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Temporal variation of transit time of rainfall-runoff water and groundwater flow dynamics inferred by noble gasses concentration (SF_6, CFCs) in a forested small catchment (Fukushima, Japan)

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Time variant transit time of water in catchments can fundamentally describe catchment function, controlling rainfall-runoff generation, groundwater flow pathway and water storage. Though rainstorm event has been recognized as active phase on catchment hydrology, accurate and precise time variance of water transit time and related water dynamics during rainstorm have not been well clarified yet. Here, in order to reveal temporal variation of mean transit time of groundwater and related hydrological processes in a forested small catchment during rainstorm event, periodic and intensive field observations (15 - 17^{th} July 2015, rainfall of 100.8 mm in total) were conducted in Yamakiya district (Fukushima, Japan) from September 2014 to December 2015. Discharge volume, groundwater table and precipitation amount were measured in 10 minutes interval. Water samples were taken from groundwater, discharge water, soil water and precipitation for determination of stable isotopic compositions (δ^{18}O, δ^{2}H), inorganic solutes concentration and dissolved noble gasses concentration (CFC11, CFC12, CFC113, SF_6) in water.

Storm hydrograph and groundwater table clearly responded to rainfall event especially with more than 30 mm per day throughout monitoring period. According to SF_6 concentration in water, the mean transit time of discharge water (perennial spring) showed 3 - 6.5 years in the no-rainfall period (steady state), but fluctuated from zero to 12.5 years in the rainstorm event with totally 100.8 mm (unsteady state). The mean transit time of discharge water dramatically altered from zero to 12.5 years from before to after the tentative hydrograph peak in the rising limb, indicating new water components were dominant before tentative hydrograph peak, whereas deep groundwater component with longer residence time contributed much to discharge after the tentative hydrograph peak. On the other hand, mean residence time of groundwater (water in 5 m well) ranged from 0.5 to 11.5 years during the rainstorm event, which followed temporal transit time variation of discharge water. Stable isotopic compositions and chloride ions as conservative tracers presented clear different signals between rainfall and discharge water, and chloride ion concentration in discharge water increased to as high as deeper groundwater (water in 20 m well) just after tentative hydrograph peak in the rising limb. Additionally, CFCs concentration especially in discharge water obviously decreased below the level of current atmospheric CFCs concentration. All of the facts suggest that the contribution of deep groundwater with longer residence time for the discharge water becomes significant at the jumping phase of runoff during intense rainfall, causing dynamic change of groundwater flow system in a catchment.