LETTER

# Reduced nitrogen dominated nitrogen deposition in the United States, but its contribution to nitrogen deposition in China decreased

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Recently, Li et al. (1) report that reduced nitrogen (N) dominated both wet and dry deposition of inorganic N, following long-term N oxides ($NO_x$) emission controls introduced in 1990. They systematically compare wet deposition of inorganic N, measured by the US National Atmospheric Deposition Program (NADP) between 1990–1992 and 2010–2012, and calculate N dry deposition from measurements of concentrations made by Clean Air Status and Trends Network, NADP Ammonia Monitoring Network, and Interagency Monitoring of Protected Visual Environments $NH_x$ in 2011–2013. Their results show the transition from oxidized N-dominated wet deposition in the early 1990s to reduced N-dominated wet deposition in the early 2010s. According to their analysis (1), this transition reflects increases in agricultural ammonia ($NH_3$) emissions and the success of regulatory policies in decreasing $NO_x$ emissions, which was consistent with an earlier report on wet deposition (2). If correct, this is a significant change that needs to be noted by the science community and policy makers working to reduce atmospheric pollution in the United States (3).

In rapidly developing countries like China, however, with the simultaneous intensive growth in industry and agriculture, another N deposition pattern was observed. Liu et al. (4) found that wet (i.e., bulk) N deposition increased significantly (with average increase of 0.41 kg N·ha$^{-1}$·y$^{-1}$) while the ratios of reduced N to oxidized N in precipitation decreased significantly between the 1980s (~5.0) and 2000s (~2.0). Their N deposition data were consistent with China's national $NH_3$ and $NO_x$ emission trends and similar decreasing ratios of $NH_3$–N:$NO_x$–N from 1980 to 2010, suggesting the increased importance of oxidized N emissions and deposition in China. More recently, Xu et al. (5) reported that the reduced N content of wet deposition was on average 55% (34–71%) in the early 2010s (2010–2014) (5), compared with 62% between the mid-1990s and 2000s (6) and 80% in the 1980s (4). Although reduced N still dominates N deposition in China especially in northern China (7), oxidized N has been increasing in importance and will soon dominate, unless strict emission control measures are adopted (8).

One other important point to note is that Li et al. (1) do not include dry $NO_2$, dry particulate organic N, and wet organic N deposition in total N deposition estimate. Benedict et al. (9) showed the deposition of these N species can be up to 0.7 kg N·ha$^{-1}$·y$^{-1}$ in the Rocky Mountain area. Moreover, Li et al.'s important finding fails to consider particulate ammonium and nitrate dry deposition from coarse particles. This omission will especially lead to an underestimation of dry nitrate deposition because the majority of the dry-deposited nitrate results from coarse particulate matter rather than fine particles (e.g., $PM_{2.5}$) (7). Taken together, Li et al. (1) may have therefore calculated a higher contribution of reduced N in total N deposition budget. If wet and dry deposition of the non-included N species (i.e., $NO_2$, coarse nitrate, and organic N) averaged 1 kg N·ha$^{-1}$·y$^{-1}$, the reduced N contribution to total N deposition in the United States would be no more than 50%. Assuming that reduced N, essentially $NH_3$, dominates, emissions and deposition could result in inappropriate air pollution policies.

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