Applied Radiation and Isotopes 95 (2015) 72–75

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Technical note

Isotopic composition of water in precipitation due to seasonal variation and variation in intensity of rain fall at a place

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HIGHLIGHTS

- New pattern, plot of slope versus intercept between $\delta^{18}O$ and $\delta^{2}H$ at the same location for seasons and rainfall are given.
- These patterns are analyzed to arrive at the original isotopic composition to be on GMWL.
- It is found that the original isotopic composition is same for different seasons and amount of rainfall.

ARTICLE INFO

Article history:
Received 29 April 2014
Received in revised form
29 September 2014
Accepted 29 September 2014
Available online 8 October 2014

Keywords:
Isotope
Environmental
Hydrology
Data analysis

ABSTRACT

An attempt has been made to analyze the data to find the original precipitate on GMWL, when there is seasonal variation and variations in intensity of rain fall at the same longitude, latitude and altitude. This has been done using the data as available for each month, weighted average of month and individual year for $\delta^{2}H$ and $\delta^{18}O$ for a 10-year periods. Correlation equations between $\delta^{2}H$ and $\delta^{18}O$ are available giving slopes and intercepts on the $\delta^{2}H$ axis for 10-year periods. The data of slope versus intercept for each month, weighted monthly average value and individual year are plotted to arrive at isotope composition of meteoric water $\delta^{18}O$ and $\delta^{2}H$, the method suggested by (Singh B.P. 2013, Isotopic composition of water in precipitation in a region or place, Applied Radiation and Isotopes, vol. 75, pp. 22–25; Singh B.P. 2014, Isotopic composition of river water across a continent, Applied Radiation and Isotopes, vol. 85, pp. 14–18). The results of the original meteoric isotopic composition of water are within the experimental errors as analyzed on a yearly basis, the average of each month of yearly basis and on the basis of each month and also some different amounts of precipitation giving the same value of $\delta^{18}O = -16.72$ and $\delta^{2}H = -129.86$ on GMWL.

1. Introduction

Stable isotopes of water (^{18}O and ^{2}H) are commonly used as tracers. These isotopes undergo measurable and systematic fractionation as they move in different phases of the water cycle. Stable isotope ratios of deuterium/hydrogen ($^{2}H/^{1}H$) and $^{18}O/^{16}O$ of water are conventionally expressed as $\delta^{2}H$ and $\delta^{18}O$ per mil ($^{0}/_{00}$). These are taken with respect to SMOW (Standard Mean Ocean Water) or VSMOW (Vienna SMOW) so that δ sample$=(R_{sample}/R_{SMOW}-1)$ 1000 where $R={}^{2}H/{}^{1}H$ or $^{18}O/^{16}O$. $\delta^{2}H$ and $\delta^{18}O$ values in precipitation were studied by Craig (1961). He obtained a relation $\delta^{2}H=8.0\ \delta^{18}O+10$ per mil ($^{0}/_{00}$). This is known as the Global Meteoric Water Line (GMWL). However, the meteoric relationship between $\delta^{18}O$ and $\delta^{2}H$ in precipitation is plotted on global basis monitored at the stations in IAEA Global Network, by Rozanski et al. (1993), who reported the relation as $\delta^{2}H=8.13\ \delta^{18}O+10.8$ per mil ($^{0}/_{00}$). This has been discussed experimentally and theoretically, by various investigators, Craig (1961), Friedman (1953), Dansgaard (1964), Yurtsever (1975), Singh and Kumar (2005) and Gibson et al. (1993).

Sub-continental studies were carried out by Kendall and Coplen (2001) in the United States of America. Indian sub-continental studies were carried out by Kumar et al. (2010) and Ayalon et al. (2004). Many such studies were carried out in other places. Peng et al. (2004) carried out such studies at Calgary, Alberta, Canada for a long period of 10 years on monthly and annual amount weighted average of $\delta^{2}H$ and $\delta^{18}O$ values for precipitation. These studies at a place are very useful to analyze to understand the original meteoric isotopic water composition of precipitation on the basis of slopes versus intercepts in the correlation equations due to seasonal variation and due to intensity of rainfall. A new approach has been suggested to arrive at isotopic composition of water at a place with the same longitude, latitude and altitude.

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http://dx.doi.org/10.1016/j.apradiso.2014.09.021

2. The methodology for interpretation of data

Let us take the water with isotopic composition to be $\delta^{18}O = -5$, -7, -10, -15, -18, -20 $^{0}/_{00}$, and then we can find the corresponding value of δ^2H from GMWL as $\delta^2H = 8.13\ \delta^{18}O + 10.8$ to be as $\delta^2H = -29.85$, -46.11, -70.50, -111.16, -135.54 and -151.80 $^{0}/_{00}$ respectively. Let us take water with these isotopic compositions and take different slopes, for example 7.4 to 8.1 (as found in the measurements) and calculate the intercepts by the equation:

$$\delta^2H = \text{slope}(x\ \text{axis})\delta^{18}O + \text{Intercept}(y\ \text{axis}) \quad (1)$$

The intercepts thus calculated are plotted for different slopes for different isotope compositions of water Eq. (1) on GMWL as given in Fig. 1 along with Table 1 of the calculations. The different lines 1 to 6 in the plot are straight lines for different isotope compositions of water and therefore, the plot of experimental slopes versus intercept of δ^2H axis is suggestive that if it is a straight line, this should correspond to isotopic composition of water in precipitation which are subjected to evaporation (temperature and humidity). Therefore, the plot of experimental slopes on x versus intercepts on y shall be the isotopic composition of water as calculated from Eq. (1), which is the water of the precipitation to be on GMWL having value of $\delta^{18}O$ and δ^2H. This is the basis of interpretation of data as suggested by Singh (2013, 2014).

3. Experimental data

Peng et al. (2004) have published 10 year records of stable isotope ratio of hydrogen and oxygen in precipitation. They reported the weighted mean value of $\delta^2H = -136.1$ $^{0}/_{00}$ and $\delta^{18}O = -17.9$ $^{0}/_{00}$. $\delta^{18}O = -31.2$ $^{0}/_{00}$ in November 1993 and average $\delta^{18}O$ was -9.7 $^{0}/_{00}$, in May 1998. They further reported that δ^2H and $\delta^{18}O$ from June to September to be $\delta^2H = -125$ $^{0}/_{00}$ and $\delta^{18}O = -16.0$ $^{0}/_{00}$ but in the month of January it is different. Due to the change in season and climate conditions the observations were most of the time different between slope vs. intercept on δ^2H as given by Peng et al. (2004). Table 2(a)–(c) shows the waters in individual years, weighted monthly average value and each month. The data are given in Fig. 2(a)–(c) at Calgary 51.01°N, 114.01 W, 1049 m ASL is located on eastern side of the Canadian Cordillera in Southern Alberta Canada. The original isotopic composition at a place is to be on GMWL (Rozanski et al., 1993) but may be different due to seasonal variation and due to the amount effect. It is so considered in this technical note.

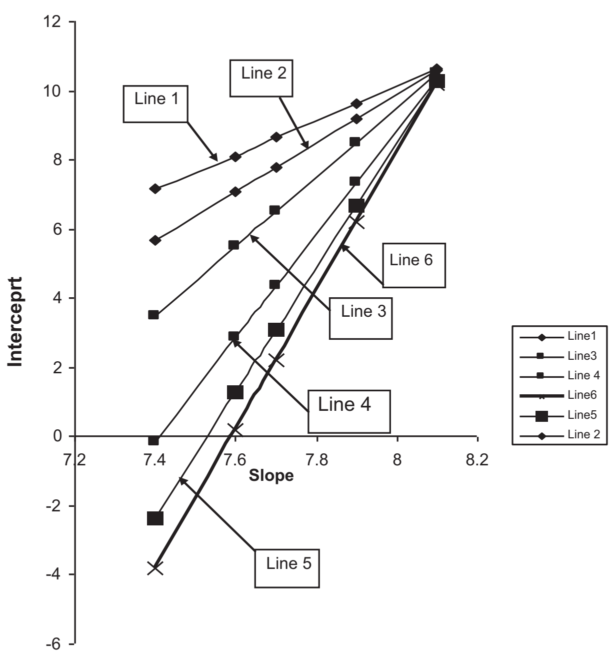

Fig. 1. Intercept on δ^2H axis versus the theoretical values of the slope of δ^2H and $\delta^{18}O$ plot for different waters having $\delta^{18}O$ from -5 to -20 $^{0}/_{00}$ corresponding values of δ^2H as given by line 1 to line 6.

Line 1: $\delta^{18}O = -5$ $^{0}/_{00}$, $\delta^2H = -29.85$ $^{0}/_{00}$.
Line 2: $\delta^{18}O = -7$ $^{0}/_{00}$, $\delta^2H = -46.11$ $^{0}/_{00}$.
Line 3 $\delta^{18}O = -10.0$ $^{0}/_{00}$, $\delta^2H = -70.50$ $^{0}/_{00}$.
Line 4: $\delta^{18}O = -15$ $^{0}/_{00}$, $\delta^2H = -111.16$ $^{0}/_{00}$.
Line 5: $\delta^{18}O = -18$ $^{0}/_{00}$, $\delta^2H = -135.54$ $^{0}/_{00}$.
Line 6: $\delta^{18}O = -20$ $^{0}/_{00}$, $\delta^2H = -151.80$ $^{0}/_{00}$.

Table 1
Slopes/Intercept using relation $\delta^2H = \text{Slope}\ \delta^{18}O + \text{intercept}$ for the isotopic composition of water as given in Fig. 1.

Lines	1	2	3	4	5	6
Slope	Intercept					
7.4	7.15	5.69	3.5	−0.15	−2.34	−3.8
7.6	8.1	7.09	5.5	2.85	1.3	0.2
7.7	8.65	7.79	6.5	4.35	3.1	2.2
7.9	9.65	9.19	8.5	7.35	6.7	6.2
8.1	10.65	10.59	10.5	10.35	10.3	10.2

4. Interpretation of data

The data of yearly average, monthly average of each year and average of each month is taken from Peng et al. (2004) and reanalyzed.

All the measurements and plots between δ^2H and $\delta^{18}O$ are made at Calgary, Canada in different years over a period of time i.e. 10 years. Will there be any correlation between the measurements of different samples in different years, year of the month and each month? If there is any correlation, what does it reflect? This is a main theme for analysis of these data as reported by Peng et al. (2004) and therefore, plots were made as given in Fig. 2(a)–(c) between the slope versus intercept of the δ^2H-axis on the basis of observations by Peng et al. (2004).

The following are the best fit lines. All the lines as drawn are straight lines, as we get the values of δ^2H and $\delta^{18}O$.

1. Individual year value
   $y = 14.80x - 118.48$ or $-118.48 = -14.80x + y$
   $R^2 = 0.6548$.
2. Amount of weighted monthly average
   $y = 15.38x - 117.91$ or $-117.81 = -15.38x + y$
   $R^2 = 0.8331$.
3. Individual sample in each month
   $y = 14.73x - 119.6$ or $-119.6 = -14.73x + y$
   $R^2 = 0.698$.

The weighted mean value of this composition of water of δ^2H and $\delta^{18}O$ for the above three cases are as given below. x and y are the slope and intercept on δ^2H axis of all the observations.

1. $\delta^{18}O = -14.8$ $^{0}/_{00}$ and $\delta^2H = -118.48$ $^{0}/_{00}$.
2. $\delta^{18}O = -15.38$ $^{0}/_{00}$ and $\delta^2H = -117.91$ $^{0}/_{00}$.
3. $\delta^{18}O = -14.73$ $^{0}/_{00}$ and $\delta^2H = -119.6$ $^{0}/_{00}$.

It is reported that in these measurements, the variation of δ^2H can be of the order of 2.0 $^{0}/_{00}$ and $\delta^{18}O$ will be of 0.2 $^{0}/_{00}$. The average value for $\delta^{18}O$ is -14.97 $^{0}/_{00}$ and for δ^2H is -118.66 $^{0}/_{00}$. This is on the GMWL line within experimental error.