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Hydrogeochemical analysis of groundwater in residential areas around the Terjun landfill in Medan city, Indonesia

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Abstract. Open dumping is the type of landfill used in Terjun landfill. This type of landfill has a high potential for pollution to the environment, especially in groundwater quality. This study aims to determine the quality of groundwater in the Terjun landfill area and its hydrogeochemistry. The methods proposed in this research are Trilinear Piper Diagram Analysis (1944), Stiff Quadrangle Diagram Analysis (1951) and Durov Diagram Analysis (1948). The elements analyzed include Calcium (Ca^{2+}), Sodium (Na^{+}), Magnesium (Mg^{2+}), Potassium (K^{+}), Chloride (Cl^{-}), Bicarbonate (HCO_3^{-}) and Sulfate (SO_4^{2-}). The results obtained on the electrical conductivity value ranged from 100-1100 micromhos/cm, indicating the classification of the water as fresh water. Analysis of the major ion test results of each sample using the three methods shows that the dominant ion content in the borehole groundwater is Cl- ions in borehole 1 and HCO3- ions in the other boreholes. On the Piper diagram, it can be determined that the facies or type of borehole groundwater that has been tested is Ca2+-HCO3-. Then the Durov diagram can be divided into 2 groups, namely the simple dissolution or mixing and reverse ion exchange groups. When looking at the results of the major ion test, sample point 1 has a high level of Cl- ions influenced by leachate water and a fairly close distance to the landfill.

1. Introduction

Water is very important in life because all living things in this world need water. Water is utilized by humans for various needs of daily life. The need for water for individual purposes varies for each place and each level of need. The higher the standard of living in a place, the more the need for water increases. The use of water is very extensive, so it must be pursued in such a way as to remain available and meet certain physical, biological and chemical requirements [1, 2]. Groundwater is the largest and most important source of drinking water worldwide and more than 1.5 million people depend on it daily [3]. However, the vulnerability of groundwater to contamination has been a growing concern. Groundwater pollution mainly results from increasing urbanization and industrialization. These developments encourage the generation of solid waste, its indiscriminate disposal, and mismanagement in landfills and open dumpsites. Landfilling is a common solid waste management approach worldwide although such facilities pose a pre-existing pollution threat to surface water and groundwater through leachate infiltration in closed and uncovered landfills [4].

Landfill is a place for various kinds of waste so that leachate contains various types of pollutants that have the potential to disturb the environment and human health. Leachate can seep into the ground, or flow on the ground surface and lead to river water flow [5, 6, 7, 8, 9]. Each landfill has different leachate characteristics depending on the processes that occur in the landfill, which include physical, chemical and biological processes [10]. Open dumping is a type of landfill that is widely used in Indonesia. This type of landfill has a high potential for pollution to the environment, especially to the surrounding groundwater quality because it does not have an environmental sanitation system and cover layer [11]. Solid waste disposal can impact groundwater quality. Solid waste is commonly managed by landfilling as it is the simplest and least expensive waste management technique [9, 12]. Landfilling produces leachate which is loaded with nutrients such as Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, NH_4^{+}, NO^{3-}, F^{-}, Cl^{-}, PO_4^{3-}, and HCO^{3-}. Many scientific reports

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emphasize that groundwater close to landfills is often polluted through leachate [5, 13]. High concentrations of pollutants in water make it unsuitable or affect human and animal health as well as agriculture [14]. Relevant information on the nutrient or pollutant status of groundwater around plunge landfills is lacking. This study aims to determine the quality of groundwater in the plunge landfill area and its hydrogeochemistry. Good groundwater quality will have a certain type of groundwater chemistry, with a certain main element content, in accordance with the limits recommended by the government [15]. The methods proposed in this study are Trilinear Piper Diagram Analysis (1944) [16], Stiff Quadrangle Diagram Analysis (1951) [17] and Durov Diagram Analysis (1948) [18].

2. Research Methods

2.1 Time and Location of Research

This research was conducted from October 2022 to December 2022 and the research location was in settlements around the Terjun landfill with a radius of 1 km (PERMEN PU No.3/PRT/M/2013) from the center of the landfill, Medan Marelan District, North Sumatra Province.

The implementation of this research was conducted by considering the following points:

1. The distance of residential areas is quite close to the landfill site.
2. There are still people who use deep borehole groundwater to fulfil their daily needs.

Fig. 1. Location of the Research Area

Sampling Location Data:

Table 1. Sampling Location Data

No.	Name	Depth(m)
1	Borehole 1 (SB 1)	66 m
2	Borehole 2 (SB 2)	120 m
3	Borehole 3 (SB 3)	60 m
4	Borehole 4 (SB 4)	72 m
5	Borehole 5 (SB 5)	72 m
6	Borehole 6 (SB 6)	60 m
7	Borehole 7 (SB 7)	54 m
8	Borehole 8 (SB 8)	72 m
9	Borehole 9 (SB 9)	72 m
10	Borehole 10 (SB 10)	72 m
11	Borehole 11 (SB 11)	66 m
12	Borehole 12 (SB 12)	54 m

This research was conducted to test deep borehole water in settlements around Terjun landfill, Medan Marelan sub-district with a total of 12 sampling points of deep well groundwater samples.

2.2 Research Methods and Parameters

Groundwater sampling in the study area was conducted periodically in wells scattered in the study area. Sampling groundwater as much as 1 liter of water for each sample point and then analyzed in the laboratory. The elements analyzed in this study include major elements in groundwater. The elements analyzed include Calcium (Ca^{2+}), Sodium

(Na^+), Magnesium (Mg^{2+}), Potassium (K^+), Chloride (Cl^-), Bicarbonate (HCO_3^-) dan Sulfate (SO_4^{2-}). The results of the analysis of groundwater samples were then analyzed using the Stiff diagram, 1951 to determine the chemical type of groundwater. The principle of making this diagram uses the dominant ions dissolved in water. The thing to note on the sfiff diagram is the shape and size. The shape of the stiff diagram shows the chemical nature of groundwater based on the dominant ions in the groundwater in it, while the size or size of the diagram shows the amount of the dominant ions. Laboratory data analysis results at each sample location are used as basic input data to determine the dominance of cation and anion distribution at each sample location. Analysis of the evolution of groundwater hydrogeochemistry that occurs is carried out using the Piper Trilinear Diagram method, 1944 is the most widely used graphical method for analyzing water geochemical data. Based on this diagram, to evaluate the relative concentration of major cations and anions in water samples. Thus, the hydrogeochemical evolution of groundwater can be determined. Durov diagrams in hydrochemistry are used to assist in interpreting groundwater evolution trends and processes taking place within groundwater systems [19].

3. Results

Electrical Conductivity content analysis results

Table 2. Electrical Conductivity Content

Num	Sample	Depth	Conductivity(µs/cm)	Clasification
1	SB 1	66 m	1100	Fresh water
2	SB 2	120 m	200	Fresh water
3	SB 3	60 m	200	Fresh water
4	SB 4	72 m	200	Fresh water
5	SB 5	72 m	100	Fresh water
6	SB 6	60 m	200	Fresh water
7	SB 7	54 m	200	Fresh water
8	SB 8	72 m	100	Fresh water
9	SB 9	72 m	100	Fresh water
10	SB 10	72 m	100	Fresh water
11	SB 11	66 m	100	Fresh water
12	SB 12	54 m	200	Fresh water

The electrical conductivity value at the research location ranges from 100-1100 µs/cm. These results indicate that the classification of deep borehole water at the study site is classified as freshwater.
Cation and anion content test results of borehole water samples.

Table 3. Percentage of Cation and Anion Content

Borehole	Major Ion (%)						
	Na	K	Ca	Mg	Cl	HCO3	SO4
SB 1	0	0	95,608	4,392	48,683	51,116	0,200
SB 2	0	0	66,432	33,568	5,099	94,901	0,000
SB 3	0	0	86,821	13,179	7,576	92,424	0,000
SB 4	0	0	92,175	7,825	4,587	95,338	0,075
SB 5	0	0	85,587	14,413	6,382	93,514	0,104
SB 6	0	0	93,701	6,299	13,586	86,414	0,000
SB 7	0	0	85,587	14,413	5,519	94,391	0,090
SB 8	0	0	79,831	20,169	7,491	92,344	0,165
SB 9	0	0	83,143	16,857	5,575	93,966	0,458
SB 10	0	0	92,249	7,751	5,133	94,445	0,422
SB 11	0	0	90,839	9,161	5,754	94,246	0,000
SB 12	0	0	88,773	11,227	6,714	93,286	0,000

Results of anion and cation analysis with Stiff Diagram (1951) [17] is shown in Figure 2.
Based on the results of the stiff diagram, the dominant ions in the borehole groundwater are Cl- ions in borehole 1 and HCO3- ions in other boreholes. In general, HCO3 in the borehole groundwater system indicates the type of freshwater while the higher Cl- concentration in borehole 1 can be influenced by leachate water and the close proximity of the well to Tejun landfill. The high concentration of chloride ions can be sourced from waste leachate water which is the result of waste decomposition from the landfill that seeps into the borehole groundwater aquifer [20].

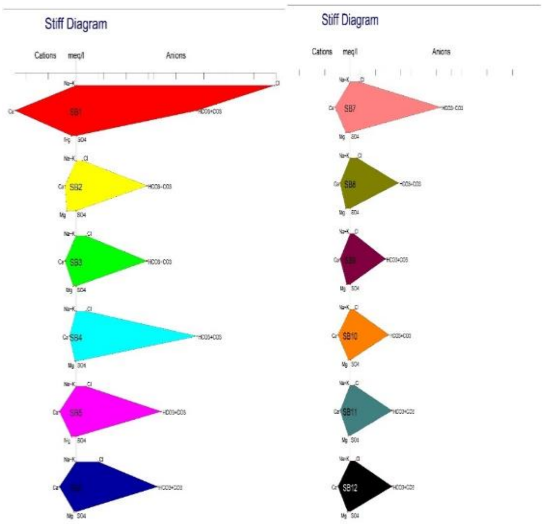

Fig. 2. Results of Stiff Diagram Plotting

Results of anion and cation analysis with Piper Diagram is shown in Figure 3.

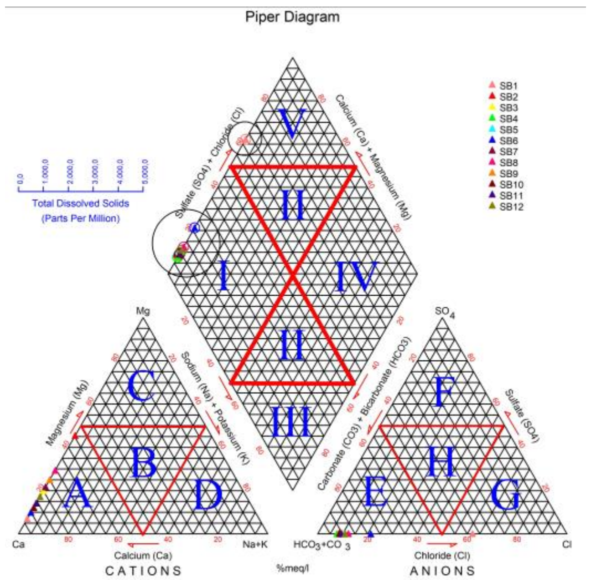

Fig. 3. Results of Piper Diagram Plotting

Description of Figure 3 is given below:
A: Calcium Type, *B*: No dominant type, *C*: Magnesium type, *D*: Sodium or Calcium type, *E*: Bicarbonate type, *F*: Sulfate Type, *G*: Chloride Type, *H*: No dominant type, *I*: Mg(HCO3)2 type, *II*: Mixed type, *III*: Na-HCO3 Type, *IV*: Na-Cl type, *V*: Ca-Cl type

In the fields of hydrogeology and groundwater examination, a piper plot is a diagram that can interpret the ion content in a water sample [21].
Based on the piper diagram, it shows that the dominant cation in all borehole samples is calcium (Ca^{2+}) and the dominant anion is chloride (Cl^-) in borehole 1 and Bicarbonate (HCO_3^-) in other boreholes. The presence of Ca^{2+} ions in water can cause water hardness [22]. Calcium is one of the important elements in igneous minerals such as silica, pyroxene, amphibole and feldspar. Calcium is in water due to the contact of water with igneous and metamorphic rocks which generally have low concentrations because the rate of decomposition is slow. Most calcium is found in carbonate sedimentary rocks [23]. The degree of freedom of a borehole groundwater sample is expressed in a value called

alkalinity. In other words, alkalinity is defined as how much acid is used to neutralize borehole groundwater. High alkalinity in borehole groundwater can be caused by the ionization of carbonic acid, especially in water that contains a lot of carbon dioxide. Carbon dioxide in water reacts with bases found in rocks and soil and forms bicarbonate [23]. Overall, the borehole groundwater sampled in this study has cations dominated by calcium (Ca^{2+}) and anions dominated by bicarbonate ions (HCO_3^-) shown in sections A and E of the Piper diagram as the content that has the dominant percent concentration.

The groundwater facies of the borehole in the study area include Mg-HCO_3 and Ca-Cl facies. However, what is drawn in the conclusion is the facies that has the dominant content. The content of the borehole groundwater tested in this study, based on the piper diagram and stiff diagram, is dominated by Ca^{2+} and HCO_3^- ions. Therefore, it can be stated that the borehole groundwater in this study belongs to the Ca-HCO_3 facies. This facies shows that the borehole groundwater circulation is not too far away and the emergence of this facies is likely due to the dominant influence of lithology on the borehole groundwater. Ca content is produced during ion exchange of borehole groundwater with the rocks it passes through [23]. In addition, the element HCO_3 has an anion facies is bicarbonate type (HCO_3^-). Water changes with the process of dissolving CO_2 with carbonate minerals through soil and rock then releases HCO_3 [23]. In this case, it can be concluded that the borehole groundwater facies is included in the freshwater type that has not been contaminated by sea water. According to Afriyani (2020) [24], the borehole groundwater at the sampling location is a bicarbonate groundwater group (I). The high content of bicarbonate and alkali in water can increase water hardness, where one of the elements that cause water hardness is Ca and Mg elements. The type of Ca and Mg in the facies comes from the interaction of water with minerals in the rock. These minerals are feldspar and mafic minerals in the Damar Formation.

Results of anion and cation analysis with Durov Diagram.

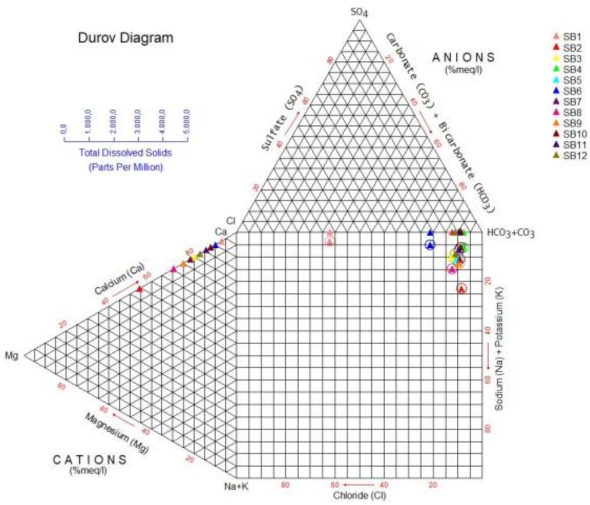

Fig. 4. Results of Durov Diagram Plotting

The results of the plotting can be divided into two groups, namely the simple dissolution or mixing group and the reverse ion exchange group. In the simple dissolution process the dissolution rate depends on the solubility of a mineral. This group indicates that the borehole groundwater experienced a mixing process in several aquifers located at that location. The mixing can also occur in leaking aquifers, resulting in the mixing of borehole groundwater from different aquifers [25]. The reverse ion exchange group indicates the reverse ion exchange process and the dominant ions involved are Ca^{2+} and HCO_3^- ions.

4. Conclusion

The major ion content at the research site using the Stiff Diagram method is divided into anions and cations. Based on cations, calcium ions (Ca^{2+}) dominate in all samples while based on anions, chloride ions (Cl^-) dominate in sample SB 1 and bicarbonate elements (HCO_3^-) dominate in other samples. The hydrogeochemical types or facies of deep borehole groundwater at the research site using the Piper Diagram method are Mg-HCO_3 and Ca-Cl. The dominant groundwater facies is Ca-HCO_3 followed by Mg-HCO_3. The borehole groundwater at the research site is a bicarbonate (I) groundwater group. Based on the Durov Diagram method, a simple dissolution or mixing process occurs in borehole sample 1. In this process, it indicates that the borehole groundwater undergoes a mixing process in several aquifers located at the research site. In other borehole samples, the reverse ion exchange process occurs and the dominant ions are Ca^{2+} and HCO_3^- ions.

References

1. Yoga, I. Gede Arma Prima Reka, Ni Putu Widya Astuti, Nyoman Ngurah Adi Sanjaya, Analisis Hubungan Kondisi Fisik dengan Kualitas Air Pada Sumur Gali Plus di Wilayah Kerja Puskesmas II Denpasar Selatan, *HIGIENE: Jurnal Kesehatan Lingkungan* **6**, 52-63 (2020)
2. J.C. Egbueri, Evaluation and characterization of the groundwater quality and hydrogeochemistry of Ogbaru farming district in southeastern Nigeria, *SN Applied Sciences* **1**(8), 851 (2019)
3. C.K. Tay, E.K. Hayford, I.O.A. Hodgson, Application of multivariate statistical technique for hydrogeochemical assessment of groundwater within the Lower Pra Basin, Ghana, *Applied water science* **7**, 1131-1150 (2017)
4. J. Nyika, E. Onyari, Hydrogeochemical analysis and spatial distribution of groundwater quality in roundhill landfill vicinity of South Africa, *Air, Soil and Water Research* **12**, 1178622119872771 (2019).
5. Z. Han, H. Ma, G. Shi, L. He, L. Wei, Q. Shi, A review of groundwater contamination near municipal solid waste landfill sites in China, *Science of the Total Environment* **569**, 1255-1264 (2016)
6. Y.L. Yang, T.Y. Yang, X.H. Yu, B. Zhao, Reach on groundwater pollution caused by landfills in Karst region in Guangzhou, *Ground Water* **35**, 77–80 (2013)
7. Y. Li, J.H. Li, C. Deng, Occurrence, characteristics and leakage of polybrominated diphenyl ethers in leachate from municipal solid waste landfills in China. Environ, *Pollution* **184**, 94–100 (2014)
8. D.S. Fernández, M.E. Puchulu, S.M. Georgieff, Identification and assessment of water pollution as a consequence of a leachate plume migration from a municipal landfill site (Tucumán, Argentina), *Environ. Geochem. Health* **36**, 489-503 (2014)
9. M. Bagheri, A. Bazvand, M. Ehteshami, Application of artificial intelligence for the management of landfill leachate penetration into groundwater, and assessment of its environmental impacts, *Journal of Cleaner Production* **149**, 784-796 (2017)
10. R.N. Sari, A. Afdal, Karakteristik Air Lindi (Leachate) di Tempat Pembuangan Akhir Sampah Air Dingin Kota Padang, *Jurnal Fisika Unand* **6**(1), 93-99 (2017)
11. D. Hilmawan, M. F. Alghifari, A.A. Sari, Analisis Kualitas Airtanah Dengan Studi Kerentanan Airtanah Metode Susceptibility Index Dan Studi Hidrogeokimia Terhadap Pencemaran Di TPA Sarimukti Dan Sekitarnya, Indonesia (2021)
12. S. Kumar, N. Nimchuk, R. Kumar, J. Zietsman, T. Ramani, C. Spiegelman, M. Kenney, Specific model for the estimation of methane emission from municipal solid waste landfills in India, *Bioresour. Technol*. **216**, 981-987 (2016)
13. D. Smahi, O.E. Hammoumi, A. Fekri, Assessment of the impact of the landfill on groundwater quality: a case study of the Mediounasite, Casablanca, Morocco, *J. Water Resour. Prot*. **5**, 440–445 (2013)
14. G. Feuyit, J.N. Lambi, E. Njoyim-Tamungang, S. Laminsi, Assessment of the nutrients in the leachate and the groundwater quality for drinking and farming around the nkolfoulou landfill in Yaoundé, Cameroon, *Journal of Chemistry* **2019**, 6362134 (2019)
15. T.L. RA, S.N. Peni, Chemical Type Variation of Groundwater in Borobudur and Surroundings Area, Magelang District, *E3S Web of Conferences* **202**, 12005 (2020)
16. A.M. Piper, A graphic procedure in the geochemical interpretation of water-analyses, *Eos, Transactions American Geophysical Union* **25**(6), 914–928 (1944)
17. H.A. Stiff, The interpretation of chemical water analysis by means of patterns, *Journal of Petroleum Technology* **3**, 15-16 (1951)
18. S.A. Durov, Classification of natural waters and graphical representation of their composition, *Dokl. Akad. Nauk. USSR* **59**(1), 87-90 (1948)
19. A. Lesmana, B.Y. CSSSA, T.Y.W.M. Iskandarsyah, Karakteristik Hidrokimia Air Tanah Pada Bagian Timur Cekungan Air Tanah Bandung-Soreang: Studi Kasus Sebagian Kecamatan Cicalengka Dan Kecamatan Cimanggung, Provinsi Jawa Barat, *Geoscience Journal* **5**(6), 546-561 (2021)
20. A. Arbain, N.K. Mardana, I.B. Sudana, Pengaruh Air Lindi Tempat Pembuangan Akhir Sampah Suwung terhadap Kualitas Air Tanah Dangkal di Sekitarnya di Kelurahan Pedungan Kota Denpasar, *Ecotrophic* **3**(2), 387818 (2009)
21. M. Shah, H. Patel, P. Viramgama, D. Varanava, D. Maheshwari, Characterization and assessment of groundwater aquifers from Bakreshwar and Tantloi geothermal fields for its industrial applications, *Groundwater for Sustainable Development* **12**, 100535 (2021)

22. K. Kasmawati, M. Sehol, R. Mangesa, S.H. Loilatu, Uji Kualitas Air Minum Pada Depot Air Minum Isi Ulang Di Desa Lala Kecamatan Namlea Kabupaten Buru Tahun 2019:(Testing the Quality of Drinking Water in a Refilled Drinking Water Depot in Lala Village, Buru Regency 2019), *Uniqbu Journal of Exact Sciences* **1**(3), 73-81 (2020)
23. L.H.S. Widya, Analisis Kualitas Dan Fasies Air Tanah Di Daerah Kelurahan Titian Antui Kecamatan Pinggir Kabupaten Bengkalis Provinsi Riau, Doctoral dissertation, Universitas Islam Riau (2022)
24. M.P. Afriyani, L.W. Santosa, T.N. Adji, Analisis Genesa Hidrogeokimia Airtanah Menggunakan Diagram Piper Segiempat Di Wilayah Pesisir, *Media Komunikasi Geografi* **21**(1), 01-11 (2020)
25. K. Dianardi, S.D. Hadian, T. Y. W. Iskandarsyah, F. Muhamadsjah, Studi Hidrokimia dan Karakteristik Airtanah di Kecamatan Cibiru dan Cileunyi, Bandung, Jawa Barat, Indonesia, *Bulletin of Scientific Contribution: GEOLOGY* **16**(2), 71-78 (2018)