Stable isotopic evidence for the excess leaching of unprocessed atmospheric nitrate from a forested catchment in Fukuoka, Japan

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Forest ecosystems are deficient in nitrogen in general. Excess loading of nitrogen, however, often leads to “nitrogen saturation” (Aber et al., 1989) in forest ecosystems from which significant quantify of nitrogen is eluted as nitrate. The forested stream eluted from Fernow Experimental Forest USA, for instance, showed elevated average nitrate concentration of 60 μM, so that the forest has been classified into stage 3, the highest stage of nitrogen saturation (Rose et al., 2015). Such enrichment of stream nitrate often caused environmental problems such as degradation of water quality, eutrophication, and N_2O emission in downstream area.

In recent, Chiwa (2021) reported the average concentrations of the forested streams eluted from FK catchments (FK1 and FK2) in Kasuya Research Forest, Kyushu University (Japan), were more than 90 μM, implying that the forested catchments were under the extraordinary high nitrogen saturation stage. In order to verify that the forested catchments (FK1 and FK2) were under the high nitrogen saturation stage, we determined the export flux of unprocessed atmospheric nitrate relative to the entire deposition flux (M_{atm}/D_{atm} ratio) in the catchments, based on the ^{17}O-excess of nitrate eluted from the catchments, because Nakagawa et al. (2018) proposed this M_{atm}/D_{atm} ratio in each forested catchment as an objective, more reliable index to clarify each nitrogen saturation stage. Specifically, we determined temporal variation in the concentrations and stable isotopic compositions, including $\Delta^{17}O$, of stream nitrate in the FK catchments for more than two years. Besides, the same parameters of the MY forested catchment in Shiiba Research Forest, Kyushu University (Japan) were also monitored during the same period for comparison, where the average stream nitrate concentration was low. While showing the average nitrate concentrations of 109.5, 94.2, and 7.2 μM in FK1, FK2, and MY, respectively, the catchments showed average $\Delta^{17}O$ values of +2.6, +1.7, and +0.6 ‰in FK1, FK2, and MY, respectively. As a result, the average concentration of unprocessed atmospheric nitrate ($[NO_3^-{}_{atm}]$) were estimated to be 10.8, 6.1, and 0.2 μM in FK1, FK2, and MY, respectively, and the M_{atm}/D_{atm} ratio were estimated to be 15.1, 8.5, and 1.1 % in FK1, FK2, and MY, respectively. The M_{atm}/D_{atm} ratio determined in FK1 (15.1 %) were the highest ever reported from temperate forested catchments. Thus, we concluded the nitrogen saturation was responsible for the enrichment of nitrate in the streams of FK catchments, together with the elevated $NO_3^-{}_{atm}$ leaching from the catchments. Additionally, we found that all the data of M_{atm}/D_{atm} ratios reported for the forested catchments with the annual precipitation more than 1000 mm in the word showed clear normal correlation with the average concentration of stream nitrate, indicating that the M_{atm}/D_{atm} ratio in each forested ecosystem can be a robust index for nitrogen saturation.

Keywords: nitrogen saturation, forest stream, Matm/Datm ratio

