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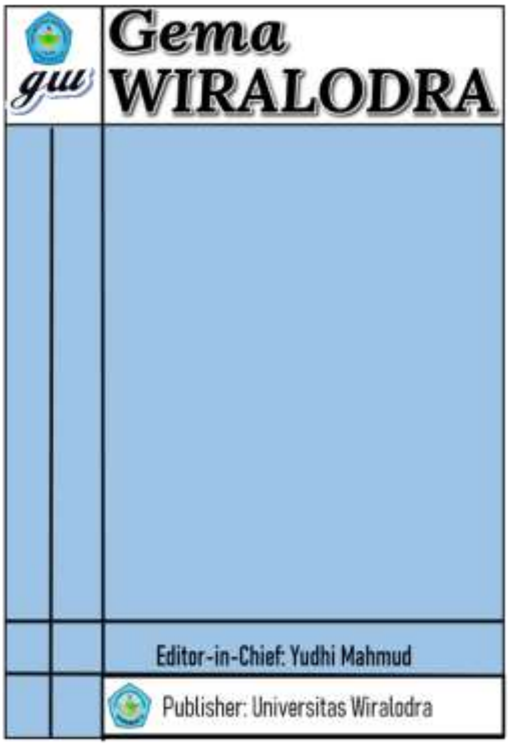

Assessment of Groundwater Vulnerability to Pollution in the Metro Subwatershed Area Using the GOD Method

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Orginal Article

Assessment of Groundwater Vulnerability to Pollution in the Metro Subwatershed Area Using the GOD Method

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Abstract
The assessment of groundwater vulnerability to contamination in the Sub-Watershed (Sub DAS) Metro plays a crucial role in maintaining the sustainability of water resources. As an integral part of a complex river system, Sub DAS Metro faces the risk of groundwater pollution caused by human activities such as agriculture, industry, and domestic. Thus, research was conducted to determine the level of groundwater vulnerability using the GOD method (Groundwater Occurrence, Depth to Water Table, and Aquifer Media). The study identified three vulnerability classes out of the five existing classes, namely very low, low, and moderate. The GOD index indicates very low vulnerability with values ranging from 0.08 to 0.10, low vulnerability ranging from 0.11 to 0.12, and moderate vulnerability with a value of 0.48. Following the vulnerability assessment using the GOD method, mapping was conducted, assigning green for very low vulnerability areas, yellow for low vulnerability, and red for moderate vulnerability. The research findings provide strategic insights for designing effective mitigation and sustainable management of groundwater quality in Sub DAS Metro, playing a crucial role in preserving the sustainability of the groundwater ecosystem in the region.
Keywords: *Groundwater Vulnerability, GOD Method, Contamination, Sub Watershed Metro, Vulnerability Level, Water Resources*

1. Introduction

Water is the most vital source of life for living things. Only about 2.5% of the global water volume is available on earth (Widodo, 2013). Groundwater is surface water that enters the fill area below the earth's surface (Juanda, 1999). The availability of groundwater plays a crucial role in maintaining human life and ecosystems in various regions. However, in recent decades, increasing human activities have posed a serious threat to groundwater quality, one of which is through pollution. Groundwater pollution can arise from a number of factors, including industrial waste, intensive agriculture, and domestic activities. The Metro subwatershed, as part of a complex river system, also faces groundwater pollution risks that require thorough evaluation. Therefore, assessing the level of groundwater vulnerability to pollution is a very important step in maintaining the sustainability of water resources in the region.

One method used to assess groundwater vulnerability to pollution is the GOD Method (Groundwater Occurrence, Depth to Water Table, and Aquifer Media) (Siswoyo, 2018). This method is often used because it is easy to determine each parameter and its application (Foster dkk, 2007). In addition, this method has been studied by previous researchers in various countries (Fernandes dkk, 2014).

In this context, the objective of this study is to investigate the level of groundwater vulnerability in the Metro Subwatershed area using the GOD Method. By understanding the geological and hydrogeological conditions of this area, it is expected to identify potential pollution risks and design effective mitigation strategies. This research is expected to make a

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positive contribution to efforts to conserve groundwater quality, maintain ecosystem sustainability, and support the welfare of local communities.

2. Method

a) Study location

Figure 1
Research location map

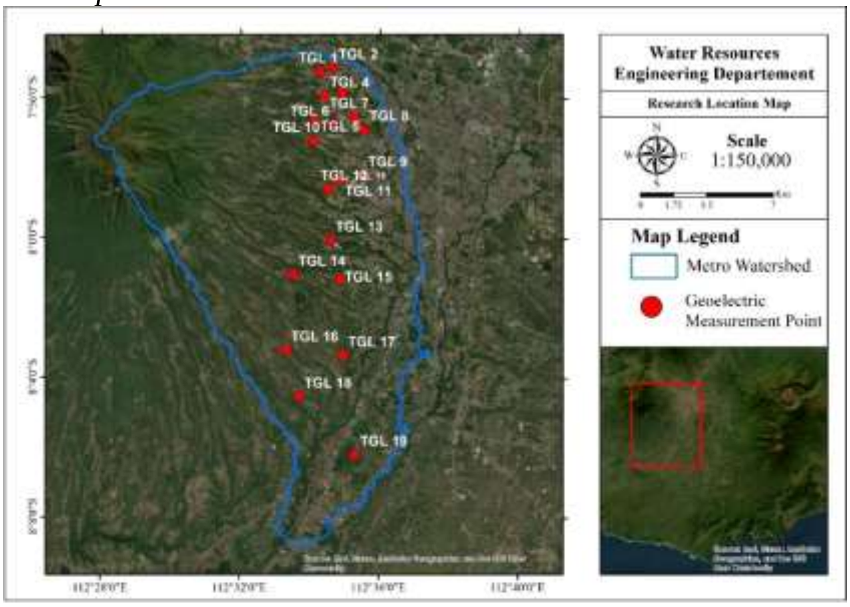

Figure 1 shows this research was conducted in the Metro watershed area which has an area of approximately 254.53 Km^2. Water accumulated from upstream in Malang City and Regency then flows downstream to Kepanjen District, Malang Regency. Geoelectric data was collected at 19 points in the Metro watershed area that experienced the most land use change from agricultural land to residential and industrial areas. With these locations will present results in the form of rock types and soil types. The following is a recapitulation of the measurement locations presented in table 1.

Table 1
Study Location

Point Name	Village	District	Coordinates		Elevation
			S	E	
TGL 1	Sumbersekar	Dau	7°55'13.40"	112°34'16.60"	631
TGL 2	Sumbersekar	Dau	7°55'7.42"	112°34'38.94"	605
TGL 3	Landungsari	Dau	7°55'49.65"	112°34'55.20"	624
TGL 4	Mulyoagung	Dau	7°55'55.26"	112°34'24.43"	690
TGL 5	Tegalweru	Dau	7°56'37.03"	112°34'7.81"	699
TGL 6	Tegalweru	Dau	7°56'44.29"	112°34'39.38"	639
TGL 7	Merjosari	Lowokwaru	7°56'30.81"	112°35'15.24	606
TGL 8	Merjosari	Lowokwaru	7°56'52.72"	112°35'32.83"	543
TGL 9	Kalisongo	Dau	7°58'11.75"	112°35'30.6"	526
TGL 10	Karangwidoro	Dau	7°57'12.68"	112°34'06.34"	694
TGL 11	Pandanlandung	Wagir	7°58'20.20"	112°34'51.05"	587

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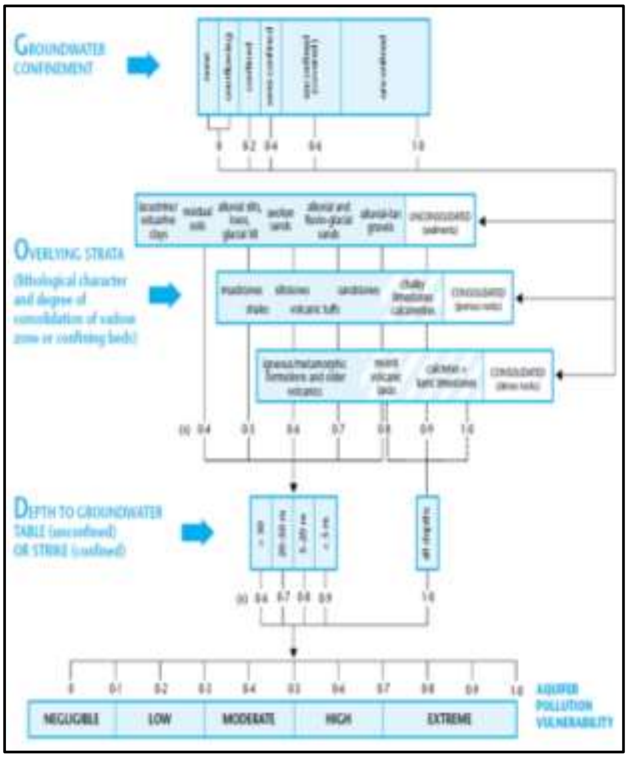
Point Name	Village	District	Coordinates		Elevation
			S	E	
TGL 12	Pandanlandung	Wagir	7°58'35.14"	112°34'31.39"	597
TGL 13	Sukodadi	Wagir	8°00'03.01"	112°34'35.38"	569
TGL 14	Sumbersuko	Wagir	8°01'02.56"	112°33'31.38"	633
TGL 15	Gondowangi	Wagir	8°01'11.35"	112°34'51.25"	501
TGL 16	Kesamben	Ngajum	8°03'12.38"	112°33'19.25"	502
TGL 17	Jatisari	Pakisaji	8°03'21.41"	112°34'57.57"	382
TGL 18	Kranggan	Ngajum	8°04'31.83"	112°33'42.29"	427
TGL 19	Jatirejoyoso	Kepanjen	8°06'11.37"	112°35'18.84"	370

b) GOD Method

Based on Foster (1987), the GOD method is a method that can determine the vulnerability of groundwater so as to analyze the potential for pollution.The GOD method consists of three parameters, including the type of aquifer (G), the rock layer above the aquifer layer (O), and the depth of the groundwater table (D) (Siswoyo, 2018). Each parameter is divided into several that have ranked values as shown in figure 2.

Figure 2

GOD Method Assessment



The index value of the GOD method is obtained from multiplying all parameters, with the following equation (Foster dkk, 2007):

$$\text{GOD index} = G \times O \times D \quad (1)$$

After obtaining the calculation results, the level of groundwater vulnerability is interpreted based on the GOD index value based on table 2.

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Table 2
Groundwater Vulnerability Level GOD Method

Index	Vulnerability Level	Description
0 - 0,1	Very Low	Limited to places without vertical groundwater flow or significant leakage
0,1 - 0,3	Low	Only susceptible to conservative pollution in the long term or when discharges are widespread and continuous
0,3 - 0,5	Medium	Susceptible to some pollutants but only when discharged continuously
0,5 - 0,7	High	Vulnerable to many pollutants occurring in pollution scenarios
0,7 - 1,0	Very High	Vulnerable to most water pollutants that have rapid impacts in pollution scenarios

Mapping the spatial distribution of the groundwater vulnerability index is done by interpolating using the IDW (Inverse Distance Weighting) method, as this method can provide a value that is close to the lowest result (Pramono, 2008).

3. Results and Discussion

a) Geoelectric Data Interpretation

Geoelectric measurements were conducted in several land uses, including fields, rice fields, settlements, and industrial areas. Measurements in various land uses are expected to determine the effect of land use changes on the surrounding rock lithology, and changes in aquifer conditions. Based on the interpretation of rock lithology in the Metro watershed consists of layers of clay, tuff, pasiran tuff, tuff breccia, pumice, volcanic breccia, lava and lava. Based on the Geological map of Indonesia System Sheet Kediri 1508-3, Blitar 1507-6, Malang 1608-1, and Turen 1607-4, the lithology of rocks in the Metro watershed is influenced by volcanic activity and volcanic sediments (Santosa, 1992; Sjarifudin, 1992; Sujanto dkk, 1992). In the upstream part influenced by Butak-Kawi volcano (Qpkb) and Malang tuff (Qvtm), while the downstream part is dominated by sedimentary deposits from weathering of volcanic rocks in the form of fine tuff or clay to pasiran tuff.

Figure 3
Rock Lithology Distribution of Metro Watershed

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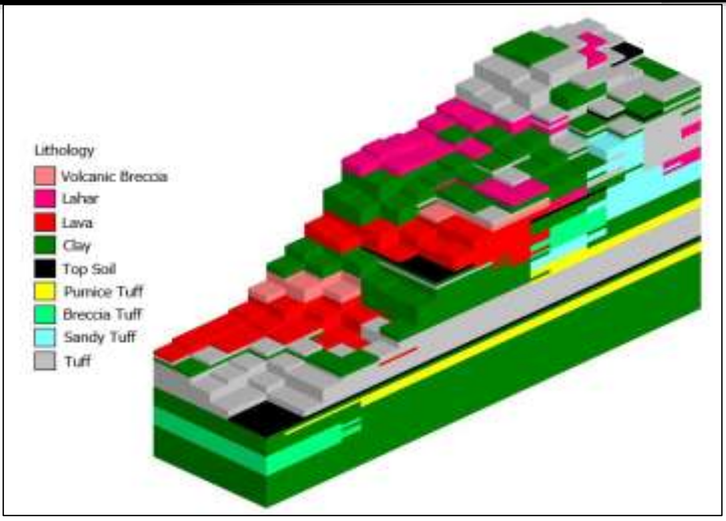

Figure 3 shows that the surface in the upper part of the Metro watershed is dominated by very hard tuff to lava layers, while the surface in the lower part of the Metro watershed is dominated by fine tuff (clay) to tuff layers.

b) Groundwater Vulnerability

Table 3
GOD Value Calculation Results

Point Name	Parameter			Nilai			Hasil	
	G	O	D	G	O	D	Indeks GOD	Kerentanan
TGL 1	Confined	Clay	3.87	0.2	0.6	0.9	0.11	Low
TGL 2	Confined	Tufa Clay	4.73 5.13	0.2	0.6	0.8	0.10	Sangat Rendah
TGL 3	Confined	Clay	3.60	0.2	0.6	0.9	0.11	Low
TGL 4	Confined	Lahar Clay	4.42 4.08	0.2	0.7	0.8	0.11	Low
TGL 5	Confined	Clay	3.60	0.2	0.6	0.9	0.11	Low
TGL 6	Confined	Clay	20.81	0.2	0.6	0.7	0.08	Very Low
TGL 7	Confined	Clay	7.72	0.2	0.6	0.8	0.10	Very Low
TGL 8	Confined	Tufa Clay	3.60 16.70	0.2	0.6	0.7	0.08	Very Low
TGL 9	Confined	Clay Breccia tuff	25.40 33.00	0.2	0.7	0.7	0.10	Very Low
TGL 10	Confined	Clay	35.50	0.2	0.6	0.7	0.08	Very Low
TGL 11	Confined	Clay	20.81	0.2	0.6	0.7	0.08	Very Low
TGL 12	Confined	Clay	20.81	0.2	0.6	0.7	0.08	Very Low
TGL 13	Confined	Clay Tufa Lahar	2.00 0.84 1.90	0.2	0.7	0.9	0.12	Low
TGL 14	Confined	Clay	3.60	0.2	0.6	0.9	0.11	Low
TGL 15	Confined	Clay Tufa Clay	2.37 2.13 4.55	0.2	0.6	0.8	0.10	Very Low

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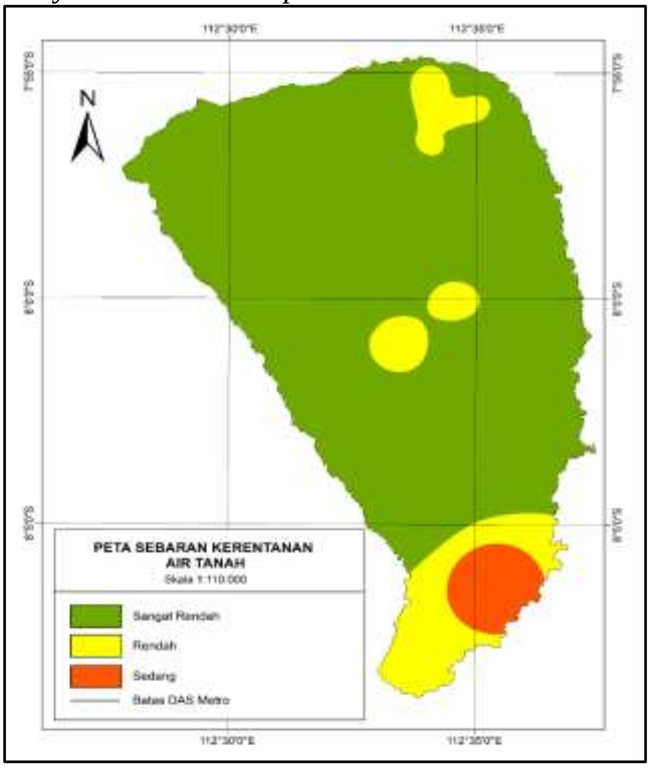
Point Name	Parameter			Nilai			Hasil	
	G	O	D	G	O	D	Indeks GOD	Kerentanan
TGL 16	Confined	Clay	6.10	0.2	0.6	0.8	0.10	Very Low
TGL 17	Confined	Tufa Clay	4.55 3.72	0.2	0.6	0.7	0.08	Very Low
TGL 18	Confined	Tufa Clay	3.60 5.06	0.2	0.6	0.7	0.08	Very Low
TGL 19	Unconfined	Clay	8.68	1.0	0.6	0.8	0.48	Medium

Table 3 shows that the results of the calculation of groundwater pollution vulnerability using the GOD method obtained a range of vulnerability from very low to moderate. The very low vulnerability level is found at points TGL 2, TGL 6 - TGL 12, and TGL 15 - TGL 18 which are located in Dau, Lowokwaru, Wagir, Pakisaji, and Ngajum sub-districts. The low vulnerability level is found at points TGL 1, TGL 3 - TGL 5, TGL 13, and TGL 14 located in Dau and Wagir sub-districts. While the moderate vulnerability level is found at point TGL 19 which is located in Kepanjen Sub-district.

Figure 4
Groundwater Vulnerability Distribution Map



From the mapping results in figure 4, it can be concluded that the upstream area is on average very low vulnerable, only at some points with low status due to the type of aquifer cover lithology in the form of siltstones and volcanic tuff and the depth of groundwater is quite high. In the downstream part of the watershed with a groundwater table close to the ground surface is generally low to medium status.

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4. Conclusion

Based on the results of the study, it can be concluded that groundwater vulnerability to pollution in the Metro watershed has a very low to moderate vulnerability status. Very low vulnerability has an index value of 0.08 - 0.10 which includes Sumbersekar Village, Tegalweru Village, Merjosari Village, Kalisongo Village, Karangwidoro Village, Pandanlandung Village, Gondowangi Village, Kesamben Village, Jatisari Village, and Kranggan Village. Low vulnerability has an index value of 0.11 - 0.12, which includes Sumbersekar, Landungsari, Mulyoagung, Tegalweru, Sukodadi, and Sumbersuko. Medium vulnerability has an index value of 0.48 which is Jatirejoyoso Village. Thus, the upstream part is dominated by a very low level of vulnerability and only at a few points has a low vulnerability status due to the groundwater table being far from the ground surface, while the downstream part of the das is dominated by low to moderate vulnerability caused by the groundwater table being close to the ground surface.

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