Potential effects of rain intensity and evaporative loss on the stable isotope compositions of surface water in Kamphaeng Phet, Thailand

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Abstract. To understand the hydrological regime of the surface water in Kanu Woralaksaburi district, Kamphaeng Phet province, the rainwater and surface water were analysed on the isotopic variability of hydrogen (δ²H) and oxygen (δ¹⁸O) collected over 3 years from 2015-2017. Surface water evaporation was verified on the basis of the isotope composition results. Based on a total of 213 rainwater samples and 152 surface water samples, stable isotope analysis was carried out and the Local Meteoric Water Line (LMWL) was defined as δ²H = 7.703 δ¹⁸O -1.333, R² = 0.952 while the Local Evaporation Line (LEL) of surface water was δ²H = 5.318 δ¹⁸O -17.618, R² = 0.935. It was observed that the isotope compositions of surface water have a linear relationship with precipitation (R² = 0.935). However, the small slope of 5.318 indicated the enrichment effect of evaporation. Depleted isotopic compositions of surface water revealed in wet season and enriched δ²H and δ¹⁸O were found in dry season with less precipitation, lower humidity and higher temperature. Presented data imply that the isotopic composition of surface water in semi-arid area of Kamphaeng Phet is predominantly due to rain intensity and evaporative loss.

1. Introduction

Water is the basic factor that influences the structure formation, development and stability of freshwater ecosystems. Due to population growth and economic development, water demand for domestic, agriculture and industrial is increasing. Water scarcity and limit of water sources are severely resulted from climate variability and climate change, with less precipitation and more extreme weather events. It is requires to improve understanding hydrological processes for implementing water resources management.

The hydrology of semi-arid areas of Kamphaeng-Phet is particularly sensitive to short and long term changes in climatic processes. The region shows a low intensity of predominantly summer and winter precipitation. The surface water in the area is mountain river water which is fed by precipitation. The Khao Chon Kan rain-fed river reveals water level rapidly fluctuating within a single year [1]. Precipitation input and evaporation loss of river water plays an important role in the hydrological cycles in this region. However, traditional investigations are inconvenient for estimating evaporation loss in such ungauged river. They are generally impractical, time consuming and costly in areas where lack appropriate infrastructure. Determination of evaporation losses and overall estimation of water budgets, particularly in highly dynamic systems can be challenging due to uncertainties in monitoring of water flow and volume measurements of water bodies. In using conservative ions
concentrations such as Cl for assessing evaporative losses are found to be limited to areas where a significant portion of salt can be recycled during subsequent wetting and drying cycles and also where transpirations are significant [2]. Water stable isotopes (\textsuperscript{2}H\textsubscript{16}O, \textsuperscript{2}H\textsubscript{18}O, HDO) are well-known powerful tracers to understand hydrological cycle. The application of stable isotope technique to study the evaporation of water bodies is indicated highly effective, especially in the semi-arid region. Improving knowledge of water isotope ratios can help increase understanding of the mountainous hydrological cycle in the study area [3].

The aim of this study are (1) to provide the δ\textsuperscript{2}H and δ\textsuperscript{18}O compositions in precipitation and surface water of Pang Makha sub district, Khanu Woralaksaburi district, Kamphaeng-Phet province and (2) to evaluate the potential effects on the δ\textsuperscript{2}H and δ\textsuperscript{18}O compositions in the surface water.

2. Methodology
2.1 Overview of study area
This study was conducted at the semi-arid Pang Makha sub district, Khanu Woralaksaburi district, Kamphaeng-Phet province in Thailand. It is approximately 358 kilometers away from Bangkok. (figure 1). The area situates in the lower north with undulating mountains in the west, which are the origin of the province’s streams and tributaries. Kamphaeng-Phet has low fertility fine-textured sandy loam soil, which has poor water-retention capacity and dries rapidly after rains. The water resources of the area are groundwater and river water originates from Khao Chon Kan Mountain. The river water runoff during wet and dry season fluctuates significantly; the high flow period starts from August to October. After October, the flow declines gradually, and the driest or the drought period occurs in February to May. Total area of the province is 8,607.5 square kilometers; arable land covers 66.52 % and paddy field of 31.12% which equal to 46.78% of total arable land area. Kamphaeng-Phet’s climate is classified as tropical with the temperature averages of 27.6 °C and precipitation falls annually of 1,027 mm. The Köppen-Geiger climate classification is Aw [1].

![Figure 1 Location of the study area in the Pang Makha sub district, Khanu Woralaksaburi district, Kamphaeng-Phet province, Thailand](image)

2.2 Rainwater and surface water sampling
Field sampling of the surface water samples were conducted every week during 2015-2017. Furthermore, daily rainfall events were sampled for the same period at the studied site. Sampling procedures for precipitation were in accordance with the International Atomic Energy Agency (IAEA) guidelines [4]. Water samples were collected in clean PE bottles and closed tightly to prevent evaporation. All samples were stored in an ice box during transported to the laboratory which was kept in the refrigerator (4°C) after arrival prior to analysis. The air temperature (°C), relative humidity (%), and precipitation amount (mm) were recorded routinely each day.

2.3 Stable isotope analyses
The isotope compositions of both rainwater and surface water were analyzed using a Cavity Ring-Down Spectrometer Analyser Picarro model L2130-i (Picarro, California, USA). Each sample was
analyzed six times and the first three results were discarded in order to minimize any instrument memory effect. The $\delta^2$H and $\delta^{18}$O raw values of samples were normalized to the VSMOW (Vienna Standard Mean Ocean Water) scale, based on three laboratory standards, each replicated twice and reported in per mil ($\%$) following the principles of the three point normalization [2]. The measurement accuracies (one standard deviation) was determined as $\pm$ 0.8‰ for $\delta^2$H and 0.06-0.08 for $\delta^{18}$O.

The isotope ratios of $^{18}$O/$^{16}$O and $^2$H/$^1$H in the water samples were expressed as per mille ($\%$o) deviation relative to the Vienna Standard Mean Ocean Water (V-SMOW) as shown in equation 1

$$\delta \% = \frac{R_{sample}/R_{VSMOW} - 1}{x 1000}$$ (1)

where $R$ represents the ratio of heavy to light isotopes ($^2$H/$^1$H or $^{18}$O/$^{16}$O) in the sample and standard, respectively. The oxygen and hydrogen isotope ratios are expressed as $\delta^{18}$O and $\delta^2$H.

Deuterium excess (d-excess) was calculated from the following equation 2 [2-6]:

$$d\text{-excess} (\%o) = \delta^2H - 8 \delta^{18}O$$ (2)

3. Result and Discussion

The $\delta^2$H and $\delta^{18}$O values of 213 rainwater and 152 surface water samples were plotted on the $\delta^2$H and $\delta^{18}$O diagram which is presented in figure 2.

![Figure 2 Plot of $\delta^2$H versus $\delta^{18}$O of rainwater and surface water](image)

The $\delta^2$H and $\delta^{18}$O values of rain event samples collected in Kamphaeng Phet province over 3 years from 2015-2017 ranged from -113.56 to 84.64‰ and -15.20‰ to 10.48‰, respectively. Linear regression of temporal $\delta^2$H versus $\delta^{18}$O for rainwater resulted in a Local Meteoric Water Line (LMWL) of $\delta^2$H = 7.703 $\delta^{18}$O -1.334, $R^2$ = 0.952, n = 213. The isotopic signatures $\delta^2$H and $\delta^{18}$O of surface water samples ranged from -80.36‰ to 50.82‰ and -11.35‰ to 13.19‰, respectively. The linear regression equation of Local Evaporation Line (LEL) was $\delta^2$H = 5.319 $\delta^{18}$O -17.619, $R^2$ = 0.935, n = 152.

The regression line of the surface water showed a significant shift from the precipitation and had a smaller value slope (~5) than the meteoric-line of the Kamphaeng Phet area (~7) indicating an occurrence of evaporation process [6, 7]. It was observed that $\delta^2$H and $\delta^{18}$O of surface water were coincident with higher air temperature, lower humidity, and less precipitation, with enriched values in dry season and depleted values in wet season. These findings suggested that the effect of evaporative loss signaled in $\delta^2$H and $\delta^{18}$O composition of surface water.

Most values of the deuterium excess (d-excess) of precipitation and surface water were much lower than 10‰ (figure 3). The d-excess of rainwater ranged from -20.37‰ to 19.37‰ while of surface water ranged from -54.78‰ to 14.10‰.
The low d-excess of precipitation in Khanu Woralaksaburi district would be caused by the semi-arid characteristics of the area with low amounts of recycled moisture evaporated from the large water body mixing with atmospheric vapors [7]. The trend line of average d-excess in each month of rainwater was observed compatible with surface water as shown in figure 2. The plotted of d-excess values of rainwater against the month of the year clearly coincided with the intensity rainfall event. The similarity of d-excess trend lines of rainwater and surface water indicated that rain intensity in daily events influenced $\delta^2$H and $\delta^{18}$O signatures of surface water. When plotted $\delta^{18}$O of surface water with precipitation (mm), the isotope composition of surface water has a linear relationship with precipitation ($R^2 = 0.2$). The low $R^2$ has been reported in the arid region around the Tarim river basin, northwestern China ($R^2 = 0.3$) due to the drought climate of the area [8].

4. Conclusion

The $\delta^2$H and $\delta^{18}$O composition of 213 precipitation daily events and 152 surface water samples collected during 2015 - 2017 in the semi-arid region of Khanu Woralaksaburi district, Kamphaeng Phet province were investigated. The Local Meteoric Water Line (LMWL) of $\delta^2$H = 7.703 $\delta^{18}$O - 1.334, $R^2 = 0.952$, $n = 213$ was established while the linear regression equation of Local Evaporation Line (LEL) was $\delta^2$H = 5.319 $\delta^{18}$O -17.619, $R^2 = 0.935$, $n = 152$. It revealed the $\delta^2$H and $\delta^{18}$O signatures of surface water were depleted in wet season and more enriched in dry season. These findings were coincident with high air temperature, low humidity and less precipitation. The plotted of average d-excess values against precipitation amount (mm) of surface water and rainwater were comparable. It suggested that the variability of isotopic composition of surface water change with the potential effect of rain intensity and evaporative loss.

References

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