

RESEARCH ARTICLE

Shallow Aquifer Groundwater Facies at Multiple Landuse Sites in Manglayang Volcanic Area, Jatinangor and Surroundings, Indonesia

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Abstract

Manglayang Mountain is generally composed by old and young volcanic materials. Older rocks are located around the northern part of mountain peak, in medial and distal parts. In the southern and southeastern parts composed by relatively young volcanic rocks starting from the proximal, medial to distal. These geologic conditions produce diverse aquifer systems. These differences in land use environments contribute to water quality conditions in local shallow aquifers. The research is therefore carried out in order to the effect of difference in land use environments on groundwater facies by dividing the area based on each land use. Land use in the research area is dominated by allotment of agricultural land, settlement, and industry. The study was conducted from the medial area to distal to the southern part of Manglayang Mountain, administratively including Sukasari, Jatinangor, and Rancaekek districts. To observe the groundwater conditions in the aquifer from the study area, physical and chemical parameters were tested. Chemical parameter test results were plotted using piper diagrams and Durov diagrams as a method that can illustrate the condition of groundwater facies. Physical characteristics of groundwater may reflect groundwater interactions with rocks. Measurable TDS concentrations of 48 - 299 mg / L and measured EC 100 - 1020 μ mhos / cm, show different interaction conditions between groundwater with rocks or have received different material subsidies. Similarly, the occurrence of temperatures that vary considerably between air and water indicates the distance of groundwater sources with various water bodies. The groundwater facies that developed in the research area are generally dominated by Ca, HCO₃ in the agricultural land use area, Mg, HCO₃ in the settlement area, and in some Cl-facing evolving places in the industrial land use zones. In addition, there are also indications of mixing of anions and cations in groundwater samples in all three land use areas. This indicates that there has been a change in groundwater characteristics in some areas of land use utilization in the research area

Keywords: *Volcanic aquifer, Manglayang Mountain, Landuse, Groundwater Facies*

1. Introduction

Bandung Geological map sheet describes the geology of regional research area, the rocks exposed in the research area consisted of only one geological unit, young volcanic product (Qy), which is an indivisible young volcanic sediment. This unit consists of sand tufa, lapilli, breccia, lava, and agglomerated stone. The rocks in this region form small plains and flat parts with low hills covered by yellow-gray and reddish soil. These rocks belong to the Quaternary volcanoes seen between Sumedang and Bandung (Silitonga, 2003).

Volcanic rock compiler of Jatinangor area resulted from Mount Tampomas and Mount Tangkuban Perahu sediment. Endogenous processes in the form of tectonic activity result in deformation of geological structures such as stocky and cesarean, while the exogenous process is influenced by various aspects such as wind, climate, temperature, rainfall, physical, chemical and biological. The geological conditions of the study area are formed by the volcanic releases of volcanic materials, loose, volcanic breccia, and lava known as strato type volcanoes, such conditions form a graded aquifer system from high elevation to low elevation. (Hadian, 2013).

Based on the distribution, the rock units in the study area can be divided into 8 units of volcanic rock products, which are Intrusion Andesite, Old Volcanic Pyroclastic Product I, Old Volcanic Pyroclastic Product II, Young Volcanic Pyroclastic Product I, Young Volcanic Pyroclastic Product II, Young Volcanic Product and Young Lake Sediment (Mardiana, 2013).

Jatinangor is located in the southern part of Manglayang Mountain which has various land use activities such as agriculture, housing, trade and industry services. Education and industrial areas in Jatinangor experiencing rapid physical development, many farming areas in Jatinangor change its function into rent for students or shopping areas; so, Jatinangor has 80% urban area characteristics (Bappeda Kabupaten Sumedang, 2009).

Groundwater conditions in Jatinangor region show a decreasing level, especially groundwater levels in shallow aquifers, allegedly due to an imbalance between the number of groundwater catchments and the amount of water absorbed into the soil. Increased demand for groundwater has led to a sharp increase in groundwater consumption so that shallow ground water conditions have always declined, especially near production wells. Exploited groundwater exceeds the amount of recharge and will reduce the volume

that will be seen in reducing groundwater levels or decreasing groundwater pressure (Hadian et al., 2013). If this condition continues, it leads to a breakthrough or inclusion of surface water into the water system into the groundwater (Takeda & Sosrodarsono, 2003)

The purpose of this study was to illustrate and analyze the various aspects of hydrogeochemical (groundwater quality) of Manglayang-shallow aquifer in various land use sites.

2. Research Methods

Groundwater samples were collected from springs and wells in residential areas on 15 different land use such as

agricultural areas, residential areas, and industrial estates. Samples were collected repeatedly during the dry and wet seasons and analyzed in PDAM Bandung Laboratory referring to Standard Methods for Water and Wastewater Inspection, 2012. Concentrations expressed in units of mg / L, converted to meq / L. Value of the concentration then plotted in Piper Trilinear Diagram to determine the type of groundwater facies. The values were also plotted in Durov diagrams to identify groundwater facies processes and groundwater mixing process in groundwater chemical evolution. The research method is presented in the following chart.

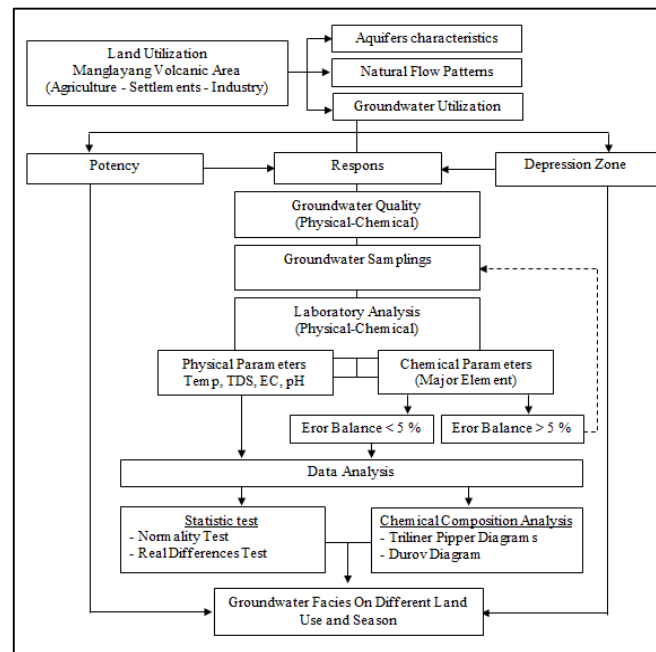


Fig 1. Research Methods Flowchart

3.1 Geology and Hydrogeology Condition

The study area covers the southern part of the Manglayang Mountain. The altitude of this area is 1220 meters above sea level in the north and 696 meters above sea level in the south. Based on the slope theme (van Zuidam, 1985 in Bermana, 2006), there are 4 geomorphological, oblique and steep units in this area, whereas based on rock distribution, the study area includes rock units of young volcanic products, young volcanic pyroclastic product, young volcanic pyroclastic product 2, old volcanic pyroclastic product 1, old volcanic pyroclastic product 2 and groundwater of Young lake (Hadian et al, 2013; Mardiana, 2013).

The study area consists of unravel volcanic sediment deposits, generally, a young volcanic sediment consisting of a mixture of loose and solid volcanic sediment with low to medium permeability. Some of the study area are productive aquifers with various transmissivity. Groundwater in this region is not widely utilized because of its deep groundwater level, in some area a plasterable spring is found. This area occupies $\pm 20\%$ in the northwest and southeast of the study area. The aquifer with moderate productivity is widespread.

Transmissivity is very diverse, groundwater level is usually deep and have less than 5 liters / sec water discharge. This region occupies $\pm 55\%$ (middle, west, east and north) of research area. And also rare groundwater areas occupy $\pm 3\%$ in the southwest and southeast, and Lake sediment in the form of tuff clay, tufan sandstone, medium to high permeability with widespread transmissivity,

various groundwater level and generally less than 5 liters / sec water discharge. This area occupies $\pm 22\%$ in the southern part of the study area (Soetrisno, 1983, processed 2018). The study area is limited by the Cibeusi watershed at West and the Cikeruh watershed at East, from the spring to the upstream each.

3.2 Landuse Condition

Based on the Indonesian landscape map of Cicalengka Sheet, 2001, the study area is grouped into the agricultural landuse ($\pm 80.61\%$), settlements ($\pm 17.28\%$) and industry ($\pm 2.10\%$). The agricultural landuse consists of irrigated rice fields, rainfed rice fields, plantations, and fields, occupying medial to distal area. Generally, lithology in this area is composed by a matrix-supported breccia up to tuf on the distal and grain supported breccia in the medial part. Groundwater flow is generally aligned with the topography and river flow that is directed from the peak (proximal) to the southeast. Rainfed rice fields are generally located in agglomerates units in the north with a rather tightly textured topography relief. The plantations and the fields are on the matrix-supported breccia rocks (loose). Irrigated rice fields are generally located around Cikeruh, Cileles and Cibeusi river. The settlements landuse consists of houses, offices, etc are spread over the distal points of the entire study area. The lithology of the settlement landuse are various from matrix supported breccia up to tuff. Ground water flow is generally aligned with the topography and river flow that is pointing from the top (proximal) to the southeast. The industrial landuse consist of process industry,

manufacturing and also service, are located in the lakes sediment with flatland morphology. Composite lithology consists of partial sandstone tuff and matrix-supported breccia. The river flows from east to west-northwest. In this section generally, flow path engineering (irrigation) has been created so that the natural flow is difficult to know. Groundwater flow in the industrial part is divided between the west and the east. This condition occurs due to excessive groundwater extraction in industrial activities so that the flow of natural ground water divided partly to the west and east. Based on Google Earth Satellite Imagery Map digitization, there are indications of landuse change in the research area. These changes are the conversion of agricultural landuse into settlements and industrial land. In 2017 agricultural landuse decreased to $\pm 75.20\%$, while settlement landuse increased to $\pm 25.78\%$ and industry ($\pm 3.02\%$).

3.3 Physical Characteristics Groundwater

The groundwater flow pattern based on the groundwater level at the good sampling points shows that the groundwater flow pattern on the agricultural landuse are from the north to the south and from the northeast to the northwest. The flow pattern on the settlement landuse is from the northeast to the northwest and the flow pattern on industrial landuse from east to west, as shown in figure 5.

The physical parameters both in water springs and wells groundwater observation are water temperature, pH (acidity degree), TDS (dissolved solids) and electrical conductivity (EC). Groundwater temperatures in the study area were below the air temperature at each observation point with a difference between 0-9 °C in the dry season and between 1 - 4 °C in the rainy season. The difference was caused by unequal measurement times (performed at 9 am – 4 pm WIB), so the air temperature at midday will be higher than

morning and evening, the condition of the research area is classified into hypothermal zone (Matthes & Harvey, 1982 in Puradimaja, 2004).

Although the changes are relatively small, pH value measured at the research points changes in some locations which indicates groundwater interaction with the rocks it passes. TDS value has increased from north to south both in the dry season and the rainy season, equal to the quite significantly increased electrical conductivity value. The increase in TDS and DHL parameters from the north to the south (young volcanic to lake sediment) is suspected resulting the occurrence of spring water and rock interactions that are more easily soluble in groundwater flows, whereas based on landuse, TDS and DHL parameters increase from agricultural landuse to industrial landuse are suspected due to material subsidies in the soil flow especially in the rainy season.

In situ measurements and laboratory analysis on physical and chemical water in the research area are performed by multivariate analysis with 2 (two) season variables and 3 (three) variables of landuse as interpreted as follows.

From the above analysis, that some parameters have significant variation in different seasons and different landuses, but generally do not have significant interaction between seasons and different landuses. The Piper and Durov trilinear diagrams were used to conclude the hydrochemical facies in groundwater samples in the study area. The two diagrams were developed to classify groundwater by measuring the chemical element of water from its major elements. The result of the groundwater quality in the Piper trilinear diagram presented in the following figure.

Table 1. The Significance of In-situ Measurement Variables and Laboratory Analysis on Physiscal and Chemical Water

Parameter	Results		Units	Significance of Variables		
	Dry Season	Rainy Season		Season	Landuse	Season & Landuse
Water Temp	19-26	20-28	°C	+	+	-
pH	5,38-7,45	5,53-7,89	-	-	-	-
TDS	48 – 449	65 – 510	mg/L	-	+	-
DHL	100-1020	141,25-1003,27	µmhos/cm	-	+	-
Na ⁺	9,11 - 28,11	2,4 - 65,8	mg/L	-	+	+
K ⁺	6,11 - 26,6	0,2 – 10	mg/L	+	-	-
Ca ²⁺	16 - 60,4	14 - 60,9	mg/L	+	-	-
Mg ²⁺	2,16 - 35,96	14 - 60,9	mg/L	-	+	-
HCO ⁺	76,8-157,15	52,3 - 125,8	mg/L	+	-	-
SO ₄ ²⁻	8,80 - 58,60	2,8 - 102,4	mg/L	-	+	+
Cl ⁻	4,88 - 86,76	1,6 - 148,8	mg/L	+	-	-

Table 2. Research Sampling Locations Table

No	Kode	X (xd)	X (xm)	X (xs)	Y (yd)	Y (ym)	Y (ys)	Z (meters ASL)	Landuse
1	CK 1	6	52	54,7	107	45	12,7	1226	Agriculture / farming
2	CK 2	6	54	13	107	46	33,0	877	Agriculture / farming
3	CK 7	6	56	5,6	107	47	14,1	731	Agriculture / farming
4	CB 1	6	53	22	107	45	20,0	1074	Agriculture / farming
5	CB 2	6	55	31,4	107	45	20,7	806	Agriculture / farming
6	CK 4	6	54	52,56	107	46	37,92	821	Settlements
7	CK 5	6	55	50,9	107	46	46,1	744	Settlements
8	CK 6	6	56	21,4	107	46	58,1	694	Settlements
9	CK 8	6	56	55,9	107	47	13,8	706	Settlements
10	CB 3	6	56	4,4	107	45	20,7	760	Settlements
11	CK 9	6	56	18,1	107	46	27,6	718	Industry
12	CK 10	6	57	17,1	107	46	9,0	696	Industry
13	CB 4	6	56	19,8	107	45	26,8	727	Industry
14	CB 5	6	56	46,5	107	45	30,3	716	Industry
15	CB 6	6	56	48,4	107	45	24,9	707	Industry

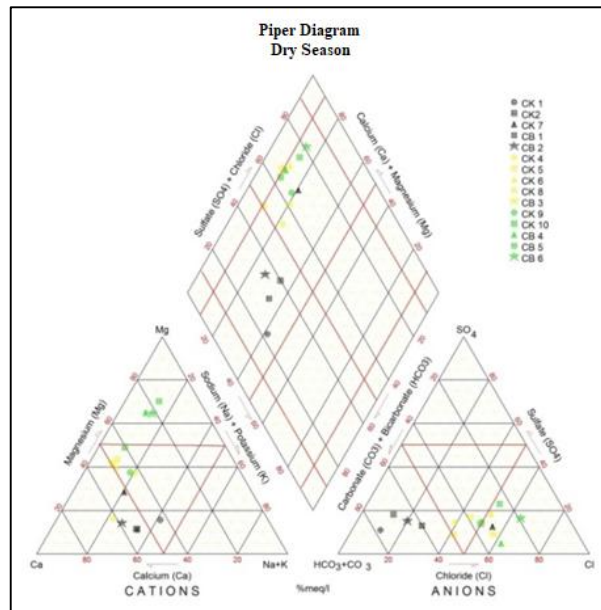


Fig 2. Trilinear Piper Diagram : Dry Season

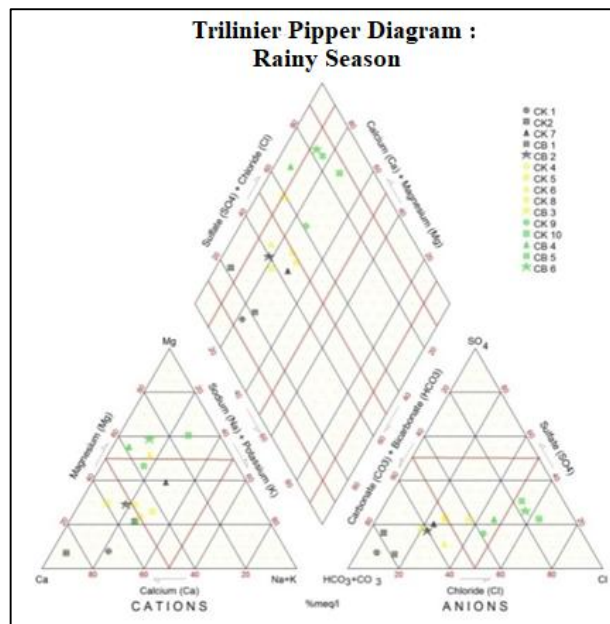


Fig 3. Trilinear Piper Diagram : Rainy Season

Table 3. Diagram trilinear Piper Plotting Results

	Dry Season			
Ca;HCO ₃	CK-1 ¹⁾	CK-2 ¹⁾	CB-1 ¹⁾	CB-2 ¹⁾
Mg;HCO ₃	CK-6 ²⁾			
Mg;Cl	CK-10 ³⁾	CB-6 ³⁾		
No Dominan; HCO ₃	CK-7 ¹⁾	CK-4 ²⁾	CK-5 ²⁾	CK-8 ²⁾
Ca No ; Dominan	CB-3	CK-9 ³⁾		
Mg No ; Dominan	CB-4 ³⁾			
No Dominan; Cl	CB-5 ³⁾			
	Rainy Season			
Ca;HCO ₃	CK-2 ¹⁾	CB-1 ¹⁾	CB-2 ¹⁾	
Mg;Cl	CB-4 ²⁾	CB-5 ²⁾	CB-6 ²⁾	
Ca;Cl	CK-7 ¹⁾			
No Dominan; HCO ₃	CK-1 ¹⁾			
Ca; No Dominan	CK-4 ²⁾			
No Dominan; Cl	CK-6 ²⁾	CB-3 ²⁾		
No Dominan ; No Dominan	CK-5 ²⁾	CK-8 ²⁾	CK-9	CK-10

Annotation: 1) Agricultural Landuse 2) Settlements Landuse ; 3) Industrial Landuse

From these figures, the research area has several different types of groundwater facies, as presented in table 3. Based on the water chemical grouping using Piper diagram, the groundwater facies are grouped into 4 (four), namely CaHCO_3 , MgHCO_3 , CaCl and MgCl . Based on the result data plotting, the majority area is in the 5 and 6 area. Based on the classification by Lloyd & Heathcote (1988), this indicates that groundwater falling on the field 5 indicates the

mixing of several types of water on the aquifer at the site, as shown in figure 2. The mixing may also occur due to the supply of water from the surrounding water bodies entering the aquifer and the also aquifer leakage, thereby allowing the mixing of groundwater from different aquifers, whereas the water properties in the field 6 indicate that groundwater undergoes a process of exchange ions and ions that are dominantly involved are Ca^{2+} , Mg^{2+} and HCO_3^- ions.

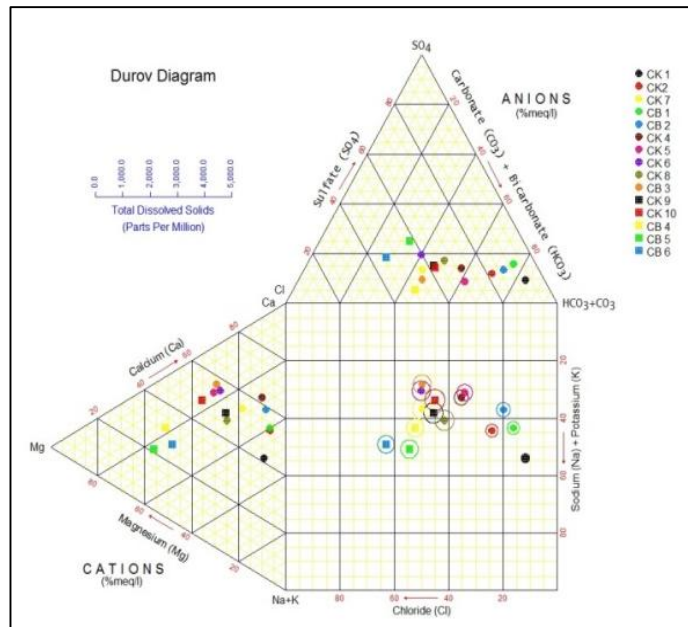


Fig 4. Durov Diagrams: Dry Season

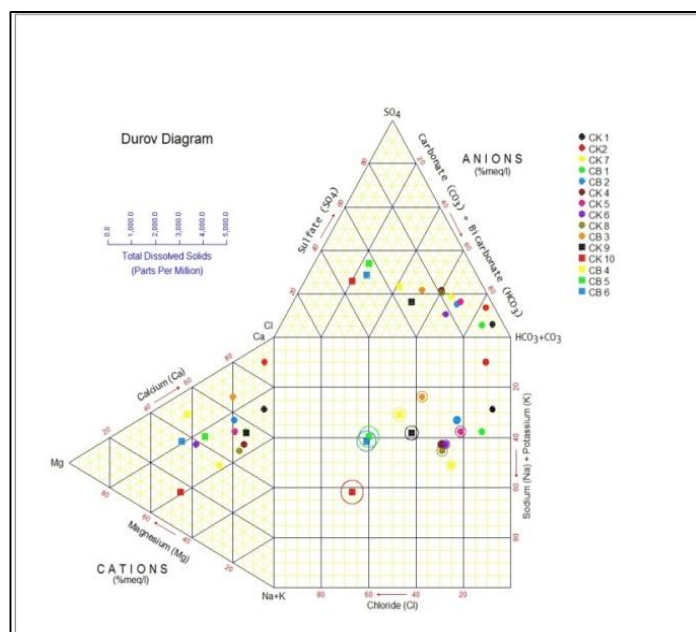


Fig 5. Durov Diagrams: Rainy Season

4. Discussion

Groundwater conditions in shallow aquifers in Manglayang Mountain have undergone changes in hydrogeochemical, from facies of CaHCO_3 , MgHCO_3 , to CaCl and MgCl facies along its journey. The facies showed that in the eastern study area (Cikeruh watershed) was found facies of CaHCO_3 , Ca and HCO_3^- in the northern to middle area (1,200 - 750 meters above sea level) which is present in the area of agricultural and settlement landuse, facies MgHCO_3 in the middle of the research area (50

meters above sea level) in the settlement area of MgCl facies in the southern part of the research area (700 mdpl) in the industrial landuse. In the western study area (Cibeusi watershed) was found CaHCO_3 , Ca and HCO_3^- facies in the north (1,025 - 750 meters above sea level) on agricultural landuse areas. Mg , Cl and MgCl facies are found in the central to southern part (<700 meters above sea level) in the industrial landuse area. The groundwater facies sampling in the Research Area is presented in the following figure. Facial conditions in the study area indicate the difference of aquifer between the north and south regions, the discovery

of Ca, HCO₃ indicates that the flow of groundwater in the center comes from the basin that is in the north. While the

discovery of Mg, Cl in the middle to the south is thought to be groundwater coming from the local area or local system.

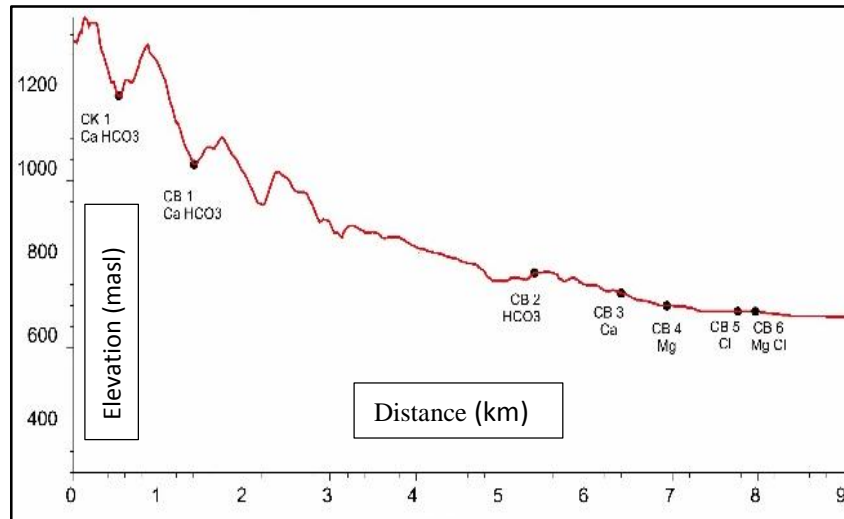


Fig 6. Groundwater Facies In The Study Area A-B Cross Section

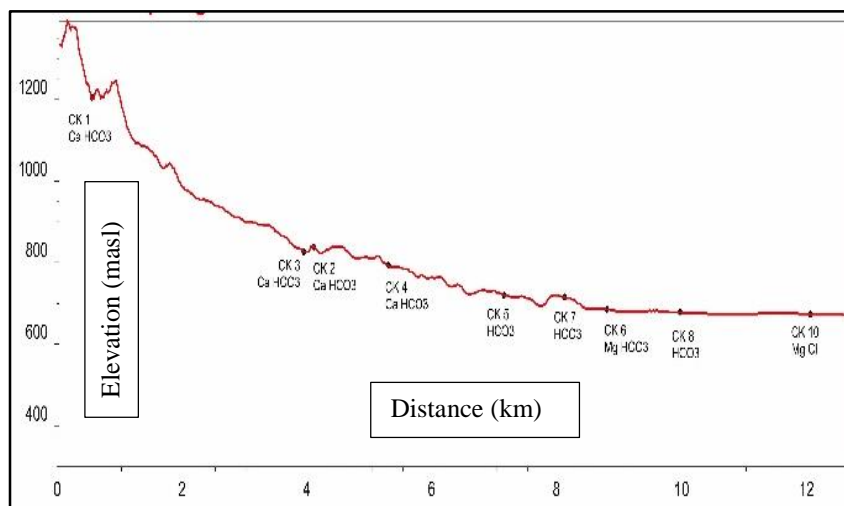


Fig 7. Groundwater Facies In The Study Area A-C Cross Section

5. Conclusion

Groundwater conditions in shallow aquifers in Manglayang Mountain have undergone hydrogeochemical changes, from facies of CaHCO₃ in agricultural landuse areas and MgHCO₃ in settlements landuse areas, then undergoing changes to CaCl and MgCl facies in the industrial landuse areas on its journey. The study area hydrochemical analysis showed that the formation of groundwater facies is influenced by hydrogeochemical processes such as groundwater washing by percolation of rainwater, cation exchange, and surface water mixing, as well as the mixing and exchange of groundwater ions.

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