Particle growth with photochemical age from new particle formation to haze in the winter of Beijing, China

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Secondary aerosol formation in the aging process of primary emission is the main reason for haze pollution in eastern China. Pollution evolution with photochemical age was studied for the first time at a comprehensive field observation during winter in Beijing (23rd of January to 31st March 2018). The photochemical age was used as an estimate of the length of the aging process and was estimated from the ratio of toluene to benzene in this study (a low photochemical age indicates a fresh emission). The photochemical ages of air masses on new particle formation (NPF) days were lower than that on haze days, but not significantly different compared to days without NPF and haze (p value less than 0.05). In general, the strongest NPF events were observed when the photochemical age was between 12 and 24 h, while NPF was completely suppressed with photochemical ages less than 12 h and became weak with photochemical ages more than 24 h. Accordingly, the formation rate of 1.5 nm ($J_{1.5}$) and 3 nm particles (J_3) showed a peak and condensation sink (CS) showed a valley with photochemical ages ranging from 12 to 24 h. When photochemical age was larger than 48 h, haze occurred and at the same time, NPF was suppressed again. Due to the balance of increasing SO_2 concentrations and CS with photochemical age in the atmosphere, the H_2SO_4 concentration showed no obvious trend with photochemical age. The high concentrations of precursor vapours within an air mass lead to persistent nucleation with photochemical age ranging from 12 to 48 h in winter. Coincidently, the fast increase of fine particle was also observed during this range of photochemical age. Besides, CS only increased with the photochemical age in NPF days, which is likely the reason that the increasing rate of $PM_{2.5}$ mass with photochemical age in NPF days was higher than that in other days. From this point of view, although the nucleation might not be identified as an NPF event due to the high CS when photochemical age further increased and haze happened, it might continuously contribute to particle growth in the winter of Beijing. The evolution of particles with photochemical age provided new insights into understanding how particles grow from NPF to haze pollution.

Keywords: new particle formation, photooxidation, aging, PM2.5