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Understanding the urban rainwater chemistry, Sources and Nutrient deposition over the Middle Indo-Gangetic Plain Region

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Study of rainwater chemistry provides scientific insights into atmospheric scavenging, the source of atmospheric pollutants, and their potential effects on ecosystems. In this study, monsoonal rainwater samples were collected during five consecutive years 2018-2022 and investigated the chemical composition, temporal variability, and major potential sources affecting rainwater in Varanasi, India. The physical properties such as pH and electrical conductivity (EC) were measured using Hanna Instrument, and the concentration of major ionic species (Cl^-, F^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, Mg^{2+}, Ca^{2+}, NH_4^+, Na^+ and K^+) were determined using ion chromatography (ICS-5000$^+$). The average pH of rainwater was recorded 6.22 ± 0.45, indicating the alkaline nature of rainfall. Most of rainwater samples (91%) were alkaline, and the neutralization factors (NF) followed the order NF_{Ca} >NF_{Mg} > NF_{NH4}, with values of 1.04, 0.99, and 0.28, respectively. This shows that Ca^{2+} was the dominant neutralizing ion, which primarily neutralizing the acidic species (NO_3^- and SO_4^{2-}) over the study area.

The present study showed high nutrient deposition flux of dissolved inorganic nitrogen (NO_3^-, NO_2^-, and NH_4^+), with an average nitrogen deposition flux of 8.04 kg ha^{-1}, mainly contributed by NH_4^+-N (4.67 kg ha^{-1}) and NO_3^--N (3.36 kg ha^{-1}). In comparison, lower contribution of inorganic phosphorus deposition (PO_4^{3-}–P) flux was low (0.72 kg ha^{-1}). Enrichment and Neutralization factor analyses indicated strong crustal and anthropogenic influences, with ~99% of Ca^{2+} and ~98% of SO_4^{2-} originating from non-marine sources. Positive Matrix Factorization (PMF) analysis resolved fossil fuel and biomass burning, sea salt, crustal dust and agricultural emissions as the dominant source factors, demonstrating the combined contribution of both natural and anthropogenic inputs to rainwater chemistry in Varanasi. The wind circulation pattern over IGP region further showed influenced by both local emissions and long-range transport, particularly from the Bay of Bengal and the western regions of India.