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Black carbon concentrations in the highly polluted Kathmandu Valley, Nepal: a three year monitoring with a dual-spot Aethalometer

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Our knowledge about ambient black carbon (BC) in the vast Himalayan region, a region vulnerable to impacts of global warming, is very limited due to unavailability of a long-term ambient monitoring. Here we present results from a continuous monitoring of ambient BC concentrations, with a new generation Aethalometer (AE33), over a three year period (January 2013- January 2016) at a semi-urban site in the highly polluted Kathmandu Valley in the foothills of the central Himalaya, one of the most polluted cities in the world. This is the longest time series of BC concentrations that have been monitored with AE33 (which uses the dual-spot technique for a real-time filter loading compensation) in highly polluted ambient environment. The measurements were carried out under the framework of project SusKat (Sustainable Atmosphere for the Kathmandu Valley). BC concentrations were found to be extremely high, especially in winter and the pre-monsoon period, with the hourly-averaged values often exceeding 50 μg/m^3. BC concentrations showed a clear diurnal cycle with a prominent peak around 8-9 am and a second peak around 8-9 pm local time in all four seasons. Night-time BC was also fairly high. The diurnal cycle was driven by a combination of increased emissions from traffic, cooking activities, garbage burning, and lower mixing heights ($\sim$200 m) and reduced horizontal ventilation in the mornings and evenings. BC concentrations showed significant seasonal variations - a maximum in winter season and minimum during the monsoon (rainy) season, with monthly average values in the range 5-30 μg/m^3. An increase in emissions from the operation of over 100 brick kilns in winter and spring, and an increase in the use of small but numerous diesel power generators during hours with power cuts contributed significantly to ambient BC concentrations in the valley. Fractional contributions of biomass burning and fossil fuel combustion to BC was estimated based on a real-time method for loading effect compensation (using compensation parameter, k) implemented in the algorithm of the new dual-spot Aethalometer. This technique indicated that fossil fuel combustion (FF) and biomass burning (BB) contribute on average 70% and 30%, respectively, to ambient BC in the Kathmandu Valley. Relative contributions changed from season to season, e.g., BB fraction increased during November-December and March-April due to the seasonal increase in agro-residue burning and forest fires in the region, while FF fraction increased in winter due to increase in use of FF in brick factories and diesel generators. These measurements provided important information for understanding the properties of ambient BC and its impacts, especially on human health and climate, in the Kathmandu Valley and the surrounding foothills of the Himalayas.