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INVESTIGATION OF HYDROLOGICAL INTERACTIONS IN THE CHAO PHRAYA RIVER SYSTEM IN BANGKOK USING STABLE ISOTOPIC COMPOSITIONS AND HYDROCHEMICAL FACIES

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Stable isotopic compositions of water ($\delta^{18}O$ and $\delta^{2}H$) have been used as environmental tracers to understand the complicated hydrogeological processes such as paleoclimate, groundwater-surface water interactions, groundwater recharge, and precipitation sources. The isotopic signatures in precipitation and groundwater identify the recharge processes and their hydrological connectivity. Therefore, the present study focuses on a detailed seasonally varying interaction and flux quantification between the river and monsoon precipitation and groundwater in the Chao Phraya River basin. This river system feeds an enormous population in central Thailand. Therefore, hydrological interaction and groundwater chemistry are necessary for the effective strategy of water conjunction.

The Chao Phraya basin is the largest watershed in Thailand, covering 35% of the country and draining 157,924 km^2. The precipitation amount is controlled by two monsoons (southwest and northeast monsoons) with 1160 mm of annual precipitation. The study area is in the mainstream, 372 km long, and covers a basin area of 20,126 km^2. Precipitation generates 23,346 million m^3 of annual runoff. The high-flow period starts from May to October, which accounts for 74% of the runoff of the entire year. The groundwater aquifer forms the geological basis as a depositional flood plain from North to Southeast with mountains of volcanic rocks surrounded in the West. The aquifer system was defined as a two-layered aquifer with the thickness of the upper, semi-confining layer varying between 10-70 m and lower confining layer between 100-300 m based on the geological conditions of similar hydrogeologic properties and their confining boundaries.

Water samples were collected in Bangkok during 2013-2015 and 2019. Most samples were shallow groundwater, precipitation, and the Chao Phraya River. Water $\delta^{18}O$ and $\delta^{2}H$ values were measured using a cavity ring-down spectroscopy isotopic water analyzer (L2130-i, Picarro Inc., Sunnyvale, CA, USA) at the Thailand Institute of Nuclear Technology and reported relative to the Vienna Standard Mean Ocean Water (VSMOW). The analytical precision (1σ) for $\delta^{18}O$ and $\delta^{2}H$ were 0.16 ‰ and 0.45 ‰, respectively. Furthermore, samples in 2019 were also measured for hydrochemical facies using an ion chromatography analyzer (Systronics, 883 Basic IC plus) at the Isotope Hydrology Laboratory in Kumamoto University.

Based on the isotope of precipitation, river water, and groundwater, the mean isotope of surface water was highest compared with others. It can be attributed to the evaporative enrichment in river water as its fundamental characteristic. On the other hand, the rainfall isotope had a wider range. This result is indicative of the altitude effect in the basin. Moreover, the relationships of $\delta^{18}O$ and $\delta^{2}H$ in precipitation are shown as the LMWL. Groundwater and river water fell along this LMWL, indicating that precipitation is the primary source supplying groundwater aquifer and river runoff.

Moreover, contributing parameters to the total river discharge on a temporal scale were estimated through three-component hydrograph separation and end-member mixing analysis using high-resolution water isotope ($\delta^{18}O$) and electrical conductivity. This model reports groundwater discharge in the river to be the highest in the dry season (26% of total discharge). In contrast, the contribution lowers to 2% during the monsoon. Monsoon precipitation directly generates river runoff during monsoon, which is also justified using the isotopic amplitude damping approach of river water and precipitation. The mean water residence time is about 30 days, meaning that monsoon precipitation molecules have stayed in the river for a month. Furthermore, hydrological interaction reflects quantitative variability depending on river morphometry.

The current study also provides insight into aquifer vulnerability due to chemical mixing through interaction and reasonable water resources management efforts. The results of the chemical analysis of 266 groundwater samples were evaluated by using the Piper diagram. The groundwater was generally found in 3 main types: Na-K-CO_3-HCO_3, Na-K-Cl-SO_4, Ca-Mg-CO_3-HCO_3. The shallow groundwater in the coastal areas had a high concentration of Na-K-Cl-SO_4. Furthermore, evaluation of the groundwater types suggested a mixing process between the upstream freshwater and saline water showing in the shallow groundwater. There was a clear indication of the contribution from the weathering of rocks. The dissolution of the minerals was the primary process occurring in the groundwater environment. Dominated Ca and Mg elements in groundwater were found in the upstream area, representing the recharge water. However, the dominance of Na and HCO_3 suggested an ion exchange process owing to sufficient rock-water interaction. The Na and Cl ions dominated the lower basin area, which represented the discharge zone and possible salt intrusion from saline water.

In conclusion, this study integrated the isotopic compositions of precipitation-river-groundwater in the lower Chao Phraya River basin for investigating a hydrologic interaction. The comparison result of water isotope suggests that the monsoon precipitation supplies the river water directly during the wet season. However, groundwater discharge increased during the post-monsoon season due to decreasing upstream runoff and rainfall, representing a distinct seasonal variation of river components. Furthermore, the result of the hydrochemistry suggests that the groundwater in the lower Chao Phraya river basin is alkaline type in nature. The groundwater quality is controlled by the cation exchange process, mineral dissolution, and saltwater intrusion. These findings are helpful information in understanding the hydrogeological processes at the rainfall-river-aquifer boundary and how they are connected to the geochemical processes and the policies for conjunctive water allocation.

Keywords: Isotopes, Hydrochemistry, watershed