology (UST), Daejeon 34113, South Korea. [5]Advanced Analysis Center, Korea Institute of Science and Technology, Seoul 02792, South Korea.

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