Journal of Radioanalytical and Nuclear Chemistry (2020) 323:1135–1143
https://doi.org/10.1007/s10967-020-07027-6

Temporal variation of ^{210}Pb concentration in the urban aerosols of Shanghai, China

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Received: 25 October 2019 / Published online: 23 January 2020

Abstract

This study monitored ^{210}Pb levels of the atmospheric aerosol in Shanghai from January 2016 to February 2017. ^{210}Pb levels were found to be low in non-haze weather events (1.46 ± 0.76 mBq/m^3, $n = 8$) and high in moderate pollution weather events (2.34 ± 1.43 mBq/m^3, $n = 12$). Similar to those of other East Asian regions, monthly averaged ^{210}Pb concentration showed a U-shaped distribution pattern, indicating that the East Asian monsoon has an impact on atmospheric ^{210}Pb. Particulate matters (PM) had a significant positive correlation with ^{210}Pb, indicating that there might occur an intensified ^{210}Pb scavenging processes. The linear correlation analysis revealed a clear link between ^{210}Pb and some gaseous pollutants, strong positive correlation between CO and ^{210}Pb (^{210}Pb/CO, $R = 0.63$, $P < 0.01$), and weak correlation between ^{210}Pb and O_3 ($R = -0.35$), NO_2 ($R = 0.42$), and SO_2 ($R = 0.34$). This phenomenon demonstrated that in haze weather, not only the general air pollutants concentrations have increased, but also the ^{210}Pb concentration. Radiation dosimetry of daily inhalation of ^{210}Pb through exposure to outdoor air is estimated to be relatively minor; children intake remains higher.

Keywords ^{210}Pb · Temporal variation · Haze events · Air pollutants · East Asian Monsoon

Introduction

The main source of ^{210}Pb (half-life = 22.4 years) is the radioactive decay of ^{222}Rn (half-life = 3.8 days) emitted to atmosphere from the earth's crust; the other possible artificial sources in the air include, burning of fossil fuels (coal) [1, 2], use of phosphate fertilizers [3], iron and steel manufacture [4], biomass combustion [5], burning of leaded gasoline used for vehicle engines and so on [6, 7]. Since most of the ^{210}Pb is originated from the ^{222}Rn emanated from terrestrial surface, its concentration in air can be expected to be influenced by the local meteorological conditions, such as temperature, atmospheric pressure, relative humidity, precipitation or soil moisture, that affect the emanation rate of ^{222}Rn from the land surface [7].

Once ^{210}Pb have been produced, they are immediately attached to sub-micron-sized aerosol particles and can be transported with atmospheric aerosols [8, 9]. When people directly inhaled aerosols with ^{210}Pb, which are collected by the respiratory tract of the body, and finally, it can be mainly accumulated in skeleton with a long-time radiation risk due to its long effective half-life. Haninger et al. [10] pointed out that in environments with enhanced radionuclides concentrations, direct inhalation of ^{210}Pb is an important source for ^{210}Pb accumulation in man. Therefore, its presence and activity levels in air is of the utmost concern in terms of radiation risk coupling with air pollutant which more and more seriously affecting public health via air inhalation.

With rapid economic development and urbanization for 40 years, China is experiencing severe haze pollution, especially in some important metropolis [11–15]. Shanghai is a mega-city with 24 million residents, ~4.3 million vehicles and nearly 60 million ton of standard coal per year, and there are many industrial facilities surrounding the city, including petrochemical factories, chemical plants, and solvent production facilities [15]. It is well known that Shanghai is still suffering from serious haze pollution though the number of

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haze day reduced from 124 in 2013 to 88 in 2017 [16]. The source of $PM_{2.5}$ in Shanghai has been reported to include coal burning, vehicle exhaust emission, biomass burning and suspended mineral dust [17].

Ambient air quality in Chinese cities is monitored and reported daily using the air quality index (AQI) that was calculated on the basis of ground-based monitoring of a 24-h average atmospheric PM ($PM_{2.5}$ and PM_{10} represent the particle aerodynamic diameter being equal or less than, 2.5 and 10 µm, respectively) [16, 18], carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) concentration. The air quality was defined into some levels with the following scale: 0–50: excellent, 51–100: good, 101–150: light pollution, 151–200: moderate pollution, 201–300: severe pollution and > 300: very serious pollution [18]. Based on the AQI values, the weather condition was divided into two categories: 0–100, non-haze day; > 100, haze day. Many studies focused on the investigation of deposition fluxes of ^{210}Pb and ^{7}Be and used them as atmospheric tracers to characterize the sources of air masses, e.g. maritime versus continental air [19], but ignore the possible radiation risk in haze weather situation and the relationship between ^{210}Pb level and air quality. And there is limited investigation on level of air ^{210}Pb in China, especially in Shanghai [20]. Meanwhile, the variation of atmospheric ^{210}Pb and its major control parameter are still unclear in Shanghai.

The aims of the study were (1) to measure temporal variations of ^{210}Pb with changing air quality in a downtown area of Shanghai, (2) to analyze the correlation of ^{210}Pb with meteorological data such as temperature and relative humidity, and air pollutants, (3) to estimate the possible radiation risk in haze and non-haze periods due to inhalation of ^{210}Pb.

Materials and method

Materials and sampling

The sampling station was installed on the roof of the State Key Laboratory of Estuarine and Coastal Research (SKLEC) building at the East China Normal University at ~ 20 m above ground level (31°13′39″N, 121°23′56″E), and ~ 50 km from the East China Sea coastline [21]. The aerosol samples were collected from January 2016 to February 2017 through a portable Staplex TF1A type (Clover Company, USA) high volume air sampler. The maximum sampling flow rate is 2 m^3/min. Quartz microfiber filters of 0.2 mm pore (Whatman Company, UK) were used to collect particles in air. The collection efficiency of the membrane was larger than 99.995% for size of particles greater than 0.3 µm. Sampling usually lasted for 10–12 h, and in general the total sampled air volume was higher than 1000 m^3. The air sampler was protected with a locked cover to avoid direct input of the rain. The location of sampling site is showed in Fig. 1.

The meteorological parameters (temperature and RH) and air pollutants (PM, SO_2, NO_2, CO, O_3) concentrations were obtained and recorded from the nearest official station (Putuo Station), which is within 1.5 km distance away from SKLEC building [22].

Measurement of ^{210}Pb by using alpha spectrometry

The aerosol samples were stored for 1.5 years to ensure the radioactive equilibrium between ^{210}Po and ^{210}Pb. Therefore, the activity of ^{210}Pb can be replaced by ^{210}Po. The analysis of ^{210}Po was referenced and modified from a previous

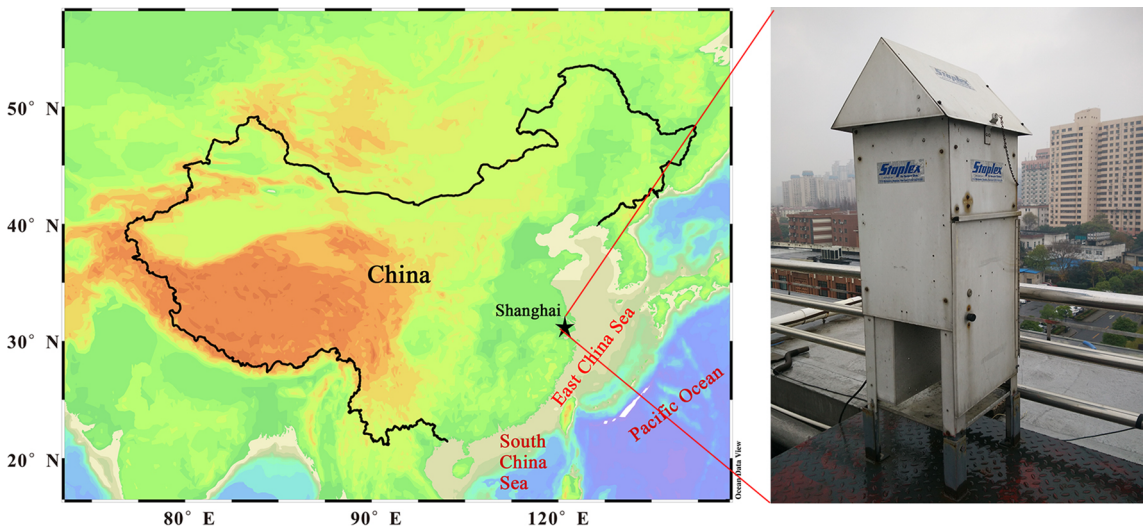

Fig. 1 Sampling location (black star) at site of Shanghai, eastern coast of China

method [2], which is described briefly here. For the determination of ^{210}Po activity, a quarter of the sample filter was acid-digested with a mixture of HNO_3, HF and H_2O_2 at a temperature of 150 °C in presence of ^{209}Po spike (1–2 dpm) in a Teflon beaker. The certified reference material ^{209}Po (1526-81-1) used in this work was purchased from the Eckert & Ziegler Isotope Products. The clear solution was taken to dryness followed by the addition of 2 ml of 2 N HCl acid and further diluted to ~ 0.2 N HCl with Milli-Q water (resistivity = 18.2 MΩ·cm). Approximately 100 mg ascorbic acid powder, 1 ml of 20% hydroxylamine hydrochloride and 1 ml of 25% sodium citrate solution were added into the solution. Polonium (^{209}Po and ^{210}Po) was automatically deposited on a silver disc while heating at 80–90 °C and stirring for 4 h. After that, the disc was taken out from the solution and rinsed with Milli-Q water and ethanol. Finally, the activities of ^{210}Po (E_α = 5.33 MeV) and ^{209}Po (E_α = 4.9 MeV) were assayed by alpha spectrometer (Canberra 7200). This ultra-low background alpha spectrometer (purchased from CANBERRA EURISYS Lit., France) was equipped with 12 PIPS detectors (active area of 600 mm^2). The warranted alpha resolution is 23 keV, and no ^{210}Po and ^{209}Po peak overlapping was found for all the aerosol samples. The correction for decay of ^{210}Po from the time of plating to mid-counting was done for obtaining accurate ^{210}Pb activity. Blank filters were also analyzed for ^{210}Po and was subtracted from the sample. The overall recoveries of Po ranged from 74.4 to 104.4% with an average of 85.1 ± 14.5% (n = 20). The error of the ^{210}Po activity was estimated on the basis of the statistical counting only.

Results and discussion

Variation of atmospheric ^{210}Pb activity concentration in Shanghai

The air quality parameters and concentrations of ^{210}Pb for 20 aerosol samples are given in Table 1. The temporal variation of ^{210}Pb activity concentration is shown in Fig. 2. ^{210}Pb had a range from 0.29 to 6.10 mBq/m^3 and an overall average of 2.07 ± 1.28 mBq/m^3 (n = 20). The average of ^{210}Pb in haze

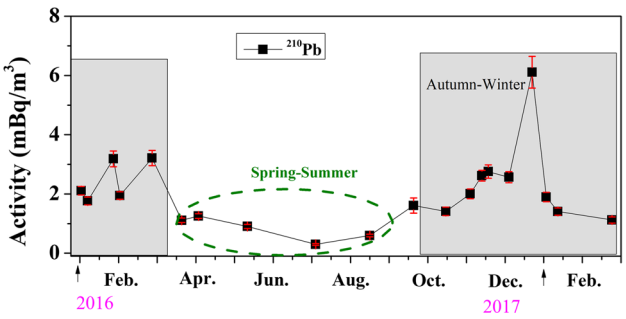

Fig. 2 Temporal variation of ^{210}Pb concentration in the Shanghai air

Table 1 Concentrations of ^{210}Pb and meteorological and air quality parameters of Shanghai's air during 2016–2017

Sample	T (°C)	RH (%)	AQI	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	SO_2 (μg/m^3)	NO_2 (μg/m^3)	O_3 (μg/m^3)	CO (mg/m^3)	^{210}Pb (mBq/m^3)
2016/1/7	6.5	49	112	84	105	33	67	72	1.1	2.11 ± 0.14
2016/1/13	4.0	55	190	144	168	46	96	64	1.8	1.76 ± 0.13
2016/2/2	2.5	52	112	77	90	27	65	85	1.2	3.18 ± 0.26
2016/2/7	7.5	47	98	73	114	24	47	121	1.0	1.94 ± 0.12
2016/3/3	17.5	72	101	47	82	20	62	97	0.7	3.21 ± 0.25
2016/3/26	11.5	49	126	95	124	26	65	140	0.9	1.11 ± 0.07
2016/4/8	18.0	79	82	51	70	15	61	96	0.6	1.25 ± 0.07
2016/5/16	22.0	54	104	39	61	14	40	164	0.6	0.90 ± 0.06
2016/7/8	27.5	88	26	10	26	9	16	50	0.5	0.29 ± 0.02
2016/8/19	30.5	83	73	24	40	11	23	125	0.7	0.59 ± 0.04
2016/9/22	23.5	76	102	22	33	14	44	101	0.6	1.61 ± 0.25
2016/10/17	23.0	83	52	26	40	14	36	95	0.7	1.41 ± 0.14
2016/11/5	22.5	75	85	56	68	16	68	97	0.8	2.00 ± 0.16
2016/11/14	17.5	84	79	40	58	15	54	71	0.8	2.61 ± 0.18
2016/11/19	21.5	87	101	76	81	18	65	43	1.4	2.75 ± 0.22
2016/12/5	14.5	71	159	121	159	25	94	72	1.5	2.56 ± 0.18
2016/12/23	8.0	67	175	132	126	26	63	62	1.8	6.10 ± 0.53
2017/1/3	13.0	81	109	74	81	20	73	73	1.1	1.89 ± 0.15
2017/1/12	8.5	73	112	77	91	24	72	51	1.2	1.40 ± 0.12
2017/2/23	6.5	66	102	76	49	14	37	93	0.9	1.12 ± 0.10

and non-haze day were 2.34 ± 1.43 mBq/m^3 ($n = 12$) and 1.46 ± 0.76 ($n = 8$) mBq/m^3, respectively.

And the 1-year average of ^{210}Pb activity level was compared with other sampling sites and summarized in Table 2. It could be found that the ^{210}Pb concentrations in most different cities of China were higher than those in districts of other countries. Most of these values have exceeded the world average ^{210}Pb value (0.5 mBq/m^3) that reported by UNSCEAR [31]. The ^{210}Pb activity in ambient aerosols in Shanghai is similar to the reported values in Chinese metropolis (typically, 1–2 mBq/m^3), such as Hangzhou [30]. From Fig. 2, the ^{210}Pb activity was significantly high during September–February and relatively low during April–August. The maximum activity of ^{210}Pb, 6.10 ± 0.53 mBq/m^3 was observed in the sample collected in 23, December (the AQI value = 175), which may be attributed to enhancement of anthropogenic emission in Shanghai in the winter. The potential artificial sources include coal fly ash, building dusts, street dusts and industrial or agricultural emissions, because these materials always have very high level of ^{210}Pb, for instance, coal fly ash (29.8–204 Bq/kg) [32], street dusts (high up to 344.7 Bq/kg) and industrial site top soils (66.4 Bq/kg) [33]. In addition, there are at least 33 units at 13 coal-fired power plants in Shanghai's 6340 km^2 area in 2017, and they consumed at least 27.6×10^6 kg coal per year [34]. Hence, the ^{210}Pb contribution from coal combustion should be high. The ^{210}Pb activity concentration in Shanghai exhibited a strong seasonal variability, nearly 3–5 times higher activity in autumn–winter season compared to that in spring–summer time (Fig. 2).

Factors controlling atmospheric concentration of ^{210}Pb in Shanghai and East Asian regions

In general, the ^{210}Pb concentrations in the urban air were controlled by its scavenging processes and by ^{222}Rn production rate (source of ^{210}Pb), and easily be influenced by local emission from some human activities and by meteorological conditions, such as temperature, atmospheric pressure, precipitation or soil moisture, that affect the scavenging strength of particle-reactive radionuclides and the emanation rate of ^{222}Rn from ground [35].

From Fig. 2, the higher ^{210}Pb activity level in dry season's (September–February) atmosphere of Shanghai indicated that less clearing processes due to the low precipitation amount may partly contribute the higher ^{210}Pb in the air. It is also necessary to mention the low values found in spring–summer period (March–September), which might be due to the high levels of rainfall. About 40% of annual rain concentrated in summer of Shanghai [21]. The decrease of washout of ^{210}Pb from air by wet precipitation might promote the accumulation of ^{210}Pb in the airborne particulate materials. The lack of precipitation during autumn–winter season caused an increase of ^{210}Pb concentration due to both lack of scavenging of ^{210}Pb-laden aerosols by rain and lack of resuspension of particles from the soil and dust, meanwhile a decrease of precipitation would have facilitated the ^{222}Rn emanation from soil.

Similar to other East Asian regions, the weather in Shanghai is also influenced by the Asian monsoon system, with the northeast–northwest wind in autumn and winter (continental air mass) from inland area (Fig. 3a) and the east-southeast wind, southeast wind in spring and summer (marine air mass) from the East China Sea, South China Sea and Pacific Ocean (Fig. 3b). In spring–summer period (from March to September), Shanghai is always covered by marine air masses, these situations would carry low atmospheric ^{210}Pb concentration due to a reduced supply of ^{222}Rn associated with low ^{226}Ra concentration in seawater, in contrast, the anticyclones would come to Shanghai from the continental Asia in which much higher atmospheric ^{210}Pb levels were obtained by an increased supply of ^{222}Rn from the Asian continent surface. Hence, the U-shaped distribution patterns of atmospheric ^{210}Pb in

Table 2 Comparison of ^{210}Pb activity concentrations in air with previous reports from different sampling sites in the world

Sites	Sampling period	*N*	Range (mBq/m^3)	Mean (mBq/m^3)	References
Michigan, USA	1999–2001	30	0.30–4.22	1.16 ± 0.81	[23]
El-Minia, Egypt	Jan–Dec 2002	130	0.17–4.49	1.20 ± 0.15	[24]
Kanpur, India	Jan 2007–Apr 2009	99	0.50–4.8	1.8 ± 1.1	[2]
Lodz, Poland	2008–2009	38	0.167–1.847	0.556	[25]
Islamabad, Pakistan	2007–2009	184	0.056–0.761	0.284 ± 0.150	[26]
Malaga, Spain	2009–2011	36	0.40–0.95	0.55	[27]
Mt. Cimone, Italy	1998–2011	2184	0.05–2.30	0.46	[28]
Granada, Spain	Jan 2010–Dec 2014	60	0.16–1.31	0.62 ± 0.18	[29]
Hangzhou, China	Jan–Nov 2012	32	0.22–2.73	1.51 ± 0.64	[30]
Changbai, China	Jan 2016–Sep 2017	30	0.24–27.95	3.39	[20]
Hunchun, China		27	0.10–1.92	0.81	
Shanghai, China	Jan 2016–Feb 2017	20	0.29–6.10	2.07 ± 1.28	This study

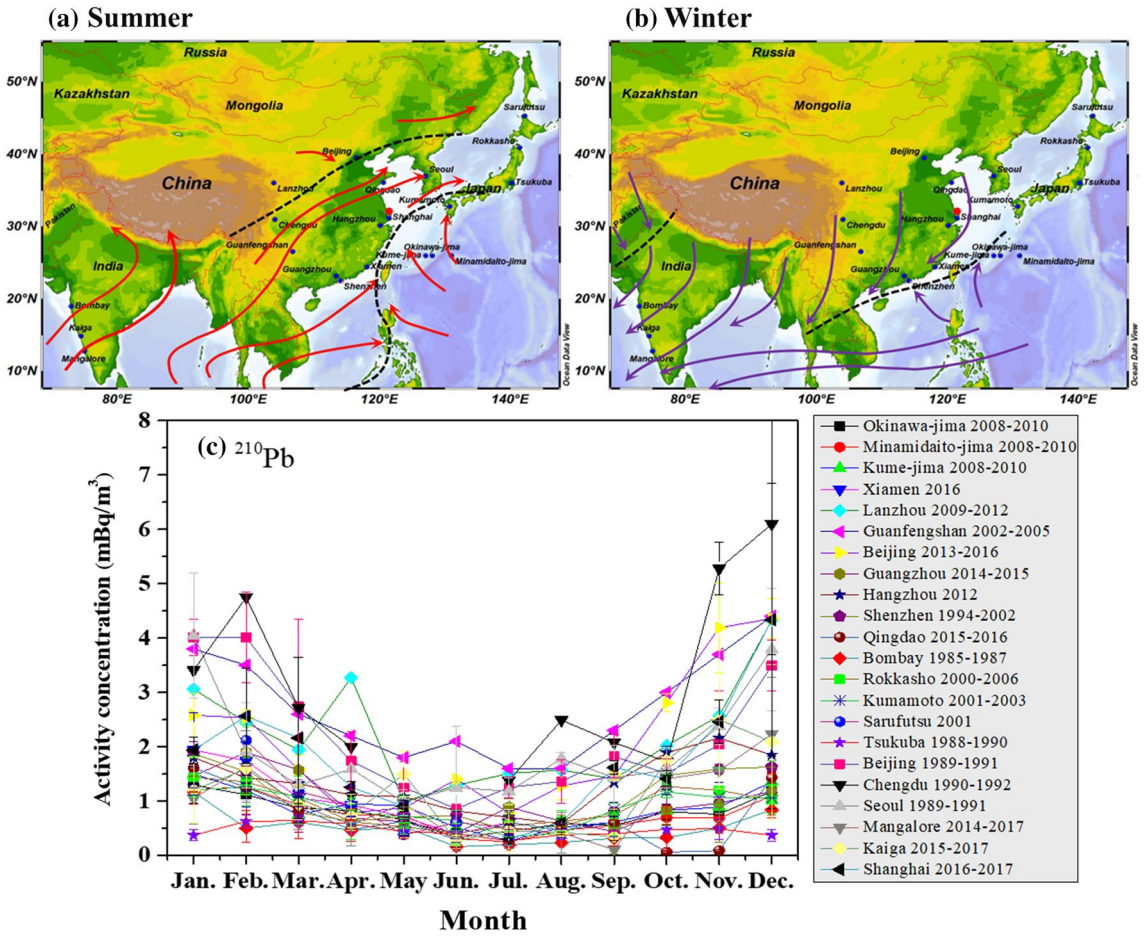

Fig. 3 East Asian Monsoon in **a** summer and **b** winter and monthly variation of atmospheric ^{210}Pb in East Asian regions (**c**). The study sites in this figure include Okinawa-jima, Minamidaito-jima, Kume-jima, 2008–2010 [36]; Xiamen, 2016 [37]; Lanzhou, 2009–2012 [38]; Guanfengshan, 2002–2005 [39]; Beijing, 2013–2016 [40]; Guangzhou, 2014–2015 [41]; Hangzhou, 2012 [42]; Shenzhen, 1994–2002 [43]; Qingdao, 2015–2016 [44]; Bombay, 1985–1987 [45]; Rokkasho, 2000–2006 [46]; Kumamoto, 2001–2003 [47]; Sarufutsu, 2001 [48]; Tsukuba, 1988–1990 [49]; Beijing, 1989–1991 [50]; Chengdu, 1990–1992 [50]; Seoul, 1989–1991 [50]; Mangalore, 2014–2017 [51]; Kaiga, 2015–2017 [51]; Shanghai, 2016–2017 (this study)

many research sites of East Asian regions were observed (Fig. 3c). From the Fig. 3c, the results indicated that we can distinguish air masses from different sources by using ^{210}Pb as a tracer and even study the possible atmospheric air mass mixing processes. In addition, weak solar heating in winter and the subsidence in a lower tropospheric air column associated with the Asian winter monsoon favor a more stable atmospheric environment, resulting in the accumulation of aerosol particles containing ^{210}Pb [52].

Other anthropogenic sources, like coal burning and associated industrial emission (iron and steel factory) have become the predominant sources of ^{210}Pb in Shanghai ambient air, because the biomass burning (agricultural waste and use of wood-fuel for domestic heating) and the use of leaded gasoline had been prohibited by the Shanghai government.

Correlation between ^{210}Pb and meteorological parameters

Meteorological conditions, such as temperature, RH, atmospheric pressure and wind speed, are primary factors that can influence pollutant levels in the atmosphere [53]. In this study, Pearson correlation analysis was preferred after normality test for all the related parameters. The spring–summer season (with relatively high RH and temperature) of Shanghai always correspond to a fairly frequent precipitation period. An inverse relationship between air temperature and ^{210}Pb level ($R = -0.40$, $P = 0.081$) was observed in this study (Fig. 4). The explanation includes: (1) high temperature favors the dispersion of aerosol particles embedded with ^{210}Pb; (2) the rainfall dominates the removal of the atmospheric ^{210}Pb, although higher temperature facilitates

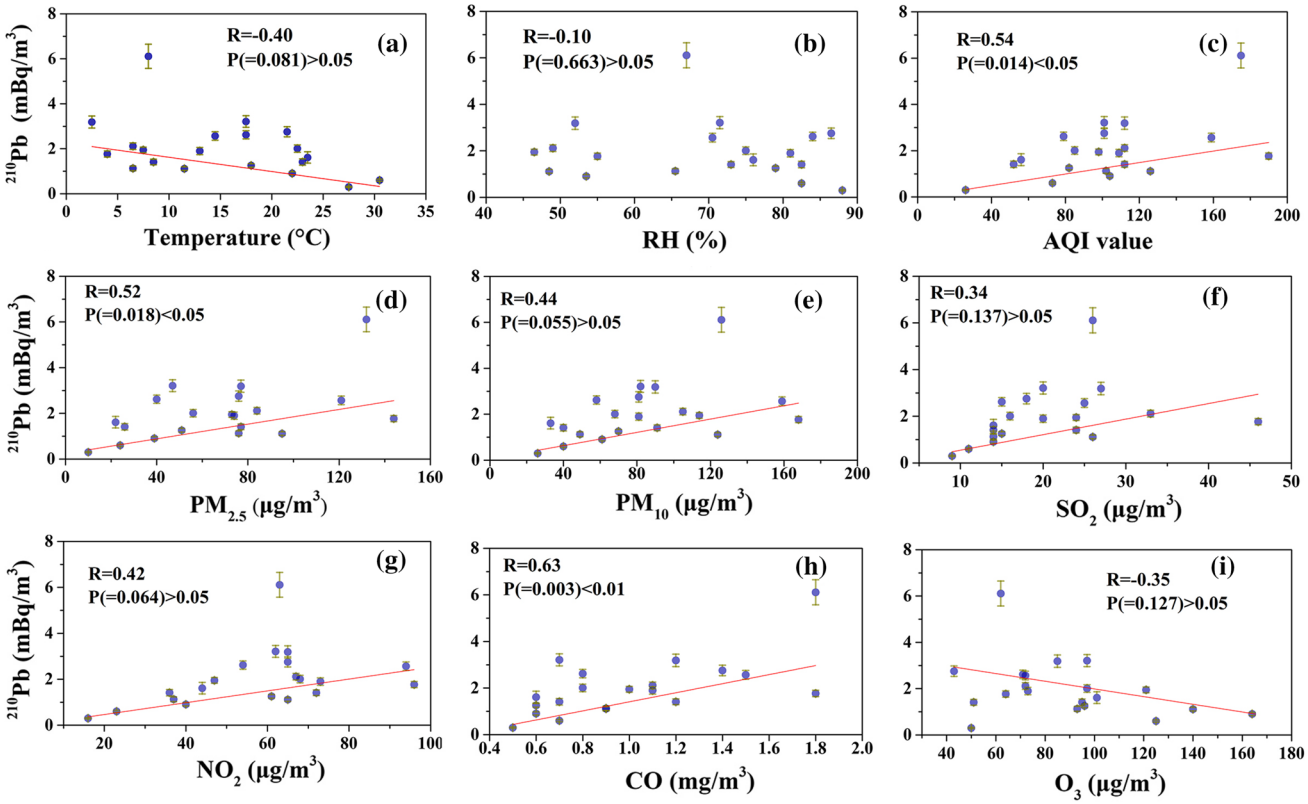

Fig. 4 Linear-regression analysis between meteorological parameters (**a** temperature, **b** RH) and air pollution parameters (**c** AQI, **d** $PM_{2.5}$, **e** PM_{10}, **f** SO_2, **g** NO_2, **h** CO, **i** O_3) and the atmospheric ^{210}Pb concentrations in Shanghai (Pearson correlation analysis performed)

the radon emanation. A weaker relationship between ^{210}Pb concentration and RH was also found, which also demonstrated the significance of wet scavenging for ^{210}Pb [35]. The relatively high RH increases the condensation processes as well as coagulation between the attached aerosol particles. The correlation may also indicate low emission of ^{222}Rn from soil in humid conditions in summer-time, as the finding reported by Li et al. [35], in which a negative correlation between RH and Rn concentration was proved.

The relations between ^{210}Pb and air quality parameters

The correlation coefficients between ^{210}Pb activity concentrations and AQI values, ^{210}Pb activity concentrations and $PM_{2.5}$ concentrations, ^{210}Pb activity concentrations and PM_{10} concentrations were 0.54 ($P<0.05$), 0.52 ($P<0.05$) and 0.44 ($P=0.055$), respectively, which indicated that there were significant relationship between ^{210}Pb activity concentration and air quality parameters. The atmospheric ^{210}Pb concentrations increased with the decrease in air quality, which were also reported by others [20, 35], showing that levels of ^{210}Pb in air of Shanghai were higher in haze day (AQI value >100) than levels in clean weather. One of the explanations was that particle-relative ^{210}Pb could be strongly scavenged to the suspended both fine and coarse particulate matters. Figure 4 shows significant positive correlations between atmospheric ^{210}Pb concentrations with concentrations of gaseous pollutant CO, which suggested that this pollutant CO might share the same source regions and transported pathway with ^{210}Pb [28]. We boldly speculated that this relationship was caused by emission from burning, because high temperature can cause the discharge of ^{210}Po, ^{210}Pb, and other volatile radionuclides (the boiling point is 962 °C for ^{210}Po, and 1749 °C for ^{210}Pb [54]). Because of the good relation between ^{210}Pb and air pollutant CO, ^{210}Pb and these air pollutants could be used as indicators together to assess the health of the atmospheric environment. Interestingly, SO_2 and NO_2 showed weak positive correlations with ^{210}Pb, but O_3 showed a negative correlation with ^{210}Pb.

Radiological hazards assessment for inhaling ^{210}Pb in aerosols

The higher ^{210}Pb levels in air in haze days implied a greater human exposure to outdoor atmospheric ^{210}Pb in haze weather events. Due to long half-live and difficult to be removed, more attention should be paid to the long-term

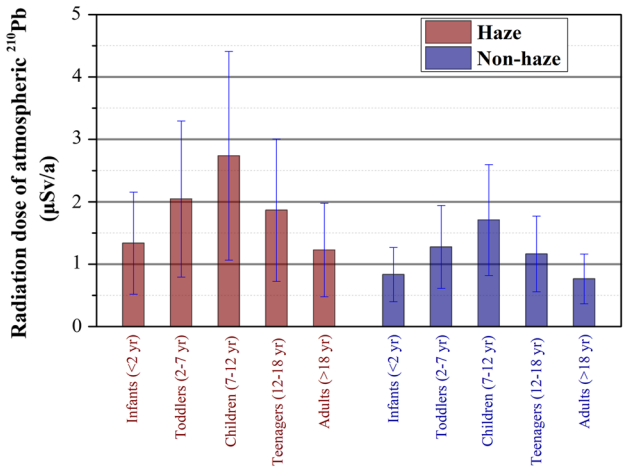

Fig. 5 The radiation dose of ^{210}Pb through inhalation to outdoor air, stratified by different age groups under two air pollution levels (non-haze and haze)

internal radiation to peoples who work in outdoor (such as traffic police, building worker) during air polluted situation in Shanghai once the ^{210}Pb deposited in respiratory system. To evaluate corresponding annual effective dose of ^{210}Pb because of inhalation for inhabitants, the committed effective dose (E_i, μSv/a) was calculated by the following formula:

$$E_i = e(g)_{i,\mathrm{inh}} \times R \times C_i \times T_\mathrm{f}$$

where, $e(g)_{i,\mathrm{inh}}$ is the ^{210}Pb dose conversion coefficient (Sv/Bq) [31]; R is the inhalation rate (m^3/day), values of R for infants, children and adults were 4.5, 7.6, 10.9, 14.0 and 13.3 m^3/day, respectively [55]; C_i is the atmospheric ^{210}Pb concentration (Bq/m^3); T_f is the exposure frequency, indicating the time spent outdoors by inhabitants of the study area, the value of T_f for the children was estimated at 0.21, whereas those for infants, teenagers and adults at 0.12 [55]. Different from oral exposure, not all ^{210}Pb in air, especially those attached to the large particles, may be captured and deposited in respiratory tract, therefore, it has to be recognized that the E_i value calculated by equation is a much more conservative estimation of the actual human radiation dosimetry of ^{210}Pb.

The estimated E_i values under two weather qualities (haze and non-haze) and different age groups are presented in Fig. 5. The results showed that internal dose through inhalation of the aerosol particles attached with ^{210}Pb was assessed to be 0.76–2.74 μSv/a. Furthermore, due to smaller body size, toddlers and children in general have higher committed effective dose values than teenagers and adults. The order of E_i value among different age group was children > toddlers > teenagers > infants > adults. This means that when being exposed to the same levels of atmospheric ^{210}Pb, kids may suffer from two times higher radiation dose than adults. However, the maximum annual effective dose is much lower than the worldwide average annual effective dose 2.4 mSv/a [31]. Considering the long half-life of ^{210}Pb (22.3 years), the organs affected by inhalation of ^{210}Pb are successively bone surface, lung tissue, kidney and external thoracic cavity. And once the ^{210}Pb deposits in the respiratory systems in the form of particulate state, especially the lung, it requires a much long time to be cleared. Besides, the potential harmfulness to human body that may be caused by the coupling effect of air pollutants and radionuclides in air (like ^{210}Po and ^{210}Pb) has not yet been assessed, which asks more people to pay more attention on this risk in the future.

Conclusion

Reports focused on ^{210}Pb's associations with different air quality weather events are relatively rare in Shanghai. Haze events that occurred frequently in the past decades are undoubtedly of great concern to people and government on economy, ecology, tourism and human health in China. Monitoring the pollutants and radionuclides (e.g. ^{210}Pb) simultaneously, in different air quality weather events can help in assessing the potential harmfulness to public. In this study, seasonal variation of ^{210}Pb was observed in the urban aerosols of Shanghai during 2016–2017. The U-shaped distribution pattern of atmospheric ^{210}Pb in the East Asian regions was influenced by the East Asian Monsoon and local weather condition. The important results in this study showed that atmospheric ^{210}Pb levels increase with decreasing air qualities and the good correlations between ^{210}Pb in aerosol particles and air pollutants indicated that ^{210}Pb cooperated with other air pollutants in atmosphere, which implied that ^{210}Pb could also be used as an indicator to evaluate the health of the atmospheric environment.

Radiation dosimetry of daily inhalation of ^{210}Pb through exposure to different air quality situations for different age groups were calculated to be much lower than the worldwide average annual effective dose. However, in the future, more research is needed to assess the coupling risks of air pollutants and radionuclides in air for human health.

Acknowledgments This research was supported by the Fundamental Research Funds for the Central Universities and the SKLEC Open Research Fund (Grant SKLEC-KF201806). We also acknowledge the students (Miss Lijun Zhao and Miss Juan Du) of the RIC group in ECNU for sampling and data analysis.

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