

Seminar Internasional

Dari: seminar STTNAS (seminar@itny.ac.id)

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Tanggal: Jumat, 19 Juli 2019 14.49 WIB

Kepada Yth
Bapak/Ibu/Sdr Ilmuwan/Peneliti/Birokrat/Mahasiswa

Dengan hormat,

Sehubungan akan diadakannya *International Conference on Industrial Technology and Information Designs* (ICITID) oleh Institut Teknologi Nasional Yogyakarta yang akan dilaksanakan pada:

Hari/Tanggal : Sabtu, 26 Oktober 2019
Waktu : 08.00 – 17.00 WIB
Tempat : Sahid Jaya Hotel & Convention
Jl. Babarsari, Caturtunggal, Depok, Sleman, Yogyakarta 55281
Tema : *Industrial Revolution 4.0: Transfers and Capacity of Technopreneur*
Keynotes Speaker :1. Prof. Hj. Dr. Zainal Alimuddin Zainal Alauddin
(Universiti Sains Malaysia, Malaysia)
2. Prof. Ing-Song Yu
(National Dong-Hua University, Taiwan)

Untuk itu kami berharap kepada Bapak/Ibu/Saudara berkenan berpartisipasi pada acara Seminar yang kami selenggarakan baik sebagai pemakalah maupun peserta.

Sebagai tambahan informasi semua artikel ilmiah yang diseminarkan akan dipublikasikan di *IOP Conference Series (indexed by Scopus)* dan artikel ilmiah terpilih akan diterbitkan di jurnal ilmiah terindeks Scopus.

Demikian undangan kami sampaikan, atas perkenan dan perhatiannya disampaikan terima kasih.

Sekretariat:
International Conference on Industrial Technology and Information Designs (ICITID)

INSTITUT TEKNOLOGI NASIONAL YOGYAKARTA
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Fwd: [REMINDER : ICITID 2019 Invitation and Schedule]

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Tanggal: Kamis, 24 Oktober 2019 21.59 WIB

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Dari: icitid itny <icitid@itny.ac.id>

Date: Kam, 24 Okt 2019 pukul 21.57

Subject: [REMINDER : ICITID 2019 Invitation and Schedule]

To: <bagoesswastiko24@gmail.com>, Novandri Kusuma <novandri.kusuma@itny.ac.id>, Cahya Damayanti <cakra.cahya@gmail.com>, Dr. Imam Kambali <imamkey@batan.go.id>, Rivan Muhfidin <rivanmuhfidin@gmail.com>, <alhussein.rizqi@yahoo.com>, <herusuharyadi34@gmail.com>, asri mariza <marizaasri1@gmail.com>, <fatim_miharna@yahoo.com>, Listiani RA <lis@sttnas.ac.id>, Akhmad Zamroni <akhmadzamroni@itny.ac.id>, <bardi_sttnas@yahoo.com>, <adeindra@itp.ac.id>, Archit Fadhilah <archit.fad@gmail.com>, <nof.hand11@gmail.com>, Wasino Wasino <wasino@fti.untar.ac.id>, wahyudi tinom <wahyuditinom@elektro.undip.ac.id>, <achmad.hidayatno@gmail.com>, RIZQI PRASTOWO <rizqi@itny.ac.id>, <ridayati@gmail.com>, Sugiarto Kadiman <sugiarto.kadiman@itny.ac.id>, ANI APRIANI <aniapriani@itny.ac.id>, Daru Sugati <daru.tm@itny.ac.id>, Tugino STTNAS <tugino@itny.ac.id>, Okki Verdiansyah <okki.verdiansyah@sttnas.ac.id>, <yudidito@gmail.com>, Hita Pandita <hita@sttnas.ac.id>, <rinaldy.mesakh.k@mail.ugm.ac.id>, HIDAYATULLAH SIDIQ <hidayatullah@itny.ac.id>, Siti Nuraini <siti.nuraini@itny.ac.id>, <hendro.purnomo.hpu@gmail.com>, Adi Prabowo <adi.prabowo@sttnas.ac.id>, <djohan_gh@yahoo.com>, BAYUROHMAN PANGACELLA <bayurohman@itny.ac.id>, BAYUROHMAN PANGACELLA <bayurohman@sttnas.ac.id>

Dear Mr / Mrs Presenters of ICITID 2019

We kindly inform you that your paper has been reviewed and accepted to be presented at *International Conference on Industrial Technology and Information Designs (ICITID) 2019* to be held,

Date : 26 October 2019

Time : 08.00 – 16.40 (Please see appendix below)

Venue : Sahid Jaya Hotel & Convention.

Babarsari, Caturtunggal, Depok, Sleman, Yogyakarta 55281, Indonesia

We cordially invite you to attend our conference and present your research. Please prepare your presentation file and submit it to the staff when the registration time.

Thank you



invitation.pdf
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Number : 32/Pan.ICITID-ReTII14/ITNY/X/2019
Appendix : 1 page
Case : ICITID Conference Presenters Invitation

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Thank you

Yogyakarta, 22 October 2019

The committee chairman



Dr. Ir. Sugiarto, MT



INTERNATIONAL CONFERENCE ON INDUSTRIAL TECHNOLOGY AND INFORMATION DESIGN (ICITID)

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RUNDOWN

International Conference on Industrial Technology and Information Designs (ICITID)
Oct,26,2019

NO	TIME	EVENT	EVENT DETAIL	Rooms
1	07.30 – 08.15	Registration	Collect presentations	Bima Room 1&2
2	08.15 – 09.00	Parallel Session I:	See Technical (Parallel Session I Schedule)	Arjuna Room 1
				Arjuna Room 2
				Gatotkaca Room
3	09.00 – 09.15	Coffee Break I		Bima Room 1&2
4	09.15 – 09.25	Opening Ceremony	Greeting from the chairman of the seminar committee By : Dr. Ir. Sugiarto, M.T	
			Official Opening by the Rector of ITNY By : Dr. Ir. Ircham, M.T	
5	09.35 – 10.35	1 st Keynote Speaker	Prof. H. Zainal A from University Sains Malaysia Penang Malaysia	
6	10.35 – 11.35	2 st Keynote Speaker	Prof. Ing Song Yu from NDHU, TAIWAN	
7	11.35 – 11.45	Announcement of award winner	Announcement of award winner and Photo Session	
8	11.45 – 13.00	Lunch		Sahid Resto
9	13.00 – 14.20	Parallel Session II:	See Technical (Parallel Session II Schedule)	Parallel Class
10	14.20 – 14.25	Closing Ceremony	Closing by a moderator	Parallel Class
10	14.25 – 14.40	Coffee Break II		Bima Room 1&2
11	14.40 – 16.40	Coaching	Reviewers	Bima Room 1&2

Influence of Rocks to The Hydrochemical Facies of Groundwater at Samigaluh Area, West Progo

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Abstract

Groundwater survey has carried out at Samigaluh and its surrounding area, West Progo. This area is included in West Progo Dome and topographic map of Sendangagung. This research has been done by hydrogeological survey, equipped with groundwater sampling of four samples for physical/chemical testing at laboratory. Field data collecting includes physical properties (color, taste, odor, turbidity) and chemical properties (pH, TDS) of groundwater as well as local geological condition. Laboratory data is similar with field data plus ion contents. Data analysis includes hydrochemistry of groundwater based on all data. Result of research show that groundwater in research area is usually colorless, no taste, no odor and clear. Groundwater develops in most variable types, such as Ca-HCO_3 , Ca , Na-HCO_3 , Ca,Na,Mg-HCO_3 and Ca,Mg-SO_4 . Groundwater types vary in some Piper class, i.e. 1-6 and 9. The hydrochemical process is dominated by ion exchange, besides simple dissolution or mixing. The dominant groundwater facies are bicarbonate, due to the influence of silicyclastic rocks that interact with groundwater through the dissolution process. The number of elements Ca^{2+} , Na^+ and silica in the groundwater is influenced by the weathering of minerals.

Keywords: hydrochemistry, groundwater, facies, process, rocks

1. Introduction

The research of groundwater was conducted in Samigaluh and its surrounding area, West Progo District (Figure 1). The area is included in West Progo Dome physiographically [1], and the Indonesian Topographic Map Sheet 1408-232 (Sendangagung) [2] scale of 1: 25.000. The research area is included in non groundwater basin of West Progo Hills.

Hydrogeological research has been developed in various regions through some methods and goal in many regions in order to know about its quality and help society to get good quality of drinking water. The water is very important for human life, therefore water must be maintained as a valuable thing. Many researches about groundwater need to be done to develop degree of life.

Recent days, groundwater is more important and replaces surface water for daily need in some areas. The potential of groundwater in an area needs to be evaluated its properties in order to provide good quality of water. The properties usually include both physical and chemical ones, and sometimes they're completed with biological assesment. However, this research is focused in physical and chemical properties of groundwater in study area.

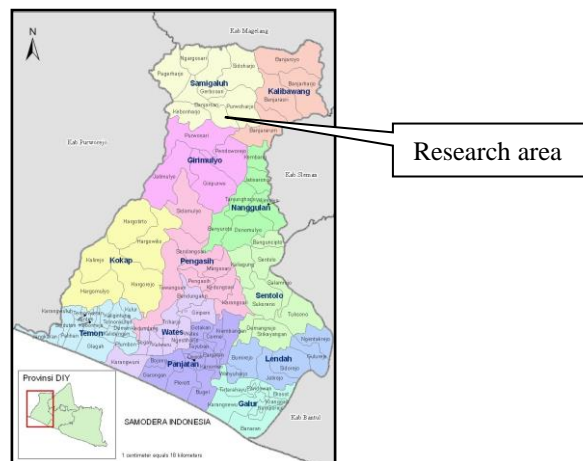


Figure 1. Research area at Samigaluh and its surrounding region, West Progo District [3].

The potential of groundwater in certain areas is important to be determined from many aspects. This research has also been done to support groundwater potential understanding, especially on physical/chemical properties, and the influencing of rocks to groundwater. Hopefully, result of the research can be united with other result of whole area, especially in West Progo Hills.

Potential groundwater in the research area has been studied using physical/chemical properties. By knowing these properties, the interpretation of groundwater quality and hydrochemical processes can be understood. The understanding of hydrochemical processes will help of understanding of geological condition in research area. Therefore, a good study of the hydrochemistry of a region is required. The various hydrochemical processes are controlled by the rocks of a region. Moreover, the hydrogeological understanding can be approached by evaluating of the diversity of the groundwater facies and its correlation with rocks in studied area.

2. Methodology

The research was primarily conducted by hydrogeological survey in field, especially for observing groundwater of dugwells and springs. There were 12 observation locations include four springs and eight dug wells. The tools used are standard geological tools (hammer, loupe, compass) and hydrogeology tools (pH-meter, TDS-meter, and sample bottles) as well as GPS equipment. Four groundwater samples were taken with polyethylene bottles, each of 1 liter of water. Then, groundwater samples tested their physical/chemical properties in the Chemical Laboratory of BBTKLP, Yogyakarta. The analysis was conducted on field data including petrology data of aquifer, geomorphology and stratigraphy, and analysis of physical/chemical of groundwater in selected locations. Groundwater samples were taken at Ngaranduo well (W7) and Tulangan (S1), Jarakan (S5), Palem (S12) springs (Figure 2). Compilation of secondary data and primary data both of field an laboratory has been done to evaluate groundwater quality in research area.

3. Literature Review

3.1. Geological of Research Area

The research area is physiographically included in West Progo Dome Zone (Fig. 2) [1]. This dome is part of the South Serayu Zone especially in the phenomena of the Dome Zone and the Hills in the Central Depression physiography. However, West Progo Dome has different orientation structurally with South Serayu Range.

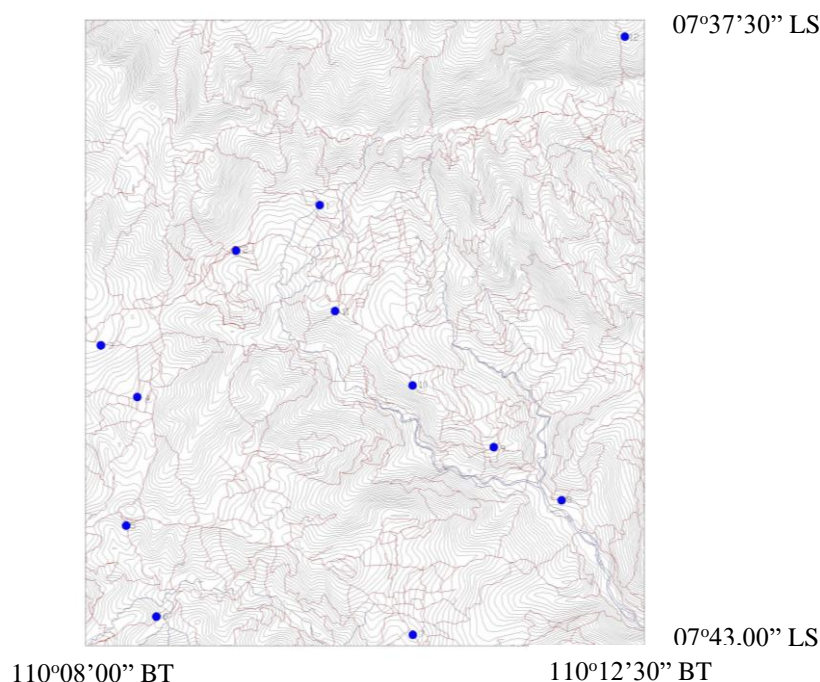


Figure 2. Observation locations of research.

Some geologists stated that the regional stratigraphy of West Progo Hill is composed from the oldest to the young by Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation, Sentolo Formation and Alluvial Deposition. The Jonggrangan and Old Andesite Formations exposed in the research area.

The Old Andesite Formation is exposed in most of research area. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapili, lapilli tuff and volcanic sandstone. The dominant lithology consists of andesite breccia with a tuff matrix, while fragments comprised of pyroxene to hornblende andesites. Beside this pyroclastic/epyclastic breccias, the intrusion of igneous rocks can be found locally.

The ancient volcanic activity located in West Progo Hills which produced Old Andesite Formation were Mt. Gadjah, Mt. Ijo and Mt. Menoreh. The Old Andesite Formation was unconformably lied above Nanggulan Formation. The Old Andesite Formation can be separated based on the two depositional facies, namely Kaligesing and Dukuh Formation [4]. Kaligesing Formation is a land facies and consists of volcanic breccia, lava and intercalation of tuff. The age of this formation is Late Oligocene to the Early Miocene, with a thickness of more than 600 m. On the other hand, Dukuh Formation has deep sea facies, and composed of volcanic breccias as well as intercalation of sandstone, limestones, and claystone. This formation was deposited in Upper Oligocene to Early Miocene age, with thickness of more than 660 m and has interfingering relationship with Kaligesing Formation.

The litology of West Progo Hills is dominated by volcanic materials such as andesite breccia, tuff, lapilli, agglomerate, and intercalation of andesite lava flows. The material is formed by the existence of ancient volcanic activity at Tertiary time. The litology is usually impermeable and less porous. As a result, the water is difficult to be stored and flown in it. Therefore, the potential of groundwater in this region is very little. The presence of groundwater in this area is sometimes found in very deep layers (> 25 meters) and found only in rock fractures [5]. The need of the water for population at West Progo Hills is generally usually fulfilled by springs.

3.2. Facies of Groundwater

Groundwater quality is determined by its physical and chemical properties. This groundwater quality can be seen from its contents. Physical properties include color, taste, odor, temperature and turbidity; while chemical properties depend on chemical composition of groundwater. The chemical composition of groundwater is influenced by minerals of rock. Each mineral has certain chemical composition which when dissolved will affect the chemical composition of groundwater.

The chemical facies of groundwater depends on chemical composition of water in recharge area and reactions that occur in groundwater flow system [6]. In its flow process groundwater will pass many kinds of rocks beneath the surface of the earth. The rock will partially dissolved and influence the chemical content of groundwater. Mineral solubility in rocks depends on several things, such as pressure and temperature in groundwater basin and resistance of rocks.

Davis & De Wiest (1966, in [7]) Groundwater quality is influenced by rock material in its path. Ion development in groundwater depends on mineral availability and mineral solubility. There is relationship between groundwater compound ions in rock's mineral. Table 1 explains briefly about some chemical composition of groundwater and possibly source of minerals/rocks which influence it.

Groundwater compositions vary in its process. This chemical contents also change or experience evolution while groundwater flows under surface. From geochemical point of view, the order of anion evolution is greatly determined by mineral's availability and solubility [9]. HCO_3^- ion content in groundwater commonly comes from CO_2 of soil and calcite/dolomite dissolution. Because of big numbers of calcite and dolomite in almost all of sedimentary basin and these minerals are easily soluble, HCO_3^- almost be always dominant anion in recharge area.

Groundwater quality is influenced by aquifer materials caused by diagenetic changes when the groundwater passes the aquifer, caused by several hydrochemical processes [6]. These processes are dissolution-hydrolisis-precipitation, adsorption, ion exchange, reduction-oxidation, mixing, membrane filtration and microbiology metabolism.

One of the causes of mineralization in deep lying water is long enough time of groundwater interaction to aquifer [6]. This fact will increase TDS from soluble salt or non resistant minerals. Besides aquifer rock, claystone can also influence the chemical composition of groundwater by ion exchange processes. Clay can be as geochemical filter, natural chromatography or semipermeable membrane.

Table 1. Mineral/rock association to chemical elements of groundwater (modified from Davis & De Wiest, 1966 in [7] and [8]).

Element / Compound	Minerals / Rocks
Ca	Marine sedimentary rocks (calcite, aragonite, dolomite, anhydrite, gypsum); product of igneous rock's weathering (feldspar, amphibole, pyroxene group, clay mineral).
Na	Product of igneous rock's weathering, feldspar (albite), clay mineral.
K	Clay mineral, igneous rock's mineral (ortoclast, microcline, mica, biotite, feldspatoid, leucite, nepheline).
Mg	Comes from soil and sediment, sedimentary rock (dolomite), igneous rock (biotite, hornblend, augit).
NO ₃	Atmosphere, the destructions of plants, animal breeds (organism activity), chemical source of industry & agriculture.
HCO ₃	CO ₂ from atmosphere and soil, soluble materials of calcareous rock (limestone & dolomite), precipitation of CaCO ₃
SO ₄	Oxidation of sulfide mineral in volcanic/igneous rock, atmospheric precipitation, organic shale
Cl	Connate water trapped when sedimentation, result of rain evaporation, atmospheric solubility.
SiO ₂	Feldspar, quartz, clay mineral, volcanic rock

As long as its flow under surface, groundwater tends to keep chemical equilibrium through chemical reactions to environment. Equilibrium achieved tends to produce stable groundwater quality to time cause of slow motion of groundwater and long residence time in geological formation [10]. Groundwater compositions vary in its flow process. The variable of groundwater quality commonly observed easier in shallow aquifer caused of seasonal variation at recharge and discharge area related with salinity fluctuation.

4. Result and Analysis

The geological setting of this region is composed by rock formations which are included in the West Progo Dome stratigraphy, such as Jonggrangan and Old Andesite Formation as well as the Quaternary sediments. The Old Andesite Formation that comprises the research area is generally include as Dukuh Formation, evenly spread in almost all part of research area. Whereas, Jonggrangan Formation has outcrops locally spread or spotly at narrow area.

The research area dominantly consists of andesite breccia. This rock can potentially act as aquifer through many cracks of joints (Figure 3). The andesite breccia show dark brown to black color when weathered and grey in fresh condition, with pyroclastic texture, and massive structure. The fragment of rock consists of andesite with feldspar, pyroxene, biotite dominantly and few quartz mineral. Whereas, the matrix usually is dark grey and consists of tuff.



Figure 3. Left: Springs at Jarakan, Kebonharjo (Loc. 5). Right: Aquifer of andesite breccia at the spring.

Field data has been taken directly from area of dug wells and springs (Figure 2; Table 2). The physical/chemical properties of groundwater results from the laboratory are given in Table 3.

Table 2. Field data of physical/chemical properties of groundwater.

No. Loc.	Type of Occurrence	Color	Taste	Odor	Turbidity	pH	TDS
1	Spring	Colorless	no taste	no odor	clear	7	83
2	Well	Colorless	no taste	no odor	clear	6.9	45
3	Well	Colorless	no taste	no odor	clear	6.8	58
4	Well	Colorless	no taste	no odor	clear	7	29
5	Spring	Colorless	no taste	no odor	clear	7	33
6	Spring	Colorless	no taste	no odor	clear	6.8	30
7	Well	Almost colorless	no taste	no odor	clear	6.8	324
8	Well	Colorless	no taste	no odor	clear	6.8	68
9	Well	Whitish	no taste	less odor	clear	6.8	44
10	Well	Colorless	no taste	no odor	clear	6.8	61
11	Well	Colorless	no taste	no odor	clear	6.8	69
12	Spring	Colorless	no taste	no odor	clear	7	48

4.1. Physical Properties of Groundwater

Field data showed good quality of groundwater both in wells and springs. They showed colorless, no taste, no odor and clear of groundwater almost in all location. Anomalous properties were only found at W7 and W9 that were slightly colored. Temperature of groundwater is usually normal, similar with the air temperature around wells and springs. Laboratory data also showed similar properties, where anomalous can be found at S12 with turbidity reached 5 NTU. Nevertheless, groundwater in research area is still good physical properties for daily needs.

Table 3. Laboratory testing of physical/chemical properties of groundwater.

No	Parameter	S1	S5	W7	S12
1	Ca (mg/l)	61.6	15.2	209.6	23.2
2	Na (mg/l)	33	24	68	38
3	K (mg/l)	3	1	8	4
4	Mg (mg/l)	8.26	5.83	63.18	5.83
5	Fe (mg/l)	0.0162	0.0541	0.0162	0.0221
6	Mn (mg/l)	0.0101	0.0101	0.0101	0.0101
7	Zn (mg/l)	0.0083	0.0083	0.0083	0.0083
8	NO ₃ (mg/l)	1.85	1.33	3.08	7.73
9	HCO ₃ (mg/l)	252.4	90.6	300.5	114.2
10	SO ₄ (mg/l)	2	1	894	6
11	Cl (mg/l)	2.5	2	6.4	4.5
12	SiO ₂	17.691	15.543	11.823	17.212
13	pH	6.1	5.7	6.8	6.1
14	Turbidity (NTU)	1	2	1	5
15	Taste	no	no	no	no
16	Odor	no	no	no	no

17	Temperature (°C)	25.2	25.2	25.2	25.2
18	TDS (mg/l)	178	85	1269	122

4.2. Chemical Properties of Groundwater

Good properties of groundwater were also shown from chemical ones, such as normal pH (6.8 – 7) at the field and 5.7 – 6.8 from laboratory. TDS commonly are low, except groundwater from W7 which reached 1269 ppm. Based on TDS value, groundwater of research area is fresh water according to Carroll, 1962 in [10].

Chemical contents of four samples show anion dominant as HCO_3^- , while cation dominant are usually vary. From laboratory data, samples from springs (S1, S5, S12) show Ca- HCO_3 , Ca, Na, Mg- HCO_3 and Ca,Na- HCO_3 facies subsequently, while sample from dug well at Ngaranduo (W7) show Ca,Mg- SO_4 facies (Table 4). The numbers of ion compositions of samples (in epm) can be seen at Stiff Diagram (Figure 5). It is clear that bicarbonate will be dominant facies of groundwater samples.

Table 4. Groundwater facies of samples of research area.

No.	Parameter	S1	S5	W7	S12
Cation					
1	Ca (%)	65.02	40.02	58.94	41.60
2	Na (%)	17.85	32.38	9.80	34.92
3	K (%)	2.76	2.29	1.96	6.25
4	Mg (%)	14.37	25.30	29.29	17.23
Anion					
5	Cl (%)	1.66	3.61	0.76	5.98
6	HCO_3 (%)	97.36	95.06	20.76	88.14
7	SO_4 (%)	0.98	1.33	78.47	5.88
Chemical type		Ca - bicarbonate	Ca,Na,Mg - bicarbonate	Ca,Mg - sulfate	Ca,Na - bicarbonate

Bicarbonate facies is dominant groundwater type in research area. The anomalous which is found in well number W7 as sulfat facies may be caused by pollution of groundwater. The pollution possibly came from human activity such as household waste, industry or agriculture, in addition to the possibility of organic shale in the place.

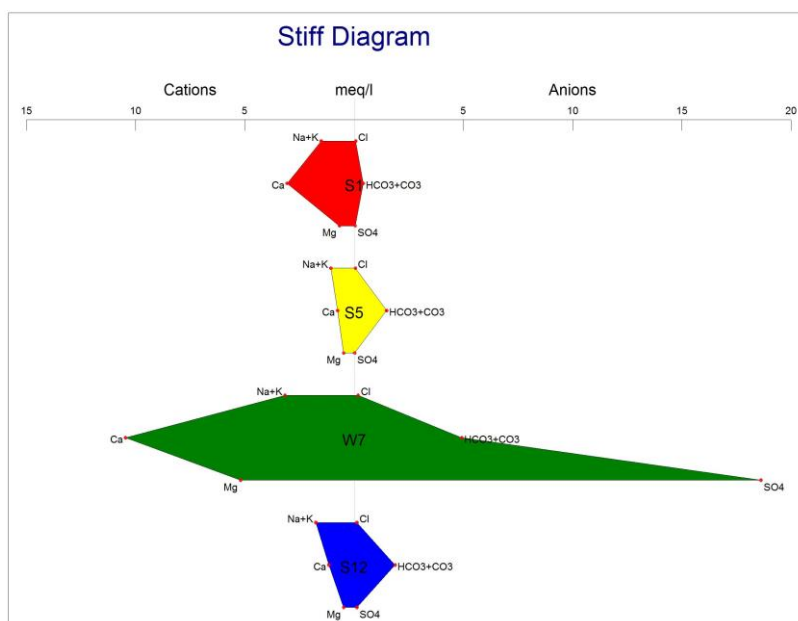


Figure 5. Stiff diagram of groundwater samples.

Plot of groundwater samples in Piper diagram (Figure 6) show that groundwater in research area have several varied types. Those samples include in many class of Piper division, i.e. class 1 – 6 and class 9.

Groundwater from S1, S5 and W7 is included in class 1, indicate that earth alkaline content more than alkaline. Groundwater from S12 is included in class 2 which means it has alkaline content more than earth alkaline. Class 3 consists of S1, S5 and S12 which means that weak acid content more than strong acid. Class 4 involves groundwater from W7 which means strong acid more than weak acid contents. Class 5 shows that calcareous hardness or secondary alkalinity more than 50%, for example groundwater of S1 and S5. Class 6 shows that non calcareous hardness or secondary salt consists of groundwater from W7 sample. Whereas, class 9 show cation-anion equilibrium in groundwater like in S12 sample.

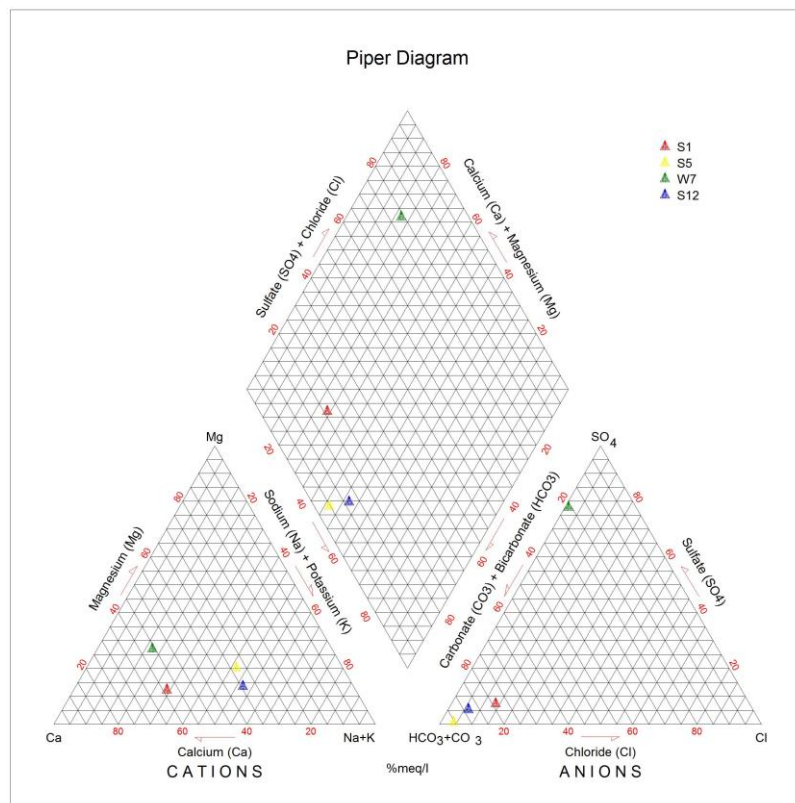


Figure 6. Plot of groundwater samples in Piper diagram.

Hydrochemical process along groundwater flow path were dominated by ion exchange, especially as shown by S12, S5 and S1 samples (Figure 7). Although the process in S1 is more advanced, this does not mean that groundwater flow from S12 to S5 and S1. It can be understood because groundwater flows locally. Whereas, the W7 sample tends to show the other dominant process i.e. simple dissolution or mixing. It may be due to pollution at well area from the environment. It also supported with high enough of TDS in groundwater of W7 sample according to laboratory test that show brackish water type (Carroll, 1962 in [10]).

The hydrochemical process as indicated in Figure 8 does not clearly describe the order of groundwater journey. The pattern of groundwater flow in the research area is still not understanding comprehensively, since the area is a non groundwater basin area. This means that groundwater flow patterns are often local, and may not be interconnected in the basin.

Groundwater in research area flows mostly in volcanic rocks with igneous rock fragments. The igneous rock origin generally contains appreciable amounts of aluminosilicate minerals such as feldspar and mica [11]. Groundwater would be acquired dissolved constituents from dissolution process. However,

silica contents (SiO₂) of groundwater in research were still low (<18 ppm). It means that dissolution process (even in W7) have not gone perfectly or or the process takes place in a relatively short time. It indicates that groundwater flow is local or near journey. This characteristic is usually possessed by a young groundwater in recharge area.

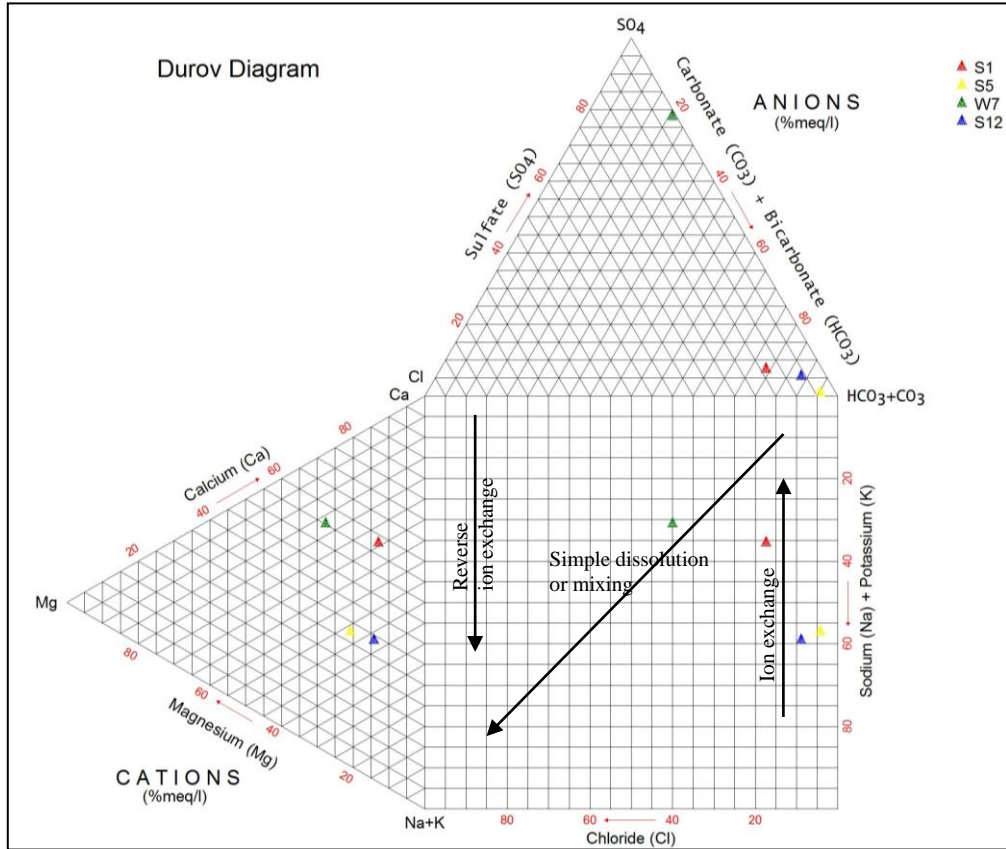


Figure 7. Plot of groundwater samples in Durov diagram.

4.3. Rock's Mineral Composition

Rocks affect the chemical characteristics of groundwater through the process of dissolving the minerals they contain [12], [13]. Therefore, the study of the influence of rocks on groundwater hydrochemicals is carried out by analyzing the mineral content of rock constituents. Table 5 below shows the composition of rock minerals in the study area. The rocks that make up the Samigaluh area are dominated by pyroclastic andesite breccias and andesite igneous rocks. The rock has the main mineral feldspar (plagioclase) and volcanic glass [14]. One example of mineral appearance in a thin section of rock is shown in Figure 8.

Table 5. Mineral composition in rocks in the study area (%) [14].

Location	Field Name	Petrographic Name	Vitric	Feldspar	Opaq Min.	Biotite	Hornblend	Pyroxene	Quartz	Lithic	Fossil	Clay Min.	Carbonate mud
Giripurwo	Tuff	Vitric tuff	85	10	5								
Giripurwo	Andesite intrusion	Andesite	10	45	1	10	14	20					
Gerbosari	Andesite lava	Andesite	17	50	5	20		22					
Purwoharjo	Fragment of breccia	Andesite	7	75				8	8				
Purwoharjo	Matrix of breccia	Tuffaceous lithic arenite	20	10	5					65			
Purwoharjo	Reef limestone	Mudstone		4	2				2		4	5	83
Purwoharjo	Fragment of polymict breccia	Andesite pyroxene	15	65	4			14	2				
Purwoharjo	Matrix of polymict breccia	Tuffaceous feldspathic arenite	15	55	2	10		8		5		5	

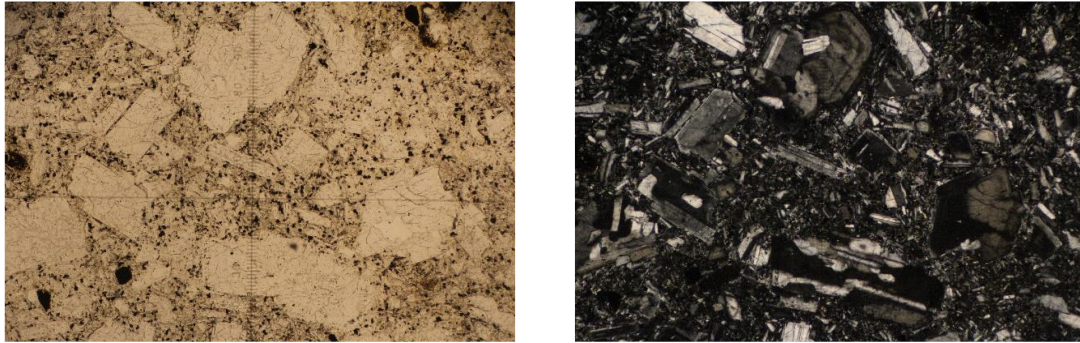


Figure 8. Examples of andesite thin cuts from the study area in parallel nikol (left) and cross nikol (right) [14].

4.4. Influence of Rosk's Mineral to Groundwater Facies

The research area is dominantly consists of volcanic rocks, especially of andesite breccia. These rocks are included in Old Andesite Formation which may become aquifer by their cracks or weathering products. The groundwater which flows in this formation may be influenced by elements of rock's minerals. The interaction of water - tuffaceous rocks on the main aquifer is the reaction of dissolution - precipitation because these rocks indicate chemically unstable phase [15]. Carbonate aquifer is also found in Samigaluh although its spread is narrow. This carbonates aquifer also have unstable chemical phase, so the reaction of dissolution is occur easily.

The dominant groundwater facies are bicarbonate, with sulphate facies anomalies. Sulfates can originate from oxidation of sulfide minerals in igneous / volcanic rocks or atmospheric precipitation (Bowen, 1986 in [13]). Significant sulfate content can also be caused by pollution factors.

Petrographic data shows the presence of rocks containing clay minerals. This might occur due to weathering in rocks. This clay mineral usually has ion exchange capacity which influence on the type and quality of groundwater.

However, the main mineral that consist rocks in the study area is plagioclase. This silicate mineral is easily weathered (Goldich, 1938, in[16]) so that the dissolution of the rock is very influential in the high silica content in the groundwater.

Minerals content in the siliciclastic tuffaceous and calcareous rocks in research area, together influence to the chemical content of groundwater. These minerals supply chemical elements such as Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , carbonates and bicarbonates (Table 6).

Table 6. Correlation of petrographic data and groundwater chemistry association with chemical groundwater data.

Mineral	Chemical association in rocks (Davis & De Wiest, 1966 in [13])	Chemical facies of groundwater	
		Dominant Cation	Dominant Anion
Feldspar	Silica, Ca^{2+} , Mg^{2+} , Na^+ , K^+		
Clay mineral	Silica, Fe^{2+} , Fe^{3+} , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , SO_4^{2-}		
Opaque mineral	Silica, Fe^{2+} , Fe^{3+} , Mg^{2+}		
Volcanic glass	Silica, SO_4^{2-} , Cl^-		
Rock fragment	Silica, Fe^{2+} , Fe^{3+} , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , SO_4^{2-} , Cl^-	Ca^{2+} Mg^{2+} Na^+	HCO_3^- SO_4^{2-}
Quartz	Silica		
Pyroxene	Fe^{2+} , Fe^{3+} , Ca^{2+}		
Fossil & carbonate mineral	Ca^{2+} , carbonate, bicarbonate		
Hornblende	Fe^{2+} , Fe^{3+} , Ca^{2+} , Mg^{2+} , Cl^- , F		

Table 6 shows that the mineral constituent of rocks in the study area may play a role in affecting the composition of groundwater. The table shows the possibilities of supply of chemical elements from the existing mineralogy. Furthermore, the elements / compounds present in groundwater is affected by the level of mineral solubility. Several minerals can dissolve the elements contained in them.

Silica content in the groundwater supply is obtained from several minerals include feldspar, clay minerals, opaque minerals, , volcanic glass, quartz and rock fragments (lithic). The process of the dissolution of this mineral can be supported by the weathering of silicate minerals, which can be explained as follows [16].

- Changes resulting in the chemistry of groundwater is unclear because of the dissolution of weathered silicate minerals generally run very slowly. This is evident from all samples of groundwater that show the small amount of content of silicate.
- In many siliciclastic rocks area, effect of silicate weathering on groundwater chemistry is usually mainly the addition of cations and silica.
- Disappearance sequence of silicate minerals indicates differences in dissolution rate. In accordance with the Goldich sequence of weathering (1938, in [16]), feldspar is more easily weathered than quartz, then feldspar mineral is more possibly supply of silica in groundwater than quartz.

The chemical content in groundwater is strongly influenced by mineral solubility [10]. This is of course depends on their mineral stability. The dominant soluble minerals in the area are feldspar and carbonate minerals. The other silicate minerals can support the chemical content of groundwater due to leaching that occurs in quite a long time. Thus, the characteristics of the groundwater facies is heavily influenced by rock.

Volcanic rocks at Samigaluh area are pyroclastic or volcanoclastic rocks. Leaching in these volcanic sedimentary rocks (especially from its matrix) will affect the composition of the groundwater for their soluble component [17]. TDS depends on the material of rocks. Low TDS in groundwater can be caused by rainwater. The arenite sandstone may result many elements of Mg^{2+} , Ca^{2+} , Na^+ , SO_4^{2-} dan Cl^- in groundwater.

5. Conclusion

Groundwater in research area is dominated by bicarbonate types, although there was anomalous of sulfate type can be found at well in Ngaranduo. The hydrochemical types develop as $Ca-HCO_3$, Ca , Na , $Mg-HCO_3$ and $Ca,Na-HCO_3$, and $Ca,Mg-SO_4$. The other characteristics show neutral pH (5,7 – 7) and low TDS (fresh water) although in laboratory it was found brackish water at Ngaranduo well. The dominant hydrochemical process is ion exchange, in addition to simple dissolution or mixing that may be come from any pollution.

The study area is dominantly consists of volcanoclastic rocks. Some of the mineral content of the rocks are soluble easily in groundwater as a result of the weathering process. The content of cations and anions in the groundwater is affected by the composition of the minerals that compose the rock. The number of elements Ca^{2+} , Na^+ and silica in the groundwater is affected by the weathering of silicate minerals.

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Influence of Rocks to The Hydrochemical Facies of Groundwater at Samigaluh Area, West Progo

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Abstract. Groundwater survey has carried out at Samigaluh and its surrounding area, West Progo. This area is included in West Progo Dome and topographic map of Sendangagung. This research has been done by hydrogeological survey, equipped with groundwater sampling of four samples for physical/chemical testing at laboratory. Field data collecting includes physical properties (color, taste, odor, turbidity) and chemical properties (pH, TDS) of groundwater as well as local geological condition. Laboratory data is similar with field data plus ion contents. Data analysis includes hydrochemistry of groundwater based on all data. Result of research show that groundwater in research area is usually colorless, no taste, no odor and clear. Groundwater develops in most variable types, such as Ca-HCO₃, Ca, Na-HCO₃, Ca,Na,Mg-HCO₃ and Ca,Mg-SO₄. Groundwater types vary in some Piper class. The hydrochemical process is dominated by ion exchange, besides simple dissolution or mixing. The dominant groundwater facies are bicarbonate, due to the influence of siliciclastic rocks that interact with groundwater through the dissolution process. The number of elements Ca²⁺, Na⁺ and silica in the groundwater is influenced by the weathering of minerals.

Keywords: hydrochemistry, groundwater, facies, process, rocks

1. Introduction

The research of groundwater was conducted in Samigaluh and its surrounding area, West Progo District (Figure 1). The area is included in West Progo Dome physiographically [1], and the Indonesian Topographic Map Sheet 1408-232 (Sendangagung) [2] scale of 1: 25.000. The research area is included in non groundwater basin of West Progo Hills.

Hydrogeological research has been developed in various regions through some methods and goal in many regions in order to know about its quality and help society to get good quality of drinking water. The water is very important for human life, therefore water must be maintained as a valuable thing. Many researches about groundwater need to be done to develop degree of life.

Recent days, groundwater is more important and replaces surface water for daily need in some areas. The potential of groundwater in an area needs to be evaluated its properties in order to provide good quality of water. The properties usually include both physical and chemical ones, and sometimes they're completed with biological assessment. However, this research is focused in physical and chemical properties of groundwater in study area.

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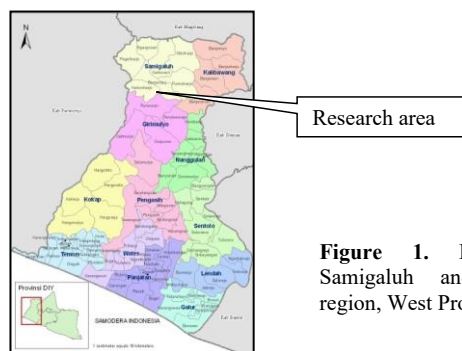


Figure 1. Research area at Samigaluh and its surrounding region, West Progo District [3].

The potential of groundwater in certain areas is important to be determined from many aspects. This research has also been done to support groundwater potential understanding, especially on physical/chemical properties, and the influencing of rocks to groundwater. Hopefully, result of the research can be united with other result of whole area, especially in West Progo Hills.

Potential groundwater in the research area has been studied using physical/chemical properties. By knowing these properties, the interpretation of groundwater quality and hydrochemical processes can be understood. The understanding of hydrochemical processes will help of understanding of geological condition in research area. Therefore, a good study of the hydrochemistry of a region is required. The various hydrochemical processes are controlled by the rocks of a region. Moreover, the hydrogeological understanding can be approached by evaluating of the diversity of the groundwater facies and its correlation with rocks in studied area.

2. Methodology

The research was primarily conducted by hydrogeological survey in field, especially for observing groundwater of dug wells and springs. There were 12 observation locations include four springs and eight dug wells. The tools used are standard geological tools (hammer, loupe, compass) and hydrogeology tools (pH-meter, TDS-meter, and sample bottles) as well as GPS equipment. Four groundwater samples were taken with polyethylene bottles, each of 1 liter of water. Then, groundwater samples tested their physical/chemical properties in the Chemical Laboratory of BBTCLP, Yogyakarta. The analysis was conducted on field data including petrology data of aquifer, geomorphology and stratigraphy, and analysis of physical/chemical of groundwater in selected locations. Groundwater samples were taken at Ngaranduo well (W7) and Tulangan (S1), Jarakan (S5), Palem (S12) springs (Figure 2). Compilation of secondary data and primary data both of field and laboratory has been done to evaluate groundwater quality in research area.

3. Literature Review

3.1. Geological of Research Area

The research area is physiographically included in West Progo Dome Zone (Fig. 2) [1]. This dome is part of the South Serayu Zone especially in the phenomena of the Dome Zone and the Hills in the Central Depression physiography. However, West Progo Dome has different orientation structurally with South Serayu Range.

Some geologists stated that the regional stratigraphy of West Progo Hill is composed from the oldest to the young by Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation,

Sentolo Formation and Alluvial Deposition. The Jonggrangan and Old Andesite Formations exposed in the research area.

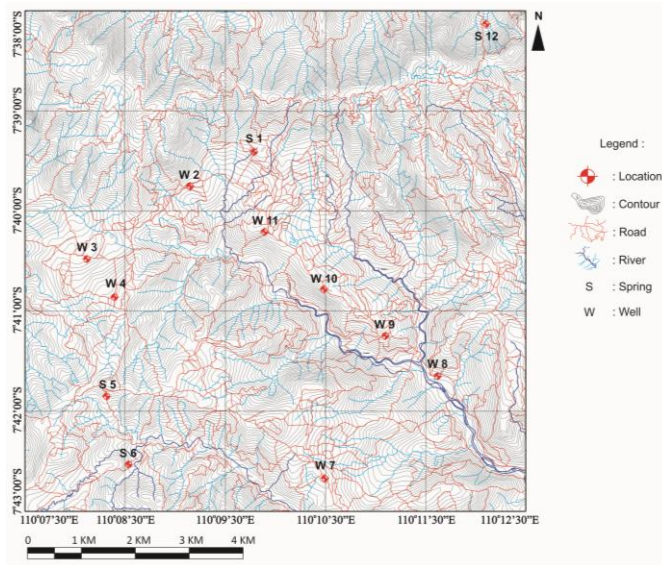


Figure 2. Observation locations of research.

The Old Andesite Formation is exposed in most of research area. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapili, lapilli tuff and volcanic sandstone. The dominant lithology consists of andesite breccia with a tuff matrix, while fragments comprised of pyroxene to hornblende andesites. Beside this pyroclastic/epyclastic breccias, the intrusion of igneous rocks can be found locally.

The ancient volcanic activity located in West Progo Hills which produced Old Andesite Formation were Mt. Gadjah, Mt. Ijo and Mt. Menoreh. The Old Andesite Formation was unconformably lied above Nanggulan Formation. The Old Andesite Formation can be separated based on the two depositional facies, namely Kaligesing and Dukuh Formation [4]. Kaligesing Formation is a land facies and consists of volcanic breccia, lava and intercalation of tuff. The age of this formation is Late Oligocene to the Early Miocene, with a thickness of more than 600 m. On the other hand, Dukuh Formation has deep sea facies, and composed of volcanic breccias as well as intercalation of sandstone, limestones, and claystone. This formation was deposited in Upper Oligocene to Early Miocene age, with thickness of more than 660 m and has interfingering relationship with Kaligesing Formation.

The lithology of West Progo Hills is dominated by volcanic materials such as andesite breccia, tuff, lapilli, agglomerate, and intercalation of andesite lava flows. The material is formed by the existence of ancient volcanic activity at Tertiary time. The lithology is usually impermeable and less porous. As a result, the water is difficult to be stored and flown in it. Therefore, the potential of groundwater in this region is very little. The presence of groundwater in this area is sometimes found in very deep layers (> 25 meters) and found only in rock fractures [5]. The need of the water for population at West Progo Hills is generally usually fulfilled by springs.

3.2. Facies of Groundwater

Groundwater quality is determined by its physical and chemical properties. This groundwater quality can be seen from its contents. Physical properties include color, taste, odor, temperature and turbidity; while chemical properties depend on chemical composition of groundwater. The chemical composition of groundwater is influenced by minerals of rock. Each mineral has certain chemical composition which when dissolved will affect the chemical composition of groundwater.

The chemical facies of groundwater depends on chemical composition of water in recharge area and reactions that occur in groundwater flow system [6]. In its flow process groundwater will pass many kinds of rocks beneath the surface of the earth. The rock will partially dissolved and influence the chemical content of groundwater. Mineral solubility in rocks depends on several things, such as pressure and temperature in groundwater basin and resistance of rocks.

Davis & De Wiest (1966, in [7]) Groundwater quality is influenced by rock material in its path. Ion development in groundwater depends on mineral availability and mineral solubility. There is relationship between groundwater compound ions in rock's mineral. Table 1 explains briefly about some chemical composition of groundwater and possibly source of minerals/rocks which influence it.

Groundwater compositions vary in its process. This chemical contents also change or experience evolution while groundwater flows under surface. From geochemical point of view, the order of anion evolution is greatly determined by mineral's availability and solubility [9]. HCO_3^- ion content in groundwater commonly comes from CO_2 of soil and calcite/dolomite dissolution. Because of big numbers of calcite and dolomite in almost all of sedimentary basin and these minerals are easily soluble, HCO_3^- almost be always dominant anion in recharge area.

Groundwater quality is influenced by aquifer materials caused by diagenetic changes when the groundwater passes the aquifer, caused by several hydrochemical processes [6]. These processes are dissolution-hydrolysis-precipitation, adsorption, ion exchange, reduction-oxidation, mixing, membrane filtration and microbiology metabolism.

One of the causes of mineralization in deep lying water is long enough time of groundwater interaction to aquifer [6]. This fact will increase TDS from soluble salt or non resistant minerals. Besides aquifer rock, claystone can also influence the chemical composition of groundwater by ion exchange processes. Clay can be as geochemical filter, natural chromatography or semipermeable membrane.

Table 1. Mineral/rock association to chemical elements of groundwater (modified from Davis & De Wiest, 1966 in [7] and [8]).

Element / Compound	Minerals / Rocks
Ca^{2+}	Marine sedimentary rocks (calcite, aragonite, dolomite, anhydrite, gypsum); product of igneous rock's weathering (feldspar, amphibole, pyroxene group, clay mineral).
Na^+	Product of igneous rock's weathering, feldspar (albite), clay mineral.
K^+	Clay mineral, igneous rock's mineral (ortoclast, microcline, mica, biotite, feldspatoid, leucite, nepheline).
Mg^{2+}	Comes from soil and sediment, sedimentary rock (dolomite), igneous rock (biotite, hornblende, augite).
NO_3^-	Atmosphere, the destructions of plants, animal breeds (organism activity), chemical source of industry & agriculture.
HCO_3^-	CO_2 from atmosphere and soil, soluble materials of calcareous rock (limestone & dolomite), precipitation of CaCO_3
SO_4^{2-}	Oxidation of sulfide mineral in volcanic/igneous rock, atmospheric precipitation, organic shale
Cl^-	Connate water trapped when sedimentation, result of rain evaporation, atmospheric solubility.
SiO_2	Feldspar, quartz, clay mineral, volcanic rock

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As long as its flow under surface, groundwater tends to keep chemical equilibrium through chemical reactions to environment. Equilibrium achieved tends to product stable groundwater quality to time cause of slow motion of groundwater and long residence time in geological formation [10]. Groundwater compositions vary in its flow process. The variable of groundwater quality commonly observed easier in shallow aquifer caused of seasonal variation at recharge and discharge area related with salinity fluctuation.

4. Result and Analysis

The geological setting of this region is composed by rock formations which are included in the West Progo Dome stratigraphy, such as Jonggrangan and Old Andesite Formation as well as the Quaternary sediments. The Old Andesite Formation that comprises the research area is generally include as Dukuh Formation, evenly spread in almost all part of research area. Whereas, Jonggrangan Formation has outcrops locally spread or locally at narrow area.

The research area dominantly consists of andesite breccia. This rock can potentially act as aquifer through many cracks of joints (Figure 3). The andesite breccia show dark brown to black color when weathered and grey in fresh condition, with pyroclastic texture, and massive structure. The fragment of rock consists of andesite with feldspar, pyroxene, biotite dominantly and few quartz mineral. Whereas, the matrix usually is dark grey and consists of tuff.



Figure 3. Left: Springs at Jarakan, Kebonharjo (Loc. 5). Right: Aquifer of andesite breccia at the spring.

Field data has been taken directly from area of dug wells and springs (Figure 2; Table 2). The physical/chemical properties of groundwater results from the laboratory are given in Table 3.

4.1. Physical Properties of Groundwater

Field data showed good quality of groundwater both in wells and springs. They showed colorless, no taste, no odor and clear of groundwater almost in all location. Anomalous properties were only found at W7 and W9 that were slightly colored. Temperature of groundwater is usually normal, similar with the air temperature around wells and springs. Laboratory data also showed similar properties, where anomalous can be found at S12 with turbidity reached 5 NTU. Nevertheless, groundwater in research area is still good physical properties for daily needs.

Table 2. Field data of physical/chemical properties of groundwater.

Loc.	Type	Color	Taste	Odor	Turbidity	pH	TDS
S1	Spring	Colorless	no taste	no odor	clear	7	83
W2	Well	Colorless	no taste	no odor	clear	6.9	45
W3	Well	Colorless	no taste	no odor	clear	6.8	58
W4	Well	Colorless	no taste	no odor	clear	7	29
S5	Spring	Colorless	no taste	no odor	clear	7	33
S6	Spring	Colorless	no taste	no odor	clear	6.8	30
W7	Well	Almost colorless	no taste	no odor	clear	6.8	324
W8	Well	Colorless	no taste	no odor	clear	6.8	68
W9	Well	Whitish	no taste	less odor	clear	6.8	44
W10	Well	Colorless	no taste	no odor	clear	6.8	61
W11	Well	Colorless	no taste	no odor	clear	6.8	69
S12	Spring	Colorless	no taste	no odor	clear	7	48

Table 3. Laboratory testing of physical/chemical properties of groundwater.

Parameter	S1	S5	W7	S12
Ca ²⁺ (mg/l)	61.6	15.2	209.6	23.2
Na ⁺ (mg/l)	33	24	68	38
K ⁺ (mg/l)	3	1	8	4
Mg ²⁺ (mg/l)	8.26	5.83	63.18	5.83
Fe ²⁺ (mg/l)	0.0162	0.0541	0.0162	0.0221
Mn ²⁺ (mg/l)	0.0101	0.0101	0.0101	0.0101
Zn ²⁺ (mg/l)	0.0083	0.0083	0.0083	0.0083
NO ₃ ⁻ (mg/l)	1.85	1.33	3.08	7.73
HCO ₃ ⁻ (mg/l)	252.4	90.6	300.5	114.2
SO ₄ ²⁻ (mg/l)	2	1	894	6
Cl ⁻ (mg/l)	2.5	2	6.4	4.5
SiO ₂	17.691	15.543	11.823	17.212
pH	6.1	5.7	6.8	6.1
Turbidity (NTU)	1	2	1	5
Taste	no	no	no	no
Odor	no	no	no	no
Temperature (°C)	25.2	25.2	25.2	25.2
TDS (mg/l)	178	85	1269	122

4.2. Chemical Properties of Groundwater

Good properties of groundwater were also shown from chemical ones, such as normal pH (6.8 – 7) at the field and 5.7 – 6.8 from laboratory. TDS commonly are low, except groundwater from W7 which reached 1269 ppm. Based on TDS value, groundwater of research area is fresh water according to Carroll, 1962 in [10].

Chemical contents of four samples show anion dominant as HCO_3^- , while cation dominant are usually vary. From laboratory data, samples from springs (S1, S5, S12) show Ca-HCO_3 , Ca, Na, Mg-HCO_3 and Ca,Na-HCO_3 facies subsequently, while sample from dug well at Ngaranduo (W7) show Ca,Mg-SO_4 facies (Table 4). The numbers of ion compositions of samples (in epm) can be seen at Stiff Diagram (Figure 5). It is clear that bicarbonate will be dominant facies of groundwater samples.

Table 4. Groundwater facies of samples of research area.

No.	Parameter	S1	S5	W7	S12
Cation					
1	Ca (%)	65.02	40.02	58.94	41.60
2	Na (%)	17.85	32.38	9.80	34.92
3	K (%)	2.76	2.29	1.96	6.25
4	Mg (%)	14.37	25.30	29.29	17.23
Anion					
5	Cl (%)	1.66	3.61	0.76	5.98
6	HCO_3 (%)	97.36	95.06	20.76	88.14
7	SO_4 (%)	0.98	1.33	78.47	5.88
Chemical type		Ca - bicarbonate	Ca,Na,Mg - bicarbonate	Ca,Mg - sulfate	Ca,Na - bicarbonate

Bicarbonate facies is dominant groundwater type in research area. The anomalous which is found in well number W7 as sulfate facies may be caused by pollution of groundwater. The pollution possibly came from human activity such as household waste, industry or agriculture, in addition to the possibility of organic shale in the place.

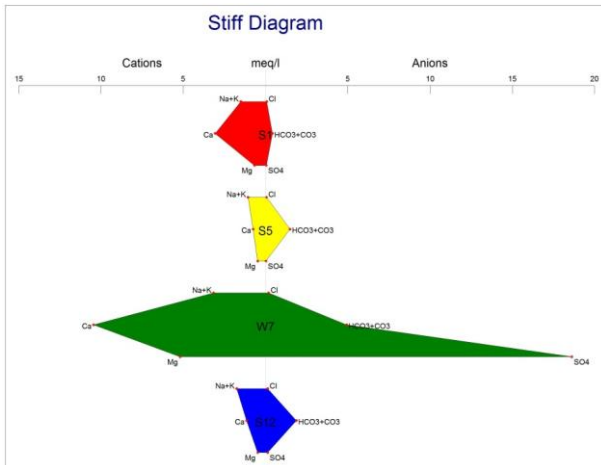


Figure 5. Stiff diagram of groundwater samples.

Plot of groundwater samples in Piper diagram (Figure 6) show that groundwater in research area have several varied types. Those samples include in many class of Piper division, i.e. class 1 – 6 and class 9.

Groundwater from S1, S5 and W7 is included in class 1, indicate that earth alkaline content more than alkaline. Groundwater from S12 is included in class 2 which means it has alkaline content more than earth alkaline. Class 3 consists of S1, S5 and S12 which means that weak acid content more than strong acid. Class 4 involves groundwater from W7 which means strong acid more than weak acid contents. Class 5 shows that calcareous hardness or secondary alkalinity more than 50%, for example groundwater of S1 and S5. Class 6 shows that non calcareous hardness or secondary salt consists of groundwater from W7 sample. Whereas, class 9 show cation-anion equilibrium in groundwater like in S12 sample.

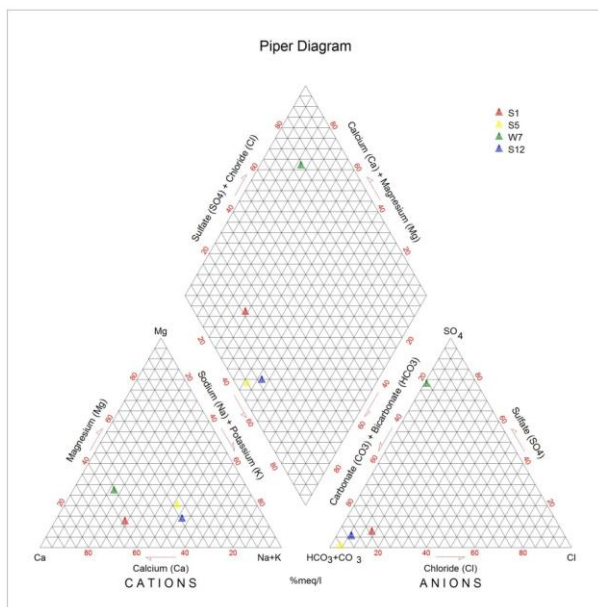


Figure 6. Plot of groundwater samples in Piper diagram.

Hydrochemical process along groundwater flow path were dominated by ion exchange, especially as shown by S12, S5 and S1 samples (Figure 7). Although the process in S1 is more advanced, this does not mean that groundwater flow from S12 to S5 and S1. It can be understood because groundwater flows locally. Whereas, the W7 sample tends to show the other dominant process i.e. simple dissolution or mixing. It may be due to pollution at well area from the environment. It also supported with high enough of TDS in groundwater of W7 sample according to laboratory test that show brackish water type (Carroll, 1962 in [10]).

The hydrochemical process as indicated in Figure 8 does not clearly describe the order of groundwater journey. The pattern of groundwater flow in the research area is still not understanding comprehensively, since the area is a non groundwater basin area. This means that groundwater flow patterns are often local, and may not be interconnected in the basin.

Groundwater in research area flows mostly in volcanic rocks with igneous rock fragments. The igneous rock origin generally contains appreciable amounts of aluminosilicate minerals such as feldspar and mica [11]. Groundwater would be acquired dissolved constituents from dissolution process. However, silica contents (SiO_2) of groundwater in research were still low (<18 ppm). It means that dissolution process (even in W7) have not gone perfectly or the process takes place in a relatively short time. It indicates that groundwater flow is local or near journey. This characteristic is usually possessed by a young groundwater in recharge area.

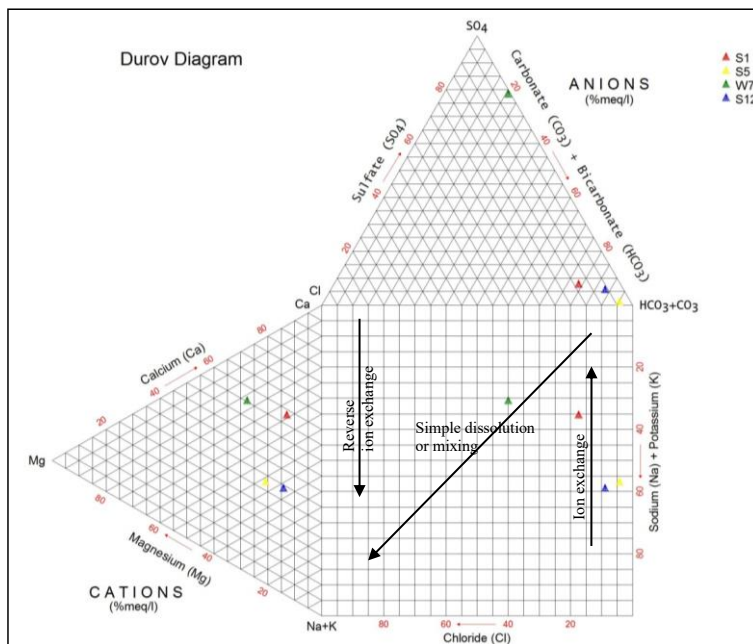


Figure 7. Plot of groundwater samples in Durov diagram.

4.3. Rock's Mineral Composition

Rocks affect the chemical characteristics of groundwater through the process of dissolving the minerals they contain [12], [13]. Therefore, the study of the influence of rocks on groundwater hydrochemical is carried out by analyzing the mineral content of rock constituents. Table 5 below shows the composition of rock minerals in the study area. The rocks that make up the Samigaluh area are dominated by pyroclastic andesite breccia and andesite igneous rocks. The rock has the main mineral feldspar (plagioclase) and volcanic glass [14]. One example of mineral appearance in a thin section of rock is shown in Figure 8.

4.4. Influence of Rock's Mineral to Groundwater Facies

The research area is dominantly consists of volcanic rocks, especially of andesite breccia. These rocks are included in Old Andesite Formation which may become aquifer by their cracks and weathering products. The groundwater which flows in this formation may be influenced by elements of rock's

minerals. The interaction of water - tuffaceous rocks on the main aquifer is the reaction of dissolution - precipitation because these rocks indicate chemically unstable phase [15]. Carbonate aquifer is also found in Samigaluh although its spread is narrow. This carbonates aquifer also have unstable chemical phase, so the reaction of dissolution is occur easily.

Table 5. Mineral composition in rocks in the study area (%) [14].

Location	Field Name	Petrographic Name	Vitric	Feldspar	Opag Min.	Bio-tite	Hom-blend	Pyroxene	Quartz	Lithic	Fossil	Clay Min.	Carbo-nate mud
Giripurwo	Tuff	Vitric tuff	85	10	5								
Giripurwo	Andesite intrusion	Andesite	10	45	1	10	14	20					
Gerbosari	Andesite lava	Andesite	17	50	5	20		22					
Purwoharjo	Fragment of breccia	Andesite	7	75				8	8				
Purwoharjo	Matrix of breccia	Tuffaceous lithic arenite	20	10	5					65			
Purwoharjo	Reef limestone	Mudstone		4	2				2		4	5	83
Purwoharjo	Fragment of polymict breccia	Andesite pyroxene	15	65	4			14	2				
Purwoharjo	Matrix of polymict breccia	Tuffaceous feldspathic arenite	15	55	2	10		8		5		5	

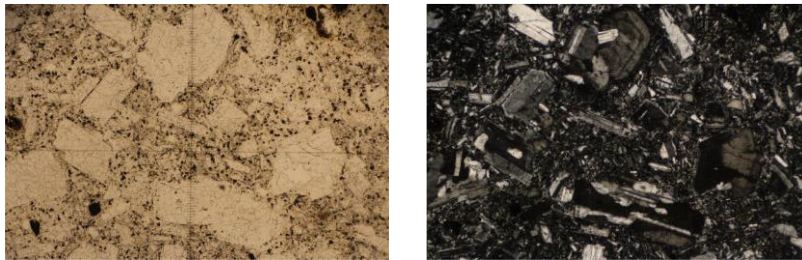


Figure 8. Examples of andesite thin cuts from the study area in parallel nicol (left) and cross nicol (right) [14].

The dominant groundwater facies are bicarbonate, with sulfate facies anomalies. Sulfates can originate from oxidation of sulfide minerals in igneous / volcanic rocks or atmospheric precipitation [8]. Significant sulfate content can also be caused by pollution factors.

Petrographic data shows the presence of rocks containing clay minerals. This might occur due to weathering in rocks. This clay mineral usually has ion exchange capacity which influence on the type and quality of groundwater.

However, the main mineral that consist rocks in the study area is plagioclase. This silicate mineral is easily weathered (Goldich, 1938, in [16]) so that the dissolution of the rock is very influential in the high silica content in the groundwater.

Minerals content in the siliciclastic tuffaceous and calcareous rocks in research area, together influence to the chemical content of groundwater. These minerals supply chemical elements such as Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , carbonates and bicarbonates (Table 6). This table shows that the mineral constituent of rocks in the study area may play a role in affecting the composition of groundwater. The table shows the possibilities of supply of chemical elements from the existing mineralogy.

Furthermore, the elements / compounds present in groundwater is affected by the level of mineral solubility. Not all minerals can dissolve the elements contained in them.

Table 6. Correlation of petrographic data and groundwater chemistry association with chemical groundwater data.

Mineral	Chemical association in rocks (Davis & De Wiest, 1966 in [13])	Chemical facies of groundwater	
		Dominant Cation	Dominant Anion
Feldspar	Silica, Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺		
Clay mineral	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻		
Opaque mineral	Silica, Fe ²⁺ , Fe ³⁺ , Mg ²⁺		
Volcanic glass	Silica, SO ₄ ²⁻ , Cl ⁻		
Rock fragment	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻ , Cl ⁻	Ca ²⁺ Mg ²⁺ Na ⁺	HCO ₃ ⁻ SO ₄ ²⁻
Quartz	Silica		
Pyroxene	Fe ²⁺ , Fe ³⁺ , Ca ²⁺		
Fossil & carbonate mineral	Ca ²⁺ , carbonate, bicarbonate		
Hornblende	Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Cl ⁻ , F ⁻		

Silica content in the groundwater supply is obtained from several minerals include feldspar, clay minerals, opaque minerals, volcanic glass, quartz and rock fragments (lithic). The process of the dissolution of this mineral can be supported by the weathering of silicate minerals, which can be explained as follows [16].

- Changes resulting in the chemistry of groundwater is unclear because of the dissolution of weathered silicate minerals generally run very slowly. This is evident from all samples of groundwater that show the small amount of content of silicate.

- In many siliciclastic rocks area, effect of silicate weathering on groundwater chemistry is usually mainly the addition of cations and silica.

- Disappearance sequence of silicate minerals indicates differences in dissolution rate. In accordance with the Goldich sequence of weathering (1938, in [16]), feldspar is more easily weathered than quartz, then feldspar mineral is more possibly supply of silica in groundwater than quartz.

The chemical content in groundwater is strongly influenced by mineral solubility [10]. This is of course depends on their mineral stability. The dominant soluble minerals in the area are feldspar and carbonate minerals. The other silicate minerals can support the chemical content of groundwater due to leaching that occurs in quite a long time. Thus, the characteristics of the groundwater facies is heavily influenced by rock.

Volcanic rocks at Samigaluh area are pyroclastic or volcanoclastic rocks. Leaching in these volcanic sedimentary rocks (especially from its matrix) will affect the composition of the groundwater for their soluble component [17]. TDS depends on the material of rocks. Low TDS in groundwater can be caused by rainwater. The arenite sandstone may result many elements of Mg²⁺, Ca²⁺, Na⁺, SO₄²⁻ dan Cl⁻ in groundwater.

The effect of rocks on hydrochemical facies is also supported by a method that connects ionic concentrations with TDS. Figure 9 shows a plot of groundwater chemical data that falls on the rock dominance and mineralization fields [18]. This reinforces the prediction of the influence of rocks on the hydrochemical facies and the effect of mineralization due to ground-rock ground interaction.

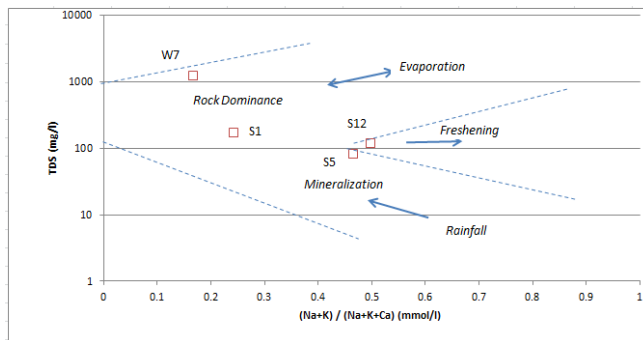


Figure 9. Plot data in Gibb's diagram show rock dominance and mineralization as major process of hydrochemical in research area.

5. Conclusion

Groundwater in research area is dominated by bicarbonate types, although there was anomalous of sulfate type can be found at well in Ngaranduo. The hydrochemical types develop as Ca-HCO_3 , Ca, Na, Mg-HCO_3 and Ca, Na-HCO_3 , and Ca, Mg-SO_4 . The other characteristics show neutral pH (5,7 – 7) and low TDS (fresh water) although in laboratory it was found brackish water at Ngaranduo well. The dominant hydrochemical process is ion exchange, in addition to simple dissolution or mixing that may be come from any pollution.

The study area is dominantly consists of volcanoclastic rocks. Some of the mineral content of the rocks are soluble easily in groundwater as a result of the weathering process. The content of cations and anions in the groundwater is affected by the composition of the minerals that compose the rock. The number of elements Ca^{2+} , Na^+ and silica in the groundwater is affected by the weathering of silicate minerals.

Commented [U4]: Describe the minerals

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Revised paper

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Influence of Rocks to The Hydrochemical Facies of Groundwater at Samigaluh Area, West Progo

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Abstract. Groundwater survey has carried out at Samigaluh and its surrounding area, West Progo. This area is included in West Progo Dome and topographic map of Sendangagung. This research has been done by hydrogeological survey, equipped with groundwater sampling of four samples for physical/chemical testing at laboratory. Field data collecting includes physical properties (color, taste, odor, turbidity) and chemical properties (pH, TDS) of groundwater as well as local geological condition. Laboratory data is similar to field data plus ion contents. Data analysis includes hydrochemistry of groundwater based on all data. Results of research show that groundwater in research area is usually colorless, no taste, no odor and clear. Groundwater develops in most variable types, such as Ca-HCO₃, Ca, Na-HCO₃, Ca,Na,Mg-HCO₃ and Ca,Mg-SO₄. Groundwater types vary in some Piper class. The hydrochemical process is dominated by ion exchange, besides simple dissolution or mixing. The dominant groundwater facies are bicarbonate, due to the influence of siliciclastic rocks that interact with groundwater through the dissolution process. The number of elements Ca²⁺, Na⁺ and silica in the groundwater is influenced by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

Keywords: hydrochemistry, groundwater, facies, process, rocks

1. Introduction

The research of groundwater was conducted in Samigaluh and its surrounding area, Kulon Progo District (Figure 1). The area is included in West Progo Dome physiographically [1], and the Indonesian Topographic Map Sheet 1408-232 (Sendangagung) [2] scale of 1: 25.000. The research area is included in non groundwater basin of West Progo Hills.

Hydrogeological research has been developed in various regions through some methods and goals in many regions in order to know about its quality and help society to get good quality of drinking water. The water is very important for human life, therefore water must be maintained as a valuable thing. Many kinds of research about groundwater need to be done to develop degree of life.

In recent days, groundwater is more important and replaces surface water for daily needs in some areas. The potential of groundwater in an area needs to be evaluated its properties in order to provide good quality of water. The properties usually include both physical and chemical ones, and sometimes they're completed with biological assessment. However, this research is focused on the physical and chemical properties of groundwater in study area.

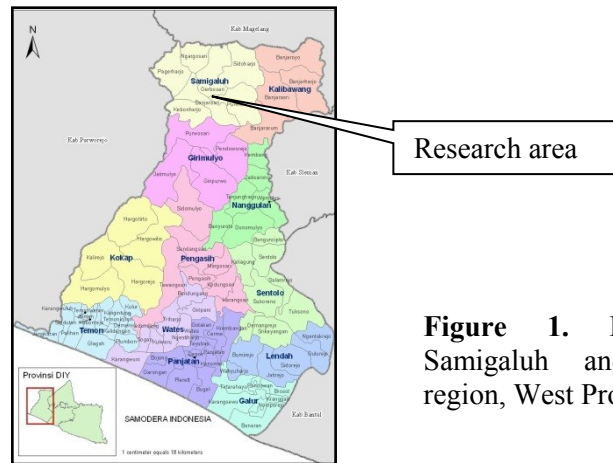


Figure 1. Research area at Samigaluh and its surrounding region, West Progo District [3].

The potential of groundwater in certain areas is important to be determined from many aspects. This research has also been done to support groundwater potential understanding, especially on physical/chemical properties, and the influencing of rocks to groundwater. Hopefully, the result of the research can be united with other results of whole area, especially in West Progo Hills.

Potential groundwater in the research area has been studied using physical/chemical properties. By knowing these properties, the interpretation of groundwater quality and hydrochemical processes can be understood. The understanding of hydrochemical processes will help of understanding the geological condition in research area. Therefore, a good study of the hydrochemistry of a region is required. The various hydrochemical processes are controlled by the rocks of a region. Moreover, hydrogeological understanding can be approached by evaluating the diversity of the groundwater facies and its correlation with rocks in studied area.

2. Methodology

The research was primarily conducted by hydrogeological surveys in the field, especially for observing groundwater of dug wells and springs. There were 12 observation locations include four springs and eight dug wells. The tools used are standard geological tools (hammer, loupe, compass) and hydrogeology tools (pH-meter, TDS-meter, and sample bottles) as well as GPS equipment. Four groundwater samples were taken with polyethylene bottles, each of 1 liter of water. Then, groundwater samples tested their physical/chemical properties in the Chemical Laboratory of BBTCLP, Yogyakarta. The analysis was conducted on field data including petrology data of aquifer, geomorphology, and stratigraphy, and analysis of physical/chemical of groundwater in selected locations. Groundwater samples were taken at Ngaranduo well (W7) and Tulangan (S1), Jarakan (S5), Palem (S12) springs (Figure 2). Compilation of secondary data and primary data both of field a laboratory has been done to evaluate groundwater quality in research area.

3. Literature Review

3.1. Geological of Research Area

The research area is physiographically included in West Progo Dome Zone (Fig. 2) [1]. This dome is part of the South Serayu Zone especially in the phenomena of the Dome Zone and the Hills in the Central Depression physiography. However, West Progo Dome has different orientations structurally with South Serayu Range.

Some geologists stated that the regional stratigraphy of West Progo Hill is composed of the oldest to the young by Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation, Sentolo

Formation and Alluvial Deposition. The Jonggrangan and Old Andesite Formations exposed in the research area.

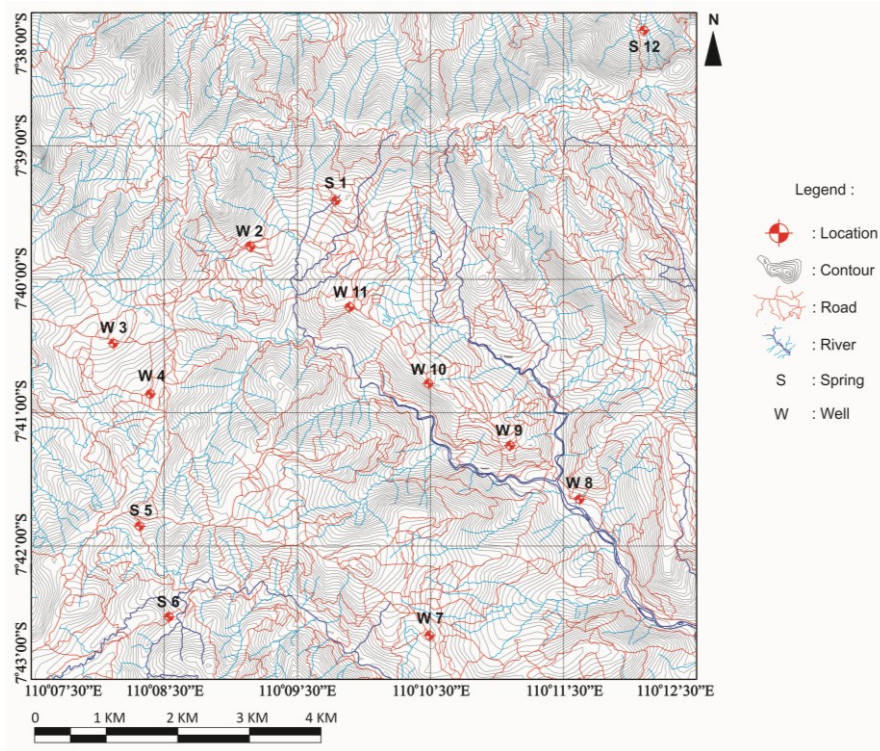


Figure 2. Observation locations of research.

The Old Andesite Formation is exposed in most of the research area. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapilli, lapilli tuff, and volcanic sandstone. The dominant lithology consists of andesite breccia with a tuff matrix, while fragments comprised of pyroxene to hornblende andesites. Besides this pyroclastic/epiclastic breccias, the intrusion of igneous rocks can be found locally.

The ancient volcanic activity located in West Progo Hills which produced Old Andesite Formation were Mt. Gajah, Mt. Ijo and Mt. Menoreh. The Old Andesite Formation unconformably lay above Nanggulan Formation. The Old Andesite Formation can be separated based on the two depositional facies, namely Kaligesing and Dukuh Formation [4]. Kaligesing Formation is a land facies and consists of volcanic breccia, lava, and intercalation of tuff. The age of this formation is Late Oligocene to the Early Miocene, with a thickness of more than 600 m. On the other hand, Dukuh Formation has deep-sea facies and composed of volcanic breccias as well as intercalation of sandstone, limestones, and claystone. This formation was deposited in Upper Oligocene to Early Miocene age, with thickness of more than 660 m and has interfingering relationship with Kaligesing Formation.

The lithology of West Progo Hills is dominated by volcanic materials such as andesite breccia, tuff, lapilli, agglomerate, and intercalation of andesite lava flows. The material is formed by the existence of ancient volcanic activity at Tertiary time. The lithology is usually impermeable and less porous. As a result, the water is difficult to be stored and flown in it. Therefore, the potential of groundwater in this region is very little. The presence of groundwater in this area is sometimes found in very deep layers (> 25 meters) and found only in rock fractures [5]. The need for the water for population at West Progo Hills is generally usually fulfilled by springs.

3.2. Facies of Groundwater

Groundwater quality is determined by its physical and chemical properties. This groundwater quality can be seen from its hydrochemical facies. Physical properties include color, taste, odor, temperature, and turbidity; while chemical properties depend on chemical composition of groundwater. The chemical composition of groundwater is influenced by minerals of rock. Each mineral has certain chemical composition which when dissolved will affect the chemical composition of groundwater.

The chemical facies of groundwater depends on the chemical composition of water in recharge area and reactions that occur in groundwater flow system [6]. In its flow process groundwater will pass many kinds of rocks beneath the surface of the earth. The rock will partially dissolved and influence the chemical content of groundwater. Mineral solubility in rocks depends on several things, such as pressure and temperature in groundwater basin and resistance of rocks.

Davis & De Wiest (1966, in [7]) Groundwater quality is influenced by rock material in its path. Ion development in groundwater depends on mineral availability and mineral solubility. There is a relationship between groundwater compound ions in rock's mineral. Table 1 explains briefly about some chemical composition of groundwater and possibly source of minerals/rocks which influence it.

Groundwater compositions vary in their flow process. This chemical contents also change or experience evolution while groundwater flows under surface. From geochemical point of view, the order of anion evolution is greatly determined by mineral availability and solubility [9]. HCO_3^- ion content in groundwater commonly comes from CO_2 of soil and calcite/dolomite dissolution. Because of big numbers of calcite and dolomite in almost all of sedimentary basin and these minerals are easily soluble, HCO_3^- almost be always dominant anion in recharge area.

Groundwater quality is influenced by aquifer materials caused by diagenetic changes when the groundwater passes the aquifer, caused by several hydrochemical processes [6]. These processes are dissolution-hydrolysis-precipitation, adsorption, ion exchange, reduction-oxidation, mixing, membrane filtration, and microbiology metabolism.

One of the causes of mineralization in deep-lying water is long enough time of groundwater interaction to aquifer [6]. This fact will increase TDS from soluble salt or non-resistant minerals. Besides aquifer rock, claystone can also influence the chemical composition of groundwater by ion exchange processes. Clay can be a geochemical filter, natural chromatography or semipermeable membrane.

Table 1. Mineral/rock association to chemical elements of groundwater (modified from Davis & De Wiest, 1966 in [7] and [8]).

Element / Compound	Minerals / Rocks
Ca^{2+}	Marine sedimentary rocks (calcite, aragonite, dolomite, anhydrite, gypsum); a product of igneous rock's weathering (feldspar, amphibole, pyroxene group, clay mineral).
Na^+	Product of igneous rock's weathering, feldspar (albite), clay mineral.
K^+	Clay mineral, igneous rock's mineral (orthoclase, microcline, mica, biotite, feldspathoid, leucite, nepheline).
Mg^{2+}	It comes from soil and sediment, sedimentary rock (dolomite), igneous rock (biotite, hornblende, augite).
NO_3^-	The atmosphere, the destructions of plants, animal breeds (organism activity), chemical source of industry & agriculture.
HCO_3^-	CO_2 from atmosphere and soil, soluble materials of calcareous rock (limestone & dolomite), precipitation of CaCO_3
SO_4^{2-}	Oxidation of sulfide mineral in volcanic/igneous rock, atmospheric precipitation, organic shale
Cl^-	Connate water trapped when sedimentation, the result of rain evaporation, atmospheric solubility.
SiO_2	Feldspar, quartz, clay mineral, volcanic rock

As long as its flow under surface, groundwater tends to keep chemical equilibrium through chemical reactions to the environment. Equilibrium achieved tends to product stable groundwater quality to time cause of slow motion of groundwater and long residence time in geological formation [10]. Groundwater compositions vary in their flow process. The variable of groundwater quality commonly observed easier in shallow aquifer caused by seasonal variation at recharge and discharge area related to salinity fluctuation.

4. Result and Analysis

The geological setting of this region is composed of rock formations that are included in the West Progo Dome stratigraphy, such as Jonggrangan and Old Andesite Formation as well as the Quaternary sediments. The Old Andesite Formation that comprises the research area is generally included as Dukuh Formation, evenly spread in almost all parts of research area. Whereas, Jonggrangan Formation has outcrops locally spread or locally at narrow area.

The research area dominantly consists of andesite breccias. This rock can potentially act as aquifer through many cracks of joints (Figure 3). The andesite breccias show dark brown to black color when weathered and grey in fresh condition, with pyroclastic texture, and massive structure. The fragment of rock consists of andesite with feldspar, pyroxene, biotite dominantly and fewer quartz minerals. Whereas, the matrix usually is dark grey and consists of tuff.



Figure 3. Left: Springs at Jarakan, Kebonharjo (Loc. 5). Right: Aquifer of andesite breccia in the spring.

Field data has been taken directly from the area of dug wells and springs (Figure 2; Table 2). The physical/chemical properties of groundwater results from the laboratory are given in Table 3.

4.1. Physical Properties of Groundwater

Field data showed good quality of groundwater both in wells and springs. They showed colorless, no taste, no odor and clear of groundwater almost in all locations. Anomalous properties were only found at W7 and W9 that were slightly colored. The temperature of groundwater is usually normal, similar to the air temperature around wells and springs. Laboratory data also showed similar properties, where anomalous can be found at S12 with turbidity reached 5 NTU. Nevertheless, groundwater in research area is still a good physical property for daily needs.

Table 2. Field data of the physical/chemical properties of groundwater.

Loc.	Type	Color	Taste	Odor	Turbidity	pH	TDS
S1	Spring	Colorless	no taste	no odor	clear	7	83
W2	Well	Colorless	no taste	no odor	clear	6.9	45
W3	Well	Colorless	no taste	no odor	clear	6.8	58
W4	Well	Colorless	no taste	no odor	clear	7	29
S5	Spring	Colorless	no taste	no odor	clear	7	33
S6	Spring	Colorless	no taste	no odor	clear	6.8	30
W7	Well	Almost colorless	no taste	no odor	clear	6.8	324
W8	Well	Colorless	no taste	no odor	clear	6.8	68
W9	Well	Whitish	no taste	less odor	clear	6.8	44
W10	Well	Colorless	no taste	no odor	clear	6.8	61
W11	Well	Colorless	no taste	no odor	clear	6.8	69
S12	Spring	Colorless	no taste	no odor	clear	7	48

Table 3. Laboratory testing of the physical/chemical properties of groundwater.

Parameter	S1	S5	W7	S12
Ca²⁺ (mg/l)	61.6	15.2	209.6	23.2
Na⁺ (mg/l)	33	24	68	38
K⁺ (mg/l)	3	1	8	4
Mg²⁺ (mg/l)	8.26	5.83	63.18	5.83
Fe²⁺ (mg/l)	0.0162	0.0541	0.0162	0.0221
Mn²⁺ (mg/l)	0.0101	0.0101	0.0101	0.0101
Zn²⁺ (mg/l)	0.0083	0.0083	0.0083	0.0083
NO₃⁻ (mg/l)	1.85	1.33	3.08	7.73
HCO₃⁻ (mg/l)	252.4	90.6	300.5	114.2
SO₄²⁻ (mg/l)	2	1	894	6
Cl⁻ (mg/l)	2.5	2	6.4	4.5
SiO₂	17.691	15.543	11.823	17.212
pH	6.1	5.7	6.8	6.1
Turbidity (NTU)	1	2	1	5
Taste	no	no	no	no
Odor	no	no	no	no
Temperature (°C)	25.2	25.2	25.2	25.2
TDS (mg/l)	178	85	1269	122

4.2. Chemical Properties of Groundwater

Good properties of groundwater were also shown from chemical ones, such as normal pH (6.8 – 7) at the field and 5.7 – 6.8 from the laboratory. TDS commonly are low, except groundwater from W7 which reached 1269 ppm. Based on TDS value, groundwater of research area is freshwater according to Carroll, 1962 in [10].

Chemical contents of four samples show anion dominant as HCO_3^- , while cation dominant is usually varied. From laboratory data, samples from springs (S1, S5, S12) show Ca- HCO_3 , Ca, Na, Mg- HCO_3 and Ca,Na- HCO_3 facies subsequently, while sample from dug well at Ngaranduo (W7) show Ca,Mg- SO_4 facies (Table 4). The numbers of ion compositions of samples (in epm) can be seen at Stiff Diagram (Figure 5). It is clear that bicarbonate will be dominant facies of groundwater samples.

Table 4. Groundwater facies of samples of the research area.

No.	Parameter	S1	S5	W7	S12
Cation					
1	Ca (%)	65.02	40.02	58.94	41.60
2	Na (%)	17.85	32.38	9.80	34.92
3	K (%)	2.76	2.29	1.96	6.25
4	Mg (%)	14.37	25.30	29.29	17.23
Anion					
5	Cl (%)	1.66	3.61	0.76	5.98
6	HCO_3 (%)	97.36	95.06	20.76	88.14
7	SO_4 (%)	0.98	1.33	78.47	5.88
Chemical type		Ca - bicarbonate	Ca,Na,Mg - bicarbonate	Ca,Mg - sulfate	Ca,Na - bicarbonate

Bicarbonate facies is the dominant groundwater type in the research area. The anomalous which is found in well number W7 as sulfate facies may be caused by pollution of groundwater. The pollution possibly came from human activity such as household waste, industry or agriculture, in addition to the possibility of organic shale in the place.

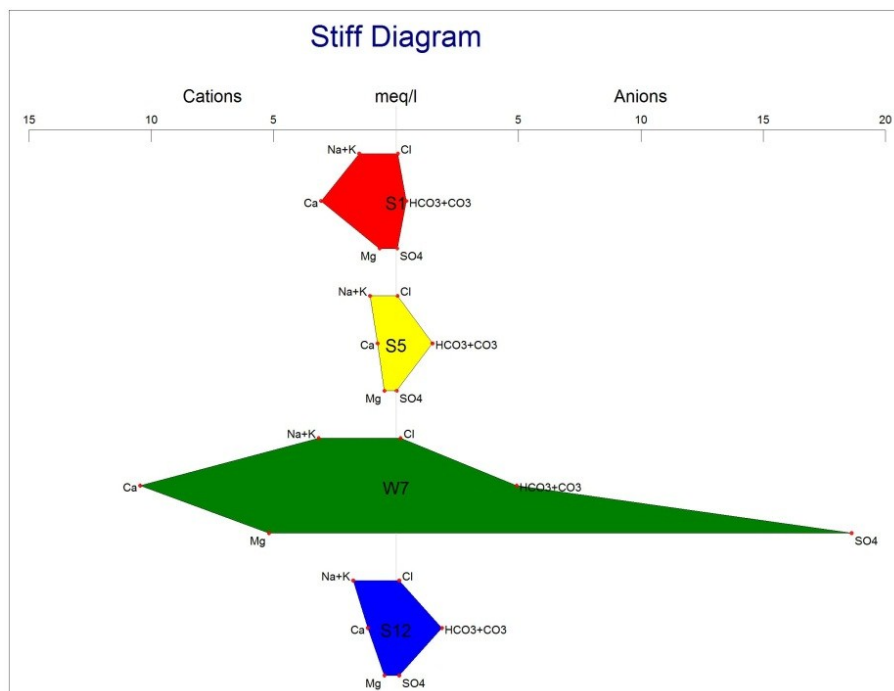


Figure 5. Stiff diagram of groundwater samples.

The plot of groundwater samples in Piper diagram (Figure 6) shows that groundwater in research area has several varied types. Those samples include in many classes of Piper division, i.e. class 1 – 6 and class 9.

Groundwater from S1, S5 and W7 are included in class 1, indicate that earth alkaline content more than alkaline. Groundwater from S12 is included in class 2 which means it has alkaline content more than earth alkaline. Class 3 consists of S1, S5, and S12 which means that weak acid content more than strong acid. Class 4 involves groundwater from W7 which means strong acid more than weak acid contents. Class 5 shows that calcareous hardness or secondary alkalinity more than 50%, for example groundwater of S1 and S5. Class 6 shows that non calcareous hardness or secondary salt consists of groundwater from W7 sample. Whereas, class 9 show cation-anion equilibrium in groundwater like in S12 sample.

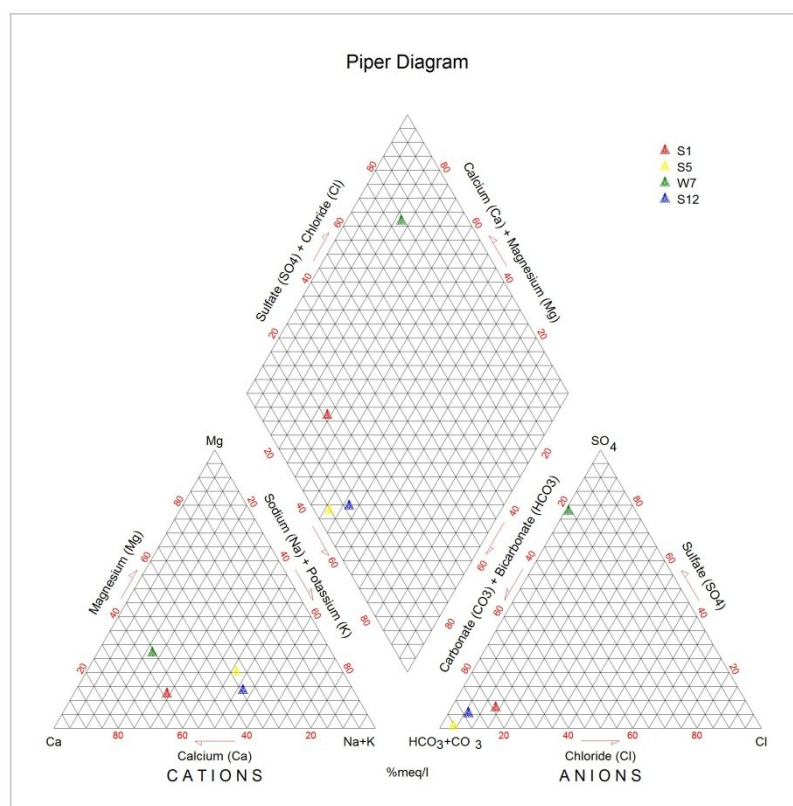


Figure 6. A plot of groundwater samples in Piper diagram.

The hydrochemical process along the groundwater flow path was dominated by ion exchange, especially as shown by S12, S5 and S1 samples (Figure 7). Although the process in S1 is more advanced, this does not mean that groundwater flows from S12 to S5 and S1. It can be understood because groundwater flows locally. Whereas, the W7 sample tends to show the other dominant process i.e. simple dissolution or mixing. It may be due to pollution in the dug well area from the environment. It also supported high enough of TDS in groundwater of W7 sample according to laboratory tests that show brackish water type (Carroll, 1962 in [10]).

The hydrochemical process as indicated in Figure 8 does not clearly describe the order of the groundwater journey. The pattern of groundwater flow in the research area is still not understanding comprehensively since the area is a non groundwater basin area. This means that groundwater flow patterns are often local, and may not be interconnected in the basin.

Groundwater in research area flows mostly in volcanic rocks with igneous rock fragments. The igneous rock origin generally contains appreciable amounts of aluminosilicate minerals such as feldspar and mica [11]. Groundwater would be acquired dissolved constituents from the dissolution process. However, silica contents (SiO_2) of groundwater in research were still low (<18 ppm). It means that dissolution process (even in W7) has not gone perfectly or the process takes place in a relatively short time. It indicates that groundwater flow is local or near journey. This characteristic is usually possessed by young groundwater in recharge area.

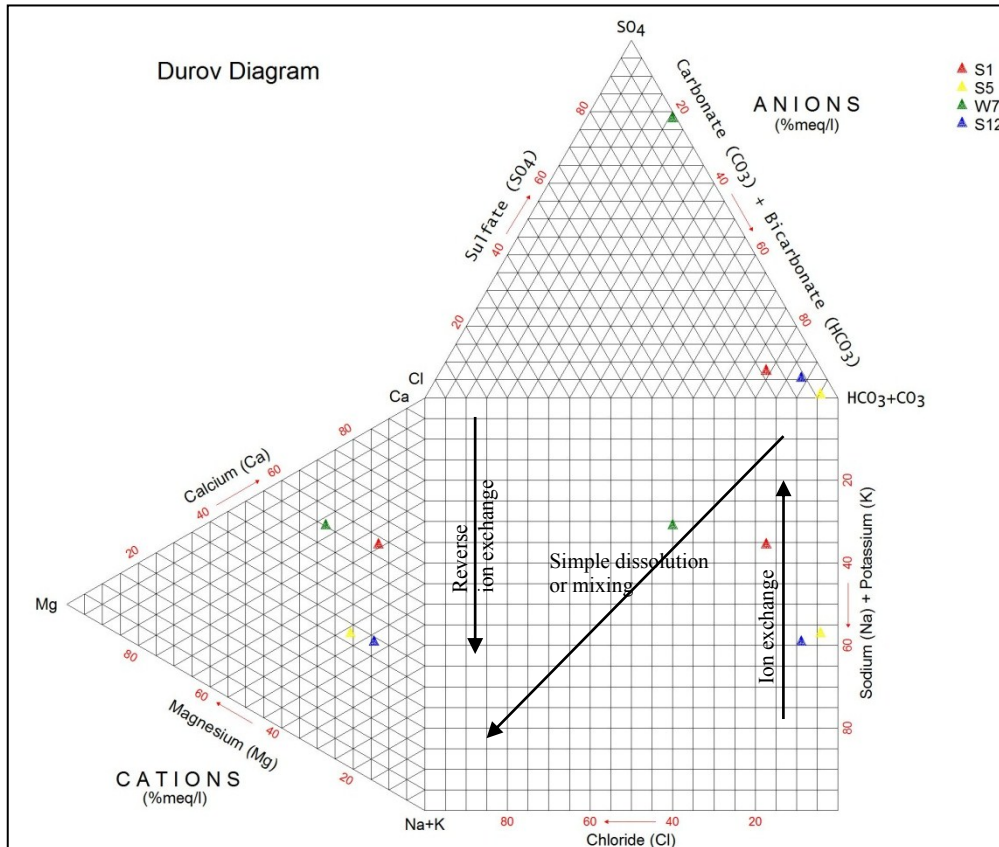


Figure 7. A plot of groundwater samples in Durov diagram.

4.3. Rock's Mineral Composition

Rocks affect the chemical characteristics of groundwater through the process of dissolving the minerals they contain [12], [13]. Therefore, the study of the influence of rocks on groundwater hydrochemical is carried out by analyzing the mineral content of rock constituents. Table 5 below shows the composition of rock minerals in the study area. The rocks that make up the Samigaluh area are dominated by pyroclastic andesite breccia and andesite igneous rocks. The rock has the main mineral feldspar (plagioclase) and volcanic glass [14]. One example of mineral appearance in a thin section of rock is shown in Figure 8.

4.4. Influence of Rock's Mineral to Groundwater Facies

The research area dominantly consists of volcanic rocks, especially of andesite breccia. These rocks are included in Old Andesite Formation which may become aquifer by their cracks or weathering products. The groundwater which flows in this formation may be influenced by elements of rock's

minerals. The interaction of water - tuffaceous rocks on the main aquifer is the reaction of dissolution - precipitation because these rocks indicate chemically unstable phase [15]. Carbonate aquifer is also found in Samigaluh although its spread is narrow. This carbonate aquifer also has unstable chemical phase, so the reaction of dissolution is occurring easily.

Table 5. Mineral composition in rocks in the study area (%) [14].

Location	Field Name	Petrographic Name	Vitric	Feldspar	Opag Min.	Bio-tite	Horn-blend	Pyro-xene	Quartz	Lithic	Fossil	Clay Min.	Carbo-nate mud
Giripurwo	Tuff	Vitric tuff	85	10	5								
Giripurwo	Andesite intrusion	Andesite	10	45	1	10	14	20					
Gerbosari	Andesite lava	Andesite	17	50	5	20		22					
Purwoharjo	Fragment of breccia	Andesite	7	75				8	8				
Purwoharjo	Matrix of breccia	Tuffaceous lithic arenite	20	10	5					65			
Purwoharjo	Reef limestone	Mudstone		4	2				2		4	5	83
Purwoharjo	Fragment of polymict breccia	Andesite pyroxene	15	65	4			14	2				
Purwoharjo	Matrix of polymict breccia	Tuffaceous feldsphatic arenite	15	55	2	10		8		5		5	

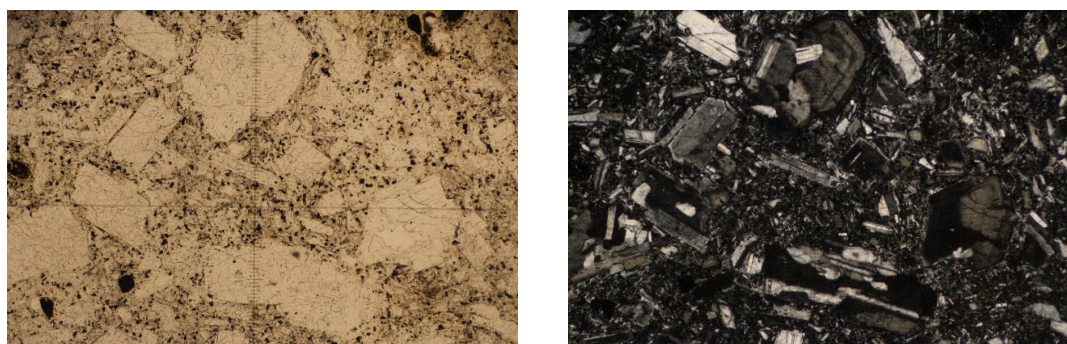


Figure 8. Examples of andesite thin cuts from the study area in parallel nicol (left) and cross nicol (right) [14].

The dominant groundwater facies are bicarbonate, with sulfate facies anomalies. Sulfates can originate from oxidation of sulfide minerals in igneous/volcanic rocks or atmospheric precipitation [8]. Significant sulfate content can also be caused by pollution factors.

Petrographic data shows the presence of rocks containing clay minerals. This might occur due to weathering in rocks. This clay mineral usually has ion exchange capacity which influences the type and quality of groundwater.

However, the main mineral that consists of rocks in the study area is plagioclase. This silicate mineral is easily weathered (Goldich, 1938, in [16]) so that the dissolution of the rock is very influential in the high silica content in the groundwater.

Minerals content in the siliciclastic tuffaceous and calcareous rocks in a research area, together influence the chemical content of groundwater. These minerals supply chemical elements such as Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , carbonates, and bicarbonates (Table 6). This table shows that the mineral constituent of rocks in the study area may play a role in affecting the composition of groundwater. The table shows the possibilities of supply of chemical elements from the existing mineralogy.

Furthermore, the elements / compounds present in groundwater is affected by the level of mineral solubility. Not all minerals can dissolve the elements contained in them.

Table 6. Correlation of petrographic data and groundwater chemistry association with chemical groundwater data.

Mineral	Chemical association in rocks (Davis & De Wiest, 1966 in [13])	Chemical facies of groundwater	
		Dominant Cation	Dominant Anion
Feldspar	Silica, Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺		
Clay mineral	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻		
Opaque mineral	Silica, Fe ²⁺ , Fe ³⁺ , Mg ²⁺		
Volcanic glass	Silica, SO ₄ ²⁻ , Cl ⁻		
Rock fragment	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻ , Cl ⁻	Ca ²⁺ Mg ²⁺ Na ⁺	HCO ₃ ⁻ SO ₄ ²⁻
Quartz	Silica		
Pyroxene	Fe ²⁺ , Fe ³⁺ , Ca ²⁺		
Fossil & carbonate mineral	Ca ²⁺ , carbonate, bicarbonate		
Hornblende	Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Cl ⁻ , F		

Silica content in the groundwater supply is obtained from several minerals include feldspar, clay minerals, opaque minerals, volcanic glass, quartz and rock fragments (lithic). The process of the dissolution of this mineral can be supported by the weathering of silicate minerals, which can be explained as follows [16].

- Changes resulting in the chemistry of groundwater is unclear because of the dissolution of weathered silicate minerals generally run very slowly. This is evident from all samples of groundwater that show the small amount of content of silicate.

- In many siliciclastic rocks area, effect of silicate weathering on groundwater chemistry is usually mainly the addition of cations and silica.

- The disappearance sequence of silicate minerals indicates differences in the dissolution rate. In accordance with the Goldich sequence of weathering (1938, in [16]), feldspar is more easily weathered than quartz, then feldspar mineral is more possibly supply of silica in groundwater than quartz.

The chemical content in groundwater is strongly influenced by mineral solubility [10]. This is, of course, depends on their mineral stability. The dominant soluble minerals in the area are feldspar and carbonate minerals. The other silicate minerals can support the chemical content of groundwater due to leaching that occurs in quite a long time. Thus, the characteristics of the groundwater facies are heavily influenced by rock.

Volcanic rocks at the Samigaluh area are pyroclastic or volcanoclastic rocks. Leaching in these volcanic sedimentary rocks (especially from its matrix) will affect the composition of the groundwater for their soluble component [17]. TDS depends on the material of rocks. Low TDS in groundwater can be caused by rainwater. The arenite sandstone may result many elements of Mg²⁺, Ca²⁺, Na⁺, SO₄²⁻ dan Cl⁻ in groundwater.

The effect of rocks on hydrochemical facies is also supported by a method that connects ionic concentrations with TDS. Figure 9 shows a plot of groundwater chemical data that falls on rock dominance and mineralization fields [18]. This reinforces the prediction of the influence of rocks on the hydrochemical facies and the effect of mineralization due to ground-rock ground interaction.

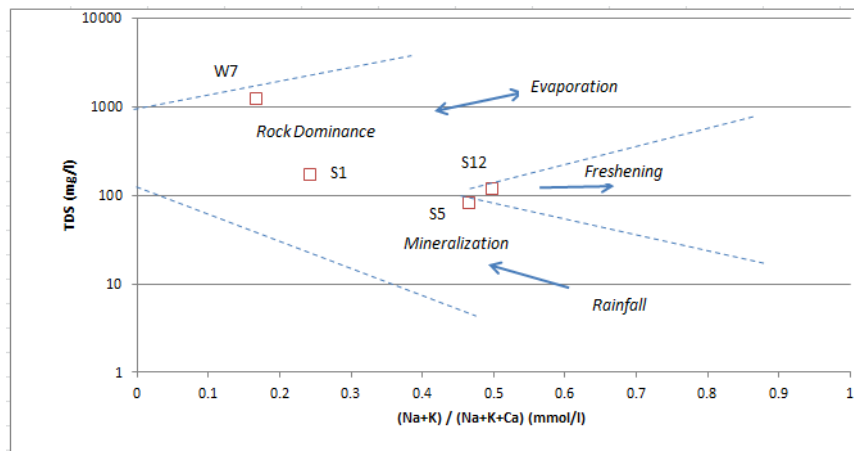


Figure 9. Plot data in Gibb's diagram show rock dominance and mineralization as a major process of hydrochemical in research area.

5. Conclusion

Groundwater in the research area is dominated by bicarbonate types, although there was anomalous of sulfate type can be found at well in Ngaranduo. The hydrochemical types develop as Ca-HCO_3 , Ca, Na, Mg-HCO_3 and Ca,Na-HCO_3 , and Ca,Mg-SO_4 . The other characteristics show neutral pH (5,7 – 7) and low TDS (freshwater) although in laboratory it was found brackish water at Ngaranduo well. The dominant hydrochemical process is ion exchange, in addition to simple dissolution or mixing that may become from any pollution.

The study area dominantly consists of volcanoclastic rocks. Some of the mineral content of the rocks are soluble easily in groundwater as a result of the weathering process. The content of cations and anions in the groundwater is affected by the composition of the minerals that compose the rock. The number of elements Ca^{2+} , Na^+ , and silica in the groundwater is affected by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

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Influence of Rocks to The Hydrochemical Facies of Groundwater at Samigaluh Area, West Progo

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Abstract. Groundwater survey has carried out at Samigaluh and its surrounding area, West Progo. This area is included in West Progo Dome and topographic map of Sendangagung. This research has been done by hydrogeological survey, equipped with groundwater sampling of four samples for physical/chemical testing at laboratory. Field data collecting includes physical properties (color, taste, odor, turbidity) and chemical properties (pH, TDS) of groundwater as well as local geological condition. Laboratory data is similar to field data plus ion contents. Data analysis includes hydrochemistry of groundwater based on all data. Results of research show that groundwater in research area is usually colorless, no taste, no odor and clear. Groundwater develops in most variable types, such as Ca-HCO₃, Ca, Na-HCO₃, Ca,Na,Mg-HCO₃ and Ca,Mg-SO₄. Groundwater types vary in some Piper class. The hydrochemical process is dominated by ion exchange, besides simple dissolution or mixing. The dominant groundwater facies are bicarbonate, due to the influence of siliciclastic rocks that interact with groundwater through the dissolution process. The number of elements Ca²⁺, Na⁺ and silica in the groundwater is influenced by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

Keywords: hydrochemistry, groundwater, facies, process, rocks

1. Introduction

The research of groundwater was conducted in Samigaluh and its surrounding area, Kulon Progo District (Figure 1). The area is included in West Progo Dome physiographically [1], and the Indonesian Topographic Map Sheet 1408-232 (Sendangagung) [2] scale of 1: 25.000. The research area is included in non groundwater basin of West Progo Hills.

Hydrogeological research has been developed in various regions through some methods and goals in many regions in order to know about its quality and help society to get good quality of drinking water. The water is very important for human life, therefore water must be maintained as a valuable thing. Many kinds of research about groundwater need to be done to develop degree of life.

In recent days, groundwater is more important and replaces surface water for daily needs in some areas. The potential of groundwater in an area needs to be evaluated its properties in order to provide good quality of water. The properties usually include both physical and chemical ones, and sometimes they're completed with biological assessment. However, this research is focused on the physical and chemical properties of groundwater in study area.

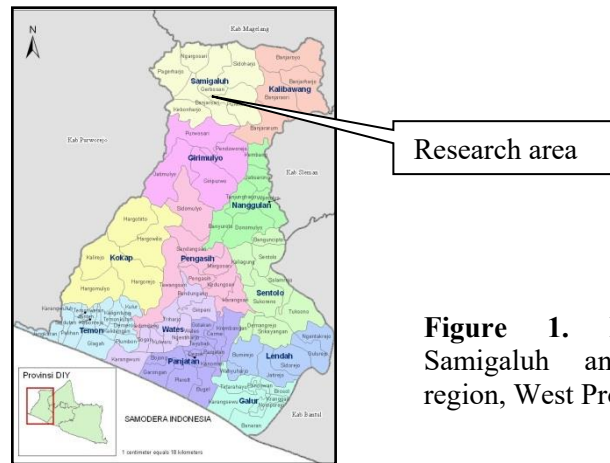


Figure 1. Research area at Samigaluh and its surrounding region, West Progo District [3].

The potential of groundwater in certain areas is important to be determined from many aspects. This research has also been done to support groundwater potential understanding, especially on physical/chemical properties, and the influencing of rocks to groundwater. Hopefully, the result of the research can be united with other results of whole area, especially in West Progo Hills.

Potential groundwater in the research area has been studied using physical/chemical properties. By knowing these properties, the interpretation of groundwater quality and hydrochemical processes can be understood. The understanding of hydrochemical processes will help of understanding the geological condition in research area. Therefore, a good study of the hydrochemistry of a region is required. The various hydrochemical processes are controlled by the rocks of a region. Moreover, hydrogeological understanding can be approached by evaluating the diversity of the groundwater facies and its correlation with rocks in studied area.

2. Methodology

The research was primarily conducted by hydrogeological surveys in the field, especially for observing groundwater of dug wells and springs. There were 12 observation locations include four springs and eight dug wells. The tools used are standard geological tools (hammer, loupe, compass) and hydrogeology tools (pH-meter, TDS-meter, and sample bottles) as well as GPS equipment. Four groundwater samples were taken with polyethylene bottles, each of 1 liter of water. Then, groundwater samples tested their physical/chemical properties in the Chemical Laboratory of BBTKLP, Yogyakarta. The analysis was conducted on field data including petrology data of aquifer, geomorphology, and stratigraphy, and analysis of physical/chemical of groundwater in selected locations. Groundwater samples were taken at Ngaranduo well (W7) and Tulangan (S1), Jarakan (S5), Palem (S12) springs (Figure 2). Compilation of secondary data and primary data both of field a laboratory has been done to evaluate groundwater quality in research area.

3. Literature Review

3.1. Geological of Research Area

The research area is physiographically included in West Progo Dome Zone (Fig. 2) [1]. This dome is part of the South Serayu Zone especially in the phenomena of the Dome Zone and the Hills in the Central Depression physiography. However, West Progo Dome has different orientations structurally with South Serayu Range.

Some geologists stated that the regional stratigraphy of West Progo Hill is composed of the oldest to the young by Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation, Sentolo

Formation and Alluvial Deposition. The Jonggrangan and Old Andesite Formations exposed in the research area.

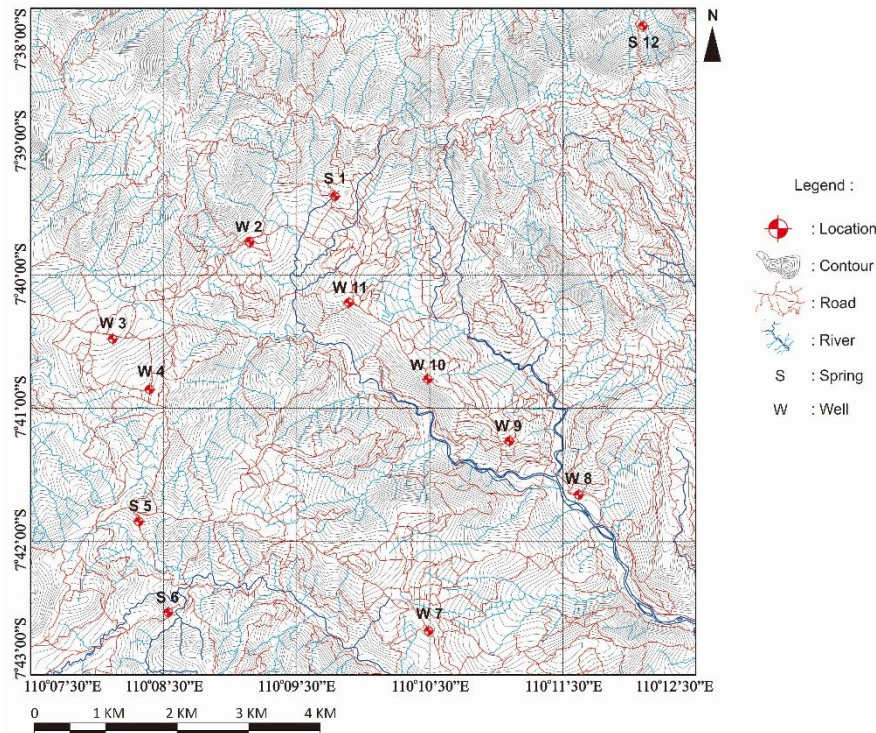


Figure 2. Observation locations of research.

The Old Andesite Formation is exposed in most of the research area. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapilli, lapilli tuff, and volcanic sandstone. The dominant lithology consists of andesite breccia with a tuff matrix, while fragments comprised of pyroxene to hornblende andesites. Besides this pyroclastic/epiclastic breccias, the intrusion of igneous rocks can be found locally.

The ancient volcanic activity located in West Progo Hills which produced Old Andesite Formation were Mt. Gadjah, Mt. Ijo and Mt. Menoreh. The Old Andesite Formation unconformably lay above Nanggulan Formation. The Old Andesite Formation can be separated based on the two depositional facies, namely Kaligesing and Dukuh Formation [4]. Kaligesing Formation is a land facies and consists of volcanic breccia, lava, and intercalation of tuff. The age of this formation is Late Oligocene to the Early Miocene, with a thickness of more than 600 m. On the other hand, Dukuh Formation has deep-sea facies and composed of volcanic breccias as well as intercalation of sandstone, limestones, and claystone. This formation was deposited in Upper Oligocene to Early Miocene age, with thickness of more than 660 m and has interfingering relationship with Kaligesing Formation.

The lithology of West Progo Hills is dominated by volcanic materials such as andesite breccia, tuff, lapilli, agglomerate, and intercalation of andesite lava flows. The material is formed by the existence of ancient volcanic activity at Tertiary time. The lithology is usually impermeable and less porous. As a result, the water is difficult to be stored and flown in it. Therefore, the potential of groundwater in this region is very little. The presence of groundwater in this area is sometimes found in very deep layers (> 25 meters) and found only in rock fractures [5]. The need for the water for population at West Progo Hills is generally usually fulfilled by springs.

3.2. Facies of Groundwater

Groundwater quality is determined by its physical and chemical properties. This groundwater quality can be seen from its **hydrochemical facies**. Physical properties include color, taste, odor, temperature, and turbidity; while chemical properties depend on chemical composition of groundwater. The chemical composition of groundwater is influenced by minerals of rock. Each mineral has certain chemical composition which when dissolved will affect the chemical composition of groundwater.

The chemical facies of groundwater depends on the chemical composition of water in recharge area and reactions that occur in groundwater flow system [6]. In its flow process groundwater will pass many kinds of rocks beneath the surface of the earth. The rock will partially dissolved and influence the chemical content of groundwater. Mineral solubility in rocks depends on several things, such as pressure and temperature in groundwater basin and resistance of rocks.

Davis & De Wiest (1966, in [7]) Groundwater quality is influenced by rock material in its path. Ion development in groundwater depends on mineral availability and mineral solubility. There is a relationship between groundwater compound ions in rock's mineral. Table 1 explains briefly about some chemical composition of groundwater and possibly source of minerals/rocks which influence it.

Groundwater compositions vary in their **flow process**. This chemical contents also change or experience evolution while groundwater flows under surface. From geochemical point of view, the order of anion evolution is greatly determined by mineral availability and solubility [9]. HCO_3^- ion content in groundwater commonly comes from CO_2 of soil and calcite/dolomite dissolution. Because of big numbers of calcite and dolomite in almost all of sedimentary basin and these minerals are easily soluble, HCO_3^- almost be always dominant anion in recharge area.

Groundwater quality is influenced by aquifer materials caused by diagenetic changes when the groundwater passes the aquifer, caused by several hydrochemical processes [6]. These processes are dissolution-hydrolysis-precipitation, adsorption, ion exchange, reduction-oxidation, mixing, membrane filtration, and microbiology metabolism.

One of the causes of mineralization in deep-lying water is long enough time of groundwater interaction to aquifer [6]. This fact will increase TDS from soluble salt or **non-resistant** minerals. Besides aquifer rock, claystone can also influence the chemical composition of groundwater by ion exchange processes. Clay can be a geochemical filter, natural chromatography or semipermeable membrane.

Table 1. Mineral/rock association to chemical elements of groundwater (modified from Davis & De Wiest, 1966 in [7] and [8]).

Element / Compound	Minerals / Rocks
Ca^{2+}	Marine sedimentary rocks (calcite, aragonite, dolomite, anhydrite, gypsum); a product of igneous rock's weathering (feldspar, amphibole, pyroxene group, clay mineral).
Na^+	Product of igneous rock's weathering, feldspar (albite), clay mineral.
K^+	Clay mineral, igneous rock's mineral (orthoclase, microcline, mica, biotite, feldspathoid, leucite, nepheline).
Mg^{2+}	It comes from soil and sediment, sedimentary rock (dolomite), igneous rock (biotite, hornblende, augite).
NO_3^-	The atmosphere, the destructions of plants, animal breeds (organism activity), chemical source of industry & agriculture.
HCO_3^-	CO_2 from atmosphere and soil, soluble materials of calcareous rock (limestone & dolomite), precipitation of CaCO_3
SO_4^{2-}	Oxidation of sulfide mineral in volcanic/igneous rock, atmospheric precipitation, organic shale
Cl^-	Connate water trapped when sedimentation, the result of rain evaporation, atmospheric solubility.
SiO_2	Feldspar, quartz, clay mineral, volcanic rock

As long as its flow under surface, groundwater tends to keep chemical equilibrium through chemical reactions to the environment. Equilibrium achieved tends to product stable groundwater quality to time cause of slow motion of groundwater and long residence time in geological formation [10]. Groundwater compositions vary in their flow process. The variable of groundwater quality commonly observed easier in shallow aquifer caused by seasonal variation at recharge and discharge area related to salinity fluctuation.

4. Result and Analysis

The geological setting of this region is composed of rock formations that are included in the West Progo Dome stratigraphy, such as Jonggrangan and Old Andesite Formation as well as the Quaternary sediments. The Old Andesite Formation that comprises the research area is generally included as Dukuh Formation, evenly spread in almost all parts of research area. Whereas, Jonggrangan Formation has outcrops locally spread or locally at narrow area.

The research area dominantly consists of andesite breccias. This rock can potentially act as aquifer through many cracks of joints (Figure 3). The andesite breccias show dark brown to black color when weathered and grey in fresh condition, with pyroclastic texture, and massive structure. The fragment of rock consists of andesite with feldspar, pyroxene, biotite dominantly and fewer quartz minerals. Whereas, the matrix usually is dark grey and consists of tuff.



Figure 3. Left: Springs at Jarakan, Kebonharjo (Loc. 5). Right: Aquifer of andesite breccia in the spring.

Field data has been taken directly from the area of dug wells and springs (Figure 2; Table 2). The physical/chemical properties of groundwater results from the laboratory are given in Table 3.

4.1. Physical Properties of Groundwater

Field data showed good quality of groundwater both in wells and springs. They showed colorless, no taste, no odor and clear of groundwater almost in all locations. Anomalous properties were only found at W7 and W9 that were slightly colored. The temperature of groundwater is usually normal, similar to the air temperature around wells and springs. Laboratory data also showed similar properties, where anomalous can be found at S12 with turbidity reached 5 NTU. Nevertheless, groundwater in research area is still a good physical property for daily needs.

Table 2. Field data of the physical/chemical properties of groundwater.

Loc.	Type	Color	Taste	Odor	Turbidity	pH	TDS
S1	Spring	Colorless	no taste	no odor	clear	7	83
W2	Well	Colorless	no taste	no odor	clear	6.9	45
W3	Well	Colorless	no taste	no odor	clear	6.8	58
W4	Well	Colorless	no taste	no odor	clear	7	29
S5	Spring	Colorless	no taste	no odor	clear	7	33
S6	Spring	Colorless	no taste	no odor	clear	6.8	30
W7	Well	Almost colorless	no taste	no odor	clear	6.8	324
W8	Well	Colorless	no taste	no odor	clear	6.8	68
W9	Well	Whitish	no taste	less odor	clear	6.8	44
W10	Well	Colorless	no taste	no odor	clear	6.8	61
W11	Well	Colorless	no taste	no odor	clear	6.8	69
S12	Spring	Colorless	no taste	no odor	clear	7	48

Table 3. Laboratory testing of the physical/chemical properties of groundwater.

Parameter	S1	S5	W7	S12
Ca²⁺ (mg/l)	61.6	15.2	209.6	23.2
Na⁺ (mg/l)	33	24	68	38
K⁺ (mg/l)	3	1	8	4
Mg²⁺ (mg/l)	8.26	5.83	63.18	5.83
Fe²⁺ (mg/l)	0.0162	0.0541	0.0162	0.0221
Mn²⁺ (mg/l)	0.0101	0.0101	0.0101	0.0101
Zn²⁺ (mg/l)	0.0083	0.0083	0.0083	0.0083
NO₃⁻ (mg/l)	1.85	1.33	3.08	7.73
HCO₃⁻ (mg/l)	252.4	90.6	300.5	114.2
SO₄²⁻ (mg/l)	2	1	894	6
Cl⁻ (mg/l)	2.5	2	6.4	4.5
SiO₂	17.691	15.543	11.823	17.212
pH	6.1	5.7	6.8	6.1
Turbidity (NTU)	1	2	1	5
Taste	no	no	no	no
Odor	no	no	no	no
Temperature (°C)	25.2	25.2	25.2	25.2
TDS (mg/l)	178	85	1269	122

4.2. Chemical Properties of Groundwater

Good properties of groundwater were also shown from chemical ones, such as normal pH (6.8 – 7) at the field and 5.7 – 6.8 from the laboratory. TDS commonly are low, except groundwater from W7 which reached 1269 ppm. Based on TDS value, groundwater of research area is freshwater according to Carroll, 1962 in [10].

Chemical contents of four samples show anion dominant as HCO_3^- , while cation dominant is usually varied. From laboratory data, samples from springs (S1, S5, S12) show Ca- HCO_3 , Ca, Na, Mg- HCO_3 and Ca,Na- HCO_3 facies subsequently, while sample from dug well at Ngaranduo (W7) show Ca,Mg- SO_4 facies (Table 4). The numbers of ion compositions of samples (in epm) can be seen at Stiff Diagram (Figure 5). It is clear that bicarbonate will be dominant facies of groundwater samples.

Table 4. Groundwater facies of samples of the research area.

No.	Parameter	S1	S5	W7	S12
Cation					
1	Ca (%)	65.02	40.02	58.94	41.60
2	Na (%)	17.85	32.38	9.80	34.92
3	K (%)	2.76	2.29	1.96	6.25
4	Mg (%)	14.37	25.30	29.29	17.23
Anion					
5	Cl (%)	1.66	3.61	0.76	5.98
6	HCO_3 (%)	97.36	95.06	20.76	88.14
7	SO_4 (%)	0.98	1.33	78.47	5.88
Chemical type		Ca - bicarbonate	Ca,Na,Mg - bicarbonate	Ca,Mg - sulfate	Ca,Na - bicarbonate

Bicarbonate facies is the dominant groundwater type in the research area. The anomalous which is found in well number W7 as sulfate facies may be caused by pollution of groundwater. The pollution possibly came from human activity such as household waste, industry or agriculture, in addition to the possibility of organic shale in the place.

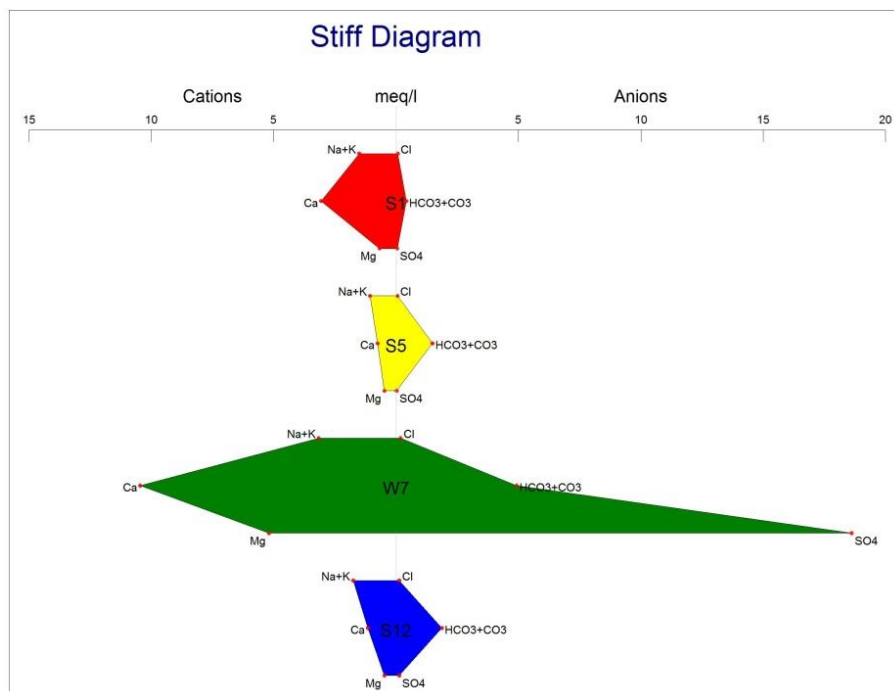


Figure 5. Stiff diagram of groundwater samples.

The plot of groundwater samples in Piper diagram (Figure 6) shows that groundwater in research area has several varied types. Those samples include in many classes of Piper division, i.e. class 1 – 6 and class 9.

Groundwater from S1, S5 and W7 are included in class 1, indicate that earth alkaline content more than alkaline. Groundwater from S12 is included in class 2 which means it has alkaline content more than earth alkaline. Class 3 consists of S1, S5, and S12 which means that weak acid content more than strong acid. Class 4 involves groundwater from W7 which means strong acid more than weak acid contents. Class 5 shows that calcareous hardness or secondary alkalinity more than 50%, for example groundwater of S1 and S5. Class 6 shows that non calcareous hardness or secondary salt consists of groundwater from W7 sample. Whereas, class 9 show cation-anion equilibrium in groundwater like in S12 sample.

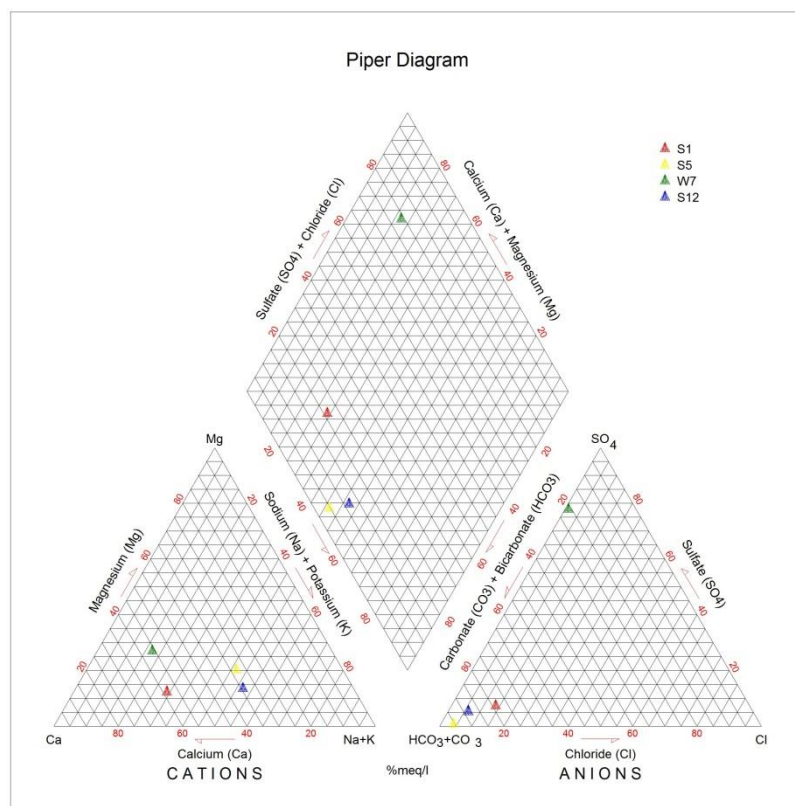


Figure 6. A plot of groundwater samples in Piper diagram.

The hydrochemical process along the groundwater flow path was dominated by ion exchange, especially as shown by S12, S5 and S1 samples (Figure 7). Although the process in S1 is more advanced, this does not mean that groundwater flows from S12 to S5 and S1. It can be understood because groundwater flows locally. Whereas, the W7 sample tends to show the other dominant process i.e. simple dissolution or mixing. It may be due to pollution in the dug well area from the environment. It also supported high enough of TDS in groundwater of W7 sample according to laboratory tests that show brackish water type (Carroll, 1962 in [10]).

The hydrochemical process as indicated in Figure 8 does not clearly describe the order of the groundwater journey. The pattern of groundwater flow in the research area is still not understanding comprehensively since the area is a non groundwater basin area. This means that groundwater flow patterns are often local, and may not be interconnected in the basin.

Groundwater in research area flows mostly in volcanic rocks with igneous rock fragments. The igneous rock origin generally contains appreciable amounts of aluminosilicate minerals such as feldspar and mica [11]. Groundwater would be acquired dissolved constituents from the dissolution process. However, silica contents (SiO_2) of groundwater in research were still low (<18 ppm). It means that dissolution process (even in W7) has not gone perfectly or the process takes place in a relatively short time. It indicates that groundwater flow is local or near journey. This characteristic is usually possessed by young groundwater in recharge area.

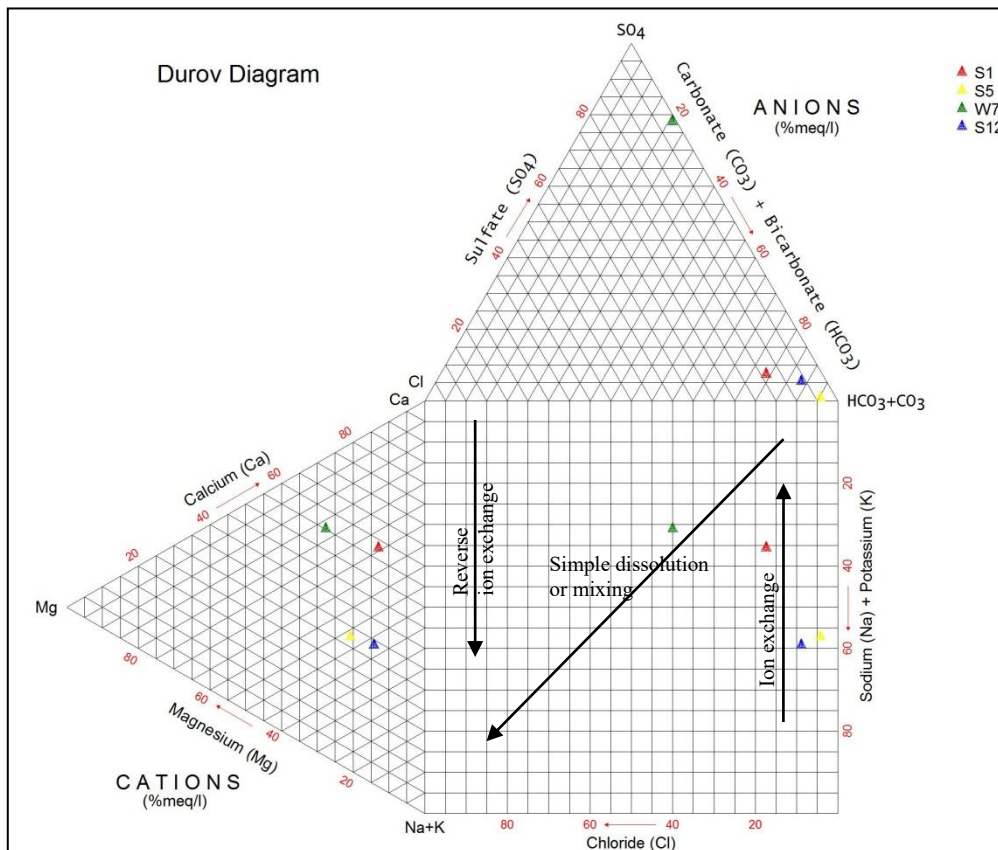


Figure 7. A plot of groundwater samples in Durov diagram.

4.3. Rock's Mineral Composition

Rocks affect the chemical characteristics of groundwater through the process of dissolving the minerals they contain [12], [13]. Therefore, the study of the influence of rocks on groundwater hydrochemical is carried out by analyzing the mineral content of rock constituents. Table 5 below shows the composition of rock minerals in the study area. The rocks that make up the Samigaluh area are dominated by pyroclastic andesite breccia and andesite igneous rocks. The rock has the main mineral feldspar (plagioclase) and volcanic glass [14]. One example of mineral appearance in a thin section of rock is shown in Figure 8.

4.4. Influence of Rock's Mineral to Groundwater Facies

The research area dominantly consists of volcanic rocks, especially of andesite breccia. These rocks are included in Old Andesite Formation which may become aquifer by their cracks or weathering products. The groundwater which flows in this formation may be influenced by elements of rock's

minerals. The interaction of water - tuffaceous rocks on the main aquifer is the reaction of dissolution - precipitation because these rocks indicate chemically unstable phase [15]. Carbonate aquifer is also found in Samigaluh although its spread is narrow. This carbonate aquifer also has unstable chemical phase, so the reaction of dissolution is occurring easily.

Table 5. Mineral composition in rocks in the study area (%) [14].

Location	Field Name	Petrographic Name	Vitric	Feldspar	Opag Min.	Bio-tite	Horn-blend	Pyro-xene	Quartz	Lithic	Fossil	Clay Min.	Carbo-nate mud
Giripurwo	Tuff	Vitric tuff	85	10	5								
Giripurwo	Andesite intrusion	Andesite	10	45	1	10	14	20					
Gerbosari	Andesite lava	Andesite	17	50	5	20		22					
Purwoharjo	Fragment of breccia	Andesite	7	75				8	8				
Purwoharjo	Matrix of breccia	Tuffaceous lithic arenite	20	10	5					65			
Purwoharjo	Reef limestone	Mudstone		4	2				2		4	5	83
Purwoharjo	Fragment of polymict breccia	Andesite pyroxene	15	65	4			14	2				
Purwoharjo	Matrix of polymict breccia	Tuffaceous feldspathic arenite	15	55	2	10		8		5		5	

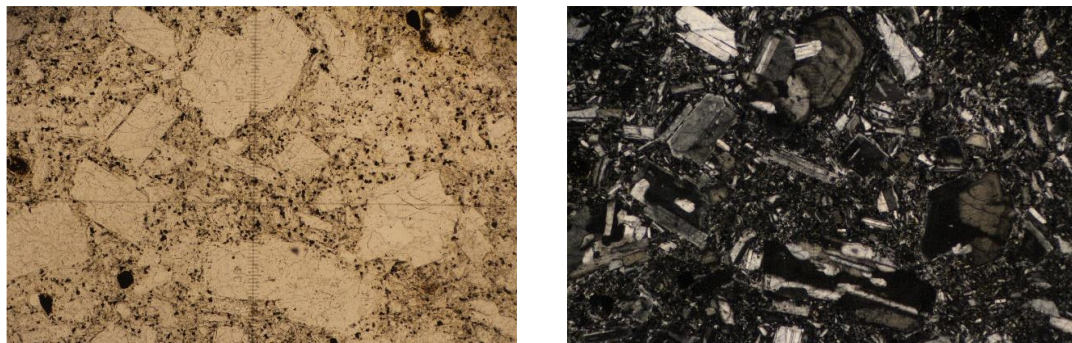


Figure 8. Examples of andesite thin cuts from the study area in parallel nicol (left) and cross nicol (right) [14].

The dominant groundwater facies are bicarbonate, with sulfate facies anomalies. Sulfates can originate from oxidation of sulfide minerals in igneous/volcanic rocks or atmospheric precipitation [8]. Significant sulfate content can also be caused by pollution factors.

Petrographic data shows the presence of rocks containing clay minerals. This might occur due to weathering in rocks. This clay mineral usually has ion exchange capacity which influences the type and quality of groundwater.

However, the main mineral that consists of rocks in the study area is plagioclase. This silicate mineral is easily weathered (Goldich, 1938, in [16]) so that the dissolution of the rock is very influential in the high silica content in the groundwater.

Minerals content in the siliciclastic tuffaceous and calcareous rocks in a research area, together influence the chemical content of groundwater. These minerals supply chemical elements such as Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , carbonates, and bicarbonates (Table 6). This table shows that the mineral constituent of rocks in the study area may play a role in affecting the composition of groundwater. The table shows the possibilities of supply of chemical elements from the existing mineralogy.

Furthermore, the elements / compounds present in groundwater is affected by the level of mineral solubility. Not all minerals can dissolve the elements contained in them.

Table 6. Correlation of petrographic data and groundwater chemistry association with chemical groundwater data.

Mineral	Chemical association in rocks (Davis & De Wiest, 1966 in [13])	Chemical facies of groundwater	
		Dominant Cation	Dominant Anion
Feldspar	Silica, Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺		
Clay mineral	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻		
Opaque mineral	Silica, Fe ²⁺ , Fe ³⁺ , Mg ²⁺		
Volcanic glass	Silica, SO ₄ ²⁻ , Cl ⁻		
Rock fragment	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻ , Cl ⁻	Ca ²⁺ Mg ²⁺ Na ⁺	HCO ₃ ⁻ SO ₄ ²⁻
Quartz	Silica		
Pyroxene	Fe ²⁺ , Fe ³⁺ , Ca ²⁺		
Fossil & carbonate mineral	Ca ²⁺ , carbonate, bicarbonate		
Hornblende	Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Cl ⁻ , F		

Silica content in the groundwater supply is obtained from several minerals include feldspar, clay minerals, opaque minerals, volcanic glass, quartz and rock fragments (lithic). The process of the dissolution of this mineral can be supported by the weathering of silicate minerals, which can be explained as follows [16].

- Changes resulting in the chemistry of groundwater is unclear because of the dissolution of weathered silicate minerals generally run very slowly. This is evident from all samples of groundwater that show the small amount of content of silicate.

- In many siliciclastic rocks area, effect of silicate weathering on groundwater chemistry is usually mainly the addition of cations and silica.

- The disappearance sequence of silicate minerals indicates differences in the dissolution rate. In accordance with the Goldich sequence of weathering (1938, in [16]), feldspar is more easily weathered than quartz, then feldspar mineral is more possibly supply of silica in groundwater than quartz.

The chemical content in groundwater is strongly influenced by mineral solubility [10]. This is, of course, depends on their mineral stability. The dominant soluble minerals in the area are feldspar and carbonate minerals. The other silicate minerals can support the chemical content of groundwater due to leaching that occurs in quite a long time. Thus, the characteristics of the groundwater facies are heavily influenced by rock.

Volcanic rocks at the Samgaluh area are pyroclastic or volcanoclastic rocks. Leaching in these volcanic sedimentary rocks (especially from its matrix) will affect the composition of the groundwater for their soluble component [6]. TDS depends on the material of rocks. Low TDS in groundwater can be caused by rainwater. The arenite sandstone may result many elements of Mg²⁺, Ca²⁺, Na⁺, SO₄²⁻ dan Cl⁻ in groundwater.

The effect of rocks on hydrochemical facies is also supported by a method that connects ionic concentrations with TDS. Figure 9 shows a plot of groundwater chemical data that falls on rock dominance and mineralization fields [17]. This reinforces the prediction of the influence of rocks on the hydrochemical facies and the effect of mineralization due to ground-rock ground interaction.

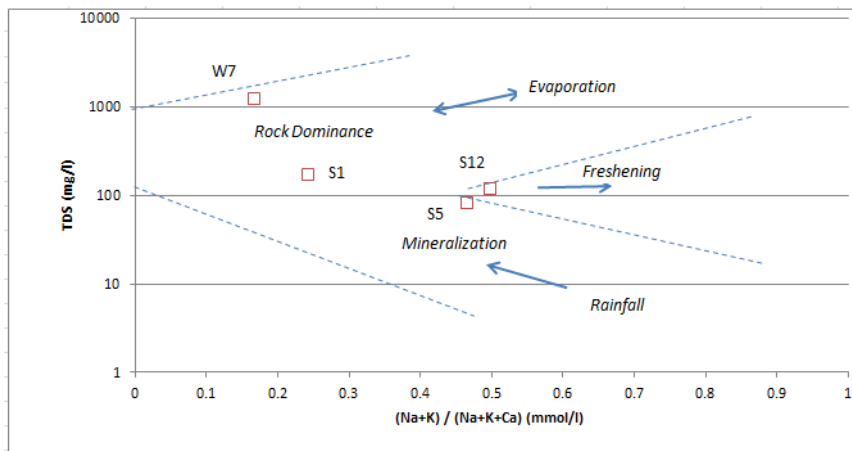


Figure 9. Plot data in Gibb's diagram show rock dominance and mineralization as a major process of hydrochemical in research area.

5. Conclusion

Groundwater in the research area is dominated by bicarbonate types, although there was anomalous of sulfate type can be found at well in Ngaranduo. The hydrochemical types develop as Ca-HCO_3 , Ca, Na, Mg-HCO_3 and Ca,Na-HCO_3 , and Ca,Mg-SO_4 . The other characteristics show neutral pH (5,7 – 7) and low TDS (freshwater) although in laboratory it was found brackish water at Ngaranduo well. The dominant hydrochemical process is ion exchange, in addition to simple dissolution or mixing that may become from any pollution.

The study area dominantly consists of volcanoclastic rocks. Some of the mineral content of the rocks are soluble easily in groundwater as a result of the weathering process. The content of cations and anions in the groundwater is affected by the composition of the minerals that compose the rock. The number of elements Ca^{2+} , Na^+ , and silica in the groundwater is affected by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

Acknowledgment

The author would like to thank the STTNAS / ITNY institution for supporting internal research funds until the publication of the results at this international seminar.

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Influence of Rocks to The Hydrochemical Facies of Groundwater at Samigaluh Area, West Progo

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Abstract. Groundwater survey has carried out at Samigaluh and its surrounding area, West Progo. This area is included in West Progo Dome and topographic map of Sendangagung. This research has been done by hydrogeological survey, equipped with groundwater sampling of four samples for physical/chemical testing at laboratory. Field data collecting includes physical properties (color, taste, odor, turbidity) and chemical properties (pH, TDS) of groundwater as well as local geological condition. Laboratory data is similar to field data plus ion contents. Data analysis includes hydrochemistry of groundwater based on all data. Results of research show that groundwater in research area is usually colorless, no taste, no odor and clear. Groundwater develops in most variable types, such as Ca-HCO₃, Ca, Na-HCO₃, Ca,Na,Mg-HCO₃ and Ca,Mg-SO₄. Groundwater types vary in some Piper class. The hydrochemical process is dominated by ion exchange, besides simple dissolution or mixing. The dominant groundwater facies are bicarbonate, due to the influence of siliciclastic rocks that interact with groundwater through the dissolution process. The number of elements Ca²⁺, Na⁺, and silica in the groundwater is influenced by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

Keywords: hydrochemistry, groundwater, facies, process, rocks

1. Introduction

The research of groundwater was conducted in Samigaluh and its surrounding area, Kulon Progo District (Figure 1). The area is included in West Progo Dome physiographically [1], and the Indonesian Topographic Map Sheet 1408-232 (Sendangagung) [2] scale of 1: 25.000. The research area is included in non groundwater basin of West Progo Hills.

Hydrogeological research has been developed in various regions through some methods and goals in many regions in order to know about its quality and help society to get good quality of drinking water. The water is very important for human life, therefore water must be maintained as a valuable thing. Many kinds of research about groundwater need to be done to develop degree of life.

In recent days, groundwater is more important and replaces surface water for daily needs in some areas. The potential of groundwater in an area needs to be evaluated its properties in order to provide good quality of water. The properties usually include both physical and chemical ones, and sometimes they're completed with biological assessment. However, this research is focused on the physical and chemical properties of groundwater in study area.

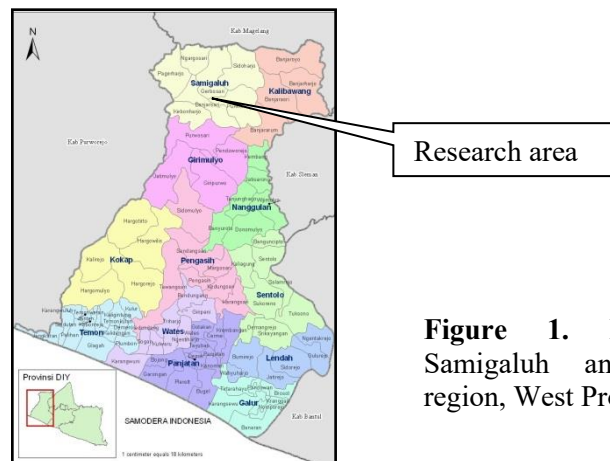


Figure 1. Research area at Samigaluh and its surrounding region, West Progo District [3].

The potential of groundwater in certain areas is important to be determined from many aspects. This research has also been done to support groundwater potential understanding, especially on physical/chemical properties, and the influencing of rocks to groundwater. Hopefully, the result of the research can be united with other results of whole area, especially in West Progo Hills.

Potential groundwater in the research area has been studied using physical/chemical properties. By knowing these properties, the interpretation of groundwater quality and hydrochemical processes can be understood. The understanding of hydrochemical processes will help of understanding the geological condition in research area. Therefore, a good study of the hydrochemistry of a region is required. The various hydrochemical processes are controlled by the rocks of a region. Moreover, hydrogeological understanding can be approached by evaluating the diversity of the groundwater facies and its correlation with rocks in studied area.

2. Methodology

The research was primarily conducted by hydrogeological surveys in the field, especially for observing groundwater of dug wells and springs. There were 12 observation locations include four springs and eight dug wells. The tools used are standard geological tools (hammer, loupe, compass) and hydrogeology tools (pH-meter, TDS-meter, and sample bottles) as well as GPS equipment. Four groundwater samples were taken with polyethylene bottles, each of 1 liter of water. Then, groundwater samples tested their physical/chemical properties in the Chemical Laboratory of BBTKLP, Yogyakarta. The analysis was conducted on field data including petrology data of aquifer, geomorphology, and stratigraphy, and analysis of physical/chemical of groundwater in selected locations. Groundwater samples were taken at Ngaranduo well (W7) and Tulangan (S1), Jarakan (S5), Palem (S12) springs (Figure 2). Compilation of secondary data and primary data both of field a laboratory has been done to evaluate groundwater quality in research area.

3. Literature Review

3.1. Geological of Research Area

The research area is physiographically included in West Progo Dome Zone (Fig. 2) [1]. This dome is part of the South Serayu Zone especially in the phenomena of the Dome Zone and the Hills in the Central Depression physiography. However, West Progo Dome has different orientations structurally with South Serayu Range.

Some geologists stated that the regional stratigraphy of West Progo Hill is composed of the oldest to the young by Nanggulan Formation, Old Andesite Formation, Jonggrangan Formation, Sentolo

Formation and Alluvial Deposition. The Jonggrangan and Old Andesite Formations exposed in the research area.

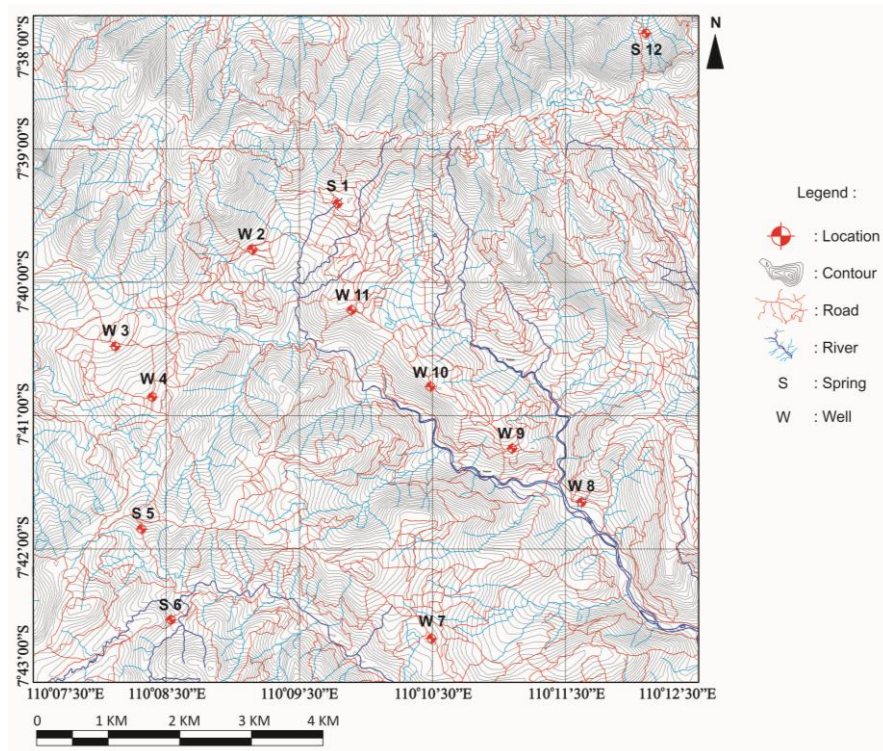


Figure 2. Observation locations of research.

The Old Andesite Formation is exposed in most of the research area. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapilli, lapilli tuff, and volcanic sandstone. The dominant lithology consists of andesite breccia with a tuff matrix, while fragments comprised of pyroxene to hornblende andesites. Besides this pyroclastic/epiclastic breccias, the intrusion of igneous rocks can be found locally.

The ancient volcanic activity located in West Progo Hills which produced Old Andesite Formation were Mt. Gadjah, Mt. Ijo and Mt. Menoreh. The Old Andesite Formation unconformably lay above Nanggulan Formation. The Old Andesite Formation can be separated based on the two depositional facies, namely Kaligesing and Dukuh Formation [4]. Kaligesing Formation is a land facies and consists of volcanic breccia, lava, and intercalation of tuff. The age of this formation is Late Oligocene to the Early Miocene, with a thickness of more than 600 m. On the other hand, Dukuh Formation has deep-sea facies and composed of volcanic breccias as well as intercalation of sandstone, limestones, and claystone. This formation was deposited in Upper Oligocene to Early Miocene age, with thickness of more than 660 m and has interfingering relationship with Kaligesing Formation.

The lithology of West Progo Hills is dominated by volcanic materials such as andesite breccia, tuff, lapilli, agglomerate, and intercalation of andesite lava flows. The material is formed by the existence of ancient volcanic activity at Tertiary time. The lithology is usually impermeable and less porous. As a result, the water is difficult to be stored and flown in it. Therefore, the potential of groundwater in this region is very little. The presence of groundwater in this area is sometimes found in very deep layers (> 25 meters) and found only in rock fractures [5]. The need for the water for population at West Progo Hills is generally usually fulfilled by springs.

3.2. Facies of Groundwater

Groundwater quality is determined by its physical and chemical properties. This groundwater quality can be seen from its hydrochemical facies. Physical properties include color, taste, odor, temperature, and turbidity; while chemical properties depend on chemical composition of groundwater. The chemical composition of groundwater is influenced by minerals of rock. Each mineral has certain chemical composition which when dissolved will affect the chemical composition of groundwater.

The chemical facies of groundwater depends on the chemical composition of water in recharge area and reactions that occur in groundwater flow system [6]. In its flow process groundwater will pass many kinds of rocks beneath the surface of the earth. The rock will partially dissolved and influence the chemical content of groundwater. Mineral solubility in rocks depends on several things, such as pressure and temperature in groundwater basin and resistance of rocks.

Davis & De Wiest (1966, in [7]) Groundwater quality is influenced by rock material in its path. Ion development in groundwater depends on mineral availability and mineral solubility. There is a relationship between groundwater compound ions in rock's mineral. Table 1 explains briefly about some chemical composition of groundwater and possibly source of minerals/rocks which influence it.

Groundwater compositions vary in their flow process. This chemical contents also change or experience evolution while groundwater flows under surface. From geochemical point of view, the order of anion evolution is greatly determined by mineral availability and solubility [9]. HCO_3^- ion content in groundwater commonly comes from CO_2 of soil and calcite/dolomite dissolution. Because of big numbers of calcite and dolomite in almost all of sedimentary basin and these minerals are easily soluble, HCO_3^- almost be always dominant anion in recharge area.

Groundwater quality is influenced by aquifer materials caused by diagenetic changes when the groundwater passes the aquifer, caused by several hydrochemical processes [6]. These processes are dissolution-hydrolysis-precipitation, adsorption, ion exchange, reduction-oxidation, mixing, membrane filtration, and microbiology metabolism.

One of the causes of mineralization in deep-lying water is long enough time of groundwater interaction to aquifer [6]. This fact will increase TDS from soluble salt or non-resistant minerals. Besides aquifer rock, claystone can also influence the chemical composition of groundwater by ion exchange processes. Clay can be a geochemical filter, natural chromatography or semipermeable membrane.

Table 1. Mineral/rock association to chemical elements of groundwater (modified from Davis & De Wiest, 1966 in [7] and [8]).

Element / Compound	Minerals / Rocks
Ca^{2+}	Marine sedimentary rocks (calcite, aragonite, dolomite, anhydrite, gypsum); a product of igneous rock's weathering (feldspar, amphibole, pyroxene group, clay mineral).
Na^+	Product of igneous rock's weathering, feldspar (albite), clay mineral.
K^+	Clay mineral, igneous rock's mineral (orthoclase, microcline, mica, biotite, feldspathoid, leucite, nepheline).
Mg^{2+}	It comes from soil and sediment, sedimentary rock (dolomite), igneous rock (biotite, hornblende, augite).
NO_3^-	The atmosphere, the destructions of plants, animal breeds (organism activity), chemical source of industry & agriculture.
HCO_3^-	CO_2 from atmosphere and soil, soluble materials of calcareous rock (limestone & dolomite), precipitation of CaCO_3
SO_4^{2-}	Oxidation of sulfide mineral in volcanic/igneous rock, atmospheric precipitation, organic shale
Cl^-	Connate water trapped when sedimentation, the result of rain evaporation, atmospheric solubility.
SiO_2	Feldspar, quartz, clay mineral, volcanic rock

As long as its flow under surface, groundwater tends to keep chemical equilibrium through chemical reactions to the environment. Equilibrium achieved tends to product stable groundwater quality to time cause of slow motion of groundwater and long residence time in geological formation [10]. Groundwater compositions vary in their flow process. The variable of groundwater quality commonly observed easier in shallow aquifer caused by seasonal variation at recharge and discharge area related to salinity fluctuation.

4. Result and Analysis

The geological setting of this region is composed of rock formations that are included in the West Progo Dome stratigraphy, such as Jonggrangan and Old Andesite Formation as well as the Quaternary sediments. The Old Andesite Formation that comprises the research area is generally included as Dukuh Formation, evenly spread in almost all parts of research area. Whereas, Jonggrangan Formation has outcrops locally spread or locally at narrow area.

The research area dominantly consists of andesite breccias. This rock can potentially act as aquifer through many cracks of joints (Figure 3). The andesite breccias show dark brown to black color when weathered and grey in fresh condition, with pyroclastic texture, and massive structure. The fragment of rock consists of andesite with feldspar, pyroxene, biotite dominantly and fewer quartz minerals. Whereas, the matrix usually is dark grey and consists of tuff.



Figure 3. Left: Springs at Jarakan, Kebonharjo (Loc. 5). Right: Aquifer of andesite breccia in the spring.

Field data has been taken directly from the area of dug wells and springs (Figure 2; Table 2). The physical/chemical properties of groundwater results from the laboratory are given in Table 3.

4.1. Physical Properties of Groundwater

Field data showed good quality of groundwater both in wells and springs. They showed colorless, no taste, no odor and clear of groundwater almost in all locations. Anomalous properties were only found at W7 and W9 that were slightly colored. The temperature of groundwater is usually normal, similar to the air temperature around wells and springs. Laboratory data also showed similar properties, where anomalous can be found at S12 with turbidity reached 5 NTU. Nevertheless, groundwater in research area is still a good physical property for daily needs.

Table 2. Field data of the physical/chemical properties of groundwater.

Loc.	Type	Color	Taste	Odor	Turbidity	pH	TDS
S1	Spring	Colorless	no taste	no odor	clear	7	83
W2	Well	Colorless	no taste	no odor	clear	6.9	45
W3	Well	Colorless	no taste	no odor	clear	6.8	58
W4	Well	Colorless	no taste	no odor	clear	7	29
S5	Spring	Colorless	no taste	no odor	clear	7	33
S6	Spring	Colorless	no taste	no odor	clear	6.8	30
W7	Well	Almost colorless	no taste	no odor	clear	6.8	324
W8	Well	Colorless	no taste	no odor	clear	6.8	68
W9	Well	Whitish	no taste	less odor	clear	6.8	44
W10	Well	Colorless	no taste	no odor	clear	6.8	61
W11	Well	Colorless	no taste	no odor	clear	6.8	69
S12	Spring	Colorless	no taste	no odor	clear	7	48

Table 3. Laboratory testing of the physical/chemical properties of groundwater.

Parameter	S1	S5	W7	S12
Ca²⁺ (mg/l)	61.6	15.2	209.6	23.2
Na⁺ (mg/l)	33	24	68	38
K⁺ (mg/l)	3	1	8	4
Mg²⁺ (mg/l)	8.26	5.83	63.18	5.83
Fe²⁺ (mg/l)	0.0162	0.0541	0.0162	0.0221
Mn²⁺ (mg/l)	0.0101	0.0101	0.0101	0.0101
Zn²⁺ (mg/l)	0.0083	0.0083	0.0083	0.0083
NO₃⁻ (mg/l)	1.85	1.33	3.08	7.73
HCO₃⁻ (mg/l)	252.4	90.6	300.5	114.2
SO₄²⁻ (mg/l)	2	1	894	6
Cl⁻ (mg/l)	2.5	2	6.4	4.5
SiO₂	17.691	15.543	11.823	17.212
pH	6.1	5.7	6.8	6.1
Turbidity (NTU)	1	2	1	5
Taste	no	no	no	no
Odor	no	no	no	no
Temperature (°C)	25.2	25.2	25.2	25.2
TDS (mg/l)	178	85	1269	122

4.2. Chemical Properties of Groundwater

Good properties of groundwater were also shown from chemical ones, such as normal pH (6.8 – 7) at the field and 5.7 – 6.8 from the laboratory. TDS commonly are low, except groundwater from W7 which reached 1269 ppm. Based on TDS value, groundwater of research area is freshwater according to Carroll, 1962 in [10].

Chemical contents of four samples show anion dominant as HCO_3^- , while cation dominant is usually varied. From laboratory data, samples from springs (S1, S5, S12) show Ca- HCO_3 , Ca, Na, Mg- HCO_3 and Ca,Na- HCO_3 facies subsequently, while sample from dug well at Ngaranduo (W7) show Ca,Mg- SO_4 facies (Table 4). The numbers of ion compositions of samples (in epm) can be seen at Stiff Diagram (Figure 5). It is clear that bicarbonate will be dominant facies of groundwater samples.

Table 4. Groundwater facies of samples of the research area.

No.	Parameter	S1	S5	W7	S12
Cation					
1	Ca (%)	65.02	40.02	58.94	41.60
2	Na (%)	17.85	32.38	9.80	34.92
3	K (%)	2.76	2.29	1.96	6.25
4	Mg (%)	14.37	25.30	29.29	17.23
Anion					
5	Cl (%)	1.66	3.61	0.76	5.98
6	HCO_3 (%)	97.36	95.06	20.76	88.14
7	SO_4 (%)	0.98	1.33	78.47	5.88
Chemical type		Ca - bicarbonate	Ca,Na,Mg - bicarbonate	Ca,Mg - sulfate	Ca,Na - bicarbonate

Bicarbonate facies is the dominant groundwater type in the research area. The anomalous which is found in well number W7 as sulfate facies may be caused by pollution of groundwater. The pollution possibly came from human activity such as household waste, industry or agriculture, in addition to the possibility of organic shale in the place.

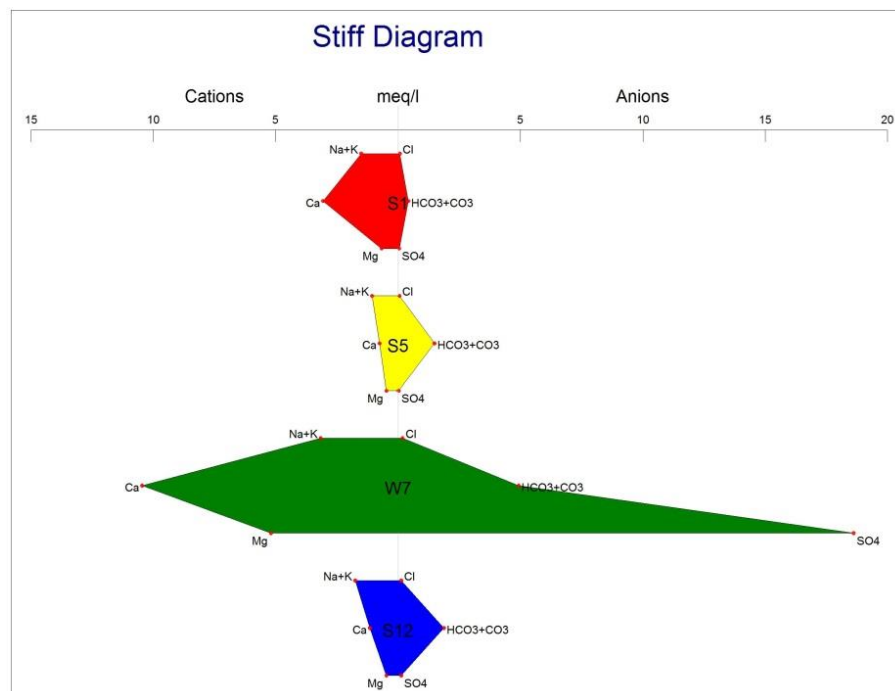


Figure 5. Stiff diagram of groundwater samples.

The plot of groundwater samples in Piper diagram (Figure 6) shows that groundwater in research area has several varied types. Those samples include in many classes of Piper division, i.e. class 1 – 6 and class 9.

Groundwater from S1, S5 and W7 are included in class 1, indicate that earth alkaline content more than alkaline. Groundwater from S12 is included in class 2 which means it has alkaline content more than earth alkaline. Class 3 consists of S1, S5, and S12 which means that weak acid content more than strong acid. Class 4 involves groundwater from W7 which means strong acid more than weak acid contents. Class 5 shows that calcareous hardness or secondary alkalinity more than 50%, for example groundwater of S1 and S5. Class 6 shows that non calcareous hardness or secondary salt consists of groundwater from W7 sample. Whereas, class 9 show cation-anion equilibrium in groundwater like in S12 sample.

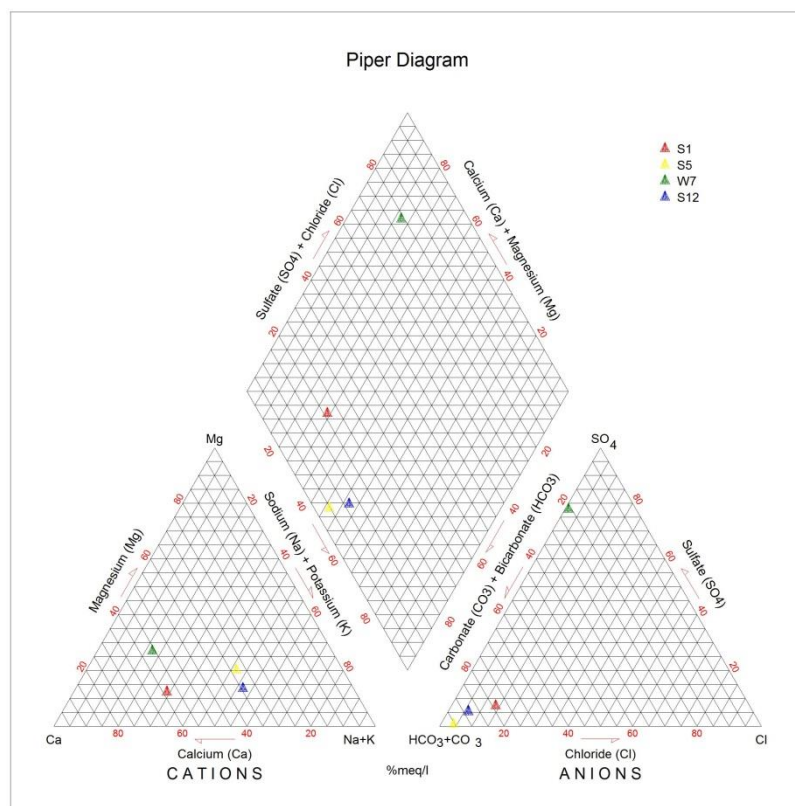


Figure 6. A plot of groundwater samples in Piper diagram.

The hydrochemical process along the groundwater flow path was dominated by ion exchange, especially as shown by S12, S5 and S1 samples (Figure 7). Although the process in S1 is more advanced, this does not mean that groundwater flows from S12 to S5 and S1. It can be understood because groundwater flows locally. Whereas, the W7 sample tends to show the other dominant process i.e. simple dissolution or mixing. It may be due to pollution in the dug well area from the environment. It also supported high enough of TDS in groundwater of W7 sample according to laboratory tests that show brackish water type (Carroll, 1962 in [10]).

The hydrochemical process as indicated in Figure 8 does not clearly describe the order of the groundwater journey. The pattern of groundwater flow in the research area is still not understanding comprehensively since the area is a non groundwater basin area. This means that groundwater flow patterns are often local, and may not be interconnected in the basin.

Groundwater in research area flows mostly in volcanic rocks with igneous rock fragments. The igneous rock origin generally contains appreciable amounts of aluminosilicate minerals such as feldspar and mica [11]. Groundwater would be acquired dissolved constituents from the dissolution process. However, silica contents (SiO_2) of groundwater in research were still low (<18 ppm). It means that dissolution process (even in W7) has not gone perfectly or the process takes place in a relatively short time. It indicates that groundwater flow is local or near journey. This characteristic is usually possessed by young groundwater in recharge area.

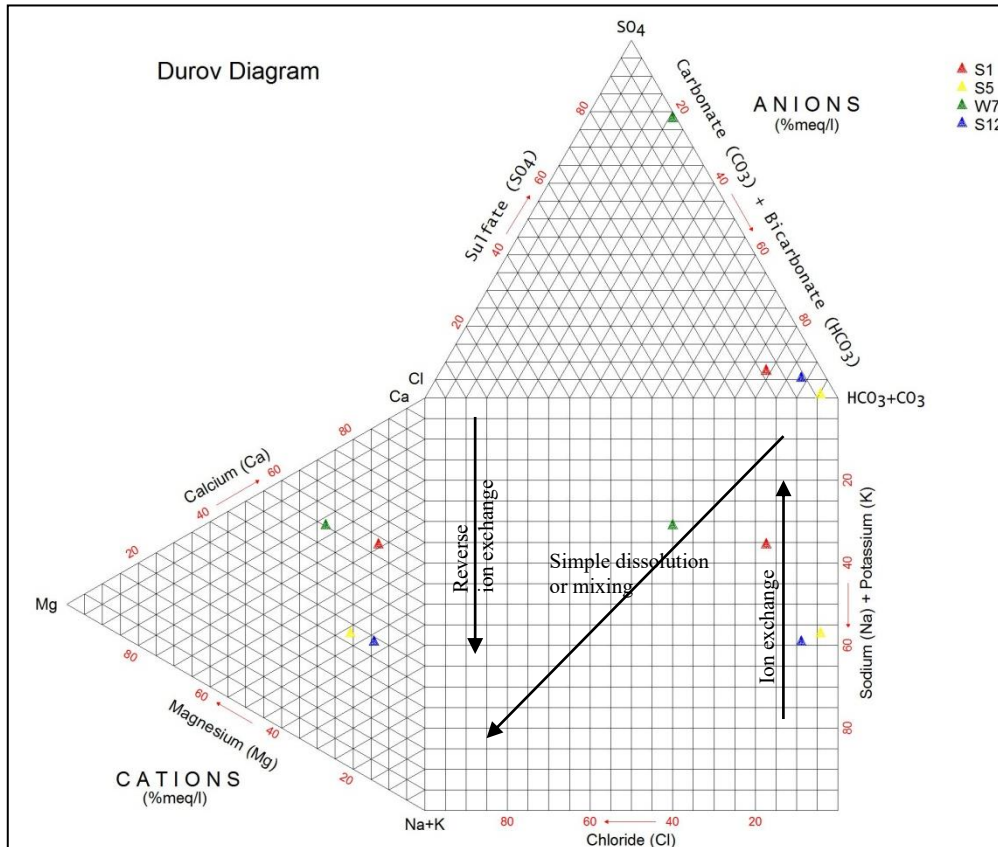


Figure 7. A plot of groundwater samples in Durov diagram.

4.3. Rock's Mineral Composition

Rocks affect the chemical characteristics of groundwater through the process of dissolving the minerals they contain [12], [13]. Therefore, the study of the influence of rocks on groundwater hydrochemical is carried out by analyzing the mineral content of rock constituents. Table 5 below shows the composition of rock minerals in the study area. The rocks that make up the Samigaluh area are dominated by pyroclastic andesite breccia and andesite igneous rocks. The rock has the main mineral feldspar (plagioclase) and volcanic glass [14]. One example of mineral appearance in a thin section of rock is shown in Figure 8.

4.4. Influence of Rock's Mineral to Groundwater Facies

The research area dominantly consists of volcanic rocks, especially of andesite breccia. These rocks are included in Old Andesite Formation which may become aquifer by their cracks or weathering products. The groundwater which flows in this formation may be influenced by elements of rock's

minerals. The interaction of water - tuffaceous rocks on the main aquifer is the reaction of dissolution - precipitation because these rocks indicate chemically unstable phase [15]. Carbonate aquifer is also found in Samigaluh although its spread is narrow. This carbonate aquifer also has unstable chemical phase, so the reaction of dissolution is occurring easily.

Table 5. Mineral composition in rocks in the study area (%) [14].

Location	Field Name	Petrographic Name	Vitric	Feldspar	Opag Min.	Bio-tite	Horn-blend	Pyro-xene	Quartz	Lithic	Fossil	Clay Min.	Carbo-nate mud
Giripurwo	Tuff	Vitric tuff	85	10	5								
Giripurwo	Andesite intrusion	Andesite	10	45	1	10	14	20					
Gerbosari	Andesite lava	Andesite	17	50	5	20		22					
Purwoharjo	Fragment of breccia	Andesite	7	75				8	8				
Purwoharjo	Matrix of breccia	Tuffaceous lithic arenite	20	10	5					65			
Purwoharjo	Reef limestone	Mudstone		4	2				2		4	5	83
Purwoharjo	Fragment of polymict breccia	Andesite pyroxene	15	65	4			14	2				
Purwoharjo	Matrix of polymict breccia	Tuffaceous feldsphatic arenite	15	55	2	10		8		5		5	

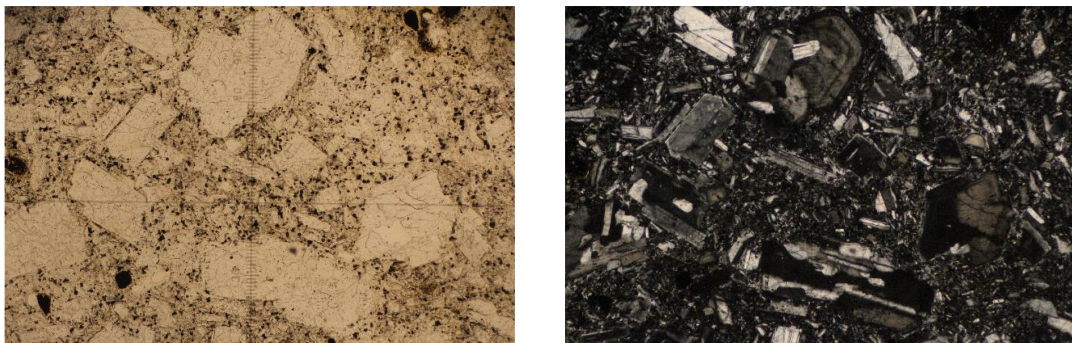


Figure 8. Examples of andesite thin cuts from the study area in parallel nicol (left) and cross nicol (right) [14].

The dominant groundwater facies are bicarbonate, with sulfate facies anomalies. Sulfates can originate from oxidation of sulfide minerals in igneous/volcanic rocks or atmospheric precipitation [8]. Significant sulfate content can also be caused by pollution factors.

Petrographic data shows the presence of rocks containing clay minerals. This might occur due to weathering in rocks. This clay mineral usually has ion exchange capacity which influences the type and quality of groundwater.

However, the main mineral that consists of rocks in the study area is plagioclase. This silicate mineral is easily weathered (Goldich, 1938, in [16]) so that the dissolution of the rock is very influential in the high silica content in the groundwater.

Minerals content in the siliciclastic tuffaceous and calcareous rocks in a research area, together influence the chemical content of groundwater. These minerals supply chemical elements such as Ca^{2+} , Mg^{2+} , Na^+ , Cl^- , carbonates, and bicarbonates (Table 6). This table shows that the mineral constituent of rocks in the study area may play a role in affecting the composition of groundwater. The table shows the possibilities of supply of chemical elements from the existing mineralogy.

Furthermore, the elements / compounds present in groundwater is affected by the level of mineral solubility. Not all minerals can dissolve the elements contained in them.

Table 6. Correlation of petrographic data and groundwater chemistry association with chemical groundwater data.

Mineral	Chemical association in rocks (Davis & De Wiest, 1966 in [13])	Chemical facies of groundwater	
		Dominant Cation	Dominant Anion
Feldspar	Silica, Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺		
Clay mineral	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻		
Opaque mineral	Silica, Fe ²⁺ , Fe ³⁺ , Mg ²⁺		
Volcanic glass	Silica, SO ₄ ²⁻ , Cl ⁻		
Rock fragment	Silica, Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Na ⁺ , K ⁺ , SO ₄ ²⁻ , Cl ⁻	Ca ²⁺ Mg ²⁺ Na ⁺	HCO ₃ ⁻ SO ₄ ²⁻
Quartz	Silica		
Pyroxene	Fe ²⁺ , Fe ³⁺ , Ca ²⁺		
Fossil & carbonate mineral	Ca ²⁺ , carbonate, bicarbonate		
Hornblende	Fe ²⁺ , Fe ³⁺ , Ca ²⁺ , Mg ²⁺ , Cl ⁻ , F		

Silica content in the groundwater supply is obtained from several minerals include feldspar, clay minerals, opaque minerals, volcanic glass, quartz and rock fragments (lithic). The process of the dissolution of this mineral can be supported by the weathering of silicate minerals, which can be explained as follows [16].

- Changes resulting in the chemistry of groundwater is unclear because of the dissolution of weathered silicate minerals generally run very slowly. This is evident from all samples of groundwater that show the small amount of content of silicate.

- In many siliciclastic rocks area, effect of silicate weathering on groundwater chemistry is usually mainly the addition of cations and silica.

- The disappearance sequence of silicate minerals indicates differences in the dissolution rate. In accordance with the Goldich sequence of weathering (1938, in [16]), feldspar is more easily weathered than quartz, then feldspar mineral is more possibly supply of silica in groundwater than quartz.

The chemical content in groundwater is strongly influenced by mineral solubility [10]. This is, of course, depends on their mineral stability. The dominant soluble minerals in the area are feldspar and carbonate minerals. The other silicate minerals can support the chemical content of groundwater due to leaching that occurs in quite a long time. Thus, the characteristics of the groundwater facies are heavily influenced by rock.

Volcanic rocks at the Samigaluh area are pyroclastic or volcanoclastic rocks. Leaching in these volcanic sedimentary rocks (especially from its matrix) will affect the composition of the groundwater for their soluble component [17]. TDS depends on the material of rocks. Low TDS in groundwater can be caused by rainwater. The arenite sandstone may result many elements of Mg²⁺, Ca²⁺, Na⁺, SO₄²⁻ dan Cl⁻ in groundwater.

The effect of rocks on hydrochemical facies is also supported by a method that connects ionic concentrations with TDS. Figure 9 shows a plot of groundwater chemical data that falls on rock dominance and mineralization fields [18]. This reinforces the prediction of the influence of rocks on the hydrochemical facies and the effect of mineralization due to ground-rock ground interaction.

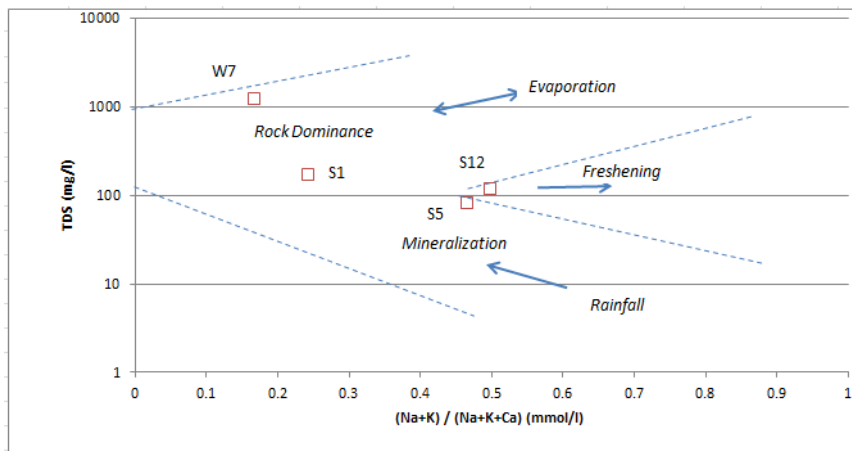


Figure 9. Plot data in Gibb's diagram show rock dominance and mineralization as a major process of hydrochemical in research area.

5. Conclusion

Groundwater in the research area is dominated by bicarbonate types, although there was anomalous of sulfate type can be found at well in Ngaranduo. The hydrochemical types develop as Ca-HCO_3 , Ca , Na , Mg-HCO_3 and Ca,Na-HCO_3 , and Ca,Mg-SO_4 . The other characteristics show neutral pH (5,7 – 7) and low TDS (freshwater) although in laboratory it was found brackish water at Ngaranduo well. The dominant hydrochemical process is ion exchange, in addition to simple dissolution or mixing that may become from any pollution.

The study area dominantly consists of volcanoclastic rocks. Some of the mineral content of the rocks are soluble easily in groundwater as a result of the weathering process. The content of cations and anions in the groundwater is affected by the composition of the minerals that compose the rock. The number of elements Ca^{2+} , Na^+ , and silica in the groundwater is affected by the weathering of silicate minerals such as feldspar, plagioclase and clay minerals which derived from weathering minerals.

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