doi: 10.34312/jgeosrev.v5i2.14866 ejurnal.ung.ac.id/index.php/jgeosrev

Vol. 5, No. 2, July 2023: 98-108

Jambura Geoscience Review

p-ISSN 2623-0682 | e-ISSN 2656-0380

Department of Earth Science and Technology, Universitas Negeri Gorontalo

Assessment of Hydrochemical Facies on Groundwater Quality in Daenaa Village and its Surroundings, West Limboto District

Dela Pusfika Sari Napu[1], Fitryane Lihawa[2], Ahmad Zainuri[1]

[1]*Geological Engineering Study Program, Universitas Negeri Gorontalo, Gorontalo, Indonesia*
[2]*Department of Earth Science and Technology, Universitas Negeri Gorontalo, Gorontalo, Indonesia*

ARTICLE INFO

Article history:
Received: 13 June 2022
Accepted: 12 July 2023
Published: 25 July 2023

Keywords:
Chemical Facies; Groundwater Quality; Lithology

Corresponding author:
Fitryane Lihawa
Email: fitryane.lihawa@ung.ac.id

ABSTRACT

The study is required to evaluate the groundwater condition, such as finding the relationship with the lithology, determining the facies of groundwater, and providing an overview of the present groundwater conditions, genetics, and groundwater quality. This study aims to explain the relationship between lithology and groundwater chemistry, groundwater quality, and the determination of the chemical facies of groundwater to determine the genetic type of groundwater. This study uses field survey methods and random sampling techniques, measurements of groundwater physical properties, trilinear piper diagrams, and laboratory analysis in the form of rock geochemical analysis (XRF) at the PSDMBP Laboratory and chemical analysis of groundwater at the PT Global Quality Analytical Laboratory. The results show that the lithology in the study area consists of clastic limestone, sandstone, breccia, and dacite. Lithology in the study area primarily plays an essential role in chemical ion enrichment in groundwater. Determination of groundwater quality is based on Permenkes, Permen ESDM, and ISDW, which obtained eleven well points in the good quality category, five well points in the poor quality category, and four other well points categorized as poor quality. Based on the analysis results in the trilinear piper diagram, there is one type of groundwater chemical facies (not varied), namely the Ca-Cl type facies. The presence of the Ca-Cl facies type is interpreted as a seawater intrusion phase.

How to cite: Napu, D. P. S., Lihawa, F., & Zainuri, A. (2023). Assessment of Hydrochemical Facies on Groundwater Quality in Daenaa Village and its Surroundings, West Limboto District. *Jambura Geoscience Review, 5*(2), 98-108. doi:https://doi.org/10.34312/jgeosrev.v5i2.14866

1. INTRODUCTION

Water is the main source of life, even as a natural resource for the livelihood of many people. All living things need water, so their existence must be maintained and utilized (Lihawa & Mahmud, 2017). Humans need water for their life needs, such as drinking, bathing, washing, etc. Water also undergoes a circulation called the water cycle or the hydrological cycle, which occurs naturally. One of the main sources of water that humans often use is groundwater. Groundwater is a water source located below the earth's surface and fills the pores of the soil or rock layers (Handayani et al., 2020). However, when too much accumulates in the soil, in certain conditions and situations, it will experience landslides due to water seepage and will affect the clarity of the groundwater itself, for example, in unstable lithology conditions, which are one of the controllers for landslides (Hutagalung, 2013). Groundwater is also an important element to meet life's needs. This water demand is principally sourced from the groundwater content utilized through springs or shallow wells (Zainuri, 2007).

Gorontalo Province is grouped into three morphological units, namely the mountainous morphological units with steep slopes which occupy the central and northern parts of the Gorontalo region which form the boundary between the east and north of the Limboto groundwater basin, this area generally consists of acid and intermediate igneous rocks, while sedimentary rocks sourced from volcanoes (Manyoe, 2018, 2019) as well as the presence of limestone around the Limboto Lake Region (Permana et al., 2021), then the undulating hill morphological unit that occupies the southern and western parts of the basin which are the boundaries of the basin to the south and north, as well as the plains morphological unit that occupies the lowland area in the central part of the Limboto Basin Region, namely, around Lake Limboto which is a marine depositional zone, transition and terrestrial as evidenced by the presence of deposits characteristic of marine, transitional and terrestrial depositional environments (Amin et al., 2019).

Based on previous research by Usman (2020), the lithology in the Daenaa area consists of reef limestone units, clastic limestones, and igneous rocks. However, this study has not discussed groundwater conditions in the area by relating the lithological conditions. Therefore, research is needed to determine the groundwater condition, such as determining the relationship with the lithology determining the facies of groundwater, which will provide an overview of the existing groundwater conditions, genetics, and groundwater quality. The benefit is that it can be a reference to controlling the use of water demand in the research area for household needs and other purposes.

This study aimed to conduct a field survey by seeking information on lithology data, measuring the physical properties of groundwater, and geochemical analysis in the laboratory in the form of groundwater and rock geochemistry. The purpose of this research was to explain the relationship between lithology and the chemical elements of groundwater in the study area, to analyze the quality of groundwater based on the physical and chemical properties of groundwater in the study area, and to determine the chemical facies types of groundwater in the study area.

2. METHOD

2.1. Research Sites

The astronomical research area is located at coordinates 0° 41' 10.10" - 0° 41' 10.20" N and 122° 54' 05.03" – 122° 54' 05.26" E. The research location is administratively located in Daenaa Village, West Limboto District, Gorontalo Regency, Gorontalo Province. The research area can be accessed using two-wheeled or four-wheeled motorized vehicles at a distance of ± 30.3 km in an estimated time of 44 minutes. Based on the geographical conditions, the study area is bordered by North Gorontalo Regency in the north, Tabongo District in the south, Limboto District and Gorontalo City in the east, and Tibawa District in the west (Figure 1).

2.2. Tools and Materials

Conducting this research required tools and materials as supporting research materials. The tools and materials used in this study were divided into two parts: those used for geological surveys and those used for water samples. The tools used for the geological survey are a geological hammer, a geological compass, and a magnifying lens (30X loupe), while the materials used are a 1:10.000 scale topographic map and a sample bag. The tools used for water samples are GPS, water sample data filling sheets, meter rolls, clear tape, water storage containers, water samplers, small water funnels, cool boxes, permanent markers, and rubber gloves (handscoons) while the materials used for water sample is ice cubes.

2.3. Data Collection

The primary data obtained is from lithological survey data, measurement of the physical properties of groundwater, and groundwater sampling. The lithology survey was carried out by taking four rock samples around the residents' wells to be linked to the chemistry of the groundwater to be analyzed. Measurement of the physical properties of groundwater was carried out by taking in-situ data in the form of temperature (°C), pH, Daya Hantar Listrik (Electrical Conductivity henceforth called DHL/EC), and Total Dissolve Solid (TDS) data in the study area. Groundwater sampling was carried out by taking groundwater samples from the research

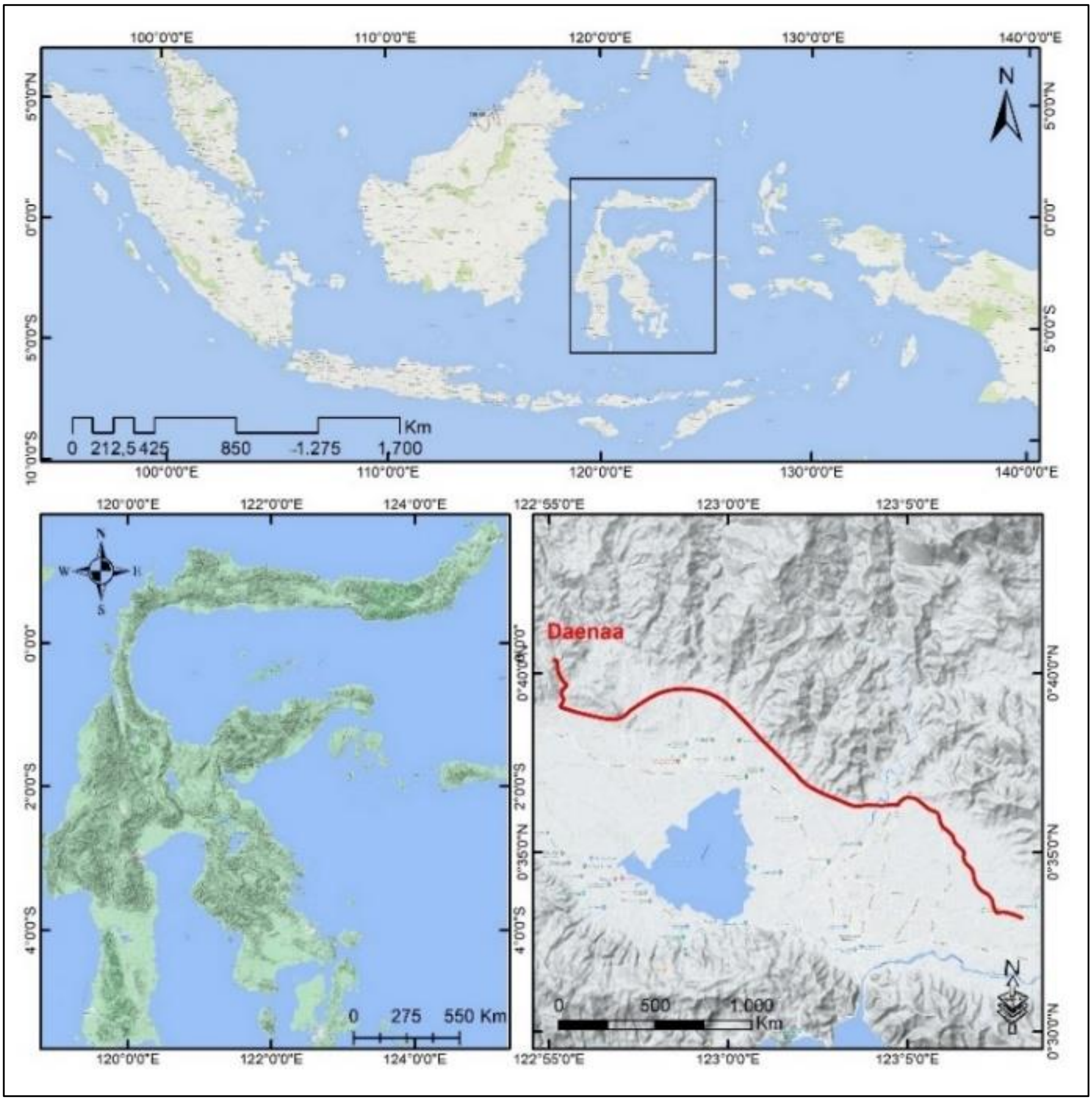

Figure 1. Research location map

area totaling six dug wells with 600 ml of groundwater each, then examined in the laboratory to determine the condition of the geochemical levels of groundwater in the dug wells. Sampling of groundwater in the field using random sampling techniques.

Secondary data analysis was obtained from previous researchers' Regional Geological Maps and Geological Maps. Regional Geological Map obtained according to Apandi & Bachri (1997). Geological Map of Kotamobagu Sheet. Sulawesi Scale 1:250.000. Bandung: Geological Research and Development Center. Meanwhile, the Geological Map of the previous researcher was obtained from a thesis by Usman (2020).

2.4. Laboratory Analysis: Rock and Groundwater Chemistry

Laboratory analysis was obtained in the form of rock geochemical analysis at the Pusat Sumber Daya Mineral Batubara dan Panas Bumi (Center for Mineral, Coal, and Geothermal Resources, henceforth called PSDMBP) to determine the levels of the main elements contained in the rock. Analysis and interpretation of the results of the analysis of the chemical composition of XRF rocks was carried out using the analytical method, namely Petrograph. The second analysis is the chemical analysis of shallow groundwater at the PT Global Quality Analytical Laboratory to determine the type of chemical facies of groundwater on groundwater quality.

Table 1. Source of some ions in water (Todd, 1980).

Ions	Source of minerals
Ca^{2+}	Amphibole, feldspar, gypsum, pyroxene, aragonite, calcite, dolomite, clay minerals
Mg^{2+}	Amphibole, olivine, pyroxene, dolomite, magnesite, clay minerals
Na^{+}	Feldspar (albite), clay minerals, halite, mirabilite, and industrial waste
K^{+}	Feldspar (orthoclase and microcline), feldspathoids, mica, clay minerals
HCO_3^{-}	*Limestone*, dolomite
SO_4^{2-}	Sulfide oxidation, gypsum, anhydrite
Cl^{-}	The main source of evaporites, minor sources of igneous rock

Groundwater samples for the chemical properties of groundwater will be analyzed based on the cation-anion element parameters, which include the major elements in groundwater. The elements analyzed ion concentrations of Sodium (Na^+), Potassium (K^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Bicarbonate (HCO_3^-), and Carbonate (CO_3^{2-}), Chloride (Cl^-) and Sulfate (SO_4^{2-}). Then, the analysis and interpretation of the results of the analysis of the chemical composition of groundwater is carried out using the analytical method, namely the Piper diagram.

2.5. Data Analysis

Data processing was carried out after data collection and laboratory analysis had been completed. Data analysis in this study was initiated by analyzing the relationship between lithology and groundwater chemistry, groundwater quality, and facies types of groundwater chemistry. The following are the stages of data analysis as follows:

2.5.1. Analysis of Lithology's Relationship with Groundwater Chemistry

At this analysis stage, lithology data obtained from the field is used. The lithology data is then linked to chemical elements or compounds in groundwater obtained from the groundwater chemical laboratory analysis results. The results of this analysis are to find parameters related to lithology in the research area, using the classification table from Todd (1980) as general information for interpreting the relationship between lithology and groundwater chemistry. This analysis is also assisted by rock geochemical analysis (XRF) results.

2.5.2. Groundwater Quality Analysis

At this stage, the parameters of the physical and chemical properties of groundwater are used to determine the quality of groundwater in the research area based on the Peraturan Menteri Kesehatan (Minister of Health regulations, henceforth called Permenkes) Number 492 of 2010 concerning the quality of drinking water, Peraturan Menteri Energi dan Sumber Daya Mineral (Minister of Energy and Mineral Resources Regulation, henceforth called Permen ESDM) Number 31 of 2018 concerning guidelines for establishing groundwater conservation zones, and the International Standard for Drinking Water (henceforth called ISDW) (WHO, 1971).

2.5.3. Facies Type Analysis of Groundwater Chemistry

At this stage, the analysis methodology is used, namely by using the trilinear piper diagram (Piper, 1944), which is a method for determining the chemical facies of groundwater, or a diagram commonly used to see the chemical facies in groundwater.

Data from laboratory analysis uses the mg/L unit, while data that must be input into the Piper diagram uses the meq/L unit. Therefore, the formula used to convert data from mg/L to meq/L can be seen in the formula below, as follows:

$$\text{Concentration (meq/L)} = \frac{\text{Concentration (mg/L)}}{\text{Ion Equivalent Weight}}$$

where,

$$\text{Ion Equivalent Weight} = \frac{\text{Relative Atomic Weight}}{\text{Ion Valence}}$$

Or based on Table 2.

The converted data is then plotted into a trilinear piper diagram using Grapher software. In the Piper diagram, there are two equilateral triangles at the bottom; namely, the triangle on the

Table 2. Value of the equivalent weight of each ion (Matthess, 1982)

Ions		Conversion rate
Cation	Na^+	22.99
	K^+	39.10
	Ca^{2+}	20.04
	Mg^{2+}	12.16
Anions	Cl^-	35.45
	SO_4^{2-}	48.04
	HCO_3^-	61.02
	CO_3^{2-}	30.01

Table 3. Results of XRF analysis of lithology samples

No.	Sample code	Parameters (%)												
		SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	SO_3	HD	H2O
1	DN 001 (ST 1)	36.23	11.34	5.86	2.97	24.50	0.88	0.38	0.64	0.05	0.11	0.02	16.15	1.39
2	DN 002 (ST 2)	53.25	19.88	6.46	3.58	3.23	0.57	0.63	0.91	0.06	0.07	0.01	10.76	2.97
3	DN 005 (ST 5)	8.13	2.55	1.51	0.58	45.62	0.04	0.08	0.16	0.03	0.05	0.01	40.48	0.82
4	DN 006 (ST 6)	63.47	14.01	5.00	2.65	5.65	2.94	1.77	0.63	0.13	0.12	0.01	3.21	0.29

left is a cation consisting of Ca^{2+} (Calcium), Mg^{2+} (Magnesium), Na^++ K^+, and the triangle on the right is an anion consisting of Cl^- (Chloride), SO_4^{2-} (Sulfate) and HCO_3^-+CO_3^{2-}.

At the top of the two triangles is a parallelogram (rhombus), a merger of the plotted points on cations and anions. Before starting the analysis, the data plotted was divided into six classes because six water samples were analyzed, and each class was distinguished by symbol and color. After that, the facies type is determined based on the shape of the rhombus. The data that has been plotted is then seen to determine which classes are included in a particular facies type and recorded how many facies are obtained.

3. RESULTS AND DISCUSSION

The lithology conditions of an area determine the hydrogeological conditions of the area. In the research area, lithology was obtained as limestone and dacite. This was seen based on the lithological distribution of the Geological Map of the previous researcher by Usman (2020).

3.1. Analysis of Lithology's Relationship with Groundwater Chemistry

The relationship between rock and groundwater chemistry is based on Todd's classification (1980) and reinforced by rock XRF geochemical data (Table 3), then compared with groundwater chemical data. Based on the table from Todd (1980) (Table 1), the relationship between lithology and chemical compounds owned by groundwater shows a small Ca^{2+} element content and has a range of values ranging from 3.67 – 5.86 mg/L. It is interpreted that this element originates from the dissolution of plagioclase minerals with a low percentage of Ca^{2+} elements, such as andesine and oligoclase, or the dissolution of calcite minerals in carbonate sedimentary rocks.

The highest element of Calcium (Ca^{2+}) is found in the DN 01 water sample and the lowest in the DN 02 water sample. This element is related to the presence of lithology in the study area: sandy limestone carbonate sedimentary rock lithology because it is close to the DN 01 water sample (Figure 2). In general, carbonate sedimentary rocks contain elements of Ca^{2+}, namely calcite. This is evidenced by the Ca^{2+} content in the XRF geochemistry of sample rock DN 001 which has a CaO percentage of 24.50%. In addition, the elements Na and K in the DN 01 groundwater sample were very small, and the data on the XRF results also showed very few K_2O and Na_2O compounds, namely 0.38% K_2O and 0.88% Na_2O.

Based on the explanation above, it can also be strengthened by the Geological Map of the previous research area that where the lithology obtained in the research area is in the form of carbonate sedimentary rocks, it is still included in the geological unit of clastic limestone or more

doi: 10.34312/jgeosrev.v5i2.14866 ejurnal.ung.ac.id/index.php/jgeosrev

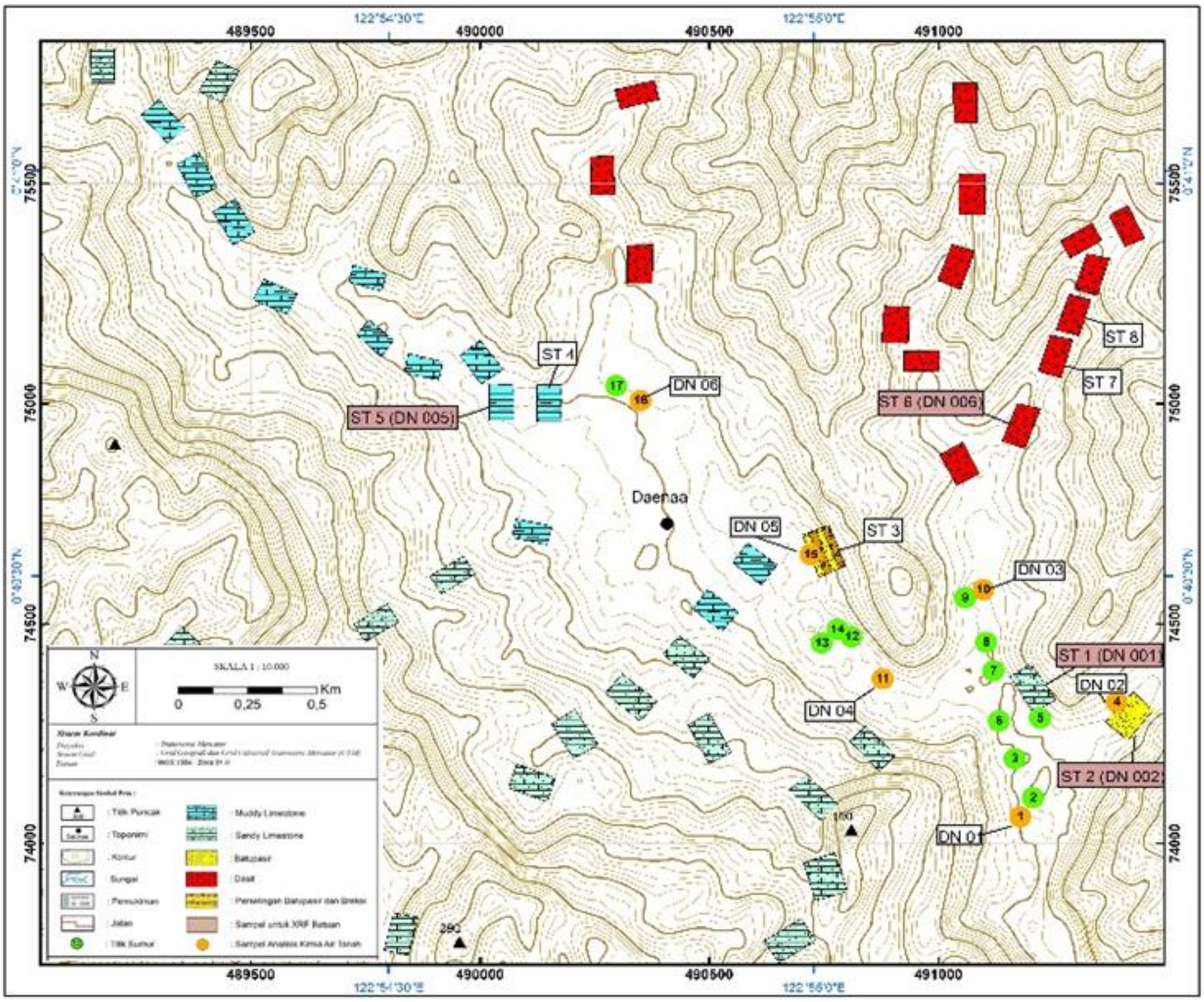

Figure 2. Map of distribution of lithology and well points

or less the same distribution of lithology as the Geological Map of the research area by Usman (2020), this can be seen in Figure 3.

According to Todd (1980), Magnesium (Mg) comes from the minerals mica, amphibole, pyroxene, and olivine, whereas it is obtained in compounds with carbonates in sedimentary rocks. The laboratory analysis results showed that the levels of magnesium compounds were slightly in the range of 0.70 – 0.83 mg/L. This can be seen in the value of the Mg compound content, which is at the water sample point code DN 02 and the water sample point code DN 01. This is compared with the closest lithology, namely, at the XRF geochemical sample code DN 001 (Calkerenit) and XRF geochemical sample code DN 006 (Dasit) (Figure 2). Thus, the XRF geochemistry results showed that the MgO content in calkerenite was 2.97%, and in dacite, it was 2.65%. These results show that the Mg^{2+} content still comes from dacite and calkerenite lithology.

Chloride (Cl) in the study area showed levels ranging from 11.40 – 20.29 mg/L. The lowest content point is at the DN 03 water sample point, and the highest is at the DN 01 water sample point. According to Todd (1980), groundwater's element Chloride (Cl) originates from the seawater intrusion phase, precipitation, water pollution, or rock contact. In the research area, lithology that has the potential to contain Cl elements was not found, but the low Cl ions in the study area are likely from the seawater intrusion phase or maybe just domestic waste pollution such as used dishwashing waste, and so on.

Sulfate content (SO_4^{2-}) shows levels ranging from 1.53 – 3.41 mg/L. According to Todd (1980), these compounds are generally mainly sourced from sedimentary and igneous rocks with metal sulfide minerals (sulfide metal). This is reinforced that the research area has igneous rocks in the form of dacite, with a pyrite mineral. The carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) content in the study area showed very low levels. It likely originated from dissolving the

doi: 10.34312/jgeosrev.v5i2.14866

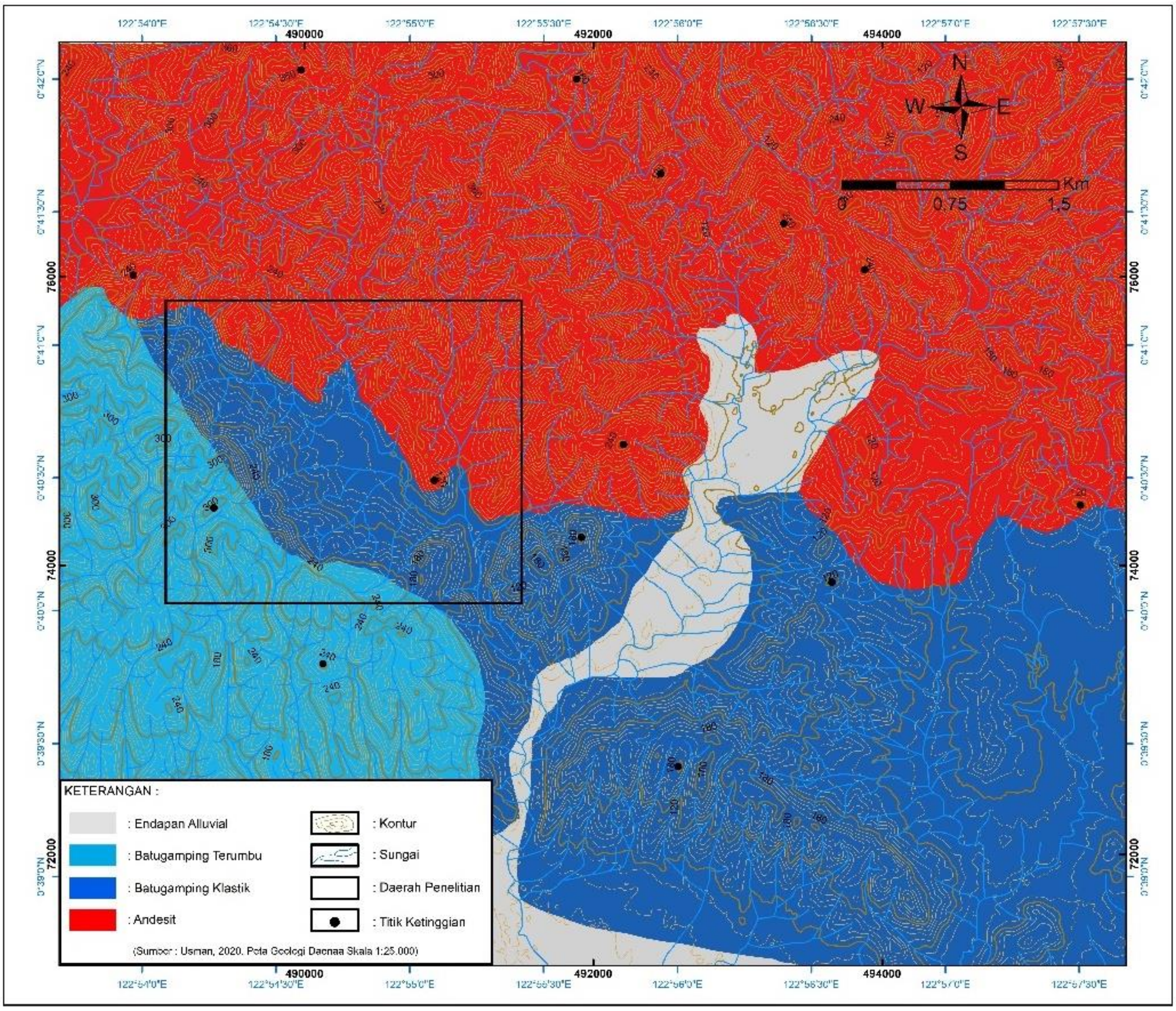

Figure 3. Geological map of the study area by Usman (2020)

surrounding limestone, and most of it decomposed and seeped into the groundwater. According to Afitha et al. (2013), low bicarbonate is caused by weather or seasonal factors. During the rainy season, bicarbonate ions will continue to decompose from HCO_3^- to H^+ + CO_3^{2-}, so the bicarbonate content is less. Bicarbonate is also directly proportional to the DHL/EC value. The bicarbonate content will also be low if the DHL/EC value is low. In the research area, DHL/EC levels are still classified as low – moderate or less than <2000 μs.

3.2. Groundwater Quality Analysis

The purpose of determining groundwater quality is to keep the community from consuming drinking water or for other needs according to applicable standards so that public health will also be maintained. Determination of groundwater quality in the study area is based on observations of groundwater's physical and chemical properties originating from laboratory analysis based on the applicable water quality standards based on Permenkes Number 492 of 2010, Permen ESDM Number 31 of 2018, and ISDW.

Based on the table of well measurement data in the study area (Table 4), the physical properties of TDS show that four points do not match the maximum standard values of Permenkes Number 492 of 2010, namely at well point 2, well point 4, point of well 6, and point of well 7 which has exceeded the level of 500 mg/L. The pH of groundwater in the study area has a value range of 7.6 to 9.1. Based on Permenkes Number 492 of 2010, the applicable standards are in the pH category of 6.5 to 8.5. Therefore, the observation station points on the lithology distribution map and well points (Figure 2) which have a pH above 8.5, namely at well points 1, 2, 3, 4, 6, 7, 8, 12, and 14, cannot be categorized it as clean water for drinking, because in general, it will make the chemical compounds present in the human body turn into poisons that can harm health. However, wells 5, 9, 10, 11, 13, 15, 16, and 17 are still safe for drinking water. The DHL/EC value shows the total ion concentration in groundwater, where the higher the DHL/EC, the higher the total dissolved ions in groundwater and the lower the groundwater quality. In the study area, the value range is 852 to 1092. Based on the Permen ESDM Number 31 of 2018 (Table 5), the DHL/EC for groundwater quality in the study area is categorized as safe, which can be seen in Table 5, namely at well points 1, 3, 5, 6, 8, 9, 10, 12, 13, 14, 15, 16, 17 and the vulnerable category is at well points 2, 4,7 and 11.

The chemical parameters analyzed for groundwater quality based on Permenkes Number 492 of 2010 are the content of Chloride (Cl^-), Sulfate (SO_4^{2-}), Sodium (Na^+), Bicarbonate (HCO_3^-), Calcium (Ca), Magnesium (Mg), and Potassium (K). The data in Table 6 shows a Cl^- concentration of 11.4-20.29 mg/L fulfilling the requirements because the maximum level is 300 mg/L. SO_4^{2-} concentration of 1.53-3.41 mg/L meets the requirements because the top level is 300 mg/L. Na^+ concentration of 1.09-1.47 mg/L. They still meet the stipulated requirements for Ca^+ and Mg^+ based on the ISDW. Ca^{2+} content of 3.67-5.86 mg/L and Mg of 0.70-1.28 mg/L qualifies because the maximum levels of Ca^+= 200 mg/L and Mg^+= 150 mg/L. The results of groundwater quality analysis are then connected with the presence of lithology in the study area. Points with good groundwater quality are in limestone; poor and bad quality is in dacite and sandstone. Thus, the lithology of carbonate sedimentary rocks plays an important role in controlling good groundwater quality in the study area.

3.3. Facies Type of Groundwater Chemistry

To determine the chemical content of groundwater in the study area, a

Table 4. Measurement of well data

Wells	Coordinate		Description of insitu measurement results				Elevation (masl)	Height MAT (m)	Elevation MAT	Description
	Latitude	Longitude	°C	pH	DHL/EC	TDS				
1	0°40'12.2"	122°55'14.6"	35.5	9.1	876	500	45	3.27	41.73	DN 01
2	0°40'13.6"	122°55'15.5"	34.4	8.6	1042	544	46	4	42	
3	0°40'16.5"	122°55' 14.2"	32.8	8.6	996	498	46	5	41	
4	0°40'20.7"	122°55' 21.4"	32.1	8.7	1046	523	53	2.70	50.30	DN 02
5	0°40'19.5"	122°55'16.0"	33.2	7.8	852	423	46	5	41	
6	0°40'19.3"	122°55'13.1"	31.7	8.8	962	505	49	8	41	
7	0°40'23.0"	122°55'12.7"	28.9	9.0	1092	544	50	7	43	
8	0°40'25.1"	122°55'12.2"	35.7	8.8	878	434	51	13	38	
9	0°40'28.4"	122°55' 10.7"	34.6	8.2	900	450	54	15	39	
10	0°40'29.0"	122°55' 12.0"	33.4	8.3	916	458	52	5.75	46.25	DN 03
11	0°40'22.4"	122°55' 04.9"	31.5	7.8	1036	458	54	3.5	50.50	DN 04
12	0°40'25.2"	122°55'02.7"	32.5	8.9	966	483	56	4.10	51.90	
13	0°40'24.8"	122°55' 00.6"	30.2	8.2	996	496	54	3.53	50.47	
14	0°40'26.3"	122°55' 01.7"	29.6	8.7	920	477	56	4.09	51.91	
15	0°40'31.6"	122°54' 59.8"	32.0	7.7	830	415	62	4.46	57.54	DN 05
16	0°40'43.0"	122°54' 47.8"	29.0	7.6	912	456	72	3.89	68.11	DN 06
17	0°40'44.1"	122°54'46.1"	30.9	7.8	905	450	70	2	68	

chemical analysis of groundwater was carried out according to the water sample data required for laboratory analysis, totaling six well water samples in the study area. The chemical research of groundwater is focused on the main elements consisting of Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na+), Potassium (K^{+}), Chloride (Cl^{-}), Bicarbonate (HCO_3^{-}), and Carbonate (CO_3^{2-}), as well as Sulfate (SO_4^{2-}).

Based on the results of the analysis and interpretation using the Piper diagram, the chemical facies of groundwater in the study area can only be grouped into 1 type of chemical facies of groundwater, namely: Ca-Cl (Calcium-chloride) facies in all water sample codes DN 01, DN 02, DN 03, DN 04, DN 05 and DN 06. Based on the results of the Piper diagram plot, it shows that in the study area, the enrichment of Ca^{2+} ions is dominated in the study area, while the anion values are dominated by Cl- ions. The Ca-Cl facies dominates in the study area (Figure 4a).

The presence of Ca-Cl facies, according to Gimenez & Morell (1997), is still related to the seawater intrusion phase, but it is not intense, and there has been mixing between fresh water and seawater so that there is a significant addition of Ca^{2+} concentrations. Based on the presence of the dominant calcium cation (Ca^{2+}), it can be concluded that this massive flow system is local. The influence or impact of rocks on groundwater is still relatively minimal.

When seawater influx occurs in coastal aquifers, the hydrochemical facies evolves from the Ca-HCO_3^{-} facies to the Na-Cl facies through intermediate Ca-Cl facies and other sub-facies that characterize intrusions (Akakuru et al., 2021). This intrusive phase is associated with a reverse cation exchange process simulated by sodium-rich seawater.

According to Gemilang et al. (2019), the presence of Cl^{-} elements in each type of groundwater is due to

Table 5. Results of groundwater quality analysis based on physical parameters

Well point	Results description insitu measurement				Elevation (mdpl)	Height MAT (m)	Location	Desc.	Quality
	°C	pH	DHL /EC	TDS					
1	35.3	9.1	876	500	45	3.27	Daenaa	DN 01	Less Good
2	34.4	8.6	1042	544	46	4	Daenaa		Bad
3	32.8	8.6	996	498	46	5	Daenaa		Less Good
4	32.1	8.7	1046	523	53	2.7	Daenaa	DN 02	Bad
5	33.2	7.8	852	423	46	5	Daenaa		Good
6	31.7	8.8	962	505	49	8	Daenaa		Bad
7	28.9	9.0	1092	544	50	7	Daenaa		Bad
8	35.7	8.8	878	434	51	8	Daenaa		Less Good
9	34.6	8.2	900	450	54	7	Daenaa		Good
10	33.4	8.3	916	458	52	5.75	Daenaa	DN 03	Good
11	31.5	7.8	1036	458	54	3.5	Daenaa	DN 04	Good
12	32.5	8.9	966	483	56	4.1	Daenaa		Less Good
13	30.2	8.2	996	496	54	3.53	Daenaa		Good
14	29.6	8.7	920	477	56	4.09	Daenaa		Less Good
15	32	7.7	830	415	62	4.46	Daenaa	DN 05	Good
16	29	7.6	912	456	72	3.89	Daenaa	DN 06	Good
17	30.9	7.8	905	450	70	2	Daenaa		Good

Table 6. Results of groundwater quality analysis based on chemical parameters

No.	Parameters	Location code					
		DN01	DN02	DN03	DN04	DN05	DN06
1	Cl^-	20.29	13.11	11.4	19.8	12.87	13.61
2	SO_4^2	2.08	1.53	2.10	3.41	1.85	1.87
3	CO_3^{2-}	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	HCO_3^-	0.07	0.04	0.05	0.05	0.04	0.04
5	Ca^{2+}	5.86	3.67	4.74	5.16	4.09	4.25
6	Mg^{2+}	0.70	0.83	1.28	1.02	1.05	1.07
7	K^+	2.72	2.62	2.65	4.34	1.86	3.56
8	Na^+	1.09	1.22	1.26	1.47	1.11	1.11

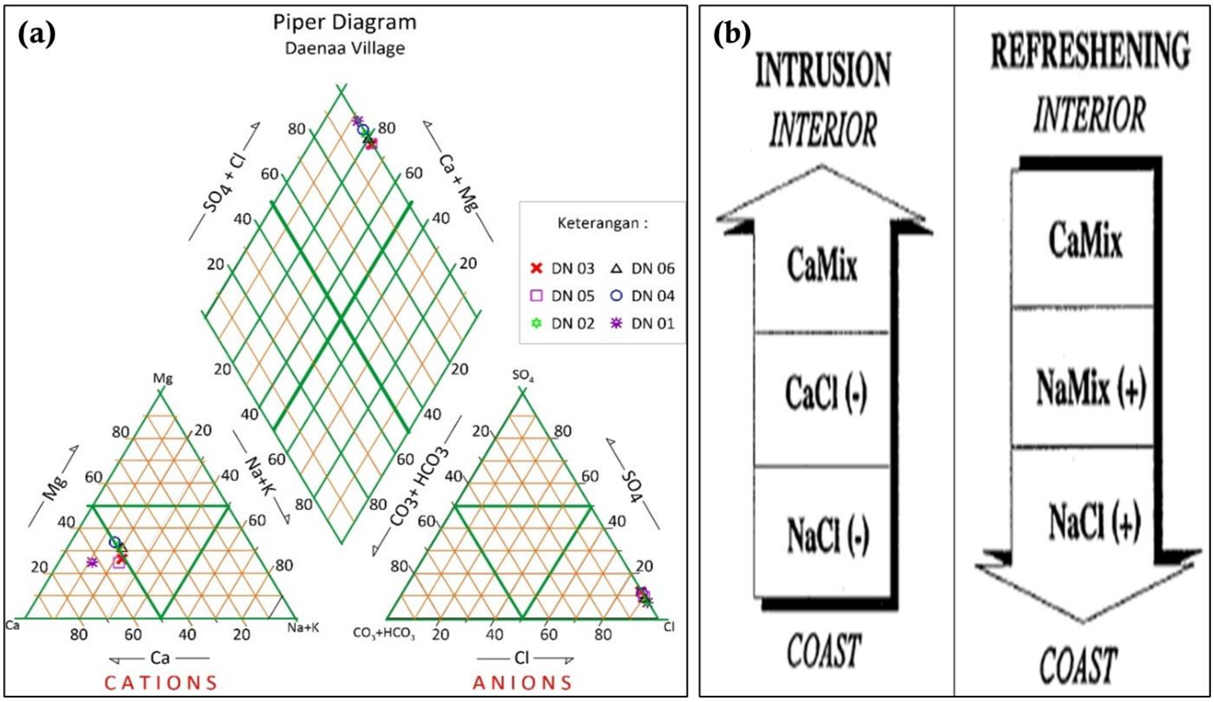

Figure 4. a) The results of plotting the chemical facies types of groundwater in the study area; b) Groundwater hydrochemical facies in the form of seawater intrusion (Gimenez & Morell, 1997)

Na-Cl elements sourced from seawater. The seawater intrusion phase in the study area does not cause TDS or DHL/EC to become saline or brine because they are far from the sea; it is different when they are close to the coast, the higher the salinity value of the water.

This is based on Figure 4b below, which explains that the seawater intrusion phase means that seawater penetrates the land, and the deeper it gets, the more it will mix with groundwater. If it continues, the content becomes CaMix, or there is no dominant seawater and no dominant groundwater, or it is said that the water has been contaminated, called ancient water. This can be compared with the results of the water and rock geochemistry analyses, which can be seen in Table 3. Therefore it can be concluded that the study area is in the transition zone, namely in the CaCl facies zone with low levels of CaCl.

4. CONCLUSIONS

Most of the lithology in the study area plays an important role in the enrichment of chemical ions contained in groundwater, such as the content of Ca^{2+}, Mg^{2+}, SO_4^{2-}, K^+, Na_2^+, CO_3^{2-} and HCO_3^- and a small part due to seawater intrusion factors or domestic waste pollution factors such as ions Cl^-. The study area's groundwater quality based on physical and chemical parameters still meets the maximum standards issued by Permenkes Number 492 of 2010, Permen ESDM Number 31 of 2018, and ISDW. Based on the results of groundwater quality analysis using the lithology of the study area, it can be concluded that limestone also plays an important role in controlling good groundwater quality. Based on the analysis results on the trilinear piper diagram, the types of groundwater facies in the study area are divided into one chemical facies of groundwater, namely the Ca-Cl (Calcium-Chloride) facies.

5. ACKNOWLEDGMENTS

The author would like to thank the laboratory of PSDMBP and the PT Global Quality Analytical Laboratory for helping to provide support and legality in the form of analysis of the results of rock geochemistry and groundwater geochemistry data for this research.

6. REFERENCES

Afitha, A. D., Haryono, E., & Wacano, D. (2013). Variabilitas Harian Bikarbonat (HCO3) yang Terlarut dalam Air pada Mata Air Karst di Kecamatan Ponjong, Kabupaten Gunung Kidul. *Ekologi Lingkungan Kawasan Karst Indonesia: Menjaga Asa Kelestarian Kawasan Karst Indonesia*, 27-40.

Akakuru, O. C., Akudinobi, B., Opara, A. I., Onyekuru, S. O., & Akakuru, O. U. (2021). Hydrogeochemical facies and pollution status of groundwater resources of Owerri and environs, Southeastern Nigeria. *Environmental Monitoring and Assessment*, *193*(10), 1-26.

Amin, A.K.M.A., Arifin, Y. I., & Akase, N. (2019). Studi fasies formasi endapan danau untuk menentukan lingkungan pengendapan danau limboto. *Jambura Geoscience Review*, *1*(2), 50-67.

Apandi, T., & Bachri, S. (1997). *Peta Geologi Lembar Kotamobagu*. Sulawesi Skala 1:250000. Bandung: Pusat Penelitian dan Pengembangan Geologi.

Gemilang, W. A., Hasanah, N. N., & Wish, U. J. J. (2019). Karakteristik Hidrogeokimia Akuifer Tak Terkekang Kawasan Pesisir Pulau Weh, Aceh. *Jurnal Sumber Daya Air*, *15*(1), 27-38.

Gimenez, E., & Morell, I. (1997). Hydrogeochemical analysis of salinization processes in the coastal aquifer of Oropesa (Castellon, Spain). *Environmental geology*, *29*(1), 118-131.

Hutagalung, R. (2013). Analisis Gerakan Tanah Pada Batuan Granite Daerah Leato Provinsi Gorontalo (Doctoral dissertation, Universitas Hasanuddin).

Handayani, W. K., Setyaningsih, W., & Sanjoto, T. B. (2020). Sebaran Dan Potensi Air Tanah Dangkal di Perbukitan Dome Sangiran dalam Pemenuhan Kebutuhan Air. *Geo-Image*, *9*(1), 49-56.

Lihawa, F., & Mahmud, M. (2017). Evaluasi karakteristik kualitas air Danau Limboto. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *7*(3), 260-266.

Manyoe, I. N. (2018). Model inversi data geolistrik untuk penentuan lapisan bawah permukaan daerah panas bumi Bongongoayu, Gorontalo. *ARTIKEL*, *1*(897).

Manyoe, I. N. (2019). Geologi dan Manifestasi Thermal Libungo. *ARTIKEL*, *1*(4323).

Matthess, G. (1982) The Properties of Groundwater. *Department of Environmental Science, John Wiley and Sons Inc.*, New York, 406 p.

Permana, A. P., Kasim, M., & Mamonto, F. K. (2021). Analisis Lingkungan Purba Batugamping Daerah Limboto Barat Kabupaten Gorontalo. *Jurnal Geosapta*, *7*(2), 97-102.

Permen ESDM. (2018). Pedoman Penetapan Zona Konservasi Air Tanah. Permen ESDM RI No 31/MEN-ESDM/PER-BAB II/2018.

Permenkes. (2010). Kualitas Air Minum. Permenkes RI No 492/MENKES/PER-IV/2010.

Piper, A.M. (1944). *A Graphic Procedure in The Geochemical Interpretation of Water Analysis.* Trans, Am. Geophys. Union, Washington, D.C.

Todd, D.K. (1980). *Groundwater Hydrology*. Second Edition, John Wiley and Sons, New York.

Usman, F. C. A. (2020). Pengaruh Struktur Geologi terhadap Gerakan Tanah di daerah Daenaa dan Sekitarnya, Kabupaten Gorontalo, Provinsi Gorontalo. Skripsi, 1(471415002).

[WHO] World Health Organization. (1971). International Standards for Drinking-Water (ISDW).tots

Zainuri, A. (2007). Aplikasi metode resistitvitas dan simulasi aliran fluida untuk menganalisa fenomena intrusi air laut di daerah pesisir: Studi kasus di Pulau Sapeken, Madura (Master Thesis). *Central Library Institute Technology Bandung*.