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Estimating the mean transit time of runoff water during storm flow using the step shift of chloride input following forest cutting at a headwater catchment in Japan

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Transit time, i.e., the time subsurface water spends within a catchment, is a fundamental parameter that provides information on the storage, flow pathways, and source of water in a catchment. Many studies have used the temporal variation of tracer concentrations, such as stable isotopes of water (18O and 2H), tritium (3H), and chemical tracers (Cl–), in precipitation, runoff, and subsurface water to estimate transit time distributions using a lumped parameter approach.

In most studies, the estimated transit times do not represent the catchment transit time because the inputs and streamwater samples were collected weekly or monthly (McGuire and McDonnell, 2006). Weekly or monthly monitoring of streamwater chemistry or isotopes cannot capture the signal of water that has a short transit time.

We used 7 years of input and output data sampled weekly, and output data samples obtained at 20- to 60-minute intervals during more than ten storm events following forest cutting at the Fukuroyamasawa Experimental Watershed, in Japan. Land use changes, including forest cutting, have dynamic influences on stream water quality. The time series of the concentrations of conservative tracers, such as Cl–, reflects the replacement of water by newly supplied water after forest cutting. We assumed that when the discharge rate was the same, the water flow path and transit time were the same. The time series of the Cl– concentration when the discharge rate was 10 mm/hr, which was the highest discharge rate in this catchment, was determined from the time series of discharge-concentration relationships. The mean transit of runoff water during storm flow (Q=10 mm/hr) was 400 to 600 days. This showed that the mean transit time exceeded 400 days and the estimated water storage contributing to runoff exceeded the storage capacity in the soil layer, indicating that bedrock groundwater contributed significantly to streamwater runoff.