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ICGoES 2021 submission 29

ICGoES 2021 <icgoes2021@easychair.org> 22 Januari 2021 18.08
Kepada: T Listyani Ra <lis@itny.ac.id>

Dear authors,

We already received your full paper submitted to International Conference on Geological Engineering and Geosciences, ICGoES 2021 with information:

Title : Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo
Authors : T Listyani Ra
Paper ID : 29

We will inform you of the review results via https://easychair.org/conferences/?conf=icgoes2021.

Thank you for submitting to ICGoES 2021.

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ICGoES 2021 submission 29 update

ICGoES 2021 <icgoes2021@easychair.org> 26 Januari 2021 20.34
Kepada: T Listyani Ra <lis@itny.ac.id>

Dear authors,

we acknowledge that we received new files for your ICGoES 2021 submission. The information about this update is shown below.

Number: 29
Authors: T Listyani Ra
Title: Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo
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  Full Paper / E-Poster, version 2 (1874028 bytes)

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ICGoES 2021 – Review Result and Decision on your Paper ID No 29

ICGoES 2021 <icgoes2021@easychair.org> 26 Februari 2021 21.58
Kepada: T Listyani Ra <lis@itny.ac.id>

Dear authors,

We have received the reports from reviewers on your paper, "Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo", which you have submitted to ICGoES 2021.

Based on the advice received, your paper is accepted with revision, which means your paper can be presented at the conference, while for publication you should incorporate all revisions suggested by reviewers.

When preparing your revised manuscript, you are asked to carefully consider the attached reviewer comments on your dashboard in the EasyChair account. The revised manuscript should be submitted through the same account page within 3 weeks after receiving this email.

Now you can process the payment and registration of the ICGoES 2021.
The payment deadline is 10 March 2021 at 23:59 pm.
Please follow the instructions of payment at https://icgoes.geologi.ugm.ac.id/registration-and-fee/
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The conference program will be emailed to you (on March 1st) or can be accessed through the website on the same date.

Thank you for your contribution and kind cooperation.

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SUBMISSION: 29
TITLE: Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo

----------------------- REVIEW 1 ---------------------
SUBMISSION: 29
TITLE: Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo
AUTHORS: T Listyani Ra

----------- Reviewer comments to author -----------
Dear Authors,

Please increase the number of word to be minimum 5000 words on this paper, you may give more explanation on the introduction and also on the result and discussion. Please describe more about the springs characteristics as the data you show on this paper is very limited. Information of LMWL is missing, although you mentioned about it since in the beginning and in the section of discussion but there is no information about LMWL on this paper. More over, in the introduction and literature study, the theory background of water isotopes changes is not given and lack of information on previous similar research activities on this topic of stable isotopic changes.
<This review contains an attachment, see the file
review_1.docx attached to this letter.>

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1047K

Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo

Commented [H1]: Please increase the number of word to be minimum 5000 words on this paper, you may give more explanation on the introduction and also on the results you may describe more about the springs characteristics as the data you show on this paper is very limited, especially you explaining since the beginning and also during discussion about LMWL but there is no information about LMWL on this paper. More over, in the introduction and literature study, theoritical background of isotopes changes is not discussed and lack of information on similar research activities on this topic.

Abstract. Hydroisotope studies were carried out on Mudal and Clapar springs located in the central part of the Progo Dome. The research was conducted by taking samples of groundwater in each spring for three periods, representing the rainy (2016), dry (2017) and rainy (2018) seasons. Data on stable isotope content of ^{18}O and D were analyzed to see the hydroisotope characteristics of groundwater. The results showed that the stable isotope content of groundwater in both springs was relatively stable, with insignificant changes over time and season. Mudal springs tend to show light isotopes, indicating deep aquifer or high elevation recharge, less affected by the season. Clapar spring shows isotopes, which may be sourced from shallow aquifer with mixing / evaporation processes and more influenced by the season. The δD enrichment shows the big change in Mudal spring, and medium - big change in Clapar spring. Meanwhile, the range value of δD in the two springs show a slightly - totally changes, indicating that the D content also changes due to seasons, although it is small. However, the d excess value shows that the dry and rainy season conditions are not much different in terms of evapotranspiration or humidity.

1. Introduction

The study of groundwater has been developed because this natural resource is becoming increasingly important over time, in line with the needs of living things for groundwater. Various groundwater studies have been carried out, both physically and chemically. Hydrochemical studies were also developed using various methods, complemented by studies of groundwater isotopes (hydroisotopes). Isotope analysis is useful to aid in the interpretation of groundwater flows as well as aid in its genetic interpretation. The results of groundwater hydrochemical analysis can be verified by isotope analysis so that it will produce a better interpretation of the groundwater flow system. In addition, isotope studies have also been developed using the stable isotopes ^{18}O and ^{2}H ((deuterium / D). One of the hydroisotope studies that can be done is related to the climate aspect in an area.

Commented [H2]: Is it really no references? Regarding various groundwater studies, hydroisotope studies, genetic interpretation of isotope data etc?

Stable isotope analysis is useful for knowing the origin of groundwater and interpretation of catchment areas. In addition, stable isotope data can also be used for analysis of hydrochemical processes, due to seasonal changes. This paper intends to discuss the characteristics of the stable isotopes ^{18}O and D, particularly in relation to seasonal changes in the Progo Hills area. The case study in this case was carried out on the Mudal and Clapar springs which are located in the central part of the Progo Dome physiography [1].

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Mudal spring is at an elevation of 664 m, emerging from the limestone aquifer of the Jonggrangan Formation in Banyunganti Hamlet, Jatimulyo Village, Girimulyo Subdistrict; meanwhile the Clapar spring is at an elevation of 437 m, emerging from the andesite breccia aquifer of the Old Andesite Formation in Clapar II Hamlet, Hargowilis Village, Kokap Subdistrict, Kulon Progo Regency (Figure 1; Table 1).

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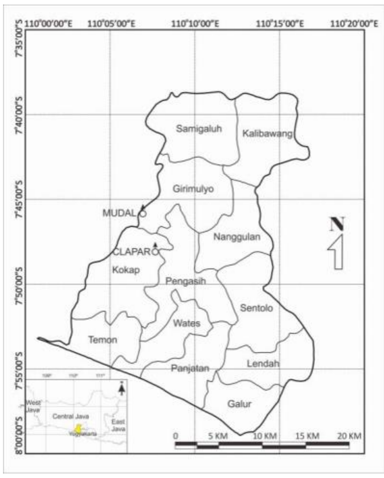

Figure 4. Location of Mudal and Clapar springs in Kulon Progo Regency.

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Table 1. Geographical data of Mudal and Clapar springs.

No.	Spring	Coordinate		Elevation (m)
		Longitude (E)	Latitude (S)	
1	Mudal	110° 06' 56.67"	-7° 45' 42.83"	664
2	Clapar	110° 07' 34.88"	-7° 47' 44.49"	437

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2. Method

The research begins with a hydrogeological survey to determine the geological conditions and springs in the study area. Several springs with small to large debris are found in the central part of the West Progo area. This area is dominated by limestones of the Jonggrangan Formation and andesite breccias of the Old Andesite Formation. Eyes with a large discharge were selected as the sample of this study. Mudal springs have large debits and represent the aquifer of the Jongrangan Formation, while the Clapar springs are medium / large enough and represent the Old Andesite Formation.

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Commented [H8]: Do you mean springs with large discharge?

Groundwater samples from both springs were taken in three periods, namely period I in the rainy season in December, 2016; period II in the dry season (August, 2017) and period III in the rainy season (March, 2018). The difference in sampling time from each period to the next is around 8 months. In each sample, 30 ml of groundwater was put into an airtight bottle (polyethylene) by inserting the bottle into a water source to avoid evaporation.

Commented [H9]: How many samples for each seasons? Can you give the information of precipitation mm/month on each months of sampling activities?

Isotope testing was carried out at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), which is located in Pasar Jumat, South Jakarta. The isotope content analyzed is oxygen-18 (^{18}O) and hydrogen (^{2}H), known as deuterium (D) isotope. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. Isotope ratios were measured by a mass spectrometer and the results were referenced against the SMOW standard. The internal standard was calibrated using V-SMOW with an analysis accuracy of ± 0.1 for $\delta^{18}O$ and ± 1 ‰ for δD [2]. Furthermore, the results of the stable isotope test were analyzed to determine the changes as well as the interpretation of the influence of the seasons / climate in the study area.

3. Literature review

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3.1. Geological setting

The study area is included in the physiography of the Dome and Hills Zone in the Central Depression [1]. The center of this dome physicigraphy forms the morphology of the Jonggrangan plateau. The Jonggrangan Formation is quite extensive in this area. Around the Jonggrangan highlands, volcanic rocks from the Old Andesite Formation are exposed.

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The regional stratigraphy of the West Progo Mountains from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations and Alluvial Deposits [1,3,4]. The Jonggrangan Formation is composed of conglomerates, tuff marl and limestone sandstones with lignite inserts, layered limestone and coral limestone. Meanwhile, the Old Andesite Formation is composed of andesite breccias, tuffs, lapilli, agglomerates and andesite lava inserts. Mudal spring appear in the Jonggrangan Formation rocks, while Clapar spring appears in the Old Andesite Formation (Figure 2).

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Figure 2. Mudal spring appear in the Jonggrangan Formation (top), while Clapar spring appear in the Old Andesite Formation (bottom).

3.2. Stable isotopes

Isotopes are elements that have the same atomic number but different mass numbers. In nature, isotopes in water can be found as stable or radioactive isotopes. The content of radioactive isotopes in water can be used to determine age, while stable isotopes are useful for determining water genetics.

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Isotope abundance is measured by the ratio of the deviation from the standard (Fritz & Fontes, 1980, in [5]. The stable isotopes ^{18}O and ^{2}H are present in water in the form of compounds $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O_2$ (Hamed, 2014, in [2]). The two isotopes are very sensitive for physical processes such as evaporation and condensation, therefore, the content of these stable isotopes can be used to see the climate effect on springs.

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Commented [H15]: Reference only [2]

The isotopes ^{18}O and D are often used in the study of chemical processes. This isotope is a stable, non-radioactive isotope and is often used as an indicator for groundwater sources [6].

To see the influence of climate / rainfall, regression line relationships δ^{18}O and δD groundwater can be plotted together with the global meteoric water line GWML or the local meteoric water line (LMWL). If the groundwater regression line is adjacent to the LMWL then the groundwater is affected by local climate (originating from local precipitation) or by topographic effects [7].

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4. Result and discussion

4.1. Spring characteristic

Mudal Springs emerge from the limestone aquifer of Jonggrangan reef, supported by large porosity, type of fracture and channel as well as large rock permeability. Jonggrangan Limestone is dominated by thick to massive layered coral limestones, around the Mudal springs this reef limestone is white to brownish white, compact and hard, with some fairly intensive tectonic stiffness. Mudal Springs has a large fluctuation in discharge; moderate discharge during the dry season, but can discharge very large during the rainy season, up to > 200 L/sec [8]. These springs are depressions, fractures and channels, with large flows that develop as runoff / rivers. These springs are parennial, and at normal temperature.

Clapar springs emerge from aquifers in andesite breccias and OAF autoclastic / lava breccias, which are supported by fracture porosity and sheeting joints with moderate intensity and low - medium permeability. Clapar springs are fracture type, with small (stagnant) - medium flow rate, intermittent, and normal temperature.

Commented [H17]: Range of discharge rate? In L/s?

Commented [H18]: Intermittent? What this means? No discharge on dry season? But you have sampling on dry season...?

Commented [H19]: Please give physico-chemical data such as pH, Temperature, TDS, EC; it needed to confirm your statement as you mentioned normal temperature etc

4.2. ^{18}O and ^{2}H isotopes contents analysis

Stable isotope content data in Mudal and Clapar spring water can be seen in Table 2 below. Furthermore, the absolute value and range value of the isotope content can be analyzed to determine the hydrochemical processes that occur in the groundwater system.

Table 2. Data on stable isotope content of groundwater from the investigated springs.

Spring	I (Dec, 2016)		II (Aug, 2017)		III (Mar, 2018)	
	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
Mudal	-7.1 ± 0.11	-41.7 ± 0.4	-7.39 ± 0.42	-45.1 ± 3.1	-6.94 ± 0.39	-50.2 ± 1.5
Clapar	-6.25 ± 0.07	-40 ± 1.8	-5.51 ± 0.32	-34.7 ± 1.0	-4.77 ± 0.34	-38.3 ± 3

4.2.1. δ^{18}O and δD absolute value. From period I to III, Mudal springs showed relatively stable O isotope, while D isotope tended to be lighter (Figure 3). Groundwater with light isotope generally flows in deep aquifers or comes from high absorption areas [9], as seen in Mudal springs which have light D isotope (-50.2 ‰) in period III (Table 3; Figure 3). This means, groundwater that appears in Mudal springs may flow in deep enough aquifers or originate from infiltration of rainwater that permeates at a high enough elevation. The infiltration zone may exist locally, because the Mudal springs are indeed at a high enough elevation.

Commented [H20]: The discussion should be included isotop data of meteoric water system in that region not only comparing the data from the spring itself. Your conclusion here is too brief , even though I believe you may have meteoric water data from previous publication etc. Please elaborate more and show the plotting of MWL and data from those two springs.

Table 3. Changes in the stable isotope content of the investigated springs.

Variable	Spring	$\delta^{18}O$ (‰)	δD (‰)
Time	Mudal	down-up, stable relatively	get lighter
		difference = 0.45 ‰	difference = 8.5 ‰
	Clapar	get heavier	up - down, stable relatively
		difference = 1.48 ‰	difference = 5.3 ‰
Season (T-effect)	Mudal	lower when dry	no effect
	Clapar	no effect	higher when dry

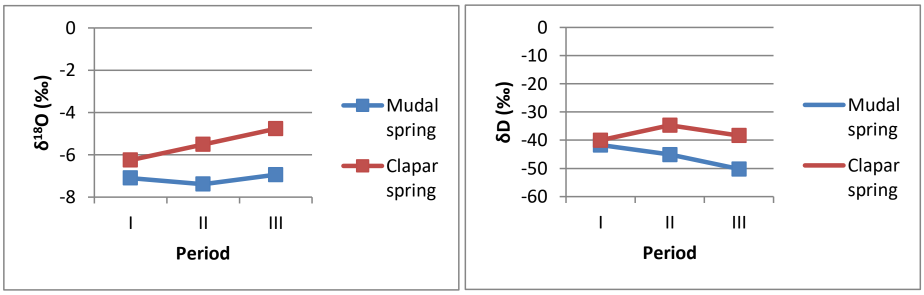

Figure 3. The development of stable isotope content over the three test periods.

Clapar springs have groundwater with ^{18}O heavier from period I to III, as well as D sotope, which is relatively stable. isotopes in springs indicate a mixing or evaporation process [7]. D isotope indicates shallow aquifer [9]. Thus, the groundwater in the Clapar springs comes from shallow aquifers that have undergone a mixing or evaporation process.

Compared to Clapar springs, Mudal springs contain lighter ^{18}O and D isotopes in the three periods studied. This shows that the stable isotopes possessed by the two springs are relatively consistent, whereas the Mudal springs tend to have genetics from deeper aquifers (Table 4).

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Table 4. Interpretation of light / isotope content.

Spring	I		II		III		Interpretation
	δ18O (‰)	δD (‰)	δ18O (‰)	δD (‰)	δ18O (‰)	δD (‰)	
Mudal	-7.1	-41.7	-7.39	-45.1	-6.94	-50.2	- deep aquifer, or - high elevation recharge
Clapar	-6.25	-40	-5.51	-34.7	-4.77	-38.3	- Shallow aquifer - Mixing / evaporation

Commented [H22]: Physico-chemical data can support this interpretation

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4.2.2. Range value of $\delta^{18}O$ and δD. The stable isotope content studied showed a short range of values and generally did not have overlapping values (Figure 4). With due regard to the $\delta^{18}O$ range value in all periods, it appears that the groundwater from Mudal springs has isotopes $\delta^{18}O$ is light, while the Clapar springs have value $\delta^{18}O$. The overlapping values in the three periods in Mudal springs indicate that groundwater in these springs is less affected by seasonal changes, while seasonal changes have more effect on Clapar springs.

The widest δD range value occurs in Mudal and Clapar springs at different periods (Figure 4). The δD value which is relatively stable, light but appears to shift in the Mudal spring indicates that the groundwater in this spring is less affected by seasonal changes, with relatively deep circulation. As for the springs Clapar has relatively stable (heavy) δD which shows significant overlapping in the rainy period, slightly different from the range value in the dry season, indicating that groundwater in these springs is quite affected by changes in the season. Referring to the opinion of Alam *et al* (2014) [9], groundwater with heavy δD as in the Clapar springs can be interpreted as a result of a fairly intensive mixing or evaporation process (Table 5).

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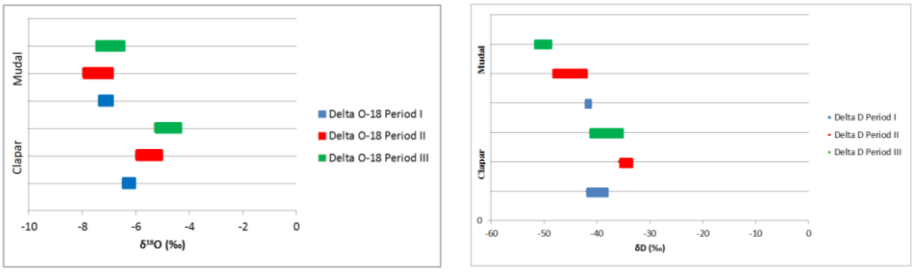

Figure 4. The values range δ^{18}O and δD for Mudal and Clapar springs. The missing values indicate the similarity of δD in different seasons.

Table 5. Value range interpretation δ^{18}O and δD.

Water springs	δ18O	δD	Analysis
Mudal	In short, some overlap	Short and long, shift	δ^{18}O and δD are relatively stable / mild, less affected by seasonal changes
Clapar	Short - long, shift, enrichment	Short-a bit long, overlap especially in the rainy season	δ^{18}O and δD relatively stable / heavy, affected by season, intensive evaporation / mixing

Change δD of groundwater usually occurs due to isotopic exchange with minerals containing hydrogen, such as gypsum and clay minerals (Clayton *et al*, 1966, in [10]. However, data support for this exchange. The δD in these two materials is not yet known, so the cause of the δD change groundwater is still difficult to determine. Moreover, this variation in value is usually not large, so this exchange is considered insignificant. Furthermore, membrane filtration is associated with increased δD, it is difficult to happen in the study area, because this process usually requires high pressure, which is equivalent to a sediment depth of 1.6 km (Graff *et al*, 1965, in [10]. In sedimentary rock formations less than 1 km deep membrane filtration is less effective [11].

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4.3. The effects of season on δ^{18}O and δD changes

The process that occurs related to the seasonal effect can be assessed based on the δ^{18}O against δD of groundwater relationship. In the dry season (period II), the regression line of springs in the study area is very close to the LMWL, indicating that the enrichment of meteoric water isotope content has not been clearly seen [12]. However, the climatic influence in this dry season can be seen from the

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presence of d-excess [7]. Further added by Craig (1961, in [7]), the value of the line gradient is in the range 3-6 indicating an evaporation process.

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The groundwater line in period III was partly below the LMWL, which indicates that it experienced isotopic enrichment [7,8], for example due to a fairly intensive evaporation process or mixing with surface water/runoff. The slope of the regression line that is smaller than the LMWL gradient indicates a variation in the rate of evaporation. In addition, it is possible that evaporation will occur in the catchment area along with the infiltration process [9].

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4.3.1. The enrichment of ^{18}O and D stable isotopes. Changes in stable isotope content associated with changing seasons can cause an δD or δ^{18}O enrichment effect. O-18 isotope enrichment during the rainy season relative to the dry season occurs in Mudal springs, while δD isotope enrichment occurs in Clapar springs in the dry season compared to the rainy season (Table 6; Figure 3).

Isotopic enrichment δ^{18}O in the rainy season relative to the dry season in Mudal springs is related to the isotopic fractionation of carbonate rocks as a result of water-rock interaction. Enrichment of δ^{18}O can be caused by carbonate minerals [13, 14]. Meanwhile, the δD enrichment of Clapar springs occurs indicating that seasonality affects the content of these stable isotopes. Season has an effect on the evaporation process which can enrich the isotopic content of groundwater.

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Table 6 shows the degrees of δD enrichment in the springs studied. Degree of δD enrichment is calculated in the dry season (period II) relative to the rainy season, both period I and III. The magnitude of the changes caused by D isotope enrichment can be seen in Figure 5.

Table 6. The δD enrichment in the dry season relative to δD in the rainy season.

Spring	δD dry (Period II)	δD rainy		Enrichment Degree	Explanation
		Period I	Period III		
Mudal	-45.1	-41.7	-50.2	-3.4 - 5.1	Uncertainty
Clapar	-34.7	-40	-38.3	3.6 – 5.3	Medium - big

*) Negative values indicate enrichment during the rainy season

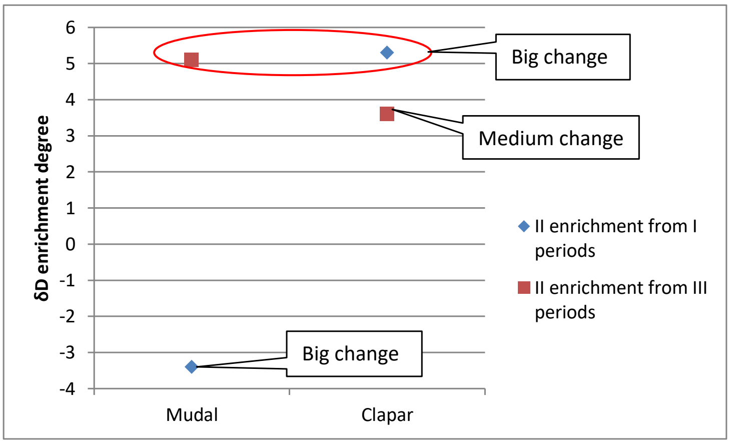

Figure 5. D enrichment of groundwater in Mudal and Clapar springs.

From Figure 5, it is shown that the Mudal spring has large δD enrichment (> 5 ‰), but not related to seasonal changes. The Clapar springs undergo moderate - large changes due to enrichment during the dry season. The δD enrichment in the Clapar springs in the dry season shows a seasonal effect on the D isotope of groundwater. This is confirmed by a shift in δD values can occur due to seasonal changes [9].

If the δD range value is taken into account, then some groundwater samples appear to have shifted (Figure 5). The two springs under study have shifted slightly - totally change.

4.3.2. The "d" value (δD-excess). Changes in stable isotope content can occur due to the influence of seasons due to differences in temperature. Isotope data in the two investigated springs showed that it was good $\delta^{18}O$ nor δD varies considerably, both in absolute value and in range. The data that are not much different are generally considered to have no seasonal variation (temperature effect) [7]. However, if we examine one by one, there is a "d" variable which is δD-excess which we can calculate (Table 7). The value of d in general can be calculated with the following formula [7].

Commented [H32]: Is it only due to differences in temperature, how about elevation, how about precipitation rate, humidity?

$$d = \delta D - 8\delta^{18}O \qquad (1)$$

Table 7. The value of the δD-excess of groundwater.

Spring	δD-excess ("d") (‰)		
	I	II	III
Mudal	15.1	14.02	5.32
Clapar	10	9.38	-0.14

The "d" value or δD excess indicates the presence of D isotope enrichment versus $\delta^{18}O$ value. The value of "d" is a relatively important parameter in relation to the climate of an area. The value of groundwater in the study area in period I ranges from 10 and 15.1 ‰; period II amounted to 9.38 and 14.02 ‰; in period III of 5.32 ‰ in Mudal, indicating that the range of "d" values in Mudal is relatively higher, in all seasons. Clapar springs do not show d excess in period III. In general, the value of d gets lower over time.

In general, d excess is influenced by air mass which is usually different, where the dry season tends to be dry, while the rainy season has humid air [7]. Liotta (2006, in [10]) states that in rural areas, the isotopic exchange between rainwater and humidity can slightly shift the value of d. However, the d value was not significant for the springs studied. However, the d values in the two springs in the two seasons varied, not showing a significant difference. This less significant difference shows that the humidity in the air during the dry and rainy seasons is not much different, as well as the evapotranspiration conditions that can occur quite intensively in the two seasons.

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Commented [H34]: How do you compare the data and mentioned that this is "not showing a signifcant differences", significancy should be measured based on the statistic analysis

Commented [H35]: Where is the data of humidity?

Commented [H36]: Where is the data of evapotranspiration?

In dry conditions, evapotranspiration as a controller for groundwater recharge is usually relatively reduced, while in the rainy season / humid air, evapotranspiration is greater [7]. In addition, in the dry season, many plants are dormant, while in the rainy season the plants are more developed. Thus, the differences in evapotranspiration and humidity conditions in all seasons were not significant.

In addition, large d values usually occur in high permeability rocks or thin soil resulting in rapid infiltration [7]. This rapid infiltration causes groundwater to experience no / less evapotranspiration. Mataair Mudal has a character like this, supported by the large number of fractures, cracks and dissolving cavities in the limestone that make up the aquifer of these springs. Significant shifts in d values can occur in both the Jonggrangan and Old Andesite Formations aquifers.

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Commented [H38]: ....please elaborate more with your interpretation about the mudal springs aquifer system

5. Conclusion

This groundwater hydroisotope study was carried out on two selected springs in the West Progo Hills, namely the Mudal springs which emerged from the limestone of the Jonggrangan Formation and the Clapar springs which emerged from the volcanic breccias of the Old Andesite Formation. Both springs have the characteristics of stable isotope content of groundwater which is relatively stable, with insignificant changes with time and season. Based on its absolute value, Mudal springs have an isotope that tends to be light, indicating deep aquifer, or high elevation recharge. Meanwhile, Clapar springs show isotopes, which come from shallow aquifers with a mixing / evaporation process and are more influenced by the season. Based on the range value of δ^{18}O and δD, Mudal springs contain isotopes that are less affected by seasonal changes, while Clapar springs are seasonal. Based on season, δD enrichment shows uncertainty, while Clapar Spring has a medium - big change character. The range value of δD in both springs is slightly - totally change, which means that it changes due to the change of seasons even though it is small. Meanwhile, the "d" value varies independently of the season, which can be interpreted that the evapotranspiration and humidity conditions during the dry and rainy seasons in the study area are not much different.

Commented [H39]: Can you find other word to replace medium-big to medium-large...or else

Acknowledgment

This paper is based on the results of the 2016 STTNAS internal research and dissertation data, therefore the authors would like to thank STTNAS for the finance of this research.

Reference

[1] Van Bemmelen RW 1949 *The Geology of Indonesia* Vol. 1A (Netherland: Martinus Nijhoff, The Hague).

[2] Satrio, Sidauruk P 2015 Karakteristik air tanah dangkal Kota Semarang pada musim penghujan berdasarkan pendekatan isotop stabil (^{18}O, ^{2}H) dan Kimia Air *J. Ilmiah Aplikasi Isotop dan Radiasi,* **11** 1.

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Commented [H40]: These two references seem to be not too relevance, the citation from these references can be found on other references which is more special on discussing about groundwater isotope

Commented [H41]: ?

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Listiani RA <lis@itny.ac.id>

ICGoES Schedule and General Information - Presenter

ICGoES Secretariat <icgoes@ugm.ac.id> 12 Maret 2021 20.12
Kepada: Lis <lis@itny.ac.id>

Dear Dr. T. Listyani R.A.,
Presenter of the ICGoES 2021

Please find attached the General Schedule and Detail Schedule for your reference. These schedules could also be downloaded from here.

Please be informed that General Information, Registration Guidelines, and Presenter Resources has been added to our website.

Presenters are expected to give a live presentation during their session, however if you are not sure with your internet connection, you are allowed to submit the recording of your presentation (maximum duration 10 minutes) to the committee **maximum 2 days before** your actual schedule via the following link.

Should you have any questions or concerns, please do not hesitate to contact us.

Sincerely yours,
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ICGoES 2021

Date	Time	Room	Moderator	Theme	Paper ID	Authors	Title	Room	Moderator	Theme	Paper Number	Authors	Title
16-Mar-21	13:30 - 13:45	1	Dr. Afikah Rahim	Applied Geophysics for Urban Areas	56	Saptono B. Samodra Rocky T. Sembiring Ghiffary R. Ramadhan Hatfan A. Kharis Theo R. Siregar	Groundwater potential zones identification in Purwobinangun, Pakem, Sleman, D.I. Yogyakarta using vertical electrical sounding (VES)	2	Sara Pena Castellnou (PhD cand.)	Seismic Hazards	3	Jaya Murjaya Subagyo Pramumijoyo Dwikorita Karnawati Daryono Daryono Irwan Meilano Pepen Supendi Suaidi Ahadi Gayatri Indah Marliyani Rudy Imananta Fajri Syukur Dimas Solomo Sianipar	Earthquake Risk Assessment of the Opak and Merapi-Merbabu Active Faults to Support Mitigation Program in Yogyakarta Province and its Vicinity
	13:45 - 14:00				18	Bondan Galih Dewanto Indra Arifianto Cahli Suhendi Margherita Fittipaldi	Regression Kriging Analysis for Predicting the Shallow Depth Water from Sentinel-2 Satellite Multi-spectral Images, Study Area: Coastline of Florida, USA				10	Aristo Pakpahan Iskandarsyah Iskandarsyah	Reviewing the characteristics of slip behaviour for megathrust earthquake at sumatera using vertical derivative of GOCE satellite gravity field
	14:00 - 14:15				13	Luthfi Yufajjiru Maryadi Maryadi	Soil Stiffness Identification using Fuzzy Logic Based on Seismic Tomography and It is Relationship with Dynamic Elastic Moduli				45	Zaw Lin Kyaw Myo Thant May Thet Aye Junji Kiyono Salahuddin Husein	Seismic Hazard Assessment of Pobbathiri Township, Nay Pyi Taw Union Territory, Myanmar By the Geophysical Surveys
	14:15 - 14:30				31	Soni Satiawan Liberte Iusti De Dili Ratih Nidya Ayu Citra Putri Pratama Pangeran Brandon Imran M. Kareem Ramadhani Sandy Nandaru Sukamto Wulan Novianti	A Correlation Study of Resistivity, Dar-Zarrouk Parameter and N-SPT Analysis for Identifying the Basement of Soil				11	Amien Widodo Wien Lestari	Analysis of the Effect of Magnetotelluric Data Quality Improvement Using Rho Variance and Edit XPR Parameters in Densely Populated Areas
	14:30 - 14:45										48	Nur Hidayati Oktavia Abdul Haris Sigit Pramono	Analysis of liquefaction potential based on shear wave velocity (Vs) in Medan, North Sumatra
	14:45 - 15:00										16	Aulia Puji Astuti Nurainun Sholihat Arifuddin Muh Imran Tahir Emelda Meva Elsera Muhammad Fawzy Ismullah Massinai	Characteristic of 27th September – 7th October 2017 Earthquake Swarms in Jailolo, West Halmahera Based on Hypocenter and b-value
	15:00 - 15:15	1	Dr. Basanta Raj Adhikari	Advances in Hazard Mitigation	60	Vanessa Steinritz Sara Pena-Castellnou Gayatri Indah Marliyani Klaus Reicherter	GIS-based study of tsunami risk in the Special Region of Yogyakarta (Central Java, Indonesia)	2	Kartika Palupi Savitri (PhD cand.)	Progress in Volcanology and Geothermal	42	M. Farel Bagaskara Alya Dhiya Oktaviani Rahmawan Setyadi Dian Abby Yoga Dyah Nindita Sahdarani Diyan Taufiq Kurniadi	Gas Geochemistry Analysis in Candradimuka Crater, Mount Lawu, Central Java, Indonesia
	15:15 - 15:30				46	Fia Tri Hamanti Supriatna Supriatna Ratna Saraswati	Distribution Area of Potential Land Movement Using Storie Index and Level of Vulnerability of Land Movement in Nyalindung Subdistrict				50	Mradipta L. A. Moktikanana Haryo E WibowoEti Rahayu Agung Harijoko	Hummock size and alignment in Gadung debris avalanche deposit, Raung Volcanic Complex, East Java, Indonesia
	15:30 - 15:45				28	Muh Imran Tahir Aulia Puji Astuti Muhammad Fawzy Ismullah Massinai	Analysis of Flood Disaster in terms of Meteorology and Seismicity in North Luwu, South Sulawesi				52	Yoga Aulia Luqman Dian Abby Yoga Muhammad Alzaid Ponka Miftah Syarif Harsya Dyah Nindita Sahdarani	Geochemical analysis of fumarole thermal manifestation in Ratu Crater area, Mount Salak, West Java, Indonesia
	15:45 - 16:00				38	Sara Pena-Castellnou Vanessa Steinritz Gayatri Indah Marliyani Klaus Reicherter	Active tectonics of the Yogyakarta area (Central Java, Indonesia): preliminary findings obtained from a tectonic-geomorphic evaluation				53	Rachmi Mustika Pertiwi Putri Gunawan Ganang Ikhwanushova Agung Harijoko Haryo Edi Wibowo Agung Setianto	Re-interpretation of distribution of Lautan Pasir caldera-forming eruption products, Bromo-Tengger Caldera Complex, East Java
	16:00 - 16:15				51	Dinda Zannuba Arifah Supriatna S Ratna Saraswati	Spatial Modeling of Tsunami for Evacuation Planning in Ciletuh Bay, Sukabumi, West Java						
	16:15 - 16:30				15	Satia Cahya Noviadi	Analysis of the Drought Distribution of the Palmer Drought Severity Index (PDSI) method in the Irrigation Jurang Sate on Lombok River Basin						
17-Mar-21	08:30 - 08:45	1	Rahmadi Hidayat (PhD. Cand.)	Progress in Unconventional Georesources	59	Nurarifah Amalian Sari I Wayan Warmada Ferian Anggara	The Potential of Lithium Enrichment in Lapindo Brantas, Mount Anyar, and Buncitan Mud Volcanoes, Sidoarjo District, East Java Province	2	Salahuddin PhD.	Advances in Geology and Geomorphology	64	Hirotaka Une Terunori Ohmoto Kazuki Kuranaga	Effect of Opening Depth of Oblique Weir with an Opening on Bed Morphology
	08:45 - 09:00				62	Wira Cakrabuana Roni Cahya Ciputra Heri Syaeful	Assessing the Undiscovered Resources of Uranium and Thorium in Mamuju, West Sulawesi				4	Muh Aris Marfai Bachtiar W Mutaqin Danang Sri Hadmoko Helvetia Wijayanti Franck Lavigne Audrey Faral	The physhical characteristics of the small volcanic island of Tidore and Hiri to support disaster management
	09:00 - 09:15				40	Dea Anisa Ayu Besari Ferian Anggara Himawan Tri Bayu Murti Petrus	Effect of Power Plant Operating Conditions on Fly Ash and Bottom Ash Composition : A Case Study From Tarahan Power Plant, Lampung, South Sumatera				27	Ghaneswari Yugamaris Agung Setianto I Wayan Warmada Prayatna Bangun	Geological structures control on the streamflow orientation pattern in the Cijulang area and its surroundings, Garut, West Java, Indonesia
	09:15 - 09:30										32	Chusni Ansori I Wayan Warmada Nugroho Imam Setiawan Hery Yogaswara	Geomorphosite Assessment at North Karangsambung -Karangbolong Geopark as Tools of Geotourism Development
	09:30 - 09:45												
	09:45 - 10:00												
	10:00 - 10:15	1	Dessy Sapardina (PhD cand.)	Machine Learning in Geological Engineering and Geosciences	24	Kazuki Yokoo Kei Ishida Takeyoshi Nagasato Yasunori Kawagoshi Hiroaki Ito	Reconstruction of Groundwater Level at Kumamoto, Japan by Means of Deep Learning	2	Dr. Nguyen Bach Tao	Advance Methods in Hydrogeology I	34	Bidhya Subedi Takafumi Kitaoka Junji Kiyono	3D Stratigraphic modelling of the Bangkok basin using Kriging on borehole data
	10:15 - 10:30				33	Umima'tum Rikhasanah Muhammad Rizqy Septyandy Supriyanto Suparno	Identification of Paleotsunami Deposits Using XRF and Artificial Intelligence Methods on the Southern Coast of Lebak, Banten				29	T Listyani Ra	Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, Progo
	10:30 - 10:45				41	Gabriella Eka Putri Abdul Haris Muhammad Rizqy Septyandy	Artificial Intelligence Approach to Depositional Facies Characterization Based on Electrical Log Data				5	Heru Hendrayana M Widyastuti Indra Agus Riyanto Azmin Nuha Mega Yulisetya Widasmara Novia Ismayuni Isfi Nurafifa Rachmi	The Validation of Thornthwaite and Mather Water Balance Method in Indonesian Tropical Area
	10:45 - 11:00				66	Erwin Fernanda Sthevanie Dhita Sudrazat Pangeran Brandon Imran Farhan Haidar Rosadi Dimas Farhan Wibowo	Mapping of Soil Vulnerability in Merapi Area with the integration of Machine Learning, HVSR, and PGA methods				25	Kazuki Yokoo Kei Ishida Takeyoshi Nagasato Ali Ercan Tongbi Tu	Comparison of three recurrent neural networks for rainfall-runoff modelling at a snow-dominated watershed
	11:00 - 11:15				26	Takeyoshi Nagasato Kei Ishida Kazuki Yokoo Masato Kiyama Motoki Amagasaki	Effects of the spatial and temporal resolution of meteorological data on the accuracy of precipitation estimation by means of CNN						
	11:15 - 11:30												
	11:30 - 12:00												
	12:00 - 13:30	BREAK											
	13:30 - 13:45							2	Claude Thielen (PhD cand.)	Advance Methods in Hydrogeology II	44	Rais Akbar Sembiring Hugo Descartes Simanjuntak Yehezkiel Stanly Viero Stefanus Gilbert Sitindaon Muhammad Chairil Talib	Groundwater Quality Study of Jakarta Groundwater Basin using STORET Method and Geochemical Analysis
	13:45 - 14:00										36	Lena Kämpfner Thomas R. Rüde Doni Prakasa Eka Putra	Characterization of Shallow Groundwater Chemistry in the Yogyakarta Basin, Central Java
	14:00 - 14:15										57	Jarrid Tschaikowski: 5 mins flash talk	Hydrogeological system analysis of the freshwater lens of Gili Air (Lombok, Indonesia)
	14:15 - 14:30										61	Benjamin Baud Patrick Lachassagne Hervé Jourde Véronique De Montety Arif Fadillah Nathalie Dörfliger Heru Hendrayana Arief Rachmansyah 5 mins flash talk	Preliminary conceptual model of the Arjuno Welirang hydrogeological system, and comparison with the Bromo Tengger: An illustration of the hydrogeological systems diversity in volcanic area.
	14:30 - 14:45												
	14:45 - 15:00												
	15:00 - 15:15	1	Dr. Jan Klimeš	Antrophogenic Geology and Environmental Degradation	17	Emmanuel Grace Manek Doni Prakasa Eka Putra Heru Hendrayana	Mass Transport Modeling of Total Organic Carbon in Groundwater to Determine the Location of Petroleum Fuel Pollutant Sources in the area of Jlagran, Yogyakarta City, Indonesia	2	Dr. Rishi Parajuli	Methods and Advances in Applied Geophysics	14	Maryadi Maryadi Prawira Bramanthyo Ahmad Zarkasyi Hideki Mizunaga	Estimation of Near-surface Temperature in Suwawa Geothermal Prospect Based on Magnetotelluric and Artificial Neural Network
	15:15 - 15:30				21	Merdeka Sandi Tazakka Budiwan Adi Tirta Monika Aprianti Popang Yulisa Afna Sariska	Study of Negative Skin Friction on Floating Piles Foundation Due to Long-Term Groundwater Extraction in Semarang Indonesia				22	Pyi Soe Thein Khinmayone Kyaw	Estimation of Sedimentary Layered Media at Amarapura Township, Mandalay Region
	15:30 - 15:45				19	Dini Fitriani Widya Utami Kartika Hajar Kirana Eleonora Agustine Siti Zulaikah	Magnetic signatures on river sediments and agricultural soils as proxy indicators of anthropogenic-derived pollution (Case study: Cikijing River, Rancaekek, West Java)				49	Kartika Luthfia Ariwibowo Aldino Maulana Riski Ahmad Syihab Fajarulloh Thomas Triadi Putranto	Analysis of the Distribution of Seawater Intrusion Using Electrical Conductivity and Total Dissolved Solid Data and Intelligence for Residents in Sayung District, Demak Regency
	15:45 - 16:00				35	Mufid Muyassar Wawan Budianta	Assessment of soil heavy metal contamination around Piyungan Landfill of Bantul, Yogyakarta, Indonesia				12	Aprilia Puspita Yosef Prihanto Sukendra Martha Agustya Adi Martha Rudy Gultom	Deformation identification using DInSAR multi temporal analysis and gravity method in supporting infrastructure development
	15:00 - 16:15				39	Andria Trisekarningsih Wawan Budianta Wayan Warmada	Urban soil assessment caused by heavy metals contamination in Yogyakarta City, Indonesia						
18-Mar-21	08:30 - 08:45	1	Dr. Arifudin Idrus	Methods and Advances in Economic Geology	8	I Gusti Agung Ayu Sugita Sari I Wayan Warmada	Characteristics and Utilization of Clay Minerals in Kuwu Mud Volcano, Kradenan District, Grobogan Regency, Central Java Province	2	Dr. Donatus Hendra Amijaya	Methods and Advances in Petroleum and Coal Geology I	30	Asep Permana Colin Ward	SEM-EDS imaging of multi-stage cleat minerals formation in the South Walker Creek Coals, Bowen Basin
	08:45 - 09:00				9	Ni'Matul Azizah Raharjanti I Wayan Warmada Himawan Tri Bayu Murti Petrus	Ore Characterization in “X” Pit, Toka Tindung Project, South Sulawesi				23	Arya Pradana Jarot Setyowiyoto Budi Prasetyo Wahdanadi Haidar	Overpressure’s Top and Generating Mechanism in “APR” Block, North Sumatra Offshore Area
	09:00 - 09:15				20	Sara Septiana Arifudin Idrus Federica Zaccarini Giorgio Garuti	Ore mineralogy of podiform-type chromite deposit in Tedubara area and its vicinity, Kabaena Island, Indonesia				43	Raditya Pascarizativa Abdul Haris Mahesa Sufi	An Integrated Approach Using Microtremor Data for Field Development and Reservoir Monitoring: Example from Betung Field, Jambi
	09:15 - 09:30				55	Elisha Tobing Felix Sihombing	Major geological structure control and influence on the alteration and mineralization of Kucing Liar deposit				72	Muhammad Luthfi Farhan Donatus Hendra Amijaya	Petrographic Composition of Coke Product from Batu Ayau Formation Coking Coal, Kutai Basin, Central Kalimantan
	09:30 - 09:45				68	Widyawan Nur Muhammad Nugroho Imam Setiawan Salahuddin Husein ochamad Nukman	A Preliminary study of Skarn and Geology of Cemorosewu Area, Bayat, Central Java, Indonesia						
	09:45 - 10:00												
	10:00 - 10:15	1	Dr. Haryo Edi Wibowo	Methods in Petrology and Petrogenesis	37	Anastasia Dewi Titisari Yolanda Karina Sari I Wayan Warmada Fahmi Hakim	Petrogenesis of Botorubuh Igneous Rocks at Gunungkidul, Yogyakarta - Indonesia	2	Dr. Pipat Laowattanabandit	Methods and Advances in Petroleum and Coal Geology II	47	Anwar Sadat Abdul Haris Haryono Gisal Dharmawan	Impact of Carbonate Facies on Rock Quality Factor in Discriminating Hydrocarbon-Bearing Reservoir, East Java, Indonesia
	10:15 - 10:30				7	Tri Winarno Jenian Marin Nurjayanti Nurjayanti	The relationship of physical properties and geochemical composition of limestone and its implications to the quality as cement raw material in Gunem District, Rembang Regency, Central Java				63	Sarju Winardi Sugeng Sapto Suryono Amijaya Donatus Hendra Wiwit Suryanto	Reservoir Resistivity Correction Factor in Low Resistivity Pyritic Sandstone Reservoir
	10:30 - 10:45				54	Anastasia Dewi Titisari Irvan Fatarwin Lubis Nada Salsabila Irsani	Textural and Mineralogical Characteristics of Sand Grains of Oyo River Deposit at Yogyakarta, Indonesia: Implications on Sedimentation and Origin				75	Lauti Dwita Santy Angga Jati Widiatama	PEDARO FORMATION, EQUIVALENT OF PLOVER SANDSTONE AT SAVU ISLAND, OUTER BANDA ARC
	10:45 - 11:00				6	Isyqi Chusni Ansori	Petrography and Geochemistry Preliminary Studi of Pucangan Serpentinite Geosite Karangsambung – Karangbolong Geopark						
	11:00 - 11:15				69	Luthfi Aryani Fahmi Hakim Anastasia Dewi Titisari Ganjar Nugraha Candra Arief Mahardika	Preliminary Study of the Origin of Mafic Mineral Megacrysts in Volcanic Rocks in the Southwestern Part of Kulon Progo Mountains, Indonesia						

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Listiani RA <lis@itny.ac.id>

ICGoES 2021 Reminder – Publication, Registration and Scheduled Program

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ICGoES 2021 <icgoes2021@easychair.org> 13 Maret 2021 17.04
Kepada: T Listyani Ra <lis@itny.ac.id>

Dear all authors,

Hope this email finds you well.
As the date of the conference approaches, this is a reminder to all of you regarding the papers and registration.

The decision on your papers has been sent to you. For publication, please incorporate all revisions suggested by reviewers.

You can upload your revised paper by click 'update file' on your EasyChair dashboard account, a maximum of 3 weeks after the conference. Otherwise, your paper will not be considered for publication. Your paper will be review again by reviewers to ensure all revisions have been addressed before we proceed with the proof-read and finalization stage.

The payment deadline has been extended to 15 March 2021 at 23:59 pm.
If you have inquiries about payment and registration, please email us at icgoes@ugm.ac.id with the Subject: Payment-registration ICGoES 2021 Paper ID No.29.

After payment, you can do the registration. Student presenter must provide their Student ID and submit together with a payment receipt.
Please follow the instructions of payment and registration at https://icgoes.geologi.ugm.ac.id/registration-and-fee/

Log in to access full ICGoES 2021 pages can be done after registration.
The committee will send by email all scheduled programs and access to the conference.
General information, registration, and presentation guidelines are already available on the website. Feel free to use your own template for the presentation.

Thank you for your contribution and kind cooperation.

Sincerely yours,
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ICGoES 2021

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Listiani RA <lis@itny.ac.id>

Acknowledgments and Announcement to Presenter ICGoES 2021

---

icgoes@ugm.ac.id <icgoes@ugm.ac.id> 5 April 2021 10.18
Kepada: lis@itny.ac.id

Dear Prof./Dr./Mr./Mrs. T Listyani Ra,

On behalf of the committee International Conference on Geological Engineering and Geosciences, and the Department of Geological Engineering UGM, we would like to say thank you very much for your kind cooperation as a presenter in our conference. We apologize if there any technical difficulties or problems during preparation, reviewing process, and during the event. Please find the attached certificate as our appreciation for your contribution.

We still have the second review process for your paper using the same EasyChair system (https://easychair.org/conferences/?conf=icgoes2021). The expected schedule is as follows:
- 8 April 2021 – Deadline for Submission Revised Full Paper
- 16 April 2021 – Documentation in Portal Website and Certificate Distribution
- 14 May 2021 – End Review Process (including second revised version if any)
- 1 May – 18 June 2021 – Proof Read to all Co-Authors
- 18 – 30 June 2021 – Approval from Editorial Board
- 5 July 2021 – Submitted to IOP Conference Series: Earth and Environmental Science

To ensure the above schedule run smoothly, we appreciate your cooperation by following the term and condition below:
- Full Paper must follow the template of IOP. See the template in https://icgoes.geologi.ugm.ac.id/paper-submission/ or https://publishingsupport.iopscience.iop.org/author-guidelines-for-conference-proceedings/
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After proof read is completed, we will ask the approval from the editorial board before we submitting the final paper to the IOP Conference Series: Earth and Environmental Science (https://iopscience.iop.org/journal/1755-1315).

If you have inquiries about publication, please email to: icgoes@ugm.ac.id with Subject: Publication ICGoES 2021 Paper ID No[..]

Information about ICGoES Announcement and Paper Publication could be downloaded here:
https://drive.google.com/file/d/1CxnuJjl8HTcWMXFd9thsy2XAWFqluU9w/view?usp=sharing

Thank you for your kind cooperation and continuous support.

Sincerely yours,
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THIS CERTIFICATE IS AWARDED TO

T Listyani Ra

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"Big City Challenges on Geo-hazard and Geo-resources"

Held by Department of Geological Engineering, Faculty of Engineering,
Universitas Gadjah Mada, on 16-18 March 2021

Yogyakarta, 18 March 2021

Dr.Eng. Ir. Agung Setianto, S.T., M.Si., IPM.
Head of Department
Department of Geological Engineering
Faculty of Engineering, Universitas Gadjah Mada, Indonesia

Hendy Setiawan, S.T., M.Eng., Ph.D.
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16-18 Mar 2021	ICGoES Conference Date
8 April 2021	Deadline for Submission Revised Full Paper
16 April 2021	Documentation in Portal Website, Certificate Distribution
14 May 2021	End Review Process (Incl. Revised Version)
1 May – 18 June 2021	Proof Read & Finishing
5 July 2021	**Submitted to IOP Publishing**

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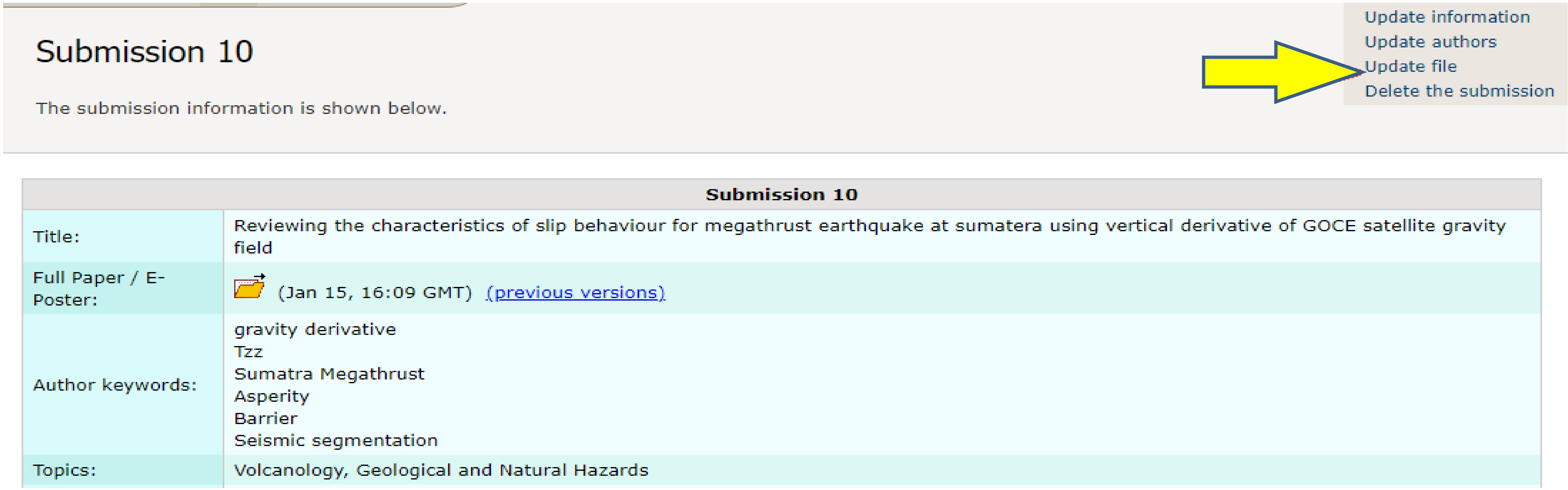
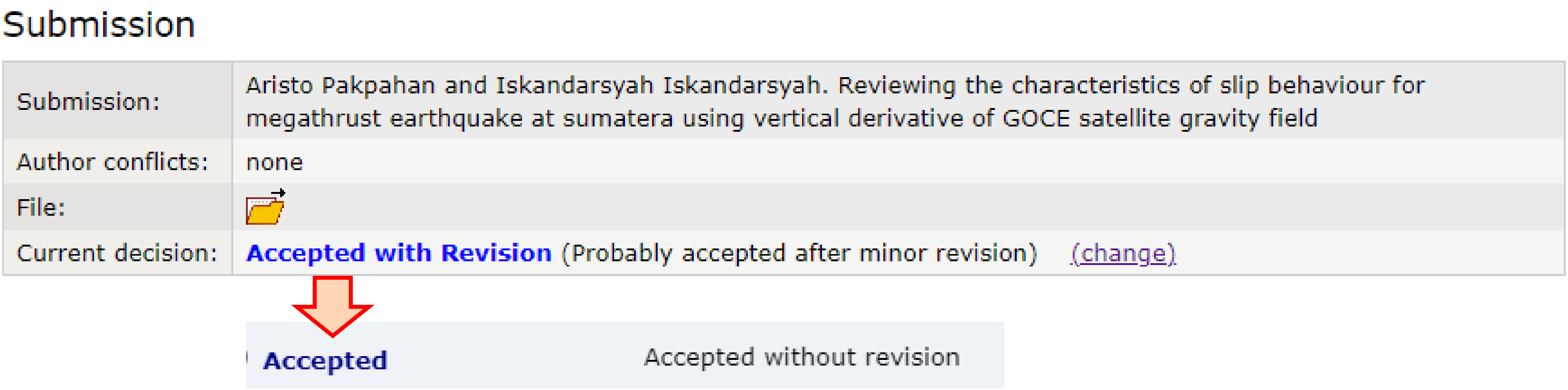


Submission 10

The submission information is shown below.

Submission 10	
Title:	Reviewing the characteristics of slip behaviour for megathrust earthquake at sumatera using vertical derivative of GOCE satellite gravity field
Full Paper / E-Poster:	(Jan 15, 16:09 GMT) (previous versions)
Author keywords:	gravity derivative Tzz Sumatra Megathrust Asperity Barrier Seismic segmentation
Topics:	Volcanology, Geological and Natural Hazards



Submission

Submission:	Aristo Pakpahan and Iskandarsyah Iskandarsyah. Reviewing the characteristics of slip behaviour for megathrust earthquake at sumatera using vertical derivative of GOCE satellite gravity field
Author conflicts:	none
File:	
Current decision:	**Accepted with Revision** (Probably accepted after minor revision) (change)

Accepted	Accepted without revision

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ICGoES 2021 submission 29 update

ICGoES 2021 <icgoes2021@easychair.org> 7 April 2021 20.18
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ICGoES 2021 – 2nd Review Result and Decision on your Paper ID 29

ICGoES 2021 <icgoes2021@easychair.org> 1 Juni 2021 21.23
Kepada: T Listyani Ra <lis@itny.ac.id>

Dear authors,

We have received the reports from reviewers on your revised paper, “Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, West Progo”, which you have submitted to ICGoES 2021.

Based on the advice received, your paper is subjected to MINOR REVISION. We still found substantial issues in your paper that need your attention. Please do revise properly as suggested by reviewers.

Please check all comments suggested by reviewers below. You should incorporate any revisions and resubmit them back to us through EasyChair within 7 days before we proceed to a final decision.

Thank you for your contribution and kind cooperation

Sincerely yours,
Editorial Committee
ICGoES 2021

SUBMISSION: 29
TITLE: Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, West Progo

----------------------- REVIEW 1 ---------------------
SUBMISSION: 29
TITLE: Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, West Progo
AUTHORS: T Listyani Ra

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Thank you for the revision of the manuscript, most of the suggestion was already revised, however there are still some basic information shall be given and also some statement which may be change according to the data and facts. Please check on my attached file.
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Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, West Progo

Abstract. Hydroisotope studies were carried out on Mudal and Clapar springs located in the central part of the West Progo Dome. The research was conducted by taking samples of groundwater in each spring for three periods, representing the rainy (2016), dry (2017) and rainy (2018) seasons. Data on stable isotope content of ^{18}O and D were analyzed to see the hydroisotope characteristics of groundwater and their relationshio to climate change. The results show that the stable isotope content of groundwater in both springs was relatively stable, with insignificant changes over time and season. Mudal springs tend to show light isotopes, indicating deep aquifer or high elevation recharge, less affected by the season. Clapar spring shows heavy isotopes, which may be sourced from shallow aquifer with mixing / evaporation processes and more influenced by the season. Meanwhile, the range value of δD in the two springs show slightly - totally changes, indicating that the D content also changes due to seasons, although it is small. The δD enrichment shows the medium - big change in both spring springs, but uncertainty in Mudal. However, the D-excess value shows that the dry and rainy season conditions which may be related to temperature or precipitation are not much different.

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1. Introduction

The study of groundwater has been developed because this natural resource is becoming increasingly important over time, in line with the needs of living things for groundwater. Various groundwater studies have been carried out, both physically and chemically [1-5]. Hydrochemical studies were also developed using various methods, complemented by studies of groundwater isotopes (hydroisotopes). Isotope analysis is useful to aid in the interpretation of groundwater flows as well as aid in its genetic interpretation. The results of groundwater hydrochemical analysis can be verified by isotope analysis so that it will produce a better interpretation of the groundwater flow system. In addition, isotope studies have also been developed using the stable isotopes ^{18}O and ^{2}H (deuterium / D). One of the hydroisotope studies that can be done is related to the climate aspect in an area.

Stable isototope analysis is useful for knowing the origin of groundwater and interpretation of catchment areas. In addition, stable isotope data can also be used for analysis of hydrochemical processes, due to seasonal changes [6]. This paper intends to discuss the characteristics of the stable isotopes ^{18}O and D, particularly in relation to seasonal changes in the West Progo Hills area. The case study in this case was carried out on the Mudal and Clapar springs which are located in the central part of the West Progo Dome physiography [7].

Mudal spring is at an elevation of 664 m, emerging from the limestone aquifer of the Jonggrangan Formation in Banyunganti Hamlet, Jatimulyo Village, Girimulyo Subdistrict; meanwhile the Clapar spring is at an elevation of 437 m, emerging from the andesite breccia aquifer of the Old Andesite Formation in Clapar II Hamlet, Hargowilis Village, Kokap Subdistrict, West Progo Regency (Figure 1).

Commented [H2]: masl? meter above sea level?

Commented [H3]: masl?meter above sea level?

The study area is included in the physiography of the Dome and Hills Zone in the Central Depression [7]. The center of this dome physiography forms the morphology of the Jonggrangan plateau. The Jonggrangan Formation is quite extensive in this area. Around the Jonggrangan highlands, volcanic rocks from the Old Andesite Formation are exposed (Figure 1) [8].

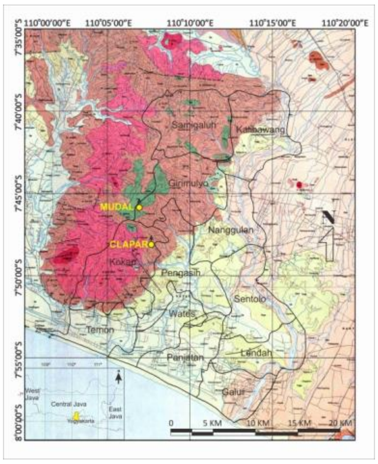

Figure 1. Location of Mudal and Clapar springs in Geological map [8]. Mudal spring is located at Jonggrangan Formation, while Clapar at Old Andesite Formation.

Commented [H4]: Please give the legend of the geological map

The regional stratigraphy of the West Progo Mountains from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations and Alluvial Deposits [7-9]. The Jonggrangan Formation is composed of conglomerates, tuff marl and limestone sandstones with lignite inserts, layered limestone and coral limestone. Meanwhile, the Old Andesite Formation is composed of andesite breccias, tuffs, lapilli, agglomerates and intercalation of andesite [8]. Mudal spring appear in the Jonggrangan Formation rocks, while Clapar spring appears in the Old Andesite Formation (Figure 2).

Figure 2. Mudal spring appear in the Jonggrangan Formation (top), while Clapar spring appear in the Old Andesite Formation (bottom).

Although West Progo Hills is classified as a non-groundwater basin [10], there are many springs can be found even though they have generally small discharge. However, several springs with moderate to large discharge can also be found on these hills. Large discharge can be found in the limestone aquifers of the Jonggrangan Formation. The presence of springs in the West Progo Hills zone is highly controlled by the local topography [11], in addition to lineament factors [12]. Geological lineaments play a role in the occurrence of springs, where the emergence of these springs is greatly influenced by the density and distance of lineaments to the location of the springs.

2. Method

The research begins with a hydrogeological survey to determine the geological conditions and springs in the study area. Several springs with small to large discharge are found in the central part of the West Progo area. This area is dominated by limestones of the Jonggrangan Formation and andesite breccias of the Old Andesite Formation. Springs with a large discharge were selected as the sample of this study. Mudal springs have large debits and represent the aquifer of the Jongrangan Formation, while the Clapar springs are medium / large enough and represent the Old Andesite Formation.This research focuses on isotope studies, but in the field, some groundwater hydrochemical data is also taken together with isotope sampling.

Groundwater samples from both springs were taken in three periods, namely period I in the rainy season in December, 2016; period II in the dry season (August, 2017) and period III in the rainy season (March, 2018). Precipitation of research area at the time of sampling can be seen in Table 1. The difference in sampling time from each period to the next is around 8 months. In each sample, 30 ml of groundwater was put into an airtight bottle (polyethylene) by inserting the bottle into a water source to avoid evaporation.

Table 1. Precipitation data in research area (mm/month) [13-15].

Spring	Dec, 2016	Aug, 2017	Mar, 2018
Mudal	216	2,5	218
Clapar	311	13	152

Isotope testing was carried out at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), which is located in Pasar Jumat, South Jakarta. The isotope content analyzed is oxygen-18 (^{18}O) and hydrogen (^{2}H), known as deuterium (D) isotope. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. Isotope ratios were measured by a mass spectrometer and the results were referenced against the SMOW standard. The internal standard was calibrated using V-SMOW with an analysis accuracy of ± 0.1 for $\delta^{18}O$ and ± 1‰ for δD [3]. Furthermore, the results of the stable isotope test were analyzed to determine the changes as well as the interpretation of the influence of the seasons / climate in the study area.

Isotope data analysis was carried out by looking at the absolute value trend and the relative value of Mudal and Clapar isotope content in three periods. In addition, the $\delta^{18}O$ and δD relationships in groundwater springs compared with meteoric water lines were also analyzed to assist in the genetic evaluation of groundwater in the springs. Analysis of changes in isotope content related with seasonal effects can be done by looking at the δD enrichment and D-excess (d) of the groundwater.

3. Stable isotope review

Isotopes are elements that have the same atomic number but different mass numbers [16]. In nature, isotopes in water can be found as stable or radioactive isotopes. The content of radioactive isotopes in water can be used to determine age, while stable isotopes are useful for determining water genetics [17].

Isotopes contained in water, namely hydrogen atoms (^{1}H, ^{2}H, ^{3}H) and oxygen atoms (^{16}O, ^{17}O, ^{18}O) often be used in hydrogeological studies [18,19]. The abundance of ^{1}H isotope is about 99.985%, ^{2}H is about 0.015%, and ^{3}H is < 0.001%, while the ^{16}O isotope is about 99.63%, ^{17}O is about 0.0375%, and ^{18}O is around 0.195%. [17]. Isotope abundance is measured by the ratio of the deviation from the standard [16]. The stable isotopes ^{18}O and ^{2}H are present in water in the form of compounds $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O_2$ [17,20]. Since the abundance of $H_2{}^{18}O$ and $HD^{16}O$ molecules compared to the abundance of $H_2{}^{16}O$ is very small, the measured abundance is usually the relative abundance of an international standard water / SMOW (Standard Mean Ocean Water). [6].

The ^{18}O and D isotopes are often used in the study of chemical processes. This isotope is a stable, non-radioactive isotope and is often used as an indicator for groundwater sources [6]. The ^{18}O and ^{2}H isotopes are natural tracers because they are stable [21-23], that is, they are not affected by the water-rock interaction process at low temperatures [24]. Therefore, isotopes are often used in genetic studies, determination of groundwater infiltration zones [5,25-28], as well as studies of mixing groundwater from different sources [29]. Even, the geological structure control in deep groundwater flow systems can also be determined by groundwater isotope analysis [5].

The ^{18}O and D isotopes are very sensitive for physical processes such as evaporation and condensation, therefore, the content of these stable isotopes can be used to see the climate effect on springs. The isotopic fractionation process in precipitation is a temperature dependent process [6]. Thus, if there is a change in seasonal temperature in a place, it will be seen that there is a variation in the stable isotope composition of the precipitation where a light value occurs in a cold month. For the same reason, precipitation will also have a lighter isotope content in the arctic / high latitudes, in places further away from the sea and in places of higher elevation. Every 100 m elevation increase, ^{18}O in rainwater will decrease of 0.15 - 0.5 ‰ and ^{2}H will be depleted by 1 - 4‰ [30].

Stable isotope content in rainwater shows a linear relationship in the form of a global meteoric water line. The relationship between $\delta^{18}O$ and δD of the precipitation water follows the equation of the meteoric water line. From the results of the global investigation [31] the equation for the meteoric waterline (GMWL) was known as $\delta D = 8\delta^{18}O + 10‰$. Rainwater tends to contain the stable isotopes $\delta^{18}O$ and $\delta^{2}H$ which are depleted at higher latitudes. This phenomenon also occurs when the two stable isotopes move deep inland. For this reason, the plot results of the two isotopes yield slightly different slopes known as the local meteoric water line [32].

Based on research of the recharge area of the underground river water system in Gunungkidul, Yogyakarta [3], it is known that the local meteoric water line (LMWL) equation for the area is $\delta^{2}H = 7.978\ \delta^{18}O + 8.423$. This LMWL value is then used for isotope studies in the West Progo area, because of its relatively close location and considering that the LMWL value in the West Progo area is not yet available.

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To see the influence of climate / rainfall, regression line relationships $\delta^{18}O$ and δD groundwater can be plotted together with the global meteoric water line GWML or the local meteoric water line (LMWL). If the groundwater regression line is adjacent to the LMWL then the groundwater is affected by local climate (originating from local precipitation) or by topographic effects [1].

4. Result and discussion

4.1. Spring characteristic

Mudal Springs emerge from the limestone aquifer of Jonggrangan reef, supported by large porosity, as well as large rock permeability. The porosity developed as fracture and channel types. Jonggrangan limestone is dominated by thick to massive layered coral limestones. Around the Mudal springs this reef limestone outcops show white to brownish white colour, compact and hard, with some fairly intensive tectonic of joints characteristics. Mudal Springs has a large fluctuation in discharge. The discharges show; moderate magnitude during the dry season, but can be very large discharge during the rainy season [11]. When the isotope sampling was carried out, the Mudal spring discharge was measured to be 100 - 236 L/s, but at the end of the dry season (September 2018), it appears that this matrix discharge has decreased drastically to <50 L/s.The spring can be classified as depressions, fractures or channels type of spring. Mudal spring has large flow that develop as runoff / rivers. This spring is a parennial spring although has big change of discharge over season. Based on its temperature, Mudal is classified as normal spring. The physico-chemical data show groundwater of Mudal spring has a temperature range of 23,1 – 24ºC, pH of 6.7 – 8.3, TDS of 225 – 254 ppm and EC of 380 – 418 μS /cm.

Commented [H6]: Matrix? Do you mean groundwater flowing through micropores system? How about the fact that you are mentioned that this spring classify as fractures or channel type spring!

Meanwhile, Clapar springs have smaller dimensions than Mudal springs.Clapar springs emerge from aquifers in andesite breccias and autoclastic / lava breccias of Old Andesite Formation, which are supported by fracture and sheeting joints porosities with moderate intensity and also controlled by low - medium permeability. Clapar springs have fracture type of springs. The discharge of springs usually small (stagnant) - medium flow rate, with small fluctuation of discharge. These springs can be classified as normal springs based on their temperature of water. The physico-chemical data of these springs show the temperature of 23.7 – 24.5ºC, with pH range of 7 – 8.2, TDS of 75 – 97 ppm and EC of 157 – 185 µS /cm.

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4.2. ^{18}O and ^{2}H isotopes contents analysis

Stable isotope content data in Mudal and Clapar spring water can be seen in Table 2 below. Furthermore, the absolute value and range value of the isotope content can be analyzed to determine the hydrochemical processes that occur in the groundwater system.

Table 2. Data on stable isotope content of groundwater from the investigated springs.

Spring	I (Dec, 2016)		II (Aug, 2017)		III (Mar, 2018)	
	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
Mudal	-7.1 ± 0.11	-41.7 ± 0.4	-7.39 ± 0.42	-45.1 ± 3.1	-6.94 ± 0.39	-50.2 ± 1.5
Clapar	-6.25 ± 0.07	-40 ± 1.8	-5.51 ± 0.32	-34.7 ± 1.0	-4.77 ± 0.34	-38.3 ± 3

4.2.1. Absolute value of δ^{18}O and δD. From period I to III, Mudal springs showed relatively stable O isotope, while D isotope tended to be lighter (Figure 3). Groundwater with light isotope generally flows in deep aquifers or comes from high absorption areas [2], as seen in Mudal springs which have light D isotope (-50.2‰) in period III (Figure 3; Table 3). It means that groundwater that appears in Mudal springs may flow in deep enough aquifers or originate from precipitation of rainwater that infiltrates at a high enough elevation. The infiltration zone may exist locally, because the Mudal springs are indeed at a high enough elevation.

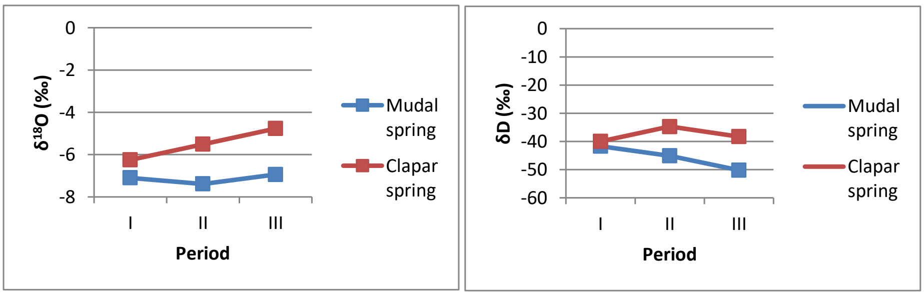

Figure 3. The development of stable isotope content over the three test periods.

Table 3. Changes in the stable isotope content of the springs.

Variable	Spring	δ^{18}O (‰)	δD (‰)
Time	Mudal	down-up, stable relatively difference = 0.45 ‰	get lighter difference = 8.5 ‰
	Clapar	get heavier difference = 1.48 ‰	up - down, stable relatively difference = 5.3 ‰
Season (T-effect)	Mudal	lower when dry	no effect
	Clapar	no effect	higher when dry

Clapar springs have groundwater with ^{18}O heavier from period I to III, as well as D isotope, which is relatively stable. The isotopes in springs indicate a mixing or evaporation process [1]. The D isotope indicates shallow aquifer [2]. Thus, the groundwater in the Clapar springs comes from shallow aquifers that have undergone a mixing or evaporation process.

Commented [H8]: This statement shall be correlated with Figure 4, however if looking to Figure 4, no indication of mixing as there is no isotope data from shallow wells/dug wells! and only one sample of Clapar spring shows evaporation enrichment process!

Compared to Clapar springs, Mudal springs contain lighter ^{18}O and D isotopes in the three periods studied. This shows that the stable isotopes possessed by the two springs are relatively consistent, whereas the Mudal springs tend to have genetics from deeper aquifers (Table 4).

Table 4. Interpretation of light / heavy isotope content.

Spring	I		II		III		Interpretation
	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	
Mudal	-7.1	-41.7	-7.39	-45.1	-6.94	-50.2	- Deep aquifer, or - High elevation recharge
Clapar	-6.25	-40	-5.51	-34.7	-4.77	-38.3	- Shallow aquifer - Mixing with run off or other source / evaporation

When compared with GMWL and LMWL, it appears that the absolute values of isotopes contained in the Mudal springs at all periods tend to move away from the two meteoric water lines (Figure 4). Clapar springs contain isotopes that tend to be close to the meteoric water line during the rainy (period I) and dry (II) seasons. This considerable deviation in period III for Clapar springs indicates the influence of water from other sources or pollution.

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The interpretation of water sources in the Mudal and Clapar springs is also supported by physico-chemical data from the groundwater. Mudal springs release water from deep aquifers characterized by cooler temperatures. The pH value which tends to be alkaline indicates a long interaction with carbonate rocks in the relatively deeper aquifer. This condition is also supported by the TDS and EC values which are much greater in the water from the Mudal springs than Clapar.

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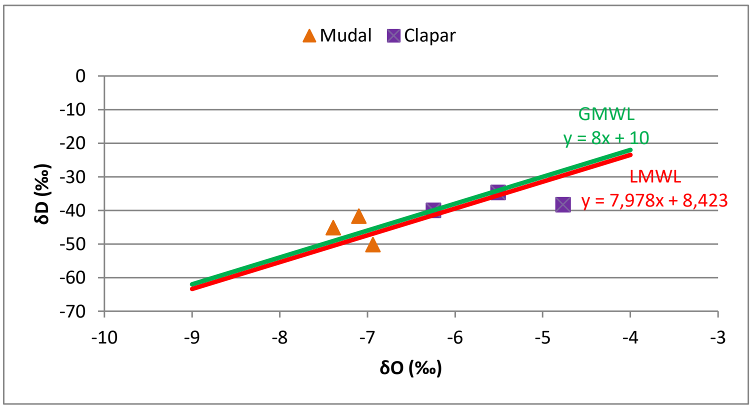

Figure 4. The relation of $\delta^{18}O$ and δD in groundwater of springs.

4.2.2. Range value of $\delta^{18}O$ and δD.

The stable isotope content studied showed a short range of values and generally did not have overlapping values (Figure 5). With due regard to the $\delta^{18}O$ range value in all periods, it appears that the groundwater from Mudal springs has isotopes $\delta^{18}O$ is light, while the Clapar springs have value $\delta^{18}O$. The overlapping values in the three periods in Mudal springs indicate that groundwater in these springs is less affected by seasonal changes, while seasonal changes have more effect on Clapar springs.

The widest δD range value occurs in Mudal and Clapar springs at different periods (Figure 5). The δD value which is relatively stable, light but appears to shift in the Mudal spring indicates that the groundwater in this spring is less affected by seasonal changes, with relatively deep circulation. As for the springs Clapar has relatively stable (heavy) δD which shows significant overlapping in the rainy period, slightly different from the range value in the dry season, indicating that groundwater in these springs is quite affected by changes in the season. Referring to the opinion of previous research [2], groundwater with heavy δD as in the Clapar springs can be interpreted as a result of a fairly intensive mixing or evaporation process (Table 5).

Monthly rainfall in the three periods shows that during the rainy season there is quite a lot of precipitation in both Mudal and Clapar (Table 1). In the dry season (period II), the precipitation is very low. However, the values range $\delta^{18}O$ for Mudal spring did not show any clear changes. This means, the ^{18}O isotope content in Mudal springs is relatively stable and less affected by the amount of precipitation. This also indicates that the Mudal springs are supported by relatively deeper aquifers.

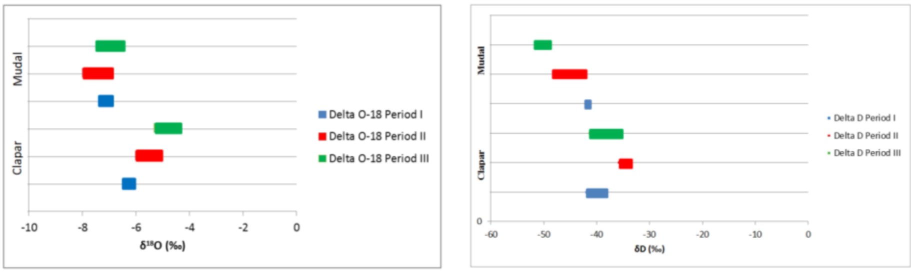

Figure 5. The values range $\delta^{18}O$ and δD for Mudal and Clapar springs. The overlaping values indicate the similarity of δD in different seasons.

Table 5. Value range interpretation $\delta^{18}O$ and δD.

Water springs	δ18O	δD	Analysis
Mudal	In short, some overlap	Short and long, shifted	$\delta^{18}O$ and δD are relatively stable / light, less affected by seasonal changes
Clapar	Short - long, shifted, enrichment	Short-a bit long, overlap especially in the rainy season	$\delta^{18}O$ and δD relatively stable / heavy, affected by season, intensive evaporation / mixing

Change δD of groundwater usually occurs due to isotopic exchange with minerals containing hydrogen, such as gypsum and clay minerals [33,34]. However, data support for this exchange. The δD in these two materials is not yet known, so the cause of the δD change groundwater is still difficult to determine. Moreover, this variation in value is usually not large, so this exchange is considered insignificant. Furthermore, membrane filtration is associated with increased δD, it is difficult to happen in the study area, because this process usually requires high pressure, which is equivalent to a sediment depth of 1.6 km [35]. In sedimentary rock formations less than 1 km deep membrane filtration is less effective [36].

Commented [H11]: please consider to check again this sentence...ex. However, data support for this exchange. (?) I have difficulties to understand the sentence.

4.3. The effects of season on δ^{18}O and δD changes

The process that occurs related to the seasonal effect can be assessed based on the δ^{18}O against δD of groundwater relationship. In the dry season (period II), the regression line of springs in the study area is very close to the LMWL, indicating that the enrichment of meteoric water isotope content has not been clearly seen [37]. However, the climatic influence in this dry season can be seen from the presence of d-excess [1]. Further reasearch added that the value of the line gradient is in the range 3-6 indicating an evaporation process [31].

The groundwater line in period III was partly below the LMWL, which indicates that it experienced isotopic enrichment [1,11], for example due to a fairly intensive evaporation process or mixing with surface water/runoff. The slope of the regression line that is smaller than the LMWL gradient indicates a variation in the rate of evaporation. In addition, it is possible that evaporation will occur in the catchment area along with the infiltration process [2].

4.3.1. The enrichment of ^{18}O and D stable isotopes. Changes in stable isotope content associated with changing seasons can cause an δD or δ^{18}O enrichment effect. O-18 isotope enrichment during the rainy season relative to the dry season occurs in Mudal springs, while δD isotope enrichment occurs in Clapar springs in the dry season compared to the rainy season (Table 6; Figure 3).

Isotopic enrichment δ^{18}O in the rainy season relative to the dry season in Mudal springs is related to the isotopic fractionation of carbonate rocks as a result of water-rock interaction. This was also supported by the TDS and EC values of groundwater in the Mudal springs which were much greater than the Clapar springs, both during the rainy and dry seasons. Enrichment of δ^{18}O can be caused by carbonate minerals [34,36]. Meanwhile, the δD enrichment of Clapar springs occurs indicating that seasonality affects the content of these stable isotopes. Season has an effect on the evaporation process which can enrich the isotopic content of groundwater.

Table 6 shows the degrees of δD enrichment in the springs studied. Degree of δD enrichment is calculated in the dry season (period II) relative to the rainy season, both period I and III. The magnitude of the changes caused by D isotope enrichment can be seen in Figure 6.

Table 6. The δD enrichment in the dry season relative to δD in the rainy season.

Spring	δD dry (Period II)	δD rainy		Enrichment Degree	Explanation
		Period I	Period III		
Mudal	-45.1	-41.7	-50.2	-3.4 - 5.1	Uncertainty
Clapar	-34.7	-40	-38.3	3.6 – 5.3	Medium - big

*) Negative values indicate enrichment during the rainy season

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Figure 6 shows that the Mudal spring has medium - large δD enrichment (>5‰), but not related to seasonal changes. The Clapar springs undergo moderate - large changes due to enrichment during the dry season. The δD enrichment in the Clapar springs in the dry season shows a seasonal effect on the D isotope of groundwater. This is confirmed by a shift in δD values can occur due to seasonal changes [2].

A spring that has δD enrichment >5‰ is classified to have a big change, while moderate change is indicated by D enrichment of >3 - 5‰, meanwhile, a small change is indicated by δD enrichment of >1 - 3‰ [2]. The enrichment δD <1 indicates no enrichment. If the δD range value is taken into account, then some groundwater samples appear to have shifted (Figure 6). The two springs have shifted slightly - totally change.

4.3.2. The “d” value (δD-excess).

Changes in stable isotope content can occur due to the influence of seasons due to differences in temperature. Usually, the temperature effect is related to the elevation of an area. However, in this study it is difficult to study the effect of elevation, considering that the two springs studied do not have a contrasting elevation difference. The humidity aspect also cannot be studied considering the absence of data. Isotope data in the two investigated springs showed that it was good $\delta^{18}O$ nor δD varies considerably, both in absolute value and in range. The data that are not much different are generally considered to have no seasonal variation (temperature effect) [1]. However, if we examine one by one, there is a "d" variable which is δD-excess which we can calculate (Table 7). The value of "d" in general can be calculated with the following formula [1].

$$d = \delta D - 8\delta^{18}O \tag{1}$$

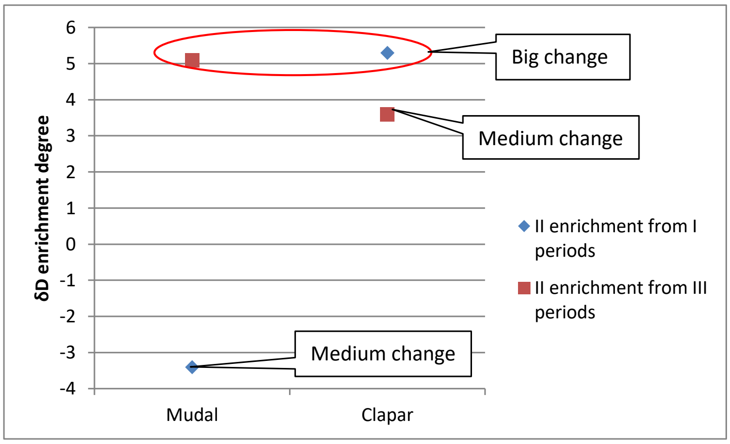

Figure 6. D-enrichment of groundwater in Mudal and Clapar springs.

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Table 7. The value of the δD-excess of groundwater.

Spring	δD-excess ("d") (‰)		
	I	II	III
Mudal	15.1	14.02	5.32
Clapar	10	9.38	-0.14

The "d" value or δD excess indicates the presence of D isotope enrichment versus $\delta^{18}O$ value. The value of "d" is a relatively important parameter in relation to the climate of an area. The values of groundwater in the study area in period I range from 10 and 15.1‰; period II range from 9.38 to 14.02‰; in period III of 5.32‰ in Mudal, indicating that the range of "d" values in Mudal is relatively higher, in all seasons. Clapar springs do not show d excess in period III. In general, the value of d gets lower over time.

In general, δD excess is influenced by air mass which is usually different, where the dry season tends to be dry, while the rainy season has humid air [1]. In rural areas, the isotopic exchange between rainwater and humidity can slightly shift the value of d [38]. However, the d value was not significant for the springs in the study area. However, the d values in the two springs in the two seasons varied, not showing a strong difference. This less difference can be interpreted that the humidity in the air during the dry and rainy seasons is not much different, as well as the evapotranspiration conditions that can occur quite intensively in the two seasons [38].

In dry conditions, evapotranspiration as a controller for groundwater recharge is usually relatively reduced, while in the rainy season / humid air, evapotranspiration is greater [1]. In addition, in the dry season, many plants are dormant, while in the rainy season the plants are more developed. Thus, the differences in evapotranspiration and humidity conditions in all seasons were not significant.

In addition, large d values usually occur in high permeability rocks or thin soil resulting in rapid infiltration [1]. This rapid infiltration causes groundwater to experience no / less evapotranspiration. Mudal spring has a character like this, supported by the large number of fractures, cracks and dissolving cavities in the limestone that consist the aquifer of these springs. Mudal aquifers are examples of karst aquifers which usually have conduit characteristics and have the potential to have underground rivers due to interconnected conduits. However, large shifting in d values can occur in both the Jonggrangan and Old Andesite Formations aquifers.

5. Conclusion

This groundwater hydroisotope study was carried out on two selected springs in the West Progo Hills, namely the Mudal springs which emerged from the limestone of the Jonggrangan Formation and the Clapar springs which emerged from the volcanic breccias of the Old Andesite Formation. Both springs have the characteristics of stable isotope content of groundwater which is relatively stable, with insignificant changes with time and season. Based on its absolute value, Mudal springs have an isotope that tends to be light, indicating deep aquifer, or high elevation recharge. Meanwhile, Clapar spring shows heavier isotopes, which come from shallow aquifers with a mixing / evaporation process and are more influenced by the season. Based on the range value of $\delta^{18}O$ and δD, Mudal springs contain isotopes that are less affected by seasonal changes, while Clapar springs are seasonal. The range value of δD in both springs is slightly - totally change, which means that it changes due to the change of seasons even though it is small. Based on season, δD enrichment in Mudal shows uncertainty, while Clapar spring has a medium - large change character. Meanwhile, the “d” value varies independently of the season, which can be interpreted that the climate conditions during the dry and rainy seasons in the study area are not much different.

Acknowledgment

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Stable isotopes changes in groundwater: case study in Mudal and Clapar springs, West Progo

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Abstract. Hydroisotope studies were carried out on Mudal and Clapar springs located in the central part of the Progo Dome. The research was conducted by taking samples of groundwater in each spring for three periods, representing the rainy (2016), dry (2017) and rainy (2018) seasons. Data on stable isotope content of ^{18}O and D were analyzed to see the hydroisotope characteristics of groundwater. The results showed that the stable isotope content of groundwater in both springs was relatively stable, with insignificant changes over time and season. Mudal springs tend to show light isotopes, indicating deep aquifer or high elevation recharge, less affected by the season. Clapar spring shows isotopes, which may be sourced from shallow aquifer with mixing / evaporation processes and more influenced by the season. The δD enrichment shows the big change in Mudal spring, and medium - big change in Clapar spring. Meanwhile, the range value of δD in the two springs show a slightly - totally changes, indicating that the D content also changes due to seasons, although it is small. However, the d excess value shows that the dry and rainy season conditions are not much different in terms of evapotranspiration or humidity.

1. Introduction

The study of groundwater has been developed because this natural resource is becoming increasingly important over time, in line with the needs of living things for groundwater. Various groundwater studies have been carried out, both physically and chemically. Hydrochemical studies were also developed using various methods, complemented by studies of groundwater isotopes (hydroisotopes). Isotope analysis is useful to aid in the interpretation of groundwater flows as well as aid in its genetic interpretation. The results of groundwater hydrochemical analysis can be verified by isotope analysis so that it will produce a better interpretation of the groundwater flow system. In addition, isotope studies have also been developed using the stable isotopes ^{18}O and ^{2}H ((deuterium / D). One of the hydroisotope studies that can be done is related to the climate aspect in an area.

Stable isotototope analysis is useful for knowing the origin of groundwater and interpretation of catchment areas. In addition, stable isotope data can also be used for analysis of hydrochemical processes, due to seasonal changes. This paper intends to discuss the characteristics of the stable isotopes ^{18}O and D, particularly in relation to seasonal changes in the Progo Hills area. The case study in this case was carried out on the Mudal and Clapar springs which are located in the central part of the Progo Dome physiography [1].

Mudal spring is at an elevation of 664 m, emerging from the limestone aquifer of the Jonggrangan Formation in Banyunganti Hamlet, Jatimulyo Village, Girimulyo Subdistrict; meanwhile the Clapar spring is at an elevation of 437 m, emerging from the andesite breccia aquifer of the Old Andesite

Formation in Clapar II Hamlet, Hargowilis Village, Kokap Subdistrict, Kulon Progo Regency (Figure 1; Table 1).

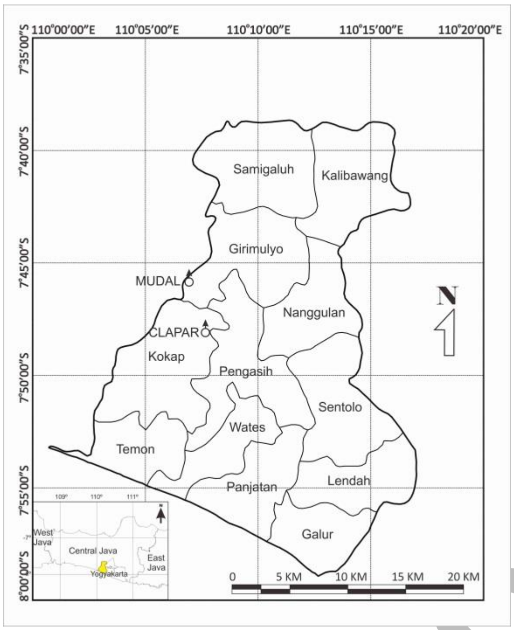

Figure 1. Location of Mudal and Clapar springs in Kulon Progo Regency.

Table 1. Geographical data of Mudal and Clapar springs.

No.	Spring	Coordinate		Elevation (m)
		Longitude (E)	Latitude (S)	
1	Mudal	110° 06' 56.67"	-7° 45' 42.83"	664
2	Clapar	110° 07' 34.88"	-7° 47' 44.49"	437

2. Method

The research begins with a hydrogeological survey to determine the geological conditions and springs in the study area. Several springs with small to large debris are found in the central part of the West Progo area. This area is dominated by limestones of the Jonggrangan Formation and andesite breccias of the Old Andesite Formation. Eyes with a large discharge were selected as the sample of this study. Mudal springs have large debits and represent the aquifer of the Jongrangan Formation, while the Clapar springs are medium / large enough and represent the Old Andesite Formation.

Groundwater samples from both springs were taken in three periods, namely period I in the rainy season in December, 2016; period II in the dry season (August, 2017) and period III in the rainy season (March, 2018). The difference in sampling time from each period to the next is around 8 months. In each sample, 30 ml of groundwater was put into an airtight bottle (polyethylene) by inserting the bottle into a water source to avoid evaporation.

Isotope testing was carried out at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), which is located in Pasar Jumat, South Jakarta. The isotope content analyzed is oxygen-18 (^{18}O) and hydrogen (^{2}H), known as deuterium (D) isotope. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. Isotope ratios were measured by a mass spectrometer and the results were referenced against the SMOW standard. The internal standard was calibrated using V-SMOW with an analysis accuracy of ± 0.1 for $\delta^{18}O$ and ± 1 ‰ for δD [2]. Furthermore, the results of the stable isotope test were analyzed to determine the changes as well as the interpretation of the influence of the seasons / climate in the study area.

3. Literature review

3.1. Geological setting

The study area is included in the physiography of the Dome and Hills Zone in the Central Depression [1]. The center of this dome physicigraphy forms the morphology of the Jonggrangan plateau. The Jonggrangan Formation is quite extensive in this area. Around the Jonggrangan highlands, volcanic rocks from the Old Andesite Formation are exposed.

The regional stratigraphy of the West Progo Mountains from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations and Alluvial Deposits [1,3,4]. The Jonggrangan Formation is composed of conglomerates, tuff marl and limestone sandstones with lignite inserts, layered limestone and coral limestone. Meanwhile, the Old Andesite Formation is composed of andesite breccias, tuffs, lapilli, agglomerates and andesite lava inserts. Mudal spring appear in the Jonggrangan Formation rocks, while Clapar spring appears in the Old Andesite Formation (Figure 2).

Figure 2. Mudal spring appear in the Jonggrangan Formation (top), while Clapar spring appear in the Old Andesite Formation (bottom).

3.2. Stable isotopes

Isotopes are elements that have the same atomic number but different mass numbers. In nature, isotopes in water can be found as stable or radioactive isotopes. The content of radioactive isotopes in water can be used to determine age, while stable isotopes are useful for determining water genetics.

Isotope abundance is measured by the ratio of the deviation from the standard (Fritz & Fontes, 1980, in [5]. The stable isotopes ^{18}O and ^{2}H are present in water in the form of compounds ${}^{1}H_2{}^{18}O$ and ${}^{1}H^{2}H^{16}O_2$ (Hamed, 2014, in [2]). The two isotopes are very sensitive for physical processes such as evaporation and condensation, therefore, the content of these stable isotopes can be used to see the climate effect on springs.

The isotopes ^{18}O and D are often used in the study of chemical processes. This isotope is a stable, non-radioactive isotope and is often used as an indicator for groundwater sources [6].

To see the influence of climate / rainfall, regression line relationships δ^{18}O and δD groundwater can be plotted together with the global meteoric water line GWML or the local meteoric water line (LMWL). If the groundwater regression line is adjacent to the LMWL then the groundwater is affected by local climate (originating from local precipitation) or by topographic effects [7].

4. Result and discussion

4.1. Spring characteristic

Mudal Springs emerge from the limestone aquifer of Jonggrangan reef, supported by large porosity, type of fracture and channel as well as large rock permeability. Jonggrangan Limestone is dominated by thick to massive layered coral limestones, around the Mudal springs this reef limestone is white to brownish white, compact and hard, with some fairly intensive tectonic stiffness. Mudal Springs has a large fluctuation in discharge; moderate discharge during the dry season, but can discharge very large during the rainy season, up to > 200 L/sec [8]. These springs are depressions, fractures and channels, with large flows that develop as runoff / rivers. These springs are parennial, and at normal temperature.

Clapar springs emerge from aquifers in andesite breccias and OAF autoclastic / lava breccias, which are supported by fracture porosity and sheeting joints with moderate intensity and low - medium permeability. Clapar springs are fracture type, with small (stagnant) - medium flow rate, intermittent, and normal temperature.

4.2. ^{18}O and ^{2}H isotopes contents analysis

Stable isotope content data in Mudal and Clapar spring water can be seen in Table 2 below. Furthermore, the absolute value and range value of the isotope content can be analyzed to determine the hydrochemical processes that occur in the groundwater system.

Table 2. Data on stable isotope content of groundwater from the investigated springs.

Spring	I (Dec, 2016)		II (Aug, 2017)		III (Mar, 2018)	
	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
Mudal	-7.1 ± 0.11	-41.7 ± 0.4	-7.39 ± 0.42	-45.1 ± 3.1	-6.94 ± 0.39	-50.2 ± 1.5
Clapar	-6.25 ± 0.07	-40 ± 1.8	-5.51 ± 0.32	-34.7 ± 1.0	-4.77 ± 0.34	-38.3 ± 3

4.2.1. δ^{18}O and δD absolute value.

From period I to III, Mudal springs showed relatively stable O isotope, while D isotope tended to be lighter (Figure 3). Groundwater with light isotope generally flows in deep aquifers or comes from high absorption areas [9], as seen in Mudal springs which have light D isotope (-50.2 ‰) in period III (Table 3; Figure 3). This means, groundwater that appears in Mudal springs may flow in deep enough aquifers or originate from infiltration of rainwater that permeates at a high enough elevation. The infiltration zone may exist locally, because the Mudal springs are indeed at a high enough elevation.

Table 3. Changes in the stable isotope content of the investigated springs.

Variable	Spring	δ^{18}O (‰)	δD (‰)

Time	Mudal	down-up, stable relatively difference = 0.45 ‰	get lighter difference = 8.5 ‰
	Clapar	get heavier difference = 1.48 ‰	up - down, stable relatively difference = 5.3 ‰
Season (T-effect)	Mudal	lower when dry	no effect
	Clapar	no effect	higher when dry

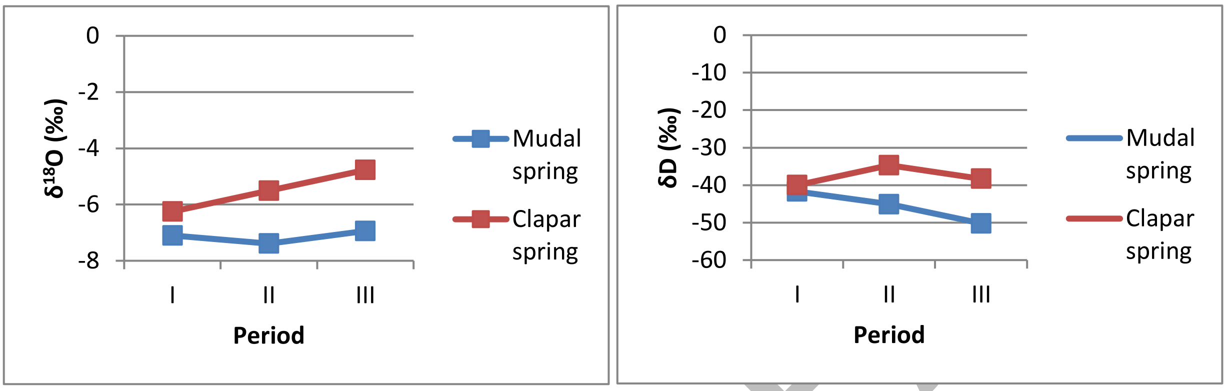

Figure 3. The development of stable isotope content over the three test periods.

Clapar springs have groundwater with ^{18}O heavier from period I to III, as well as D sotope, which is relatively stable. isotopes in springs indicate a mixing or evaporation process [7]. D isotope indicates shallow aquifer [9]. Thus, the groundwater in the Clapar springs comes from shallow aquifers that have undergone a mixing or evaporation process.

Compared to Clapar springs, Mudal springs contain lighter ^{18}O and D isotopes in the three periods studied. This shows that the stable isotopes possessed by the two springs are relatively consistent, whereas the Mudal springs tend to have genetics from deeper aquifers (Table 4).

Table 4. Interpretation of light / isotope content.

Spring	I		II		III		Interpretation
	δ18O (‰)	δD (‰)	δ18O (‰)	δD (‰)	δ18O (‰)	δD (‰)	
Mudal	-7.1	-41.7	-7.39	-45.1	-6.94	-50.2	- deep aquifer, or - high elevation recharge
Clapar	-6.25	-40	-5.51	-34.7	-4.77	-38.3	- Shallow aquifer - Mixing / evaporation

4.2.2. Range value of δ^{18}O and δD.

The stable isotope content studied showed a short range of values and generally did not have overlapping values (Figure 4). With due regard to the δ^{18}O range value in all periods, it appears that the groundwater from Mudal springs has isotopes δ^{18}O is light, while the Clapar springs have value δ^{18}O . The overlapping values in the three periods in Mudal springs indicate that groundwater in these springs is less affected by seasonal changes, while seasonal changes have more effect on Clapar springs.

The widest δD range value occurs in Mudal and Clapar springs at different periods (Figure 4). The δD value which is relatively stable, light but appears to shift in the Mudal spring indicates that the groundwater in this spring is less affected by seasonal changes, with relatively deep circulation. As for the springs Clapar has relatively stable (heavy) δD which shows significant overlapping in the rainy period, slightly different from the range value in the dry season, indicating that groundwater in these springs is quite affected by changes in the season. Referring to the opinion of Alam *et al* (2014) [9], groundwater with heavy δD as in the Clapar springs can be interpreted as a result of a fairly intensive mixing or evaporation process (Table 5).

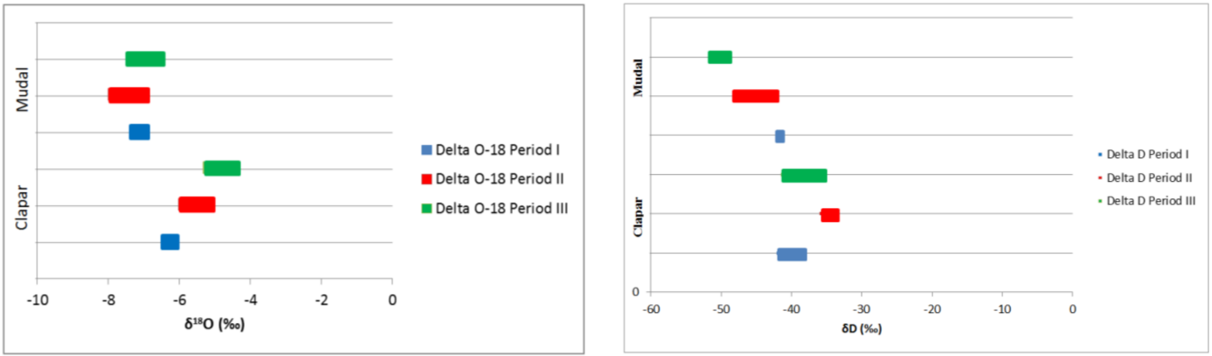

Figure 4. The values range δ^{18}O and δD for Mudal and Clapar springs. The missing values indicate the similarity of δD in different seasons.

Table 5. Value range interpretation δ^{18}O and δD.

Water springs	δ18O	δD	Analysis
Mudal	In short, some overlap	Short and long, shift	δ^{18}O and δD are relatively stable / mild, less affected by seasonal changes
Clapar	Short - long, shift, enrichment	Short-a bit long, overlap especially in the rainy season	δ^{18}O and δD relatively stable / heavy, affected by season, intensive evaporation / mixing

Change δD of groundwater usually occurs due to isotopic exchange with minerals containing hydrogen, such as gypsum and clay minerals (Clayton *et al*, 1966, in [10]. However, data support for this exchange. The δD in these two materials is not yet known, so the cause of the δD change groundwater is still difficult to determine. Moreover, this variation in value is usually not large, so this exchange is considered insignificant. Furthermore, membrane filtration is associated with increased δD, it is difficult to happen in the study area, because this process usually requires high pressure, which is equivalent to a sediment depth of 1.6 km (Graff *et al*, 1965, in [10]. In sedimentary rock formations less than 1 km deep membrane filtration is less effective [11].

4.3. The effects of season on δ^{18}O and δD changes

The process that occurs related to the seasonal effect can be assessed based on the δ^{18}O against δD of groundwater relationship. In the dry season (period II), the regression line of springs in the study area is very close to the LMWL, indicating that the enrichment of meteoric water isotope content has not been clearly seen [12]. However, the climatic influence in this dry season can be seen from the presence of d-excess [7]. Further added by Craig (1961, in [7]), the value of the line gradient is in the range 3-6 indicating an evaporation process.

The groundwater line in period III was partly below the LMWL, which indicates that it experienced isotopic enrichment [7,8], for example due to a fairly intensive evaporation process or mixing with surface water/runoff. The slope of the regression line that is smaller than the LMWL gradient indicates a variation in the rate of evaporation. In addition, it is possible that evaporation will occur in the catchment area along with the infiltration process [9].

4.3.1. The enrichment of ^{18}O and D stable isotopes.

Changes in stable isotope content associated with changing seasons can cause an δD or $\delta^{18}O$ enrichment effect. O-18 isotope enrichment during the rainy season relative to the dry season occurs in Mudal springs, while δD isotope enrichment occurs in Clapar springs in the dry season compared to the rainy season (Table 6; Figure 3).

Isotopic enrichment $\delta^{18}O$ in the rainy season relative to the dry season in Mudal springs is related to the isotopic fractionation of carbonate rocks as a result of water-rock interaction. Enrichment of $\delta^{18}O$ can be caused by carbonate minerals [13, 14]. Meanwhile, the δD enrichment of Clapar springs occurs indicating that seasonality affects the content of these stable isotopes. Season has an effect on the evaporation process which can enrich the isotopic content of groundwater.

Table 6 shows the degrees of δD enrichment in the springs studied. Degree of δD enrichment is calculated in the dry season (period II) relative to the rainy season, both period I and III. The magnitude of the changes caused by D isotope enrichment can be seen in Figure 5.

Table 6. The δD enrichment in the dry season relative to δD in the rainy season.

Spring	δD dry (Period II)	δD rainy		Enrichment Degree	Explanation
		Period I	Period III		
Mudal	-45.1	-41.7	-50.2	-3.4 - 5.1	Uncertainty
Clapar	-34.7	-40	-38.3	3.6 – 5.3	Medium - big

*) Negative values indicate enrichment during the rainy season

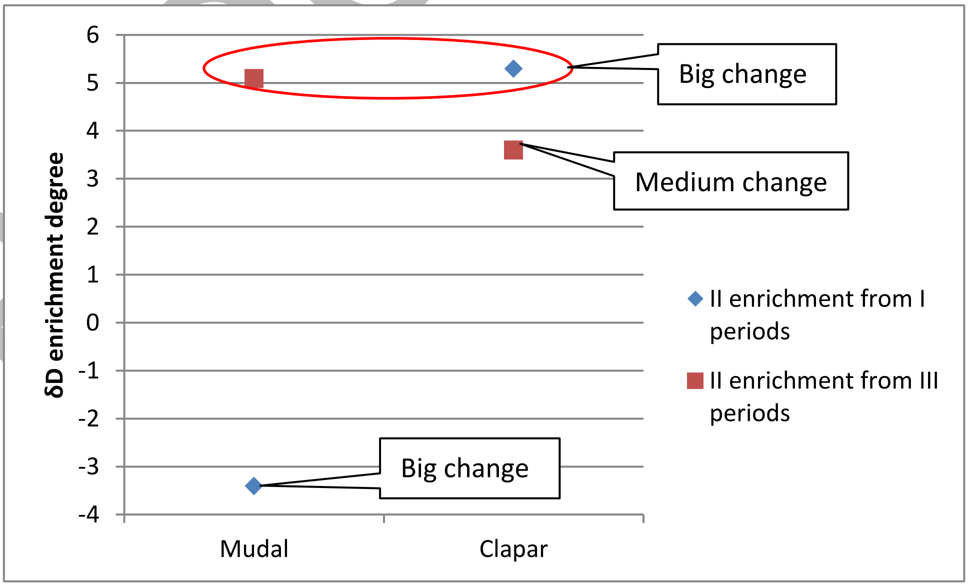

Figure 5. D enrichment of groundwater in Mudal and Clapar springs.

From Figure 5, it is shown that the Mudal spring has large δD enrichment (> 5 ‰), but not related to seasonal changes. The Clapar springs undergo moderate - large changes due to enrichment during the dry season. The δD enrichment in the Clapar springs in the dry season shows a seasonal effect on the D isotope of groundwater. This is confirmed by a shift in δD values can occur due to seasonal changes [9].

If the δD range value is taken into account, then some groundwater samples appear to have shifted (Figure 5). The two springs under study have shifted slightly - totally change.

4.3.2. The "d" value (δD-excess).

Changes in stable isotope content can occur due to the influence of seasons due to differences in temperature. Isotope data in the two investigated springs showed that it was good $\delta^{18}O$ nor δD varies considerably, both in absolute value and in range. The data that are not much different are generally considered to have no seasonal variation (temperature effect) [7]. However, if we examine one by one, there is a "d" variable which is δD-excess which we can calculate (Table 7). The value of d in general can be calculated with the following formula [7].

$$d = \delta D - 8\delta^{18}O \qquad (1)$$

Table 7. The value of the δD-excess of groundwater.

Spring	δD-excess ("d") (‰)		
	I	II	III
Mudal	15.1	14.02	5.32
Clapar	10	9.38	-0.14

The "d" value or δD excess indicates the presence of D isotope enrichment versus $\delta^{18}O$ value. The value of "d" is a relatively important parameter in relation to the climate of an area. The value of groundwater in the study area in period I ranges from 10 and 15.1 ‰; period II amounted to 9.38 and 14.02 ‰; in period III of 5.32 ‰ in Mudal, indicating that the range of "d" values in Mudal is relatively higher, in all seasons. Clapar springs do not show d excess in period III. In general, the value of d gets lower over time.

In general, d excess is influenced by air mass which is usually different, where the dry season tends to be dry, while the rainy season has humid air [7]. Liotta (2006, in [10]) states that in rural areas, the isotopic exchange between rainwater and humidity can slightly shift the value of d. However, the d value was not significant for the springs studied. However, the d values in the two springs in the two seasons varied, not showing a significant difference. This less significant difference shows that the humidity in the air during the dry and rainy seasons is not much different, as well as the evapotranspiration conditions that can occur quite intensively in the two seasons.

In dry conditions, evapotranspiration as a controller for groundwater recharge is usually relatively reduced, while in the rainy season / humid air, evapotranspiration is greater [7]. In addition, in the dry season, many plants are dormant, while in the rainy season the plants are more developed. Thus, the differences in evapotranspiration and humidity conditions in all seasons were not significant.

In addition, large d values usually occur in high permeability rocks or thin soil resulting in rapid infiltration [7]. This rapid infiltration causes groundwater to experience no / less evapotranspiration. Mataair Mudal has a character like this, supported by the large number of fractures, cracks and dissolving cavities in the limestone that make up the aquifer of these springs. Significant shifts in d values can occur in both the Jonggrangan and Old Andesite Formations aquifers.

5. Conclusion

This groundwater hydroisotope study was carried out on two selected springs in the West Progo Hills, namely the Mudal springs which emerged from the limestone of the Jonggrangan Formation and the Clapar springs which emerged from the volcanic breccias of the Old Andesite Formation. Both springs have the characteristics of stable isotope content of groundwater which is relatively stable, with insignificant changes with time and season. Based on its absolute value, Mudal springs have an isotope that tends to be light, indicating deep aquifer, or high elevation recharge. Meanwhile, Clapar springs show isotopes, which come from shallow aquifers with a mixing / evaporation process and are more influenced by the season. Based on the range value of $\delta^{18}O$ and δD, Mudal springs contain isotopes that are less affected by seasonal changes, while Clapar springs are seasonal. Based on season, δD enrichment shows uncertainty, while Clapar Spring has a medium - big change character. The range value of δD in both springs is slightly - totally change, which means that it changes due to the change of seasons even though it is small. Meanwhile, the “d” value varies independently of the season, which can be interpreted that the evapotranspiration and humidity conditions during the dry and rainy seasons in the study area are not much different.

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Stable isotopes changes in groundwater: a case study in Mudal and Clapar springs, West Progo

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Abstract. Hydroisotope studies were carried out on Mudal and Clapar springs located in the central part of the West Progo Dome. The research was conducted by taking samples of groundwater in each spring for three periods, representing the rainy (2016), dry (2017), and rainy (2018) seasons. Data on stable isotope content of ^{18}O and D were analyzed to see the hydroisotope characteristics of groundwater and their relationship to climate change. The results show that the stable isotope content of groundwater in both springs was relatively stable, with insignificant changes over time and season. Mudal springs tend to show light isotopes, indicating deep aquifer or high elevation recharge, less affected by the season. Clapar spring shows heavy isotopes, which may be sourced from a shallow aquifer with mixing/evaporation processes and are more influenced by the season. Meanwhile, the range value of δD in the two springs shows slightly - totally changes, indicating that the D content also changes due to seasons, although it is small. The δD enrichment shows the medium-large change in both spring springs, but uncertainty in Mudal. However, the D-excess value shows that the dry and rainy season conditions, which may be related to temperature or precipitation, are not much different.

1. Introduction

The study of groundwater has been developed because this natural resource is becoming increasingly important over time, in line with the needs of living things for groundwater. Various groundwater studies have been carried out, both physically and chemically [1-5]. Hydrochemical studies were also developed using various methods, complemented by studies of groundwater isotopes. Isotope analysis is helpful to aid in the interpretation of groundwater flows as well as aid in its genetic interpretation. The results of hydrochemical groundwater analysis can be verified by isotope analysis to produce a better interpretation of the groundwater flow system. In addition, isotope studies have also been developed using stable isotopes ^{18}O and ^{2}H (deuterium / D). One of the hydroisotope studies that can be done is related to the climate aspect in an area.

Stable isotope analysis helps know the origin of groundwater and the interpretation of catchment areas. In addition, stable isotope data can also analyze hydrochemical processes due to seasonal changes [6]. This paper intends to discuss the characteristics of the stable isotopes ^{18}O and D, particularly concerning seasonal changes in the West Progo Hills area. The case study, in this research, was carried out on the Mudal and Clapar springs located in the central part of the West Progo Dome physiography [7].

Mudal spring is at an elevation of 664 meters above sea level (masl), emerging from the limestone aquifer of the Jonggrangan Formation in Banyunganti Hamlet, Jatimulyo Village, Girimulyo Subdistrict. Meanwhile, the Clapar spring is at an elevation of 437 masl, emerging from the andesite breccia aquifer of the Old Andesite Formation in Clapar II Hamlet, Hargowilis Village, Kokap Subdistrict, West Progo Regency (Figure 1).

The study area is included in the physiography of the Dome and Hills Zone in the Central Depression [7]. The center of this dome physiography forms the morphology of the Jonggrangan plateau. The Jonggrangan Formation is quite extensive in this area. Around the Jonggrangan highlands, volcanic rocks from the Old Andesite Formation are exposed (Figure 1) [8].

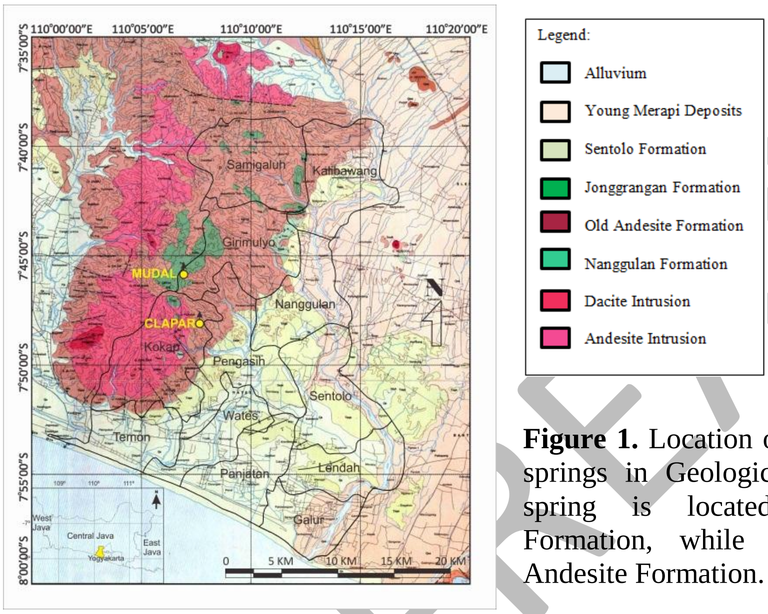

Figure 1. Location of Mudal and Clapar springs in Geological map [8]. Mudal spring is located at Jonggrangan Formation, while Clapar is at Old Andesite Formation.

The regional stratigraphy of the West Progo Mountains from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations, and Alluvial Deposits [7-9]. The Jonggrangan Formation comprises conglomerates, tuff marl, and limestone sandstones with lignite inserts, layered limestone, and coral limestone. Meanwhile, the Old Andesite Formation comprises andesite breccias, tuffs, lapilli, agglomerates, and intercalation of andesite [8]. Mudal spring appears in the Jonggrangan Formation rocks, while Clapar spring appears in the Old Andesite Formation (Figure 2).

Figure 2. Mudal spring appears in the Jonggrangan Formation (top), while Clapar spring appears in the Old Andesite Formation (bottom).

Although West Progo Hills is classified as a non-groundwater basin [10], many springs can be found even though they generally have small discharges. However, several springs with moderate to large discharge can also be found on these hills. Large discharge can be found in the limestone aquifers of the Jonggrangan Formation. The presence of springs in the West Progo Hills zone is highly controlled by the local topography [11] and lineament factors [12]. Geological lineaments influence the occurrence of springs, especially significantly controlled by the density and distance of lineaments to the location of the springs.

2. Method

The research begins with a hydrogeological survey to determine the geological conditions and springs in the study area. Several springs with small to large discharge are found in the central part of the West Progo area. This area is dominated by limestones of the Jonggrangan Formation and andesite breccias of the Old Andesite Formation. Springs with a large discharge were selected as the sample of this study. Mudal springs have large discharge and represent the aquifer of the Jongrangan Formation, while the Clapar springs are medium/large enough and represent the Old Andesite Formation. This research focuses on isotope studies, but some groundwater hydrochemical data is also taken together with isotope sampling in the field.

Groundwater samples from both springs were taken in three periods: period I in the rainy season in December 2016, period II in the dry season (August 2017), and period III in the rainy season (March 2018). Precipitation of the research area at the time of sampling can be seen in Table 1. The difference in sampling time from each period to the next is around eight months. In each sample, 30 ml of groundwater was put into an airtight bottle (polyethylene) by inserting the bottle into a water source to avoid evaporation.

Table 1. Precipitation data in research area (mm/month) [13-15].

Spring	Dec 2016	Aug 2017	Mar 2018
Mudal	216	2,5	218
Clapar	311	13	152

Isotope testing was carried out at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), located in Pasar Jumat, South Jakarta. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. The isotope content analyzed is oxygen-18 (18O) and hydrogen (2H), known as deuterium (D) isotope. A mass spectrometer measured isotope ratios, and the results were referenced against the SMOW standard. The internal standard was calibrated using V-SMOW with an analysis accuracy of ± 0.1 for $\delta^{18}O$ and ± 1‰ for δD [3]. Furthermore, the stable isotope test results were analyzed to determine the changes and interpret the influence of the seasons/climate in the study area.

Isotope data analysis was carried out by looking at the absolute value trend and the relative value of Mudal and Clapar isotope content in three periods. In addition, the $\delta^{18}O$ and δD relationships in groundwater springs compared with meteoric water lines were also analyzed to assist in the genetic evaluation of groundwater in the springs. Analysis of changes in isotope content related to seasonal effects can be done by looking at the δD enrichment and D-excess (d) of the groundwater.

3. Stable isotope review

Isotopes are elements that have the same atomic number but different mass numbers [16]. In nature, isotopes in water can be found as stable or radioactive isotopes. The content of radioactive isotopes in water can determine age, while stable isotopes help determine water genetics [17].

Isotopes contained in water, namely hydrogen atoms (^{1}H, ^{2}H, ^{3}H) and oxygen atoms (^{16}O, ^{17}O, ^{18}O), often be used in hydrogeological studies [18,19]. The abundance of ^{1}H isotope is about 99.985%, ^{2}H is about 0.015%, and ^3H is < 0.001%, while the ^{16}O isotope is about 99.63%, ^{17}O is about 0.0375%, and ^{18}O is around 0.195% [17]. Isotope abundance is measured by the ratio of the deviation from the standard [16]. The stable isotopes ^{18}O and ^2H are present in water in compounds $^1H_2{}^{18}O$ and $^1H^2H^{16}O_2$ [17,20]. Since the abundance of $H_2{}^{18}O$ and $HD^{16}O$ molecules compared to the abundance of $H_2{}^{16}O$ is very small, the measured abundance is usually the relative abundance of an international standard water / SMOW (Standard Mean Ocean Water) [6].

The ^{18}O and D isotopes are often used in the study of chemical processes. This isotope is a stable, non-radioactive isotope and is often used to indicate groundwater sources [6]. The ^{18}O and ^2H isotopes are natural tracers because they are stable [21-23]. That is, they are not affected by the water-rock interaction process at low temperatures [24]. Therefore, isotopes are often used in genetic studies to determine groundwater infiltration zones [5,25-28] and studies of mixing groundwater from different sources [29]. The geological structure control in deep groundwater flow systems can also be determined by groundwater isotope analysis [5].

The ^{18}O and D isotopes are very sensitive to physical processes such as evaporation and condensation. Therefore, the content of these stable isotopes can be used to see the climate effect on springs. The isotopic fractionation process in precipitation is a temperature-dependent process [6]. Thus, if there is a change in seasonal temperature in a place, it will be seen that there is a variation in the stable isotope composition of the precipitation where a light value occurs in a cold month. For the same reason, precipitation will also have a lighter isotope content in the arctic/high latitudes, further away from the sea, and higher elevation places. For every 100 m elevation increase, ^{18}O in the rainwater will decrease by 0.15 - 0.5 ‰, and ^2H will be depleted by 1 - 4‰ [30].

Stable isotope content in rainwater shows a linear relationship in the form of a global meteoric water line. The relationship between $\delta^{18}O$ and δD of the precipitation water follows the equation of the meteoric water line. From the results of the global investigation [31], the equation for the meteoric waterline (GMWL) was known as $\delta D = 8\delta^{18}O + 10‰$. Rainwater tends to contain the stable isotopes $\delta^{18}O$ and δ^2H, which are depleted at higher latitudes. This phenomenon also occurs when the two stable isotopes move deep inland. For this reason, the plot results of the two isotopes yield slightly different slopes known as the local meteoric water line [32].

Based on the research of the recharge area of the underground river water system in Gunungkidul, Yogyakarta [3], it is known that the local meteoric water line (LMWL) equation for the area is $\delta^2H = 7.978\ \delta^{18}O + 8.423$ ‰. This LMWL value is then used for isotope studies in the West Progo area because of its relatively close location and considering that the LMWL value in this area is not yet available.

To see the influence of climate/rainfall, regression line relationships $\delta^{18}O$ and δD groundwater can be plotted together with the global meteoric water line GWML or the local meteoric water line (LMWL). If the groundwater regression line is adjacent to the LMWL, the groundwater is affected by local climate (originating from local precipitation) or topographic effects [1].

4. Result and discussion

4.1. Spring characteristic

Mudal Springs emerge from the Jonggrangan reef limestone aquifer, supported by large porosity permeability. The porosity developed as fracture and channel types. Jonggrangan limestone is dominated by thick to massive layered coral limestones. Around the Mudal springs, these reef limestone outcrops show white to brownish-white color, compact and hard, with some fairly intensive tectonic of joints characteristics. Mudal Springs has a large fluctuation in discharge. The discharges show; moderate magnitude during the dry season but can be very large discharges during the rainy season [11]. When the isotope sampling was carried out, the Mudal spring discharge was measured to be 100 - 236 L/s, but at the end of the dry season (September 2018), it appears that this discharge has decreased drastically to <50 L/s.The spring can be classified as depressions, fractures, or channels type of spring. Mudal spring has a large flow that develops as runoff/rivers. This spring is a parennial spring, although it has a significant change of discharge over the season. Based on its temperature, Mudal is classified as a normal spring. The physicochemical data show groundwater of Mudal spring has a temperature range of 23,1 – 24^{o}C, pH of 6.7 – 8.3, TDS of 225 – 254 ppm, and EC of 380 – 418 µS /cm.

Meanwhile, Clapar springs have smaller dimensions than Mudal springs. Clapar springs emerge from aquifers in andesite breccias and autoclastic / lava breccias of the Old Andesite Formation, supported by fracture and sheeting joints porosity with moderate intensity controlled by low - medium permeability. Clapar springs have fracture-type springs. The discharge of springs is usually small (stagnant) - medium flow rate, with small discharge fluctuation. These springs can be classified as normal springs based on the temperature of the water. The physicochemical data of these springs show a temperature of 23.7 – 24.5^{o}C, with a pH range of 7 – 8.2, TDS of 75 – 97 ppm, and EC of 157 – 185 µS /cm.

4.2. ^{18}O and ^{2}H isotopes contents analysis

Stable isotope content data in Mudal and Clapar spring water can be seen in Table 2 below. Furthermore, the isotope content's absolute value and range value can be analyzed to determine the hydrochemical processes that occur in the groundwater system.

Table 2. Data on stable isotope content of groundwater from the investigated springs.

Spring	I (Dec 2016)		II (Aug 2017)		III (Mar 2018)	
	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
Mudal	-7.1 ± 0.11	-41.7 ± 0.4	-7.39 ± 0.42	-45.1 ± 3.1	-6.94 ± 0.39	-50.2 ± 1.5
Clapar	-6.25 ± 0.07	-40 ± 1.8	-5.51 ± 0.32	-34.7 ± 1.0	-4.77 ± 0.34	-38.3 ± 3

4.2.1. Absolute value of δ^{18}O and δD. From period I to III, Mudal springs showed relatively stable O isotope, while D isotope tended to be lighter (Figure 3). Groundwater with light isotope generally flows in deep aquifers or comes from high absorption areas [2], as seen in Mudal springs, which have light D isotope (-50.2‰) in period III (Figure 3; Table 3). It means that groundwater that appears in Mudal springs may flow in deep enough aquifers or originate from precipitation of rainwater that infiltrates at a high enough elevation. The infiltration zone may exist locally because the Mudal springs are indeed at a high enough elevation.

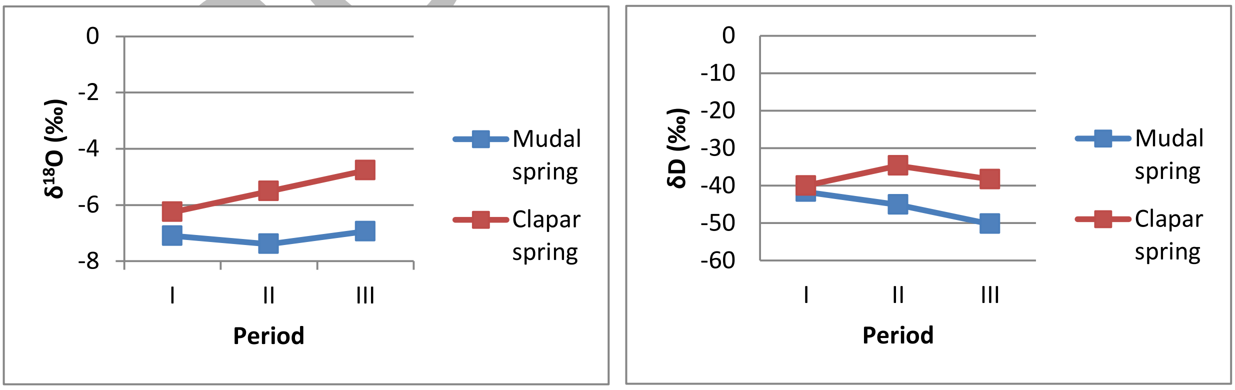

Figure 3. The development of stable isotope content over the three test periods.

Clapar springs have groundwater with ^{18}O heavier from period I to III and a relatively stable D isotope. The heavy isotopes in springs indicate a mixing or evaporation process [1, 2], strongly supported by groundwater isotopes of dug wells in the area [33]. The D isotope indicates a shallow aquifer [2]. Thus, the groundwater in the Clapar springs comes from shallow aquifers that have undergone a mixing or evaporation process.

Table 3. Changes in the stable isotope content of the springs.

Variable	Spring	$\delta^{18}O$ (‰)	δD (‰)
Time	Mudal	down-up, stable relatively difference = 0.45 ‰	get lighter difference = 8.5 ‰
	Clapar	get heavier difference = 1.48 ‰	up - down, stable relatively difference = 5.3 ‰
Season (T-effect)	Mudal	lower when dry	no effect
	Clapar	no effect	higher when dry

Compared to Clapar springs, Mudal springs contain lighter ^{18}O and D isotopes in the three periods studied. It shows that the stable isotopes possessed by the two springs are relatively consistent, whereas the Mudal springs tend to have genetics from deeper aquifers (Table 4).

Table 4. Interpretation of light / heavy isotope content.

Spring	I		II		III		Interpretation
	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	
Mudal	-7.1	-41.7	-7.39	-45.1	-6.94	-50.2	- Deep aquifer, or - High elevation recharge
Clapar	-6.25	-40	-5.51	-34.7	-4.77	-38.3	- Shallow aquifer - Mixing with runoff or other sources/evaporation

When compared with GMWL and LMWL, it appears that the absolute values of isotopes contained in the Mudal springs at all periods tend to move away from the two meteoric water lines (Figure 4). Clapar springs contain isotopes that tend to be close to the meteoric water line during the rainy (period I) and dry (II) seasons. This considerable deviation in period III for Clapar springs indicates the influence of the water from other sources or runoff.

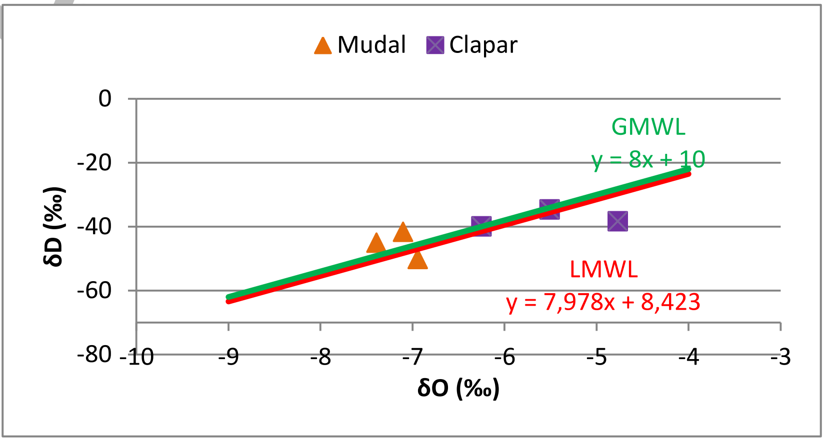

Figure 4. The relation of $\delta^{18}O$ and δD in groundwater of springs.

The interpretation of water sources in the Mudal and Clapar springs is also supported by physicochemical data from the groundwater. Mudal springs release water from deep aquifers characterized by cooler temperatures. According to other researchers, a higher temperature may be sourced from mixing groundwater and surface water [2]. The pH value, which tends to be alkaline, indicates a long interaction with carbonate rocks in the relatively deeper aquifer. This condition is also supported by the greater TDS and EC values of water from the Mudal springs than Clapar.

4.2.2 Range value of δ^{18}O and δD. The stable isotope content studied showed a short range of values and generally did not have overlapping values (Figure 5). With due regard to the δ^{18}O range value in all periods, it appears that the groundwater from Mudal springs has isotopes δ^{18}O is light, while the Clapar springs have value δ^{18}O. The overlapping values in the three periods in Mudal springs indicate that groundwater in these springs is less affected by seasonal changes, while seasonal changes have more effect on Clapar springs.

The widest δD range value occurs in Mudal and Clapar springs at different periods (Figure 5). The δD value, which is relatively stable, light but appears to shift in the Mudal spring, indicates that the groundwater in this spring is less affected by seasonal changes, with relatively deep circulation. As for the springs, Clapar has relatively stable (heavy) δD, which shows significant overlapping in the rainy period, slightly different from the range value in the dry season, indicating that groundwater in these springs is immensely affected by changes in the season. Referring to previous research [2], groundwater with heavy δD as in the Clapar springs can be interpreted as a result of a fairly intensive mixing or evaporation process (Table 5).

Monthly rainfall in the three periods shows that during the rainy season, there is quite a lot of precipitation in both Mudal and Clapar (Table 1). In the dry season (period II), the precipitation is very low. However, the values range δ^{18}O for Mudal spring did not show any clear changes. The ^{18}O isotope content in Mudal springs is relatively stable and less affected by the amount of precipitation. It also indicates that the Mudal springs are supported by relatively deeper aquifers.

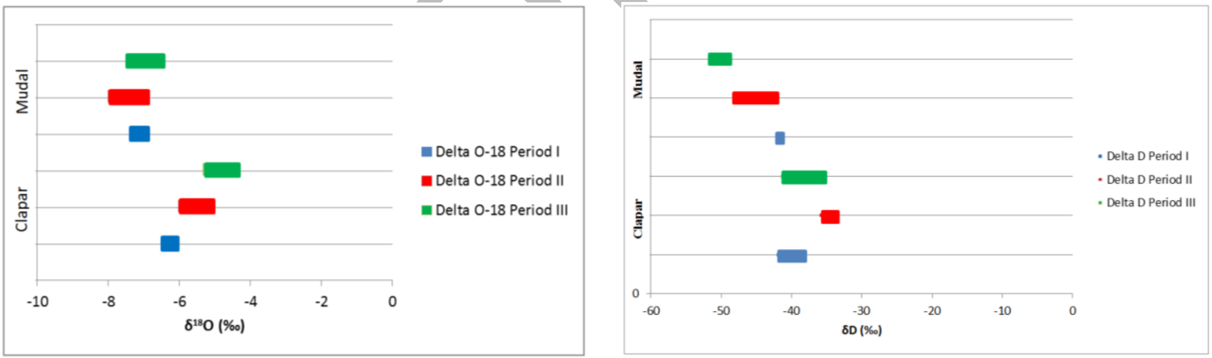

Figure 5. The values range δ^{18}O and δD for Mudal and Clapar springs. The overlapping values indicate the similarity of δD in different seasons.

Table 5. Value range interpretation δ^{18}O and δD.

Springs	δ^{18}O	δD	Analysis
Mudal	In short, some overlap	Short and long, shifted	δ^{18}O and δD are relatively stable/light, less affected by seasonal changes
Clapar	Short - long, shifted, enrichment	Short-a bit long, overlap significantly in the rainy season	δ^{18}O and δD relatively stable/heavy, affected by season, intensive evaporation/mixing

Change δD of groundwater usually occurs due to isotopic exchange with minerals containing hydrogen, such as gypsum and clay minerals [34,35]. However, data does not support this exchange. The δD in these two materials is unknown, so the cause of the δD change in groundwater is still difficult to determine. Moreover, this variation in value is usually not large, so this exchange is considered insignificant. Furthermore, membrane filtration is associated with increased δD. It is difficult to happen in the study area because this process usually requires high pressure, which is equivalent to a sediment depth of 1.6 km [36]. In sedimentary rock formations, less than 1 km deep membrane filtration is less effective [37].

4.3. The effects of season on $\delta^{18}O$ and δD changes

The process that occurs related to the seasonal effect can be assessed based on the δ^{18}O against δD of groundwater relationship. In the dry season (period II), the regression line of springs in the study area is very close to the LMWL, indicating that meteoric water isotope content enrichment has not been clearly seen [38]. However, the climatic influence in this dry season can be seen from the presence of d-excess [1]. Further research added that the value of the line gradient is in the range 3-6, indicating an evaporation process [31].

The groundwater line in period III was partly below the LMWL, which indicates that it experienced isotopic enrichment [1,11], for example, due to a fairly intensive evaporation process or mixing with surface water/runoff. The slope of the regression line smaller than the LMWL gradient indicates a variation in evaporation rate. In addition, evaporation may occur in the catchment area along with the infiltration process [2].

4.3.1. The enrichment of ^{18}O and D stable isotopes. Changes in stable isotope content associated with changing seasons can cause an δD or δ^{18}O enrichment effect. O-18 isotope enrichment during the rainy season relative to the dry season occurs in Mudal springs, while δD isotope enrichment occurs in Clapar springs in the dry season compared to the rainy season (Table 6; Figure 3).

Isotopic enrichment δ^{18}O in the rainy season relative to the dry season in Mudal springs is related to the isotopic fractionation of carbonate rocks due to water-rock interaction. It was also supported by the greater TDS and EC values of groundwater in the Mudal than Clapar springs, both during the rainy and dry seasons. Enrichment of δ^{18}O can be caused by carbonate minerals [35,37]. Meanwhile, the δD enrichment of Clapar springs occurs, indicating that seasonality affects the content of these stable isotopes. The season affects the evaporation process, which can enrich the isotopic content of groundwater.

Table 6 shows the degrees of δD enrichment in the springs studied. The degree of δD enrichment is calculated in the dry season (period II) relative to the rainy season, both periods I and III. The magnitude of the changes caused by D isotope enrichment can be seen in Figure 6.

Table 6. The δD enrichment in the dry season relative to δD in the rainy season.

Spring	δD dry (Period II)	δD rainy		Enrichment Degree	Explanation
		Period I	Period III		
Mudal	-45.1	-41.7	-50.2	-3.4 - 5.1	Uncertainty
Clapar	-34.7	-40	-38.3	3.6 – 5.3	Medium-large

*) Negative values indicate enrichment during the rainy season

Figure 6 shows that the Mudal spring has a medium-large δD enrichment (>5‰) but is not related to seasonal changes. The Clapar springs undergo moderate - large changes due to enrichment during the dry season. The δD enrichment in the Clapar springs in the dry season shows a seasonal effect on the D isotope of groundwater. It is confirmed by a shift in δD values that can occur due to seasonal changes [2].

A spring that has δD enrichment >5‰ is classified to have a large change, while moderate change is indicated by D enrichment of >3 - 5‰. Meanwhile, a small change is indicated by δD enrichment of >1 - 3‰ [2]. The enrichment δD <1 indicates no enrichment. If the δD range value is considered, some groundwater samples appear to have shifted (Figure 6). The two springs have shifted slightly - totally change.

4.3.2. The "d" value (δD-excess). Changes in stable isotope content can occur due to the influence of seasons due to temperature differences. Usually, the temperature effect is related to the elevation of an area. However, it is difficult to study the effect of elevation in this study, considering that the two springs studied do not have a contrasting elevation difference. The humidity aspect also cannot be studied considering the absence of data. Isotope data in the two investigated springs showed good $\delta^{18}O$, nor δD varies considerably, both in absolute value and in range. The data that is not much different is generally considered to have no seasonal variation (temperature effect) [1]. However, if we examine one by one, there is a "d" variable which is δD-excess which we can calculate (Table 7). The value of "d" in general can be calculated with the following formula [1].

$$d = \delta D - 8\delta^{18}O \quad (1)$$

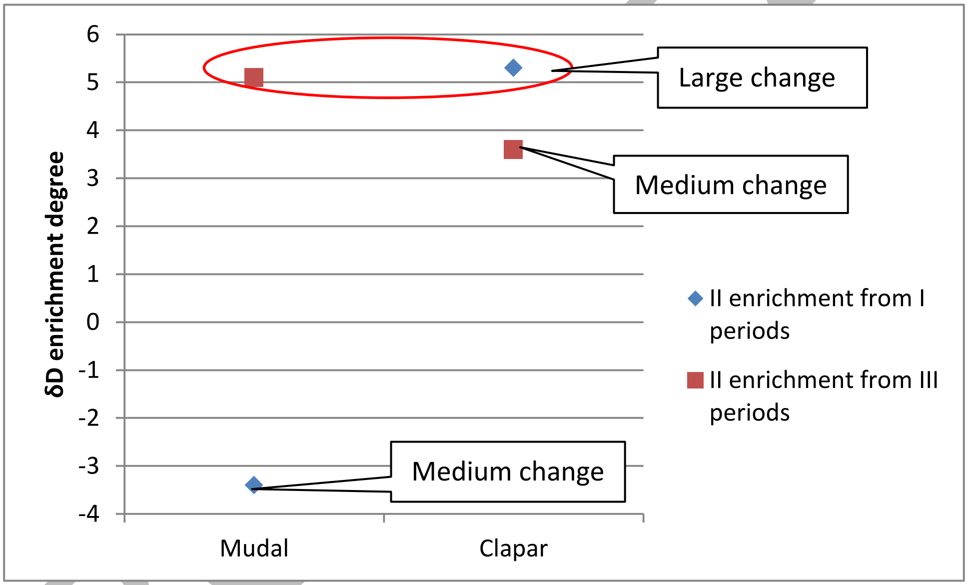

Figure 6. D-enrichment of groundwater in Mudal and Clapar springs.

Table 7. The value of the δD-excess of groundwater.

Spring	δD-excess ("d") (‰)		
	I	II	III
Mudal	15.1	14.02	5.32
Clapar	10	9.38	-0.14

The "d" value or δD excess indicates the presence of D isotope enrichment versus the $\delta^{18}O$ value. The value of "d" is a relatively important parameter concerning the climate of an area. The values of groundwater in the study area in the period I range from 10 and 15.1‰; period II range from 9.38 to 14.02‰; in period III of 5.32‰ in Mudal, indicating that the range of "d" values in Mudal is relatively higher, in all seasons. Clapar springs do not show d excess in period III. In general, the value of d gets lower over time.

In general, δD excess is influenced by air mass which is usually different, where the dry season tends to be dry, while the rainy season has humid air [1]. In rural areas, the isotopic exchange between rainwater and humidity can slightly shift d [39]. However, the d value was not significant for the springs in the study area. However, the d values in the two springs in the two seasons varied, not showing a great difference. This less difference can be interpreted that the humidity in the air during the dry and rainy seasons is not much different. The evapotranspiration conditions can occur quite intensively in the two seasons [33].

In dry conditions, evapotranspiration as a controller for groundwater recharge is usually relatively reduced, while in the rainy season / humid air, evapotranspiration is greater [1]. In addition, many plants are dormant in the dry season in the dry season, while the plants are more developed in the rainy season. Thus, the differences in evapotranspiration and humidity conditions in all seasons were not significant.

In addition, large d values usually occur in high permeability rocks or thin soil, resulting in rapid infiltration [1]. This rapid infiltration causes groundwater to experience no / less evapotranspiration. Mudal spring has a character like this, supported by many fractures, cracks, and dissolving cavities in the limestone that consist of the aquifer of these springs. Mudal aquifers are examples of karst aquifers that usually have conduit characteristics and can have underground rivers due to interconnected conduits. However, a large shifting in d values can occur in both the Jonggrangan and Old Andesite Formations aquifers.

5. Conclusion

This groundwater hydroisotope study was carried out on two selected springs in the West Progo Hills, namely the Mudal springs, which emerged from the limestone of the Jonggrangan Formation and the Clapar springs from the volcanic breccias of the Old Andesite Formation. Both springs have stable isotope content characteristics, relatively stable, with insignificant changes with time and season. Mudal springs have an isotope that tends to be light, indicating deep aquifer or high elevation recharge based on their absolute value. Meanwhile, Clapar spring shows heavier isotopes, which come from shallow aquifers with a mixing/evaporation process and are more influenced by the season. Based on the range value of δ^{18}O and δD, Mudal springs contain isotopes that are less affected by seasonal changes, while Clapar springs are seasonal. The range value of δD in both springs is slightly - totally change, which means that it changes due to the change of seasons even though it is small. Based on the season, δD enrichment in Mudal shows uncertainty, while Clapar spring has a medium-large change character. Meanwhile, the “d” value varies independently of the season, which can be interpreted that the climate conditions during the dry and rainy seasons in the study area are not much different.

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Stable isotopes changes in groundwater: a case study in Mudal and Clapar springs, West Progo

by T Listyani R A

Stable isotopes changes in groundwater: a case study in Mudal and Clapar springs, West Progo

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Abstract. Hydroisotope studies were carried out on Mudal and Clapar springs located in the central part of the West Progo Dome. The research was conducted by taking samples of groundwater in each spring for three periods, representing the rainy (2016), dry (2017), and rainy (2018) seasons. Data on stable isotope content of ^{18}O and D were analyzed to see the hydroisotope characteristics of groundwater and their relationship to climate change. The results show that the stable isotope content of groundwater in both springs was relatively stable, with insignificant changes over time and season. Mudal springs tend to show light isotopes, indicating deep aquifer or high elevation recharge, less affected by the season. Clapar spring shows heavy isotopes, which may be sourced from a shallow aquifer with mixing/evaporation processes and are more influenced by the season. Meanwhile, the range value of δD in the two springs shows slightly - totally changes, indicating that the D content also changes due to seasons, although it is small. The δD enrichment shows the medium-large change in both spring springs, but uncertainty in Mudal. However, the D-excess value shows that the dry and rainy season conditions, which may be related to temperature or precipitation, are not much different.

1. Introduction

The study of groundwater has been developed because this natural resource is becoming increasingly important over time, in line with the needs of living things for groundwater. Various groundwater studies have been carried out, both physically and chemically [1-5]. Hydrochemical studies were also developed using various methods, complemented by studies of groundwater isotopes. Isotope analysis is helpful to aid in the interpretation of groundwater flows as well as aid in its genetic interpretation. The results of hydrochemical groundwater analysis can be verified by isotope analysis to produce a better interpretation of the groundwater flow system. In addition, isotope studies have also been developed using stable isotopes ^{18}O and ^{2}H (deuterium / D). One of the hydroisotope studies that can be done is related to the climate aspect in an area.

Stable isotope analysis helps know the origin of groundwater and the interpretation of catchment areas. In addition, stable isotope data can also analyze hydrochemical processes due to seasonal changes [6]. This paper intends to discuss the characteristics of the stable isotopes ^{18}O and D, particularly concerning seasonal changes in the West Progo Hills area. The case study, in this research, was carried out on the Mudal and Clapar springs located in the central part of the West Progo Dome physiography [7]. 16

Mudal spring is at an elevation of 664 meters above sea level (masl), emerging from the limestone aquifer of the Jonggrangan Formation in Banyunganti Hamlet, Jatimulyo Village, Girimulyo Subdistrict. Meanwhile, the Clapar spring is at an elevation of 437 masl, emerging from the andesite breccia aquifer of the Old Andesite Formation in Clapar II Hamlet, Hargowilis Village, Kokap Subdistrict, West Progo Regency (Figure 1).

The study area is included in the physiography of the Dome and Hills Zone in the Central Depression [7]. The center of this dome physiography forms the morphology of the Jonggrangan plateau. The Jonggrangan Formation is quite extensive in this area. Around the Jonggrangan highlands, volcanic rocks from the Old Andesite Formation are exposed (Figure 1) [8].

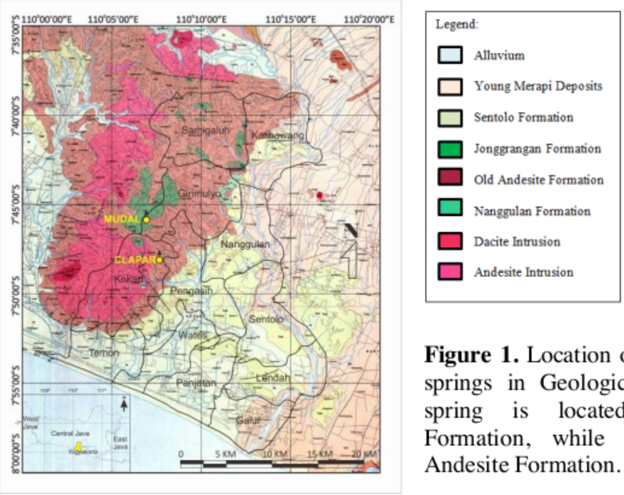

Figure 1. Location of Mudal and Clapar springs in Geological map [8]. Mudal spring is located at Jonggrangan Formation, while Clapar is at Old Andesite Formation.

The regional stratigraphy of the West Progo Mountains from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations, and Alluvial Deposits [7-9]. The Jonggrangan Formation comprises conglomerates, tuff marl, and limestone sandstones with lignite inserts, layered limestone, and coral limestone. Meanwhile, the Old Andesite Formation comprises andesite breccias, tuffs, lapilli, agglomerates, and intercalation of andesite [8]. Mudal spring appears in the Jonggrangan Formation rocks, while Clapar spring appears in the Old Andesite Formation (Figure 2).

Figure 2. Mudal spring appears in the Jonggrangan Formation (top), while Clapar spring appears in the Old Andesite Formation (bottom).

Although West Progo Hills is classified as a non-groundwater basin [10], many springs can be found even though they generally have small discharges. However, several springs with moderate to large discharge can also be found on these hills. Large discharge can be found in the limestone aquifers of the Jonggrangan Formation. The presence of springs in the West Progo Hills zone is highly controlled by the local topography [11] and lineament factors [12]. Geological lineaments influence the occurrence of springs, especially significantly controlled by the density and distance of lineaments to the location of the springs.

2. Method

The research begins with a hydrogeological survey to determine the geological conditions and springs in the study area. Several springs with small to large discharge are found in the central part of the West Progo area. This area is dominated by limestones of the Jonggrangan Formation and andesite breccias of the Old Andesite Formation. Springs with a large discharge were selected as the sample of this study. Mudal springs have large discharge and represent the aquifer of the Jongrangan Formation, while the Clapar springs are medium/large enough and represent the Old Andesite Formation. This research focuses on isotope studies, but some groundwater hydrochemical data is also taken together with isotope sampling in the field.

Groundwater samples from both springs were taken in three periods: period I in the rainy season in December 2016, period II in the dry season (August 2017), and period III in the rainy season (March 2018). Precipitation of the research area at the time of sampling can be seen in Table 1. The difference in sampling time from each period to the next is around eight months. In each sample, 30 ml of groundwater was put into an airtight bottle (polyethylene) by inserting the bottle into a water source to avoid evaporation.

Table 1. Precipitation data in research area (mm/month) [13-15].

Spring	Dec 2016	Aug 2017	Mar 2018
Mudal	216	2,5	218
Clapar	311	13	152

Isotope testing was carried out at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), located in Pasar Jumat, South Jakarta. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. The isotope content analyzed is oxygen-18 (18O) and hydrogen (2H), known as deuterium (D) isotope. A mass spectrometer measured isotope ratios, and the results were referenced against the SMOW standard. The internal standard was calibrated using V-SMOW with an analysis accuracy of ± 0.1 for δ^{18}O and ± 1‰ for δD [3]. Furthermore, the stable isotope test results were analyzed to determine the changes and interpret the influence of the seasons/climate in the study area.

Isotope data analysis was carried out by looking at the absolute value trend and the relative value of Mudal and Clapar isotope content in three periods. In addition, the δ^{18}O and δD relationships in groundwater springs compared with meteoric water lines were also analyzed to assist in the genetic evaluation of groundwater in the springs. Analysis of changes in isotope content related to seasonal effects can be done by looking at the δD enrichment and D-excess (d) of the groundwater.

3. Stable isotope review

Isotopes are elements that have the same atomic number but different mass numbers [16]. In nature, isotopes in water can be found as stable or radioactive isotopes. The content of radioactive isotopes in water can determine age, while stable isotopes help determine water genetics [17].

Isotopes contained in water, namely hydrogen atoms (^{1}H, ^{2}H, ^{3}H) and oxygen atoms (^{16}O, ^{17}O, ^{18}O), often be used in hydrogeological studies [18,19]. The abundance of ^{1}H isotope is about 99.985%, ^{2}H is about 0.015%, and ^{3}H is < 0.001%, while the ^{16}O isotope is about 99.63%, ^{17}O is about 0.0375%, and ^{18}O is around 0.195% [17]. Isotope abundance is measured by the ratio of the deviation from the standard [16]. The stable isotopes ^{18}O and ^{2}H are present in water in compounds $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O_2$ [17,20]. Since the abundance of $H_2{}^{18}O$ and $HD^{16}O$ molecules compared to the abundance of $H_2{}^{16}O$ is very small, the measured abundance is usually the relative abundance of an international standard water / SMOW (Standard Mean Ocean Water) [6].

The ^{18}O and D isotopes are often used in the study of chemical processes. This isotope is a stable, non-radioactive isotope and is often used to indicate groundwater sources [6]. The ^{18}O and ^{2}H isotopes are natural tracers because they are stable [21-23]. That is, they are not affected by the water-rock interaction process at low temperatures [24]. Therefore, isotopes are often used in genetic studies to determine groundwater infiltration zones [5,25-28] and studies of mixing groundwater from different sources [29]. The geological structure control in deep groundwater flow systems can also be determined by groundwater isotope analysis [5].

The ^{18}O and D isotopes are very sensitive to physical processes such as evaporation and condensation. Therefore, the content of these stable isotopes can be used to see the climate effect on springs. The isotopic fractionation process in precipitation is a temperature-dependent process [6]. Thus, if there is a change in seasonal temperature in a place, it will be seen that there is a variation in the stable isotope composition of the precipitation where a light value occurs in a cold month. For the same reason, precipitation will also have a lighter isotope content in the arctic/high latitudes, further away from the sea, and higher elevation places. For every 100 m elevation increase, ^{18}O in the rainwater will decrease by 0.15 - 0.5 ‰, and ^{2}H will be depleted by 1 - 4‰ [30].

Stable isotope content in rainwater shows a linear relationship in the form of a global meteoric water line. The relationship between $\delta^{18}O$ and δD of the precipitation water follows the equation of the meteoric water line. From the results of the global investigation [31], the equation for the meteoric waterline (GMWL) was known as $\delta D = 8\delta^{18}O + 10‰$. Rainwater tends to contain the stable isotopes $\delta^{18}O$ and $\delta^{2}H$, which are depleted at higher latitudes. This phenomenon also occurs when the two stable isotopes move deep inland. For this reason, the plot results of the two isotopes yield slightly different slopes known as the local meteoric water line [32].

Based on the research of the recharge area of the underground river water system in Gunungkidul, Yogyakarta [3], it is known that the local meteoric water line (LMWL) equation for the area is $\delta^{2}H = 7.978\ \delta^{18}O + 8.423$ ‰. This LMWL value is then used for isotope studies in the West Progo area because of its relatively close location and considering that the LMWL value in this area is not yet available.

To see the influence of climate/rainfall, regression line relationships $\delta^{18}O$ and δD groundwater can be plotted together with the global meteoric water line GWML or the local meteoric water line (LMWL). If the groundwater regression line is adjacent to the LMWL, the groundwater is affected by local climate (originating from local precipitation) or topographic effects [1].

4. Result and discussion

4.1. Spring characteristic

Mudal Springs emerge from the Jonggrangan reef limestone aquifer, supported by large porosity permeability. The porosity developed as fracture and channel types. Jonggrangan limestone is dominated by thick to massive layered coral limestones. Around the Mudal springs, these reef limestone outcrops show white to brownish-white color, compact and hard, with some fairly intensive tectonic of joints characteristics. Mudal Springs has a large fluctuation in discharge. The discharges show; moderate magnitude during the dry season but can be very large discharges during the rainy season [11]. When the isotope sampling was carried out, the Mudal spring discharge was measured to be 100 - 236 L/s, but at the end of the dry season (September 2018), it appears that this discharge has decreased drastically to <50 L/s.The spring can be classified as depressions, fractures, or channels type of spring. Mudal spring has a large flow that develops as runoff/rivers. This spring is a parennial spring, although it has a significant change of discharge over the season. Based on its temperature, Mudal is classified as a normal spring. The physicochemical data show groundwater of Mudal spring has a temperature range of 23,1 – 24ºC, pH of 6.7 – 8.3, TDS of 225 – 254 ppm, and EC of 380 – 418 µS /cm.

Meanwhile, Clapar springs have smaller dimensions than Mudal springs. Clapar springs emerge from aquifers in andesite breccias and autoclastic / lava breccias of the Old Andesite Formation, supported by fracture and sheeting joints porosity with moderate intensity controlled by low - medium permeability. Clapar springs have fracture-type springs. The discharge of springs is usually small (stagnant) - medium flow rate, with small discharge fluctuation. These springs can be classified as normal springs based on the temperature of the water. The physicochemical data of these springs show a temperature of 23.7 – 24.5ºC, with a pH range of 7 – 8.2, TDS of 75 – 97 ppm, and EC of 157 – 185 µS /cm.

4.2. ^{18}O and ^{2}H isotopes contents analysis

Stable isotope content data in Mudal and Clapar spring water can be seen in Table 2 below. Furthermore, the isotope content's absolute value and range value can be analyzed to determine the hydrochemical processes that occur in the groundwater system.

Table 2. Data on stable isotope content of groundwater from the investigated springs.

Spring	I (Dec 2016)		II (Aug 2017)		III (Mar 2018)	
	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
Mudal	-7.1 ± 0.11	-41.7 ± 0.4	-7.39 ± 0.42	-45.1 ± 3.1	-6.94 ± 0.39	-50.2 ± 1.5
Clapar	-6.25 ± 0.07	-40 ± 1.8	-5.51 ± 0.32	-34.7 ± 1.0	-4.77 ± 0.34	-38.3 ± 3

4.2.1. Absolute value of δ^{18}O and δD. From period I to III, Mudal springs showed relatively stable O isotope, while D isotope tended to be lighter (Figure 3). Groundwater with light isotope generally flows in deep aquifers or comes from high absorption areas [2], as seen in Mudal springs, which have light D isotope (-50.2‰) in period III (Figure 3; Table 3). It means that groundwater that appears in Mudal springs may flow in deep enough aquifers or originate from precipitation of rainwater that infiltrates at a high enough elevation. The infiltration zone may exist locally because the Mudal springs are indeed at a high enough elevation.

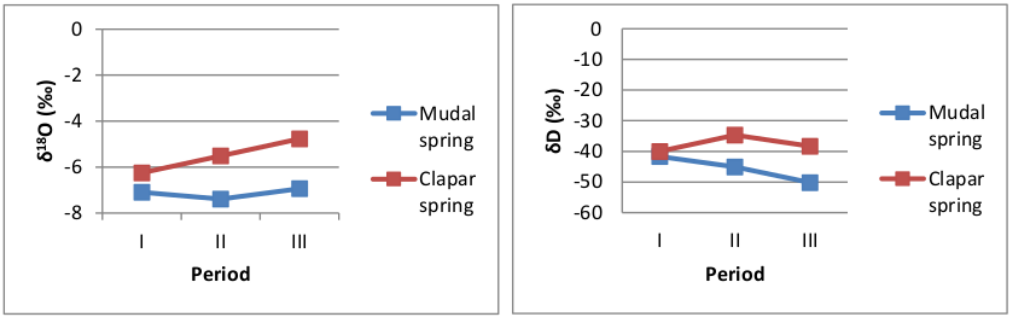

Figure 3. The development of stable isotope content over the three test periods.

Clapar springs have groundwater with ^{18}O heavier from period I to III and a relatively stable D isotope. The heavy isotopes in springs indicate a mixing or evaporation process [1, 2], strongly supported by groundwater isotopes of dug wells in the area [33]. The D isotope indicates a shallow aquifer [2]. Thus, the groundwater in the Clapar springs comes from shallow aquifers that have undergone a mixing or evaporation process.

Table 3. Changes in the stable isotope content of the springs.

Variable	Spring	$\delta^{18}O$ (‰)	δD (‰)
Time	Mudal	down-up, stable relatively difference = 0.45 ‰	get lighter difference = 8.5 ‰
	Clapar	get heavier difference = 1.48 ‰	up - down, stable relatively difference = 5.3 ‰
Season (T-effect)	Mudal	lower when dry	no effect
	Clapar	no effect	higher when dry

Compared to Clapar springs, Mudal springs contain lighter ^{18}O and D isotopes in the three periods studied. It shows that the stable isotopes possessed by the two springs are relatively consistent, whereas the Mudal springs tend to have genetics from deeper aquifers (Table 4).

Table 4. Interpretation of light / heavy isotope content.

Spring	I		II		III		Interpretation
	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{18}O$ (‰)	δD (‰)	
Mudal	-7.1	-41.7	-7.39	-45.1	-6.94	-50.2	- Deep aquifer, or - High elevation recharge
Clapar	-6.25	-40	-5.51	-34.7	-4.77	-38.3	- Shallow aquifer - Mixing with runoff or other sources/evaporation

When compared with GMWL and LMWL, it appears that the absolute values of isotopes contained in the Mudal springs at all periods tend to move away from the two meteoric water lines (Figure 4). Clapar springs contain isotopes that tend to be close to the meteoric water line during the rainy (period I) and dry (II) seasons. This considerable deviation in period III for Clapar springs indicates the influence of the water from other sources or runoff.

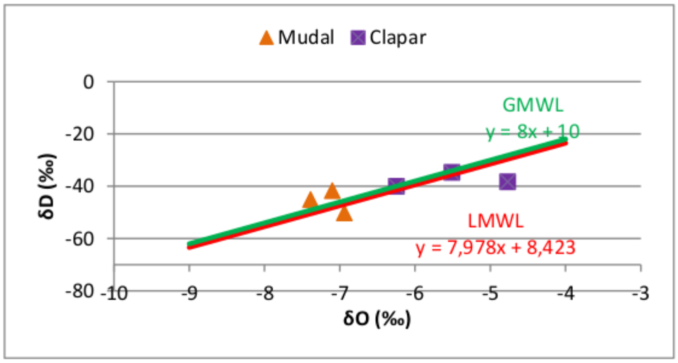

Figure 4. The relation of $\delta^{18}O$ and δD in groundwater of springs.

The interpretation of water sources in the Mudal and Clapar springs is also supported by physicochemical data from the groundwater. Mudal springs release water from deep aquifers characterized by cooler temperatures. According to other researchers, a higher temperature may be sourced from mixing groundwater and surface water [2]. The pH value, which tends to be alkaline, indicates a long interaction with carbonate rocks in the relatively deeper aquifer. This condition is also supported by the greater TDS and EC values of water from the Mudal springs than Clapar.

4.2.2 Range value of $\delta^{18}O$ and δD. The stable isotope content studied showed a short range of values and generally did not have overlapping values (Figure 5). With due regard to the $\delta^{18}O$ range value in all periods, it appears that the groundwater from Mudal springs has isotopes $\delta^{18}O$ is light, while the Clapar springs have value $\delta^{18}O$. The overlapping values in the three periods in Mudal springs indicate that groundwater in these springs is less affected by seasonal changes, while seasonal changes have more effect on Clapar springs.

The widest δD range value occurs in Mudal and Clapar springs at different periods (Figure 5). The δD value, which is relatively stable, light but appears to shift in the Mudal spring, indicates that the groundwater in this spring is less affected by seasonal changes, with relatively deep circulation. As for the springs, Clapar has relatively stable (heavy) δD, which shows significant overlapping in the rainy period, slightly different from the range value in the dry season, indicating that groundwater in these springs is immensely affected by changes in the season. Referring to previous research [2], groundwater with heavy δD as in the Clapar springs can be interpreted as a result of a fairly intensive mixing or evaporation process (Table 5).

Monthly rainfall in the three periods shows that during the rainy season, there is quite a lot of precipitation in both Mudal and Clapar (Table 1). In the dry season (period II), the precipitation is very low. However, the values range $\delta^{18}O$ for Mudal spring did not show any clear changes. The ^{18}O isotope content in Mudal springs is relatively stable and less affected by the amount of precipitation. It also indicates that the Mudal springs are supported by relatively deeper aquifers.

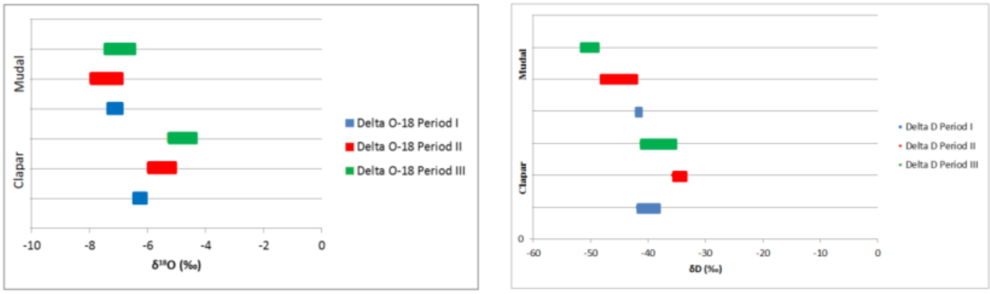

Figure 5. The values range $\delta^{18}O$ and δD for Mudal and Clapar springs. The overlapping values indicate the similarity of δD in different seasons.

Table 5. Value range interpretation $\delta^{18}O$ and δD.

Springs	$\delta^{18}O$	δD	Analysis
Mudal	In short, some overlap	Short and long, shifted	$\delta^{18}O$ and δD are relatively stable/light, less affected by seasonal changes
Clapar	Short - long, shifted, enrichment	Short-a bit long, overlap significantly in the rainy season	$\delta^{18}O$ and δD relatively stable/heavy, affected by season, intensive evaporation/mixing

Change δD of groundwater usually occurs due to isotopic exchange with minerals containing hydrogen, such as gypsum and clay minerals [34,35]. However, data does not support this exchange. The δD in these two materials is unknown, so the cause of the δD change in groundwater is still difficult to determine. Moreover, this variation in value is usually not large, so this exchange is considered insignificant. Furthermore, membrane filtration is associated with increased δD. It is difficult to happen in the study area because this process usually requires high pressure, which is equivalent to a sediment depth of 1.6 km [36]. In sedimentary rock formations, less than 1 km deep membrane filtration is less effective [37].

4.3. The effects of season on $\delta^{18}O$ and δD changes

The process that occurs related to the seasonal effect can be assessed based on the $\delta^{18}O$ against δD of groundwater relationship. In the dry season (period II), the regression line of springs in the study area is very close to the LMWL, indicating that meteoric water isotope content enrichment has not been clearly seen [38]. However, the climatic influence in this dry season can be seen from the presence of d-excess [1]. Further research added that the value of the line gradient is in the range 3-6, indicating an evaporation process [31].

The groundwater line in period III was partly below the LMWL, which indicates that it experienced isotopic enrichment [1,11], for example, due to a fairly intensive evaporation process or mixing with surface water/runoff. The slope of the regression line smaller than the LMWL gradient indicates a variation in evaporation rate. In addition, evaporation may occur in the catchment area along with the infiltration process [2].

4.3.1. The enrichment of ^{18}O and D stable isotopes. Changes in stable isotope content associated with changing seasons can cause an δD or $\delta^{18}O$ enrichment effect. O-18 isotope enrichment during the rainy season relative to the dry season occurs in Mudal springs, while δD isotope enrichment occurs in Clapar springs in the dry season compared to the rainy season (Table 6; Figure 3).

Isotopic enrichment $\delta^{18}O$ in the rainy season relative to the dry season in Mudal springs is related to the isotopic fractionation of carbonate rocks due to water-rock interaction. It was also supported by the greater TDS and EC values of groundwater in the Mudal than Clapar springs, both during the rainy and dry seasons. Enrichment of $\delta^{18}O$ can be caused by carbonate minerals [35,37]. Meanwhile, the δD enrichment of Clapar springs occurs, indicating that seasonality affects the content of these stable isotopes. The season affects the evaporation process, which can enrich the isotopic content of groundwater.

Table 6 shows the degrees of δD enrichment in the springs studied. The degree of δD enrichment is calculated in the dry season (period II) relative to the rainy season, both periods I and III. The magnitude of the changes caused by D isotope enrichment can be seen in Figure 6.

Table 6. The δD enrichment in the dry season relative to δD in the rainy season.

Spring	δD dry (Period II)	δD rainy		Enrichment Degree	Explanation
		Period I	Period III		
Mudal	-45.1	-41.7	-50.2	-3.4 - 5.1	Uncertainty
Clapar	-34.7	-40	-38.3	3.6 – 5.3	Medium-large

*) Negative values indicate enrichment during the rainy season

Figure 6 shows that the Mudal spring has a medium-large δD enrichment (>5‰) but is not related to seasonal changes. The Clapar springs undergo moderate - large changes due to enrichment during the dry season. The δD enrichment in the Clapar springs in the dry season shows a seasonal effect on the D isotope of groundwater. It is confirmed by a shift in δD values that can occur due to seasonal changes [2].

A spring that has δD enrichment >5‰ is classified to have a large change, while moderate change is indicated by D enrichment of >3 - 5‰. Meanwhile, a small change is indicated by δD enrichment of >1 - 3‰ [2]. The enrichment δD <1 indicates no enrichment. If the δD range value is considered, some groundwater samples appear to have shifted (Figure 6). The two springs have shifted slightly - totally change.

4.3.2. The "d" value (δD-excess). Changes in stable isotope content can occur due to the influence of seasons due to temperature differences. Usually, the temperature effect is related to the elevation of an area. However, it is difficult to study the effect of elevation in this study, considering that the two springs studied do not have a contrasting elevation difference. The humidity aspect also cannot be studied considering the absence of data. Isotope data in the two investigated springs showed good $\delta^{18}O$, nor δD varies considerably, both in absolute value and in range. The data that is not much different is generally considered to have no seasonal variation (temperature effect) [1]. However, if we examine one by one, there is a "d" variable which is δD-excess which we can calculate (Table 7). The value of "d" in general can be calculated with the following formula [1].

$$d = \delta D - 8\delta^{18}O \tag{1}$$

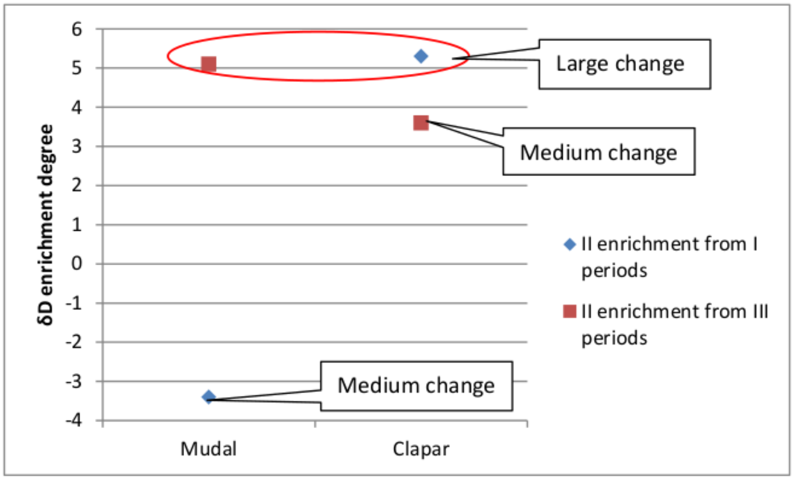

Figure 6. D-enrichment of groundwater in Mudal and Clapar springs.

Table 7. The value of the δD-excess of groundwater.

Spring	δD-excess ("d") (‰)		
	I	II	III
Mudal	15.1	14.02	5.32
Clapar	10	9.38	-0.14

The "d" value or δD excess indicates the presence of D isotope enrichment versus the $\delta^{18}O$ value. The value of "d" is a relatively important parameter concerning the climate of an area. The values of groundwater in the study area in the period I range from 10 and 15.1‰; period II range from 9.38 to 14.02‰; in period III of 5.32‰ in Mudal, indicating that the range of "d" values in Mudal is relatively higher, in all seasons. Clapar springs do not show d excess in period III. In general, the value of d gets lower over time.

In general, δD excess is influenced by air mass which is usually different, where the dry season tends to be dry, while the rainy season has humid air [1]. In rural areas, the isotopic exchange between rainwater and humidity can slightly shift d [39]. However, the d value was not significant for the springs in the study area. However, the d values in the two springs in the two seasons varied, not showing a great difference. This less difference can be interpreted that the humidity in the air during the dry and rainy seasons is not much different. The evapotranspiration conditions can occur quite intensively in the two seasons [33].

In dry conditions, evapotranspiration as a controller for groundwater recharge is usually relatively reduced, while in the rainy season / humid air, evapotranspiration is greater [1]. In addition, many plants are dormant in the dry season in the dry season, while the plants are more developed in the rainy season. Thus, the differences in evapotranspiration and humidity conditions in all seasons were not significant.

In addition, large d values usually occur in high permeability rocks or thin soil, resulting in rapid infiltration [1]. This rapid infiltration causes groundwater to experience no / less evapotranspiration. Mudal spring has a character like this, supported by many fractures, cracks, and dissolving cavities in the limestone that consist of the aquifer of these springs. Mudal aquifers are examples of karst aquifers that usually have conduit characteristics and can have underground rivers due to interconnected conduits. However, a large shifting in d values can occur in both the Jonggrangan and Old Andesite Formations aquifers.

5. Conclusion

This groundwater hydroisotope study was carried out on two selected springs in the West Progo Hills, namely the Mudal springs, which emerged from the limestone of the Jonggrangan Formation and the Clapar springs from the volcanic breccias of the Old Andesite Formation. Both springs have stable isotope content characteristics, relatively stable, with insignificant changes with time and season. Mudal springs have an isotope that tends to be light, indicating deep aquifer or high elevation recharge based on their absolute value. Meanwhile, Clapar spring shows heavier isotopes, which come from shallow aquifers with a mixing/evaporation process and are more influenced by the season. Based on the range value of $\delta^{18}O$ and δD, Mudal springs contain isotopes that are less affected by seasonal changes, while Clapar springs are seasonal. The range value of δD in both springs is slightly - totally change, which means that it changes due to the change of seasons even though it is small. Based on the season, δD enrichment in Mudal shows uncertainty, while Clapar spring has a medium-large change character. Meanwhile, the "d" value varies independently of the season, which can be interpreted that the climate conditions during the dry and rainy seasons in the study area are not much different.

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