Variations of springs water conductivity the selected springs at the flank of Mount Rajabasa, Lampung

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Abstract. Continuous Electrical conductivity (EC) monitoring has been carried out on springs in the lower slopes of The Mount Rajabasa. The research is intended to find the variation of EC in volcanic springs as a signal to understand groundwater flow regimes. Data evaluation makes use of frequency distribution from statistical methods. The results give clear information for each character of the spring measured at the research site.

1. Introduction
The springs are essential groundwater that goes out to the earth surface [1][2]. The presence of springs or seepage of water both on land and in water bodies (rivers, lakes, seas) reflects the presence of groundwater existing in aquifers[3][4]. So far, in various parts of the world, springs, as one form of water resource, have a very important role in fulfilling water demands for both humans and ecologies[4]. So, it needs good water management so that the quantity and quality of water are maintained sustainably.

The quantity of water is related to the amount of rain that falls in the recharge area to entering the soil or the rock's pores, the area of recharge, and the ability of rocks to pass water[1]. Therefore, springs that have large quantities are generally associated with volcanic rock aquifer or limestone in the karstic area. Meanwhile, the quality aspect relates to the water formation environment during its movement towards the spring. Its quality reflects groundwater and aquifer interactions, as properly as from various chemical sources on the surface[5].

Electrical conductance or conductivity or electrical conductivity (EC) is one of the water quality parameters frequently measured in the field or laboratory. EC reflects the water ability to conduct electricity[6][7][8]. In a hydrogeological study, continuous EC measurements in the field related to the availability of a proxy from the water chemical composition as a function of time[5]. The chemical composition of ions reflects the natural water quality or the presence of pollutants[9], and the total dissolved solids[8][9][10]. It illustrates the indication of changes in water quality in general[9][10] on a specified time scale or control in water analysis in the laboratory[9]. Although EC is not directly equivalent to the concentrations of major constituent species[8], it is easily measured accurately in high-resolution fields[8][11].

The quality of spring water represents the general water quality of the groundwater system[12]. Over time, EC changes in spring water indicate water-rock interaction and dilution processes along its pathway from the recharge area to its output within the spring[13]. For this reason, measuring EC continuously in the field is expected to get a better understanding of the groundwater flow regime in the volcanic region.
2. Material and methods
The study was conducted on a spring located on the lower slope of Mount Rajabasa, Lampung Province (figure 1). The geology of the research area is produced by Mount Rajabasa's young volcanic deposits consisting of lava, breccia, and tuff[14][15]. Lava flow deposits that dominate Mt. Rajabasa volcanic deposits consisting of basalt, basaltic-andesite, and andesite. However, in some places on the outside, it is found blocks of lava or autoclastic breccias[15]. Therefore, the quarter volcanic region has a high permeability that can have a high recharge capacity and rapid groundwater flow[16], so large-scale springs are often found.

EC continuous measurement uses a mini CTD diver (van Essen instrument) that automatically records data according to the specified time. EC data recording during this study is set at intervals of every 10 minutes. To protect the diver tool, we made a stable construction from PVC pipes 2 inches perforated then inserted within the soil/rocks at the mouth of the spring. This study chose a measurement that supported differences in springs control on pore type and fracture type.

EC data analysis uses frequency distribution, from now on mentioned to as conductivity frequency distribution (CFD). This method has been used to analyze the EC character of Barton Springs (Austin, Texas) concerning aquifers[8]. Frequency distribution, which is sometimes presented in a histogram, is a data arrangement based on class or category with related frequencies from each class[17]. Presentation of distribution during this study, we use the open-source software SPSS.

3. Result and discussion
Continuous EC measurements from 8 - 11 April 2017 have been carried out on four springs, namely Raja1 springs, Raja2 springs, Batur springs, and Cuppa2 springs. Raja 1 and Raja 2 are close to each other, with a distance of only about 200 m (figure 1). All of those springs are used for community needs, but unfortunately, there is no continuous discharge data. The results of estimated temporal discharges at the time of each field are 10 L/sec, 2 L/sec, 40 L/sec, and 60 L/sec. During the measurement period, CTD is set at 10-minute intervals. The descriptive statistical resume of all springs measured in table 1.

The Electrical conductivity frequency distribution (CFD) histogram for every spring has been made (figure 2). The CFD pattern for each spring has its variation, i.e., the Raja1 spring has positive distribution data with positive skewness. In contrast, the three springs Raja2, way Batur, and way Cuppa are negatively distributed with negative skewness. The peak of the distribution curve differs from one spring to another. Sequentially from the highest to the lowest curve peak are Raja2, Raja1, Cuppa, and
Batur. However, Raja1 features a peak curve frequency that's relatively equivalent to Raja2 within the frequency range of 40, while Batur is at frequency 500 and Cuppa is at frequency 250.

Table 1. Descriptive statistic data on selected springs in study area

| Spring  | Elevation, msl. | Media Type              | Electrical conductivity (EC) |             |             |             |             |
|---------|-----------------|-------------------------|-----------------------------|-------------|-------------|-------------|-------------|
|         |                 |                         | Minimum (mS cm⁻¹)          | Maximum (mS cm⁻¹) | Mean (mS cm⁻¹) | Standard deviation (mS cm⁻¹) | Skewness |
| Raja1   | 115             | Pore space              | 0.211                       | 0.296       | 0.243       | 0.021       | 0.374       |
| Raja2   | 117.5           | Pore space              | 0.293                       | 0.557       | 0.513       | 0.041       | -2.457      |
| Batur   | 128.5           | Fracture, channel       | 0.140                       | 0.142       | 0.141       | 0.0003      | -1.834      |
| Cuppa   | 190             | Fracture, channel       | 0.182                       | 0.189       | 0.188       | 0.001       | -3.942      |

Water within the porous aquifer that has the same water type will show CFD in a normal distribution[8]. A curve with a normal distribution features a skewness value of 0 or close to zero or around zero, which means that the data is symmetrically distributed[18]. The springs in the study area that are most close to the normal distribution is Raja springs1. It is possible that these springs have not changed within the flow regime during their moving in the aquifer. In other words, it is likely to be controlled only by one type of flow media. Simultaneously, the other three springs have an equivalent character in terms of CFD, namely asymmetrical distribution. The three springs are likely influenced by more than one groundwater flow.

This interpretation can be confirmed by observations within the field showing that Raja1 springs come out as seepage from inter-granules in autoclastic breccias with relatively slow groundwater flow. Especially for the Raja2 spring, although there is an autoclastic breccia aquifer, it may have interacted with surface water. Cuppa springs and Batur springs emerge from fractures, conduits, or channeling from lava blocks identified around the escarpment, where groundwater flows relatively quickly. From all EC temporal data series, the EC shows that the Raja1 and Raja 2 springs EC are several points above the EC within the Batur springs and Cuppa springs. The relevant explanation for groundwater flow in porous media on volcanic rocks[19], or fault not abundant[20], higher EC is related to retention time within the aquifer is long[19][20]. So, EC was detected due to mineral dissolution[20]. The conditions are different for groundwater, which is more fracture controlled, where groundwater movement is quicker in aquifers.

We believe that this data is related to groundwater flow media control, as mentioned above. However, this interpretation is a temporal picture of a flow system in the volcanic region's aquifer. Complete data in a long-range, annual, or even decade can explain the processes that occur in aquifers. According to[8], EC variation is the influence of time, amount of rain, unsaturated zone character, and aquifer media interaction.
Conclusions

This study's results have important implications for groundwater vulnerability research in the various aquifer types currently investigating. It provides an initial description of the spring's physical characteristics in the volcanic aquifer region. Pore and fracture media springs show different distributions of EC values. Based on CFD, pore springs, despite their proximity, have different results. The fracture spring shows CFD more varied.

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References

[1] Davis S N and De Wiest R J M 1966 Hydrogeology
[2] Bakti H 2011 Mata air sebagai sumber air bersih di Kecamatan Lasiolat, Kab. Belu, NTT J. Ris. Geol. dan Pertamb. 21 49–55
[3] Memon B A 1995 Quantitative analysis of springs Environ. Geol. 26 111–20
[4] Kresic N and Stevanovic Z 2010 Groundwater hydrology of springs: engineering, theory management and sustainability ed Neven Kresic and Zoran Stevanovic (Burlington, USA: Elsevier Ltd)
[5] White W B 2010 Physical Chemistry of natural waters Groundwater hydrology of
springs: Engineering, Theory, Management and sustainability ed N Kresic and Z Stevanovic (Burlington USA: Elsevier Ltd) pp 233–68

[6] Freeze R A and Cherry J A 1979 Groundwater (Englewood Cliffs, New Jersey: Prentice-Hall, Inc)

[7] Hem J D 1985 Study and interpretation of the chemical characteristics of natural water Dep. Inter. US Geol. Surv. 225 272

[8] Massei N, Mahler B J, Bakalowicz M, Fournier M and Dupont J P 2007 Quantitative Interpretation of Specific Conductance Frequency Distributions in Karst Ground Water 45 288–293

[9] Marandi A, Polikarpus M and Jöeleht A 2013 A new approach for describing the relationship between electrical conductivity and major anion concentration in natural waters Appl. Geochemistry 38 103–9

[10] Fotouhi F and Kresic N 2010 Springwater treatment Groundwater hydrology of springs: engineering, theory management and sustainability ed N Kresic and Z Stevanovic (Burlington USA: Elsevier Ltd) pp 269–304

[11] Moore R D (Dan), Richards G and Story A 2008 Electrical conductivity as an indicator of water chemistry and hydrologic process Watershed Manag. Bull. 11 25–9

[12] Biljana J, Stafilov T and Alfred W 2012 Assessment on physico-chemical composition of surface karst springs feeding Lake Ohrid Muced. J. Ecol. Environ. XIV 19–25

[13] Mercè Boy-Roura, Menció A M-P J 2013 Temporal analysis of spring water data to assess nitrate Sci. Total Environ. 452–453 433–45

[14] Mangga S A, Amirudin, Suwarti T and Gafoer S 1993 Geological map of the Tanjung Karang quadrangle, Sumatera (Bandung)

[15] Bronto S, Asmoro P, Hartono G S 2012 Evolution of Rajabasa Volcano in Kalianda Area and Its Vicinity, South Lampung Regency Indones J Geol 7 11–25

[16] Manga M 1998 Advective heat transport by low-temperature discharge in the Oregon Cascades Geology 26 799–802

[17] Bengtson H 2002 Hydrology (Part 2) - Frequency Analysis of Flood Data Hydraulic Design Series No. 2. In: Publication No FHWA-NHI-02-001.

[18] M H 2001 Pokok-pokok Materi Statistik I (Statistik Deskriptif). (Jakarta: Bumi Aksara)

[19] Delinom R 2009 Structural geology controls on groundwater flow: Lembang Fault case study, West Java, Hydrogeol. J. 17 1011–23

[20] Odeh, T, Salemeh E, Scheirmer M and Strauch G 2009 Structural control of groundwater flow regimes and groundwater chemistry along the lower reaches of the Zerka River, West Jordan, using remote sensing, GIS, and field methods Env Geol 58 1797–810