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Meaning of mean residence time for the biogeochemical responses of streamwater in a forested headwater catchment

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Effects of annual variation of climate conditions or residence time distributions of ground- and streamwater on long-term variations of streamwater chemistry are discussed in a forested headwater catchment, Kiryu Experimental Watershed (KEW), Japan, where hydrochemical observations have been continuing in recent two decades. The entire area of KEW is underlain by Cretaceous biotite granite, called the Tanakami granite. Mean annual precipitation was 1639.0 mm from 1990 to 2010.

In KEW, episodic increases in nitrate concentrations in streamwater due to the partial dieback of red pine trees since the end of 1980's were observed. Many of the blighted trees fell down by the typhoon No.26 at September 1994. On the other hand, the stream nitrate concentrations began to increase in 1993, peaked in 1995?97, and are then slowly decreasing. The concentrations at 2010 were about one fourth of those at the peaked values, and have not yet recovered to the pre-disturbance values. Such time lag is caused by the delay of decomposition, nitrogen leaching from dead woods, and transport through groundwater flow to the stream. The mean residence time of the streamwater estimated with oxygen isotope variation is 43 months. Considering the weighting function used in this estimation, the contribution of 1-year-age water is maximal, even though 10 or more older water is also contribute to the streamwater. Therefore, the dynamics of nitrate concentrations in streamwater are successfully explained by the weighting function, or the distribution of residence time.

The long-term variations of chloride concentrations showed the decreasing trend till around 2000, and then constant. The decreasing trend might be achieved by the decrease of chloride input because the dry chloride deposition was not collected by the forest canopy after the disturbance. Although the forest canopy is now almost closed, the groundwater has not fully turned over yet, and the concentrations have not yet recovered.

These results mean that the 'apparent' forest disturbance may relatively soon recover, however, these effects on the streamwater chemistry through the groundwater dynamics will persist for a long time. The mean residence time is one of the essential information to consider such prolonged phenomena, and thus, the long-term observation is of necessity important.

Keywords: Forested headwater catchment, Mean residence time, streamwater, hydrochemistry, Long-term observation