# Wet scavenging of particle-reactive $^{210}$Po, $^{210}$Bi, $^{210}$Pb and $^{7}$Be in Shanghai, China: temporal variation, controlling factors and stratosphere invasion

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The activities of $^{210}$Po, $^{210}$Bi, $^{210}$Pb and $^{7}$Be were measured in 77 rain/snow samples collected at a site of Shanghai, Eastern China, during July 2016 to August 2019. The observed $^{7}$Be/$^{210}$Pb, $^{210}$Po/$^{210}$Pb and $^{210}$Bi/$^{210}$Pb ratios are indicative of some episodic events (typhoon, thunderstorm, cold surge, and passage or invasion of other air mass), on account of higher ratios from high-altitude upper troposphere or lower stratosphere air mass and lower ratios from low-altitude and young air mass.

The annual wet depositional fluxes of $^{210}$Po, $^{210}$Bi, $^{210}$Pb, and $^{7}$Be were estimated to vary from 2016 to 2017. The significant inverse relations between specific activities and precipitation indicated that the radionuclide removal processes can be dominated by washout or rainout process in different stage of a single rainfall event, which also have been proved by four rainfall events that occurred on September 15-16, 2016 (caused by Typhoon Meranti), October 20-23, 2016 (caused by Typhoon Haima), September 24-25, 2017 (a strong rainfall event), and August 9-11, 2019 (caused by Typhoon Lekima). In the case of September 15-16, 2016, rain, it was calculated that washout scavenging contributed less than 10% of $^{210}$Po, $^{210}$Pb, and $^{7}$Be inventories in this wet precipitation. The strong positive correlations between $^{210}$Po and $^{210}$Pb, $^{210}$Bi and $^{210}$Pb, $^{7}$Be and $^{210}$Pb wet depositional fluxes indicated that all of these four radionuclides were largely regulated by the same processes despite their different sources and somewhat different behaviors.

In approximately 20% of the cases (13 out of 67 rains) the residence times calculated from $^{210}$Bi/$^{210}$Pb and $^{210}$Po/$^{210}$Pb ratios were near concordant. In about 80% of the cases (54 out of 67 rains) the $^{210}$Bi/$^{210}$Pb ratios yielded mean residence time values of 0.4 to 5.3 days, whereas the values calculated from $^{210}$Po/$^{210}$Pb ratios varied from 3.8 to 86 days. The discordant residence times might be shown to result from the mixing of two different air masses with different age. And the very high resolution observation for the Typhoon Lekima (August 9-11, 2019) showed that this stratosphere intrusion is very strong and remarkable. Similarly, in the case of the September 15-16, 2016 rain, October 20-23, 2016 rain, and September 24-25, 2017 rain, the $^{210}$Po/$^{210}$Pb, $^{210}$Bi/$^{210}$Pb, and $^{7}$Be/$^{210}$Pb ratios were found to vary markedly and consistently within a single rainfall, and the results of September 15-16 2016 rain implied that a mixing of two air masses occurred during the heavy rainfall: one air mass was represented by a residence time of about 30 days and the other by approximately 7 days.

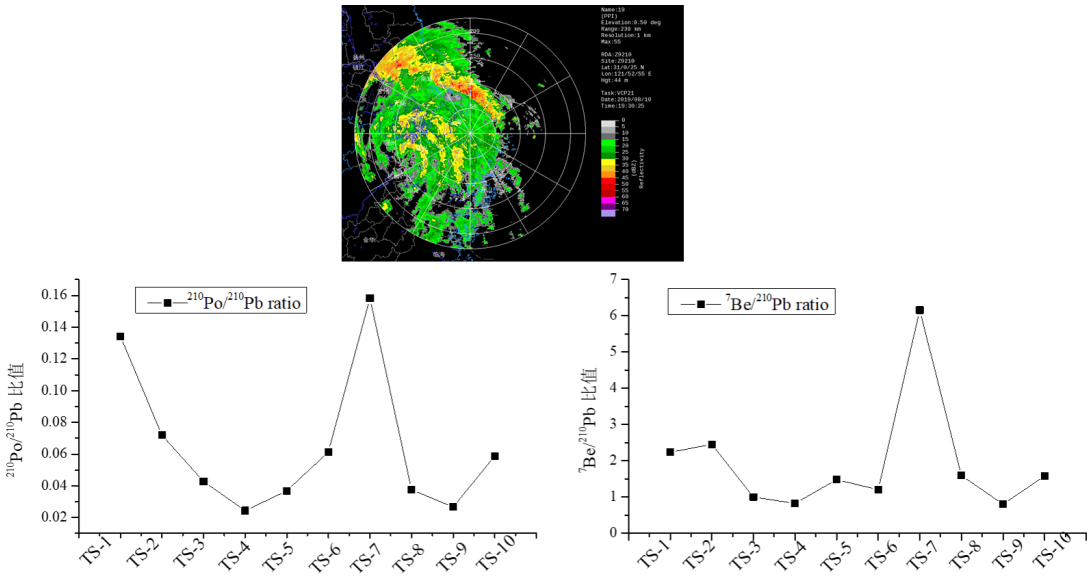


Fig.1. Activity ratios of radionuclides in rainfall event caused by Typhoon Lekima in August 9-11, 2019.