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Characteristics of the stable isotopes (δ ^{18}O and δD) composition in precipitation from Bangkok, KamPhaeng-Phet and Suphanburi, Thailand

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Abstract

The stable isotopic (δ^{18}O and δD) and water chemical compositions of the precipitation collected from Bangkok (BKK), Kamphaeng-Phet (KPP) and Suphanburi (SPB) in 2015 were performed. All water samples were weakly alkaline and the major ion (Cl^-, SO_4^{-2}, Na^{+1}, K^+) were the same magnitude with low values. The results of isotopic measurements for BKK, KPP, and SPB shown a wide magnitude of variations ranging between -12.22 to 0.51 , -11.78 to 5.45 and -15.50 to 0.73, in δ^{18}O (‰) and between -114.49 to 1.43, -86.41 to 27.29, and -81.74 to 2.79, in δD (‰), respectively. Both δ^{18}O and δD decreased significantly from BKK to SPB and KPP and from cold to warm season because of the evaporation-induced isotopic enrichments. The results of this study revealed the exact relationship between δ^{18}O and δD of precipitation changes from geographical region to region which depending on local climatic conditions. The average annual rainfall of δ^{18}O and δD for BKK, KPP and SPB were indicated the same derived source of precipitations. These isotopic data provide important baseline information of the regional characteristics of δ^{18}O and δD of meteoric water including produce maps of mean annual isotopic values of precipitation in the country.

Keywords: Stable isotope (δ^{18}O and δD), D-excess, Precipitation, Average annual rainfall

1. Introduction

The stable isotopes of ^{18}O and deuterium are components of water molecule which originate with meteoric processes. Therefore, they offer a broad range of possibilities for studying processes within the water cycle. Precipitation or rainwater is the most important input to hydrologic systems and one of the major factors of the climate system. Local meteoric water line or linear δ^{18}O - δD relationships based on local precipitation measurements of at least a 1-year period have been very useful for investigating hydrology, (groundwater recharge) meteorology and climatology (moisture origin and transport pathway, characteristics of the Asian monsoon), palaeo-climatology (climate change) and ecology (water balance in ecosystem and water use efficiency of plants)[1-4].

The objectives of this study are therefore (1) determine characteristics of stable isotope composition in precipitation in Bangkok, Kamphaeng-Phet and Suphanburi province, Thailand; (2) identify the major environmental control on δ^{18}O and δD; and (3) describe briefly deuterium excess. These isotopic data provide important baseline information of the regional characteristics of δ^{18}O and δD of meteoric water including produce maps of mean annual isotopic values of precipitation in the country

2. Materials and methods

Sampling and analytical method

Three rain collectors were installed outside in Phasi-Charoen, Bangkok; Sriprachan, Suphanburi and Khanu-Voralukburi, Kamphaeng-Phet province. Precipitation was collected in 2015 during both wet and dry period for oxygen and hydrogen isotopic analyzes including major ion (anion and cation), pH and electrical conductivity determination. Meteorological variables of precipitation amount (mm), temperature (^{0}C) and relative humidity (%) were recorded at each observation stations. Sampling procedures for precipitation were in accordance with IAEA guidelines [2]. After each daily rainfall event, rain water was collected and immediately transferred to a 50 mL polyethylene bottles, tightly capped and stored in an ice box and refrigerated at 4^{0}C to avoid evaporation until laboratory analysis. A Cavity Ring-Down Spectrometer analyzer (PICARRO model L2130-1) and the Ion Chromatography (Dionex LCS-3000) were used to analyze the isotopes and ion elements, respectively.

The isotope ratios of ^{18}O/^{16}O and D/H in the water samples were expressed as per mille (‰) deviation relative to the Vienna Standard Mean Ocean Water (V-SMOW):

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Table 1 Information of rainwater sampling stations and results

Location	***Bangkok***	***KamphaengPhet***	***Suphanburi***
Latitude of sampling point	13^0 72 125” N	05^0 53’ 760” N	06^0 39 240” N
Longitude of sampling point	100^0 452’ 553”E	17^0 61’ 060” E	16^0 04’ 818” E
Altitude (meter above sea level)	1.5 – 2.5	40 - 60	3 - 10
Land used	Orchard	Paddy field	Paddy field
Distance from the Gulf of Thailand	29	387	127
Average annual temperature (^{0}C)	27.6	26.2	25.8
Mean relative humidity (%)	79.6	73.2	71.1
Average pH	7.04	6.27	6.43
Average conductivity (μs/cm)	17.25	42.19	50.72
Number of monthly samples	79	56	39
Precipitation (mm)	1433.1	2153.9	2559.2
Regression line equation	$\delta D = 7.398\delta^{18}O + 5.739$	$\delta D = 7.317\delta^{18}O + 3.718$	$\delta D = 7.527\delta^{18}O + 5.625$
δD range (‰)	-114.49 to 1.43	-86.41 to 27.29	-81.74 to 2.79
δ^{18}O range (‰)	-12.22 to 0.51	-11.78 to 5.45	-15.50 to 0.73
$w\delta$D (‰)	-35.77	-53.35	-42.41
$w\delta^{18}$O (‰)	-5.48	-7.63	-6.24
d-excess range (‰) and d-excess mean (‰)	19.89 to -5.21 8.08	16.60 to -16.31 5.93	26.40 to -8.36 7.87

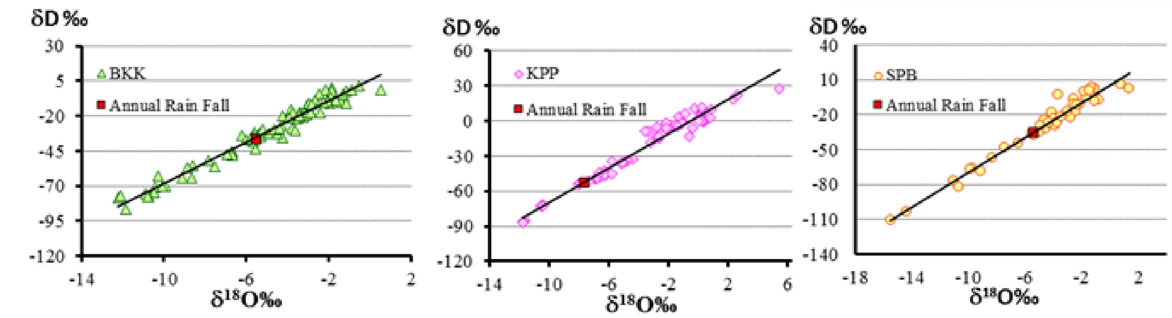

Figure 1 Linear δ^{18}O - δD relationship based on precipitation measurement in 2015

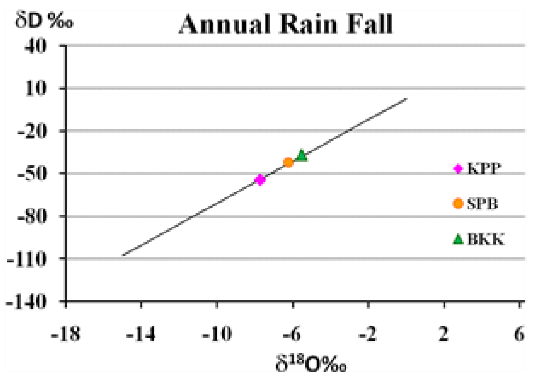

Figure 2 The $w\delta^{18}$O - $w\delta$D annual rainfall of each location

$$\delta(‰) = (R_{sample}/R_{V\text{-}SMOW} - 1) \times 1000 \quad (1)$$

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

The volume-weighted mean of δ values denoted as $w\delta^{18}$O and $w\delta$D for each month and the annual value for each locality were computed from the formulation:

$$w\delta = \frac{1}{p}\sum_{t=1}^{12}(pt \times \delta t) \quad (2)$$

where p represents the annual amount of precipitation*: pt* and δt are rainfall amounts and isotopic composition for each month, respectively. Deuterium excess (d-excess) was calculated from the following equation [1-3]:

$$\text{d-excess (‰)} = \delta D - 8\,\delta^{18}O \quad (3)$$

3. Results

Fundamental information and results for each stations are listed in Table 1.

4. Discussion

All water samples were weakly alkaline and the major ion (Cl^-, SO_4^{-2}, Na^{+1}, K^+) were the same magnitude with low values. In three localities, d-excess values in ‰ varied widely from 19.89 to -5.21 (BKK); 16.60 to -16.31 (KPP) and 26.40 to -8.36 (SPB) with a mean values of 8.08, 5.93 and 7.87, respectively. The annual mean d-excess values in precipitation were all below 10 ‰ of the Atlantic Ocean moisture [5]. The low values (<10 ‰) suggested drought climate increased from BKK > SPB > KPP and no additionally source of moisture. The d-excess values are used for comparison because in some cases with occasionally very sparse precipitation, the unweighted mean δ values maybe heavily influenced few months, in which case the greater or lesser extent of evaporation from falling drops cause extreme δ values to deviate from normal [1, 6].

The relationship between precipitation δ^{18}O and δD of BKK, KPP and SPB are shown in Figure 1. The regression line equation of the meteoric line of BKK, KPP and SPB are $\delta D = 7.398\delta^{18}O + 5.739$; $\delta D = 7.317\delta^{18}O + 3.718$ and $\delta D = 7.527\delta^{18}O + 5.625$, respectively. The δ^{18}O - δD relation is a useful means for studying the local isotope turnover and its relationships with larger pattern on the global scale [7-8]. The seasonal variations in δD and δ^{18}O of rainfall were obvious in the BKK, KPP and SPB. Enriched values were mainly associated with low dry season showers and depleted values with heavy "Vamco" depression showers suggesting an amount effect. The isotopic enrichments characterized low convective activity before and after the onset of the "Vamco" depression in all localities. The abrupt isotopic change (depletion) after the transition phase marked the depression onset in the region. High convective activity during the monsoon, typhoon and depression peaks was characterized by isotopic depletion [5-6].

The $w\delta^{18}$O - $w\delta$D annual rainfall of each location was shown in Figure 2. The slight isotopic depletion of rainfall in KPP with increasing distance from the sea indicated an apparent continental and altitude effect. However, all data were fall on the local meteoric water line (LMWL) probably reflected the same derived source of precipitations [9-10].

5. Conclusions

Stable isotopes and major ion concentrations in daily rainfall record during 2015 in Bangkok metropolitan, Kamphaeng-Phet and Suphanburi province have been investigated. Results shown wide and distinctive stable isotope variations that ranged from -15.50 to +5.45 ‰ for δ^{18}O and -114.49 to +27.29 ‰ for δD. The regression line equation of the meteoric line of BKK, KPP and SPB are $\delta D = 7.398\delta^{18}O + 5.739$; $\delta D = 7.317\delta^{18}O + 3.718$ and $\delta D = 7.527\delta^{18}O + 5.625$, respectively. Rain information processes in three areas, as reflected by δ^{18}O - δD relation indicated amount effect while d-excess shown the anomaly drought climate with lack of additionally sources of moisture (monsoon, typhoon or depression) and the results of $w\delta^{18}$O - $w\delta$D annual rainfall revealed an apparent continental effect. The annual rainfall isotopic signature that fall on the LMWL suggested the same derived source of precipitations. Long-term stable isotope records in the study area and across Thailand are highly recommended as a tool for a better water resource evaluation and climatic studies especially in a changing climate.

6. Acknowledgements

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