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POLA IMBUHAN AIR TANAH DI DAERAH PERTANIAN

GROUNDWATER RECHARGE PATTERN IN AGRICULTURAL AREA

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ABSTRAK

Kebutuhan air untuk irigasi dapat dipenuhi oleh sumber air sumur maupun air sungai. Oleh karena itu, keberlanjutan sumber air tersebut haruslah dipelihara. Salah satu upaya pengelolaan air adalah pengelolaan sumber imbuhan atau recharge air tanah. Sumber imbuhan air tanah dapat berupa air hujan, infiltrasi danau/air sungai di hulu maupun aliran lateral air tanah. Studi ini akan memaparkan penggunaan data isotop air dalam menentukan sumber imbuhan air tanah secara kualitatif. Selain itu, akan dipaparkan hasil analisis data isotope dengan menggunakan GIS. Data isotop air tanah diperoleh dari air sumur disebuah area pertanian buah buahan seluas 14 Ha. Hasil analisis menunjukkan bahwa di daerah pertanian tersebut air tanah berasal dari air hujan setempat dan sumber air tanah dari aliran air tanah yang berada dihulu lokasi pertanian. Namun pada studi ini, belum dapat diketahui sumber mana yang lebih dominan. Sehingga dibutuhkan studi kuantitatif untuk menentukan rasio sumber imbuhan air tanah.

Kata Kunci: Air tanah, Sumber Imbuhan, Isotop air, GIS

INTRODUCTION

Water resources is increasingly scarce, therefore it should be managed in a sustainable way (Setyandito, 2015). Its utilization is mainly for domestic and agriculture activities. Groundwater has been used for irrigation if it meets FAO standard (FAO, 1989). In agricultural practices where irrigated by groundwater, the sustainability of the groundwater recharge source is very important. The water isotopes can provide information recharge patterns of groundwater including recharge altitude and water sources (Mandal et al., 2011).

Stable isotopes had been utilized to trace pollutant transport in groundwater research because it did not react with the soil as it transported or diffused from land to groundwater. A major advantage of environmental isotopes is that the input function or the 'injection of tracer' into the hydrological system is provided by nature. The tracer should be non-reactive (conservative) and, of course, needs to be easily measurable. It means, tracers need to be mobile, soluble and should not be strongly retarded by the soil or aquifer matrix (Mook et al., 2000).

As oxygen and hydrogen stable isotopes are components of water, they have used to determine the characteristics of groundwater recharge (Qin et al., 2011), the residence time, and the relationship between surface water and groundwater (Mazor 2004). Landon et al., (2000) conducted a study in groundwater at a cropped site and reported the relation of pathways and time lag of recharge water with the nitrate concentrations using stable isotopes of $\delta^{18}O$-H_2O. The study of oxygen and hydrogen isotopes in the precipitation and in groundwater revealed some characteristic features of the catchment area such as recharge location and recharge rate (Boronina et al., 2005). Other studies have established that environmental isotopes and chemical tracers can be routinely used as valuable tools for investigating recharge processes and groundwater flow mechanisms in hydrologic systems (Zhu et al., 2007). O ($\delta^{18}O$) and H ($\delta^{2}H$ or δD) isotopes have been applied to determine the groundwater recharge source and location (Mandal et al., 2011, Choi et al., 2010). Lee et al., (1999,) utilized $\delta^{18}O$ and δD to evaluate the relative contribution of seasonal precipitation to groundwater recharge on Cheju Island, South Korea. Abbott et al (2000) reported that recharge is more likely to occur in significant amounts throughout the year at the higher elevations (above about 800 m asl) where evaporation and transpiration rates are relatively low even during the warmer months.

A common method of identifying the recharge rate is the analysis of ground water level fluctuations (Lee and lee, 2000). However, this method cannot discriminate between water derived from different sources of recharge, such as precipitation, irrigation, or leaking of water supply lines. Measurement of stable isotopes in the groundwater and its sources can provide useful data for the identification of recharge sources and the regional pattern of groundwater. In this study, stable isotopes of water in the groundwater were analyze dusing GIS to determine regional pattern of recharge source.

METHODOLOGY

The isotopic composition of precipitation was acquired from a study conducted by Nakamura (2010). The precipitation data was collected every month during 2006 at the Hirose, Oyasiki and Hikawa rain stations, in the upland area of the study area (±24 km, ±12 km, and ±3.5 km, respectively). The observed values of $\delta\ ^{18}O$ and δD of precipitation ranged from -6.5 to -15.8‰ and -41.9 to -113.1 ‰, respectively.

The nitrogen and oxygen isotopes of nitrate analysis were conducted at the Environmental Isotope Laboratory of University of Yamanashi. Preservation of groundwater samples for isotopic analysis of nitrate was done by cooling (< 2^{o}C). No chemicals added to avoid microbiological activity because the $\delta^{15}N$ and $\delta^{18}O$ values of NO_3 of samples were analyzed using the microbial denitrifier technique. In this technique, the isotopes of nitrogen and oxygen are measure on gaseous nitrous oxide (N_2O) which is produced under controlled conditions from microbial degradation of nitrate dissolved in the water sample (Casciotti et al., 2002, Sigman et al., 2001). The sample preparation and analysis of N isotope ratios was conducted according to Sigman et al., (2001). The amount of water per sample needed for the analysis is only 1 ml.

For O isotope analysis of NO_3 **s**ample preparation follows the method of Sigman et al., (2001). First step is to culture the denitrifying bacteria. Working cultures grown for 6-10 days are concentrated by centrifugation and then split into 2-mL aliquots in 20-mL headspace vials. The vials are crimp-sealed with Teflon-backed silicone (Shin-Etsu Chemical) and purged for about 4 hours with N_2. Samples of dissolved nitrate (10-20 nmol) are then added to the sample vials and are incubated about 12 hours in 25^{o}C to allow for complete conversion of nitrate to N_2O before the addition of 0.1 mL of 10 N NaOH to stop bacterial activity and scavenge CO_2. Using a helium carrier gas, N_2O is stripped from each sample vial, purified, and analyzed for its isotopic composition using an isotope ratio mass spectrometer The N and O isotope ratios were measured on the produced N_2O using ratio mass spectrometer (Hydra 20-20, SerCon). Stable isotope data of samples are reported in the δ notation (‰) relative to international standards:

$$\delta^{15}N_{sample} = \left[\left(\frac{\left({}^{15}N/{}^{14}N\right)_{sample}}{\left({}^{15}N/{}^{14}N\right)_{s\tan dard}}\right)-1\right]\times 1000$$

and

$$\delta^{18}O_{sample} = \left[\left(\frac{\left({}^{18}O/{}^{16}O\right)_{sample}}{\left({}^{18}O/{}^{16}O\right)_{s\tan dard}}\right)-1\right]\times 1000$$

The $\delta^{15}N$ values are reported with respect to air N_2 (AIR), $\delta^{18}O$ values relative to Vienna Standard Mean Ocean Water (V-SMOW).

The deuterium excess (d excess ‰) in water, defined as d excess = $\delta D - 8\,\delta^{18}O$, is useful in studying water movement at atmosphere–biosphere–lithosphere interfaces. This parameter can fingerprint evaporation more reliably than the slope of δD vs. $\delta^{18}O$ line, because the latter of an evaporating water body can be greater than that of the recharging sources when the sources are variable, possibly leading to the wrong conclusion that no evaporation has occurred (Barnes and Turner., 2000). Cui et al., (2009) was using d excess in rain, fog, soil water, groundwater, and river, to determine the precipitation source. The analysis of $\delta^{18}O$-H_2O of groundwater and d-excess are conducted by using ArcMap10. GIS has been widely used in groundwater characterization analysis (Jebastina, 2017). It could show spatial feature of the result.

RESULT AND DISCUSSION

Grouping the spatial variation of groundwater d-excess values

The difference in the isotopic composition of precipitation with changes in elevation and temperature allow the identification of the altitude at which source precipitation occurred in groundwater recharge. But in this study, precipitation in different altitude was not sampled in the study area. Previous research result (Wijayanti, 2013), it showed that groundwater source is from precipitation and very low seasonal difference in groundwater isotopic composition. The recharge location alluvial fan is usually take place in the higher altitude of that area (Abbott and Bierman ,2000, Mandal et al., 2011). This is in agreement with the result of recharge area evaluation of the study area.

Table 1. The recharge water line and mean d-excess of groundwater.

Recharge line	Groundwater	Mean d-excess (‰)	Altitude (m)
I	GW2, GW3, GW6	-9.28	290
II	GW4, GW10, GW11	-10.04	300
III	GW5, GW7 ,GW12	-10.64	340
IV	GW8, G6umW9	-10.87	380

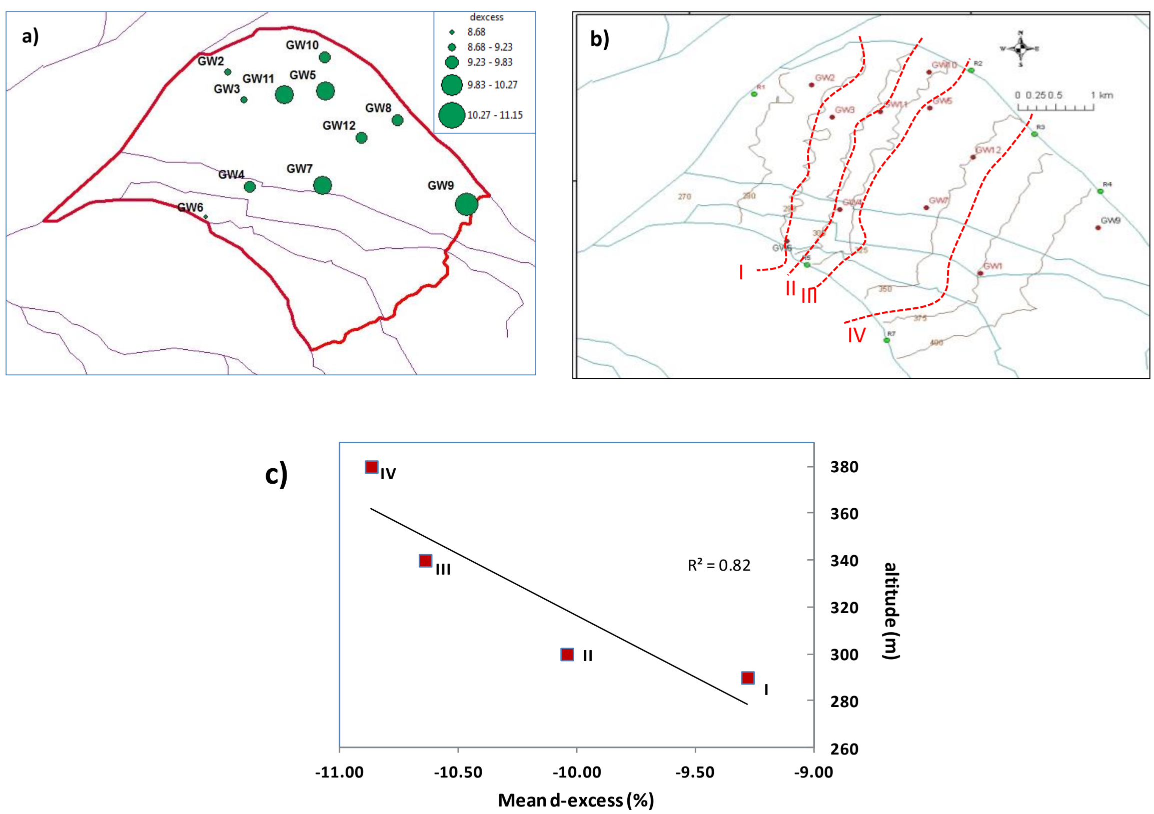
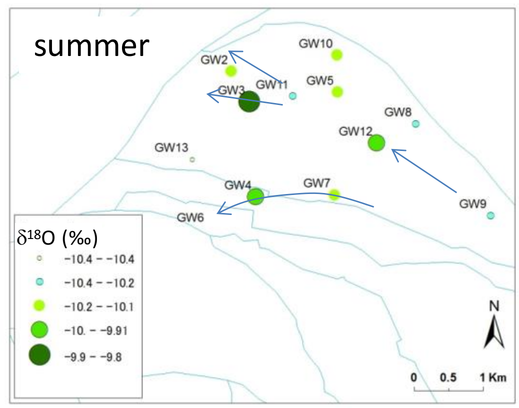


Figure 1. (a) The d-excess distribution in the study area, (b) Recharge water line from I to IV and the groundwater well locations, (c) mean d-excess as a function of recharge line altitude.

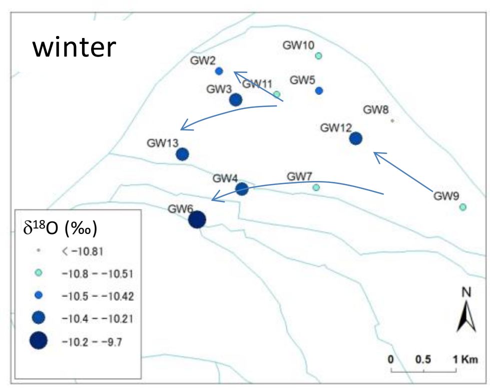
The d-excess analysis was conducted using the groundwater isotopes value of June 2011, which the most complete data set of all well. After that, the spatial distribution of d-excess was obtained (Fig 1.a). To estimate the recharge area, the average elevations of some wells were selected (Fig 1.b). However, in case of anions 60 % samples fall in chloride type considering hydro chemical facies. This approach was modified from the “recharge water line” utilized in Mandal et al., (2011) to evaluate the groundwater altitude effect. The evaluation was performed by plotting the recharge line versus the mead d-excess values of groundwater from the grouping of wells (Table 1). The relationship is shown in Figure 1.c, the groundwater is flowing from a higher altitude, GW9 and GW8 (low mean d-excess values) may become mixed with water recharge at lower altitude (high mean d-excess values).

Spatial distribution of groundwater $\delta^{18}O$ values in summer and winter.

In the previous study (Wijayanti, 2013), seasonal variations were identified in groundwater. Hence, the spatial variation was evaluated between summer and winter season. The result showed that groundwater flow from upper area to lower area, from lower $\delta^{18}O$ to higher ^{18}O. Higher mean $\delta^{18}O$ of -10.1‰ in summer (Fig 2.a) compare with -10.4‰ in winter (Fig 2.b) suggests that vertical flow from precipitation is dominant during summer.



(a)



(b)

Figure 2. Spatial distribution of groundwater $\delta^{18}O$ values in (a) summer and (b) winter.

Small difference of winter $\delta^{18}O$ with summer value inferred that mixing with upland groundwater (low $\delta^{18}O$) or river water might occur, however precipitation is still dominant. Therefore, in this area, vertical flow is over-ride lateral flow in both seasons.

CONCLUSION

a. The recharge area cannot be identified at the specific area because of the small number of sampling site and the scatter d-excess groundwater in the study area. However, by grouping the d-excess value based on its altitude, it can be conclude that generally the groundwater flowing following the contour of land surface, from higher altitude to lower altitude.
b. The seasonal differences identify in both groundwater and precipitations, was an evident that there was a locally rapid movement of recharge water. However, in both seasons, the spatial variation of $\delta^{18}O$ water isotope showed lower value of the most upper area (GW9). This inferred that slower movement of recharge water or lateral recharge from mountainous area might took place in the upper area groundwater. Precipitations as vertical flow is predominant compare to lateral flow.
c. Water isotope data analyzed using GIS can give quantitative information regarding groundwater recharge pattern and sources. However, further analysis should be performed in order to acquire the source ratio of each groundwater recharge sources.

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