Available online at: http://proceeding.rsfpress.com/index.php/ ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 1-11

Identification of Groundwater Contamination by Hydrocarbon from Gas Station at Caturtunggal Area using Geoelectrical Methods

Ayu Utami ,Ajimas Pascaning, Wisnu Aji Dwi Kristanto, Wildan Rizky Isnaini

Universitas Pembangunan Nasional "Veteran" Yogyakarta,
[1] E-mail address ayu.utami@upnyk.ac.id, [1]E-mail address wisnuaji@upnyk.ac.id, [1] E-mail address isnaini.rizky83@gmail.com [2] E-mail address ajimasps@yahoo.co.id

Abstract

Groundwater exploration is a method to produce the needs of clean water. Most of the Indonesian people use groundwater for daily consumption. Groundwater contamination can occur because of various human activities that produce pollutants. One of the activities that can affect the quality of subsurface water is the existence of a Gas Station. Caturtunggal is one of the areas in the Sleman Regency which has a dense population. Caturtunggal has varied activities such as hotels, restaurants, shopping centers, and education. If there is pollution due to hydrocarbons, the impact that occurs can pollute the densely populated area. Geophysics methods are one of the techniques to explore the groundwater, specially geoelectrical resistivity. The objective of this research is to identify the existence of hydrocarbon in the groundwater around gas stations using the geoelectrical resistivity method. This research was conducted with the methods, i.e., observation, mapping, and geophysical method, geoelectrical resistivity. The result from geoelectrical resistivity analysis shows that contamination of hydrocarbon does not occur in the groundwater. In general, the lithology of the composting area of the study area consists of loose sediments with coarse to very coarse grain sizes, which are represented by large resistivity values. At the measuring point 1 to 4, there is no indication of the presence of groundwater pollution, which is represented by the resistivity value of the aquifer zone in the Cilician area, which is still in the resistivity order of 10^1*-ohm meters. The existence of aquifers in the research area is at a depth of 12 meters to 15 meters. It was getting deeper towards the south. However, collaboration data is required to analyze more details about the contamination.*

Keywords: groundwater contamination, geoelectrical resistivity, gas stations, hydrocarbon

I. INTRODUCTION

I.1. Background

Groundwater exploration is a method to produce the needs of clean water. Groundwater is the amount of water below the ground that is collected in the well, channel, or drainage or using a pump (Kodoatie, 2012). Groundwater also can be called the natural water flow to the surface through the gush and seepage (Freeze, 1984). Groundwater exploration will increase the number of raw water needs. Most of the Indonesian people use groundwater for daily consumption. As a source of raw water, the quality of groundwater should be suitable with the quality standard from government, Ministry of Health Regulation number 32 the Year 2017 about Environmental Health and Water Health Requirements for Quality Standard for Hygiene Purposes Sanitation, Swimming Pools, Solus Per Aqua, and Public Baths (Menteri Kesehatan Republik Indonesia, 2017).

Groundwater contamination can occur because of various human activities that produce pollutants. One of the activities that can affect the quality of subsurface water is the existence of a Gas Station (Rahmawati *et al.*, 2018). Gas stations have the potential to leak so that they can contaminate underground water. The parameters that can contaminate subsurface water are the hydrocarbons contained in the water. The establishment of a gas station has operational standards, but several factors that cannot be avoided that will increase the risk of tank leakage are natural disasters (Muryani, 2012). This leaking engine fuel can enter the soil pores, flow in the groundwater flow, and float on the surface of shallow groundwater, seeps into the ground, flows with groundwater flow, and floats on the surface of shallow groundwater (Notodarmojo, 2005).

Geophysics methods are one of the techniques to explore the groundwater, specially geoelectrical resistivity. The geoelectrical resistivity method is a geophysical method that studies the electrical resistivity (resistivity) properties of rock layers in the earth (Hendrajaya and Arif, 1990). In this method, an electric current is injected into the earth through two current electrodes, and a potential difference is measured through two potential electrodes. From the results of measurements of currents and electric potential differences, it will be possible to calculate the variation of the resistivity value in the layer of the earth's surface below the sounding point (Apparao, 1997). At the time of the acquisition, there were several types of arrangement of current and potential electrodes. The rules for placing the two types of electrodes are known as configuration (Hendrajaya and Arif, 1990). In underground water exploration, the configuration commonly used is the Schlumberger configuration. This configuration can provide aquifer presence.

The investigation of groundwater contamination using geoelectrical methods has been conducted and explained in previous research. Geoelectrical methods using vertical electronic sounding was proved for detecting the groundwater contamination at some contaminated area from domestic and industrial waste contamination. This research is detecting the contamination area based on the resistivity value and also conductivity (Akankpo and Igboekwe, 2011). Previous research also combines some geophysics methods, including geoelectrical methods, to determine the vulnerability of groundwater because of organic contaminants. This research analyzes the resistivity to indicate the vulnerable aquifer (S. Okiongbo and Akpofure, 2012).

I.2. Research Area and Objective

Caturtunggal is one of the areas in Sleman Regency which has a dense population. Caturtunggal has varied activities such as hotels, restaurants, shopping centers, and education (BPS Kabupaten Sleman, 2018). In addition, there are gas stations around the area. This is what underlies the selection of the study location in this study. If there is pollution due to hydrocarbons, the impact that occurs can pollute the densely populated area.

The objective of this research is to identify the existence of hydrocarbon in the groundwater around gas stations using the geoelectrical resistivity method. The hydrocarbon that exists in the groundwater is the sign that groundwater around the gas station is contaminated. The result from this research can be use as a database for contaminated site area in Yogyakarta. Furthermore, treatment for groundwater can be conduct if the contamination occurs.

II. LITERATURE REVIEW

II.1. Groundwater Contamination

From Government Regulation (PP) Number 32 concerning the Environment, environmental pollution is the entry or inclusion of living things, substances, energy, and / or other components into the environment by human activities so that they exceed the established environmental quality standards (Republik Indonesia, 1990). However, water pollution is the entry or inclusion of living things, substances, energy, and other components into the water by human activities so that the quality drops to a certain level, which causes the water to not function according to its designation (Republik Indonesia Government, 2001).

Groundwater pollution is the entry of other components into groundwater, thus, water quality decreasing. The substances that cause groundwater contamination are not only human activities (anthropogenic) but also due to natural processes. Human activities can pollute groundwater, such as industries and agriculture. Furthermore, mineral exploration activities also can pollute groundwater. Some changes can pose a danger to human life or useful species, industrial processes, habitation, and cultural remains or can destroy the source of raw materials.

Contaminants can be anthropogenic, such as from leaking fuel tanks or toxic chemical spills, pesticides and fertilizers from agriculture applied to lawns and crops can accumulate and migrate to the water table, and leakage from septic tanks and / or waste-disposal sites can also contaminate bacteria to the water. Furthermore, a well might have been placed in land that was once used for something like a garbage or chemical dumpsite. In any case, if people use their own well to supply drinking water in their home, it is wise to have the drinking water tested from contamination(Waller, 1988).

11.2. Geoelectrical Methods

The geoelectric resistivity method is a method that is widely used in the world of exploration, especially groundwater exploration, because the resistivity of rocks is sensitive to its water content. The basic idea of this method is simple, which is to think of the earth as a resistor. The resistivity geoelectric method is one of a group in geoelectric methods that used to study subsurface conditions by studying the properties of electric currents in rocks below the earth's surface. The principle in this method is that an electric current is injected into the natural world through two current electrodes, while the difference of potential that occurs is measured through two potential electrodes. The result from measurement of current and electric potential difference, it can be obtained the variation in the value of electrical resistivity in the layer below the measuring point.

The calculation of the resistivity value obtained in the field is not an actual resistivity value, but an apparent value with homogeneous resistivity below the surface. This will provide the same resistance value for the same configuration. To determine the actual resistivity value below the surface, an inversion of the apparent resistivity value is performed using a computer program. The rocks in the earth have different resistivity values. The difference in resistivity value is influenced by several factors that affect the resistivity value. Therefore, measurements in an area will have a resistivity value that is different from other areas. From table 1 the resistivity value can be determined.

Table 1. Rock Resistivity Value Table (Telford, Geldart and Sheriff, 1990)

Material	Resistivity (Ω•m)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	$5x10^3 - 10^6$	$10^{-6} - 2x10^{-4}$
Basalt	$10^3 - 10^6$	$10^{-6} - 10^{-3}$
Slate	$6x10^2 - 4x10^7$	$2.5x10^{-8} - 1.7x10^{-3}$
Marble	$10^2 - 2.5x10^8$	$4x10^{-9} - 10^{-2}$
Quartzite	$10^2 - 2x10^8$	$5x10^{-9} - 10^{-2}$
Sedimentary Rocks		
Sandstone	$8 - 4x10^3$	$2.5x10^{-4} - 0.125$
Shale	$20 - 2x10^3$	$5x10^{-4} - 0.05$
Limestone	$50 - 4x10^2$	$2.5x10^{-3} - 0.02$
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800	$1.25 x10^{-3} - 0.1$
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	$9.074x10^{-8}$	$1.102x10^7$
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	$6.998x10^{16}$	$1.429x10^{-17}$

Based on the purpose of the research, the resistivity method can be divided into two, mapping and sounding. The geoelectric resistivity mapping method is a resistivity method that aims to study the horizontal variations in the resistivity of the subsurface layers. Therefore, this method uses a fixed electrode spacing for all datum points on the earth's surface. At the same time, the resistivity sounding method aims to study the vertical resistivity variations of the subsurface layers of the earth. In this method, the measurement at one measuring point is done by varying the electrode distance. Changing the electrode spacing is not done arbitrarily but starting with a small electrode distance then increasing gradually. This electrode distance is proportional to the depth of the detected layer.

In this case, the current electrode and the potential electrode have a different distance, that is, the current electrode is a maximum of five times the distance between the potential electrodes. Note that the four electrodes with the datum point must form a line.

III. RESEARCH METHODOLOGY

III.1.Observation and Mapping

Field observations were carried out to obtain the existing conditions of the field followed by mapping, sampling, and data analysis. The survey was conducted to obtain primary data, determine sampling points, and determine groundwater flow pattern maps. Identification the groundwater flow pattern, it is necessary to measure the groundwater level and plot the residents' wells. Groundwater sampling is conducted randomly based on the source of clean water used by residents. Furthermore, field observations are also carried out to determine geoelectric data points.

After observations was conducted, an analysis of the existing conditions, groundwater flow patterns, and geoelectricity was carried out. Mapping is done to describe the spatial pattern of groundwater flow in the study area. Another purpose of mapping is to determine sampling locations and location for geoelectric sounding points.

III.2. Geoelectrical Method

Geoelectric data is used to analyze the aquifer with hydrocarbons contamination or identify the potential presence of hydrocarbons in subsurface water. In this method, an electric current is injected into the earth through two current electrodes and a potential difference is measured through two potential electrodes. From the measurement results of current and electric potential difference, it will be possible to calculate the variation of the resistivity value in the layer of the earth's surface below the sounding point. At the time of the acquisition, there were several types of arrangement of current and potential electrodes. The rules for placing the two types of electrodes are known as configurations (Hendrajaya and Arif, 1990). In groundwater exploration, the configuration commonly used is the Schlumberger configuration. This configuration can provide aquifer presence.

Basically, the geoelectric method uses the assumption that the earth is an isotropic homogeneous rock. The rock resistivity value obtained at the time of measurement is considered as the actual rock resistivity value. However, the earth is an anisotropy, homogeneous rock. The resistivity value at the time of measurement is considered as an apparent resistivity value or apparent rho (ρa). Meanwhile, the actual resistivity value will be greatly influenced by the measurement spacing.

IV. FINDING AND DISCUSSION

IV.1. Geological Condition

The geological condition of the study area is composed of materials that have not yet experienced consolidation. According to the digital regional geological map by Bakosurtanal, the research area is included in the Young Merapi Volcano Sediment with the sediment direction to the south (Bakosurtanal, 2004). The material included in the formation of young volcanic deposits of Merapi consists of sediments with size range from clay to gravel (Kristanto and Indrawan, 2018). Based on the existing condition, it is possible that the research location has the potential for free aquifer type with shallow depths. Groundwater in free aquifers with the constituent material in the form of loose material is included in the phreatic type. The phreatic type of groundwater has a low hydrostatic pressure reaching zero. With this low hydrostatic pressure value, the flow pattern of pure phreatic type groundwater following the low height of aquifer forms on a small scale or large-scale groundwater basins with laminar flow patterns (Hardiyatmo and Widodo, 1992).

The research area with aquifers composed of materials of various sizes from clay to gravel, this type of material has a high permeability value ranging from 10^{-2} - 10^{3} mm/s and porosity of > 60% (Hardiyatmo and Widodo, 1992). The value of porosity and permeability in the study area shows the easiness of groundwater transmission with a laminar flow pattern to the south.

The existence of three gas stations in the research area has resulted in the significance of the potential for groundwater pollution by the remaining activities and fuel spill wasted from activities at the Gas Station. Based on the type and characteristics of the groundwater aquifer, the potential for pollution will easily enter the aquifer system and spread according to the aquifer flow pattern.

IV.2. Groundwater Flow

The direction of pollution can be determined from the direction of groundwater runoff. In Figure 1 the upstream of the groundwater runoff is in the north and leads to the south. The depth of the groundwater is not more than 10 meters. This can lead to easy distribution of hydrocarbon contaminants from gas stations because of the short distance. The existence of a groundwater flow pattern map will determine the distribution of pollutants.

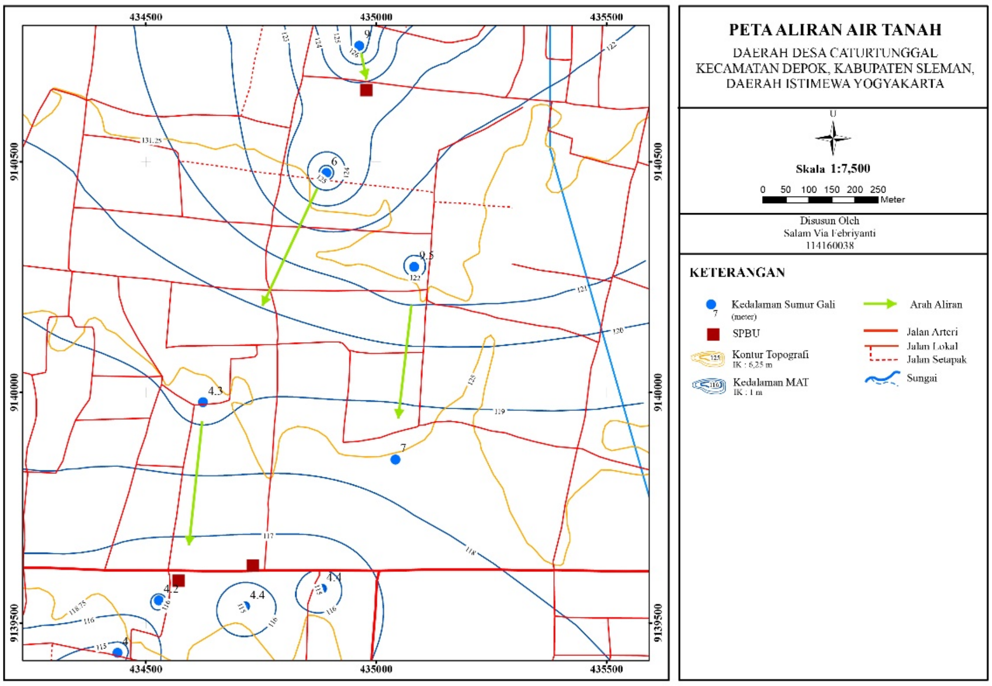

Figure 1. Groundwater Flow Pattern Map

A. Geoelectrical Analysis (One Dimension Inversion Analysis

1) Sounding 1

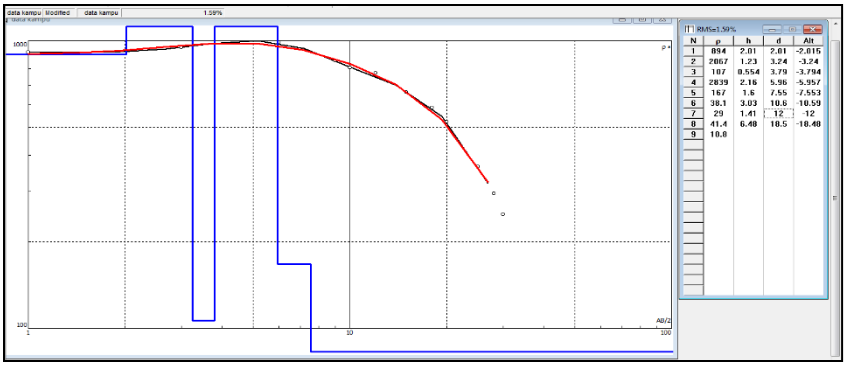

Figure 2. Sounding Point 1

Based on the results of the inversion of the VES measurement point (sounding 1) in general up to a depth of 18.5 meters, it is composed of lithology which has coarse to very coarse grain size and is not well-compensated, this can be seen from the very high resistivity at measuring point 1. The estimated aquifer at this point is at a depth of 12.1 meters with a resistivity value of 29 ohm meters. At this point, there is no indication of groundwater pollution because the resistivity order in the aquifer zone is quite high, which is in the order of 10^1 ohm meters. Areas with poor or contaminated groundwater conditions are in the resistivity order of 10^{-2} - 10^{-1} ohm meters. Figure 2 shows the result from a geoelectrical analysis at point 1.

2) Sounding 2 (434865,9140520/area Babarsari)

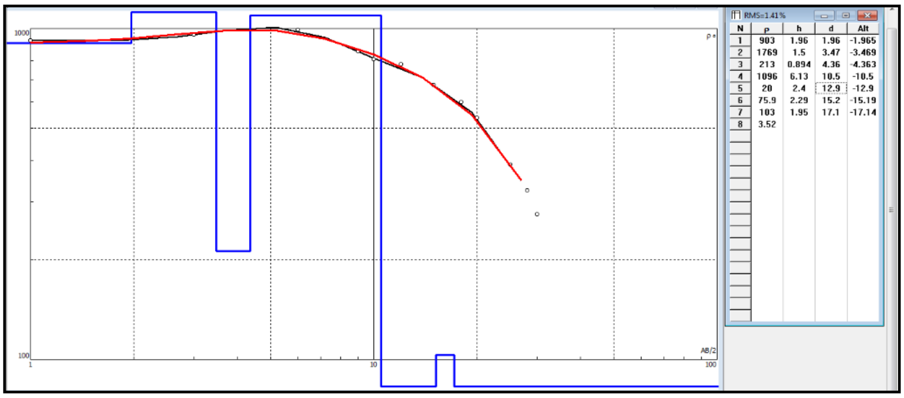

Figure 3. Sounding Point 2

Based on the results of the inversion of the VES measurement point (sounding 2) in general, to a depth of 17.1 meters, it is composed of lithology which has coarse to very coarse grain sizes and is not well-matched. The estimated aquifer at this point is at a depth of 12.9 meters with a resistivity value of 20 ohm meters. Similar to the VES 1 measuring point, at this point there is no indication of groundwater contamination because the resistivity order in the aquifer zone is quite high, which is in the order 10^{1} ohm meter. Figure 3 shows the result from a geoelectrical analysis at point 2.

3) Sounding 3 (434980,9140022/area Kledokan)

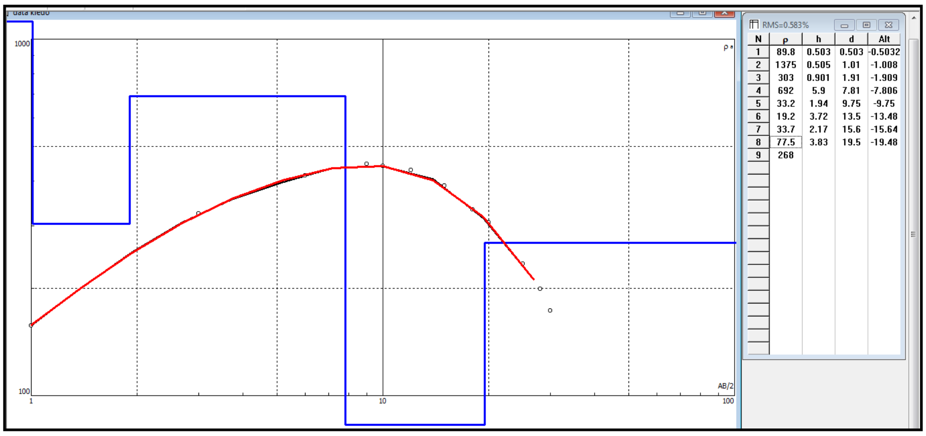

Figure 4. Sounding Point 3

Based on the results of the inversion of the VES measurement point (sounding 3), in general, up to a depth of 19.5 meters, it is composed of lithology which has coarse to very coarse grain sizes and is not well-matched. The resistivity pattern begins to decline at a depth of 9.75 meters to a depth of 13.5 meters. The estimated aquifer at this point is at a depth of 13.5 meters with a resistivity value of 19 ohm meters. Similar to the measuring points of VES 1 and 2, at this point there is no indication of groundwater contamination because the resistivity order in the aquifer zone is quite high, which is in the order 10^1 ohm meter. Figure 4 shows the result from geoelectrical analysis at point 3.

4) Sounding 4 (438119,9231575)

Based on the results of the inversion of the VES measurement point (sounding 4) in general, to a depth of 20.6 meters, it is composed of lithology which has coarse to very coarse grain sizes and is not well-matched. The estimated aquifer at this point is at a depth of 14.5 meters with a resistivity value of 17.5 ohms meters. As with other VES measuring points, at this point there is no indication of groundwater pollution because the resistivity order in the aquifer zone is quite high, which is at orde 10^1 ohm meter. Figure 5 shows the result from a geoelectrical analysis at point 4.

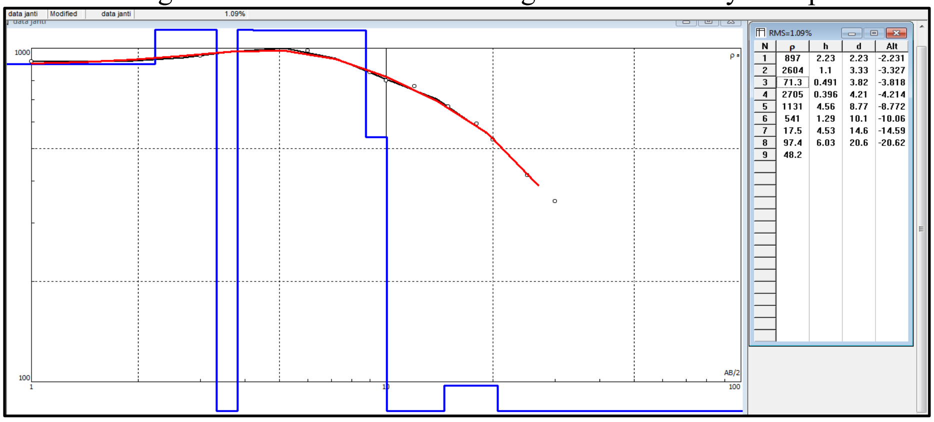

Figure 5. Sounding Point 4

V. CONCLUSION AND FURTHER RESEARCH

1. In general, the lithology of the composting area of the study area consists of loose sediments with coarse to very coarse grain sizes which are represented by large resistivity values.
2. At the measuring point 1 to 4 there is no indication of the presence of groundwater pollution which is represented by the resistivity value of the aquifer zone in the research area which is still in the resistivity order of 10^1 ohm meters. Furthermore, the collaboration result with others analysis such as the physical-chemical condition of aquifer is required to prove this hypothesis.
3. The existence of aquifers in the research area is at a depth of 12 meters to 15 meters. Getting deeper towards the south. Thus, the contamination could flow follow the depth of the aquifer.

VI. REFERENCES

Akankpo, O. and Igboekwe, M. U. (2011) “Monitoring Groundwater Contamination Using Surface Electrical Resistivity and Geochemical Methods,” *Journal of Water Resource and Protection*, 03(05), pp. 318–324. doi: 10.4236/jwarp.2011.35040.

Apparao, A. (1997) *Developments in geoelectrical methods*. India: National Geophysics Research Institute Hyderabad.

Bakosurtanal (2004) *Peta Digital Jawa Tengah*. Cibinong.

BPS Kabupaten Sleman (2018) *Kecamatan Sleman Dalam Angka 2018*. Sleman.

Freeze, R. A. (1984) “Groundwater Contamination,” *Eos*, 65(40), p. 2193.

Hardiyatmo, H. C. and Widodo, P. (1992) *Mekanika Tanah*. Gramedia Pustaka Utama, Jakarta.

Hendrajaya, L. and Arif, I. (1990) "Geolistrik Tahanan Jenis," *Laboratorium Fisika Bumi, Jurusan Fisika FMIPA ITB, Bandung*.

Kodoatie, R. J. (2012) *Tata ruang air tanah*. Penerbit Andi.

Kristanto, W. A. D. and Indrawan, I. G. B. (2018) "KARAKTERISTIK GEOLOGI TEKNIK DAERAH PRAMBANAN DAN SEKITARNYA, KECAMATAN PRAMBANAN, KABUPATEN SLEMAN, DAERAH ISTIMEWA YOGYAKARTA," *KURVATEK*, 3(2), pp. 21–29. Available at: https://journal.itny.ac.id/index.php/krvtk/article/view/755.

Menteri Kesehatan Republik Indonesia (2017) "Peraturan Menteri Kesehatan Republik Indonesia Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua dan Pemandian Umum," *Peraturan Menteri kesehatan Republik Indonesia*, pp. 17–20.

Muryani, E. (2012) "Zonasi Potensi Pencemaran Bahan Bakar Minyak terhadap Airtanah Bebas (Studi Kasus SPBU 44.552.10 Yogyakarta)," *Jurnal Sains &Teknologi Lingkungan*, 4(2), pp. 114–124. doi: 10.20885/jstl.vol4.iss2.art5.

Notodarmojo, S. (2005) "Pencemaran tanah dan air tanah," *Penerbit ITB. Bandung*.

Rahmawati, S. *et al.* (2018) "INVESTİGATİON of GroundwaterPollution By Petroleum Hydrocarbon From GasStationsİn Yogyakarta,Indonesia," *Jurnal Sains &Teknologi Lingkungan*, 10(1), pp. 67–76. doi: 10.20885/jstl.vol10.iss1.art6.

Republik Indonesia Government (2001) "PP 82 tahun 2001 TENTANG PENGELOLAAN KUALITAS AIR DAN PENGENDALIAN PENCEMARAN AIR," *Journal of Chemical Information and Modeling*. doi: 10.1017/CBO9781107415324.004.

Republik Indonesia, P. (1990) *Keputusan Presiden Republik Indonesia Nomer 32 Tahun 1990 Tentang Pengelolaan Kawasan Lindung*. Indonesia.

S. Okiongbo, K. and Akpofure, E. (2012) "Determination of Aquifer Properties and Groundwater Vulnerability Mapping Using Geoelectric Method in Yenagoa City and Its Environs in Bayelsa State, South South Nigeria," *Journal of Water Resource and Protection*, 04(06), pp. 354–362. doi: 10.4236/jwarp.2012.46040.

Telford, W. M., Geldart, L. P. and Sheriff, R. E. (1990) "Applied geophysics. 2nd edition," *Applied geophysics. 2nd edition*.

Waller, R. M. (1988) "Ground Water and the Rural Homeowner," *U.S Department of the Interior/Geological Survey*, p. 38. doi: 10.1080/713818024.