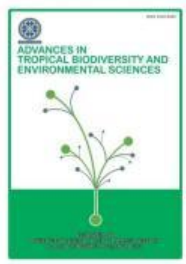

Advances in Tropical Biodiversity and Environmental Sciences
9(2): 83-92, June 2025
e-ISSN:2622-0628
DOI: 10.24843/ATBES.2025.v09.i02.p03
Available online at: https://ejournal1.unud.ac.id/index.php/atbes/article/view/1175

Analysis of Sulfate and Cadmium Distribution in Groundwater in Wonocolo Traditional Oil Mining Area, Bojonegoro Regency

Santi Amanda Tiara Putri*, Nindy Callista Elvania, and Heri Mulyanti

Program Study of Environmental Science, Faculty of Science and Engineering, University of Bojonegoro,
Jl. Lettu Suyitno No.2, Glendeng, Kalirejo, Bojonegoro Regency, 62119, East Java, Indonesia
*Corresponding author: amandatp1610@gmail.com

Abstract. Wonocolo Village in Bojonegoro Regency is one of the traditional oil mining areas that still contains old Dutch oil wells. The presence of these wells has the potential to affect groundwater quality. Petroleum that contaminates the soil can seep into groundwater, posing a serious threat to areas that rely on it as a source of clean water. This study aims to evaluate groundwater parameters, including temperature, pH, cadmium, and sulfate, by the standards set by the Indonesian Ministry of Health Regulation No. 32 of 2017, specifically regarding hygiene, sanitation, and public baths. Sampling was conducted using a purposive sampling method at 14 points. Data analysis was performed using the Inverse Distance Weighted (IDW) interpolation method. The results showed that in the densely populated southern part of the study area, the temperature at sampling point SG 13 reached 35°C, and cadmium levels across all samples ranged from 0.059 to 0.156 mg/L, exceeding the permitted quality standards. In contrast, pH and sulfate values met the quality standards set by Permenkes No. 32 of 2017. Therefore, efforts are necessary to reduce cadmium levels in the groundwater of Wonocolo Village, Bojonegoro Regency.

Keywords: cadmium; groundwater; sulfate; traditional oil mining

I. INTRODUCTION

Along with the continuous increase in water demand, there is a growing need for alternative water sources beyond surface water. One such alternative is groundwater. [1]. Groundwater is a naturally abundant resource because it is available below the surface and can be found almost everywhere. [2]. It is categorized as a renewable natural resource that plays a vital role in meeting water needs and has increasing economic value. [3]. Today, groundwater has become a valuable economic commodity, and in some areas, it has even become a strategic resource. It is estimated that 70% of the population's clean water and 90% of industrial water needs are supplied from groundwater. [4].

Groundwater is stored in water-bearing layers, known as aquifers. Water in aquifers can be one of the most important sources to help meet the growing demand for water on Earth [5]. Shallow groundwater, commonly referred to as well water, is groundwater located above the first impermeable layer [6]. However, the presence of shallow groundwater (well water) does not always guarantee high water quality. This is because shallow groundwater, which is commonly used by the public, is easily contaminated by seepage from waste disposal sites, garbage, human and animal waste, and other sources. Groundwater pollution is caused by contamination from chemical substances in liquid, solid, or gas form, which can originate from natural processes. However, human activities also often have a negative impact, both directly and indirectly, on the environment, effects which are not always well-identified [7].

In general, groundwater pollution originates from various sources that can degrade water quality and contaminate groundwater. This type of pollution can cause significant problems in areas that still rely on groundwater as their primary source of water. Clean water is essential for various activities, including bathing, washing, cooking, watering plants, and more. A previous study stated that petroleum can pollute the soil to the point where it reaches groundwater or other water sources used for domestic purposes. Petroleum is one of the major pollutants that can contaminate both soil and groundwater [8].

The oil well mining in Wonocolo Village originally consisted of 225 wells left by the Dutch Colonial Government. Over time, following the end of Dutch colonial rule, the oil well operations were managed by the residents of Wonocolo Village. The peak of oil extraction occurred in the 2000s, with the number of wells reaching 730. However, currently only 53 oil wells remain active [9]. There are approximately 505 old oil production wells in the Wonocolo Village area. This site has been a location for traditional oil and gas drilling since ancient times [10]. The presence of these old oil wells has the potential to affect the quality of shallow groundwater [11]. Approximately 65% of the population in Wonocolo Village still relies on shallow groundwater, while the rest use PAM (piped) water from other sources.

Traditional oil mining activities have both positive and negative impacts on the environment and the surrounding communities. One positive impact is the creation of new job opportunities for people living near the mines. However, traditional oil mining also has negative effects, particularly environmental pollution, with groundwater contamination being a major concern. Petroleum that pollutes the soil can seep into groundwater sources, posing a serious problem for areas that rely on groundwater as their primary source of clean or drinking water [12].

The purpose of this study is to analyze groundwater quality based on physical and chemical parameters and to identify the distribution patterns of groundwater use in relation to potential contaminants from traditional oil mining. To identify the sources of pollution, it is necessary to establish a distribution pattern of contaminants in the groundwater quality analysis in Wonocolo Village, Kedewan District, Bojonegoro Regency.

II. METHODS

This research was conducted in Wonocolo Village, Kedewan District, Bojonegoro Regency, East Java, which is geographically located between 111°25'–112°09' East Longitude and 6°59'–7°37' South Latitude, covering an area of 140,002 hectares. The area was selected as the focus of the study to analyze the distribution of groundwater pollution around traditional oil mining sites. The research was carried out from November to December 2024.

The tools used in this study included a GPS device, measuring tape, pH paper, thermometers, and glass bottles. The materials used were groundwater samples collected from dug wells owned by residents in the area surrounding the traditional oil mining site in Wonocolo Village. Subariswanti et al. [13], a groundwater modeling method using MATLAB was used to determine the distribution of groundwater contamination in Wonocolo. This analysis helped identify the sources of pollutants associated with the exploitation of old oil wells in Wonocolo Village.

The sampling technique used in this study was purposive sampling, as the well water is intended for bathing and washing, and the well owner is willing to allow their well to be used as a sample. This study used 14 sampling points because Wonocolo Village has only one residential hamlet near the mining area, where residents rely on groundwater. The measurements conducted included in situ measurements of temperature and pH, as well as ex-situ measurements of sulfate and cadmium concentrations. The collected samples were handled according to standard procedures by storing them in a cool box to preserve their condition. Subsequently, the samples were tested at the Bojonegoro Regency Regional Health Laboratory to measure cadmium and sulfate levels using a photometer.

The data analysis used in this study involves descriptive methods. Groundwater quality data obtained from laboratory test results and field measurements will be presented in table form to serve as a basis for decision-making. For mapping purposes, this analysis employs the IDW (Inverse Distance Weight) method in the Interpolation tool of the QGIS 3.34 application, based on the tested parameters, to analyze the distribution of contaminants.

Inverse Distance Weighting (IDW) is a spatial interpolation method that assumes each input point has a local influence that decreases with distance. This can be seen in Fig 1. Research flowchart. According to the Indonesian National Standard [14], the minimum number of measurement points required for interpolation is 10. However, the more data collected, the more valid the interpolation results. Yasrebi et al. [15] state that the IDW method requires a minimum of 14 measurement points with an appropriate distribution at the local scale. The formula for IDW weighting is as follows:

$$Wi = \frac{\frac{1}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}}$$

Description:
Wi= Weighting factor
di = Distance between observation point-i and the suspected point
p = Power (integer)

Advances in Tropical Biodiversity and Environmental Sciences 9(2): 83-92, June 2025 e-ISSN:2622-0628
DOI: 10.24843/ATBES.2025.v09.i02.p03 Available online at: https://ejournal1.unud.ac.id/index.php/atbes/article/view/1175

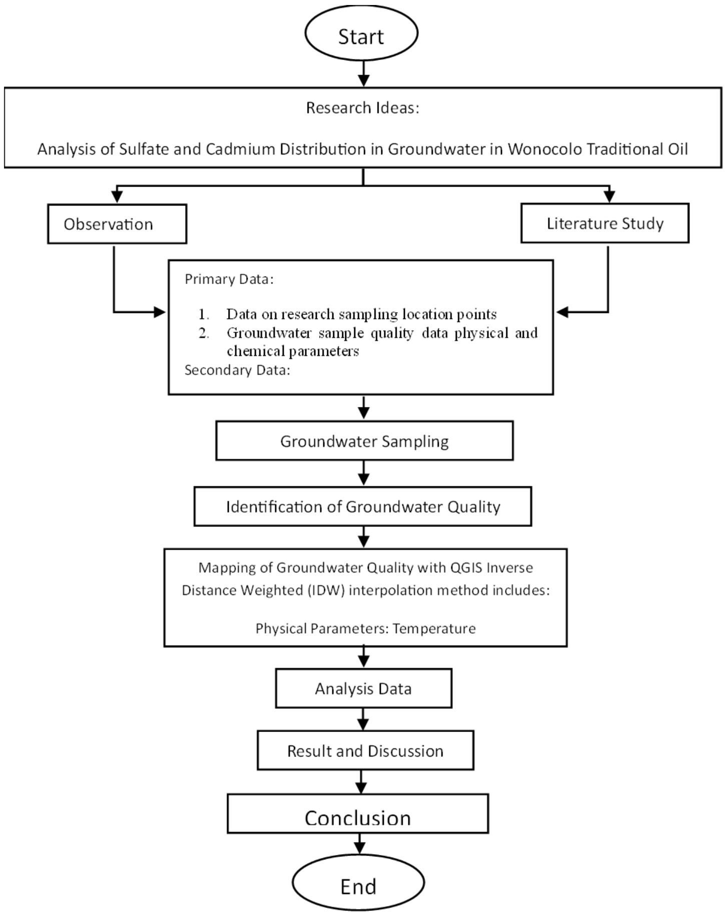

Figure 1. Research flowchart.

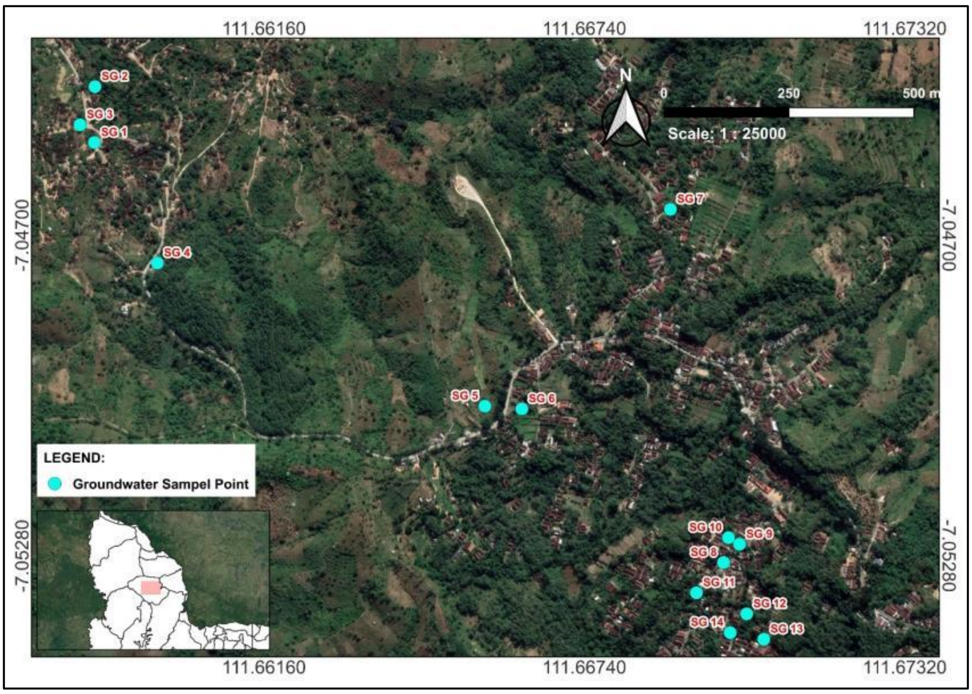

Figure 2. Sampling location.

II. RESULTS AND DISCUSSIONS

Groundwater Quality in Wonocolo Village

The groundwater in the study area is used as clean water by the residents of Wonocolo Village. The quality of the groundwater in Wonocolo Village can be analyzed using physical parameters, such as temperature, and chemical parameters, including pH, sulfate, and cadmium. Groundwater samples were collected from 14 dug wells owned by residents located near the traditional oil mining sites. Based on Table 1, it shows that the groundwater quality values for pH and sulfate levels in Wonocolo Village are following the standards set by the Indonesian Ministry of Health Regulation No. 32 of 2017, concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene Sanitation, Swimming Pools, Solus Per Aqua, and Public Baths. However, the results for temperature and cadmium levels do not meet the established quality standards.

The groundwater in Wonocolo Village has a temperature range of 29°C to 35°C (Table 2). The lowest temperature was recorded at point SG 3, with a result of 29°C, while the highest temperature was recorded at SG 13, which was 35°C. As a result, the groundwater temperature measurements exceed the standard requirements for water media used for hygiene sanitation as outlined in the Indonesian Ministry of Health Regulation No. 32 of 2017. This temperature is considered high at the sample collection point SG, which was taken during the daytime, and could affect the surrounding temperature. Temperature influences the water, and when it exceeds the normal range, it may indicate the presence of dissolved chemicals in significant amounts (such as phenols or sulfur) or that organic material is undergoing decomposition by microorganisms [16].

TABLE 1.
COORDINATES OF GROUNDWATER SAMPLING POINT

Sample Location	Coordinate		Sample Location	Coordinate	
	X	Y		X	Y
SG 1	-7.04532	111.65853	SG 8	-7.05292	111.66992
SG 2	-7.04431	111.65854	SG 9	-7.05259	111.67021
SG 3	-7.04500	111.65827	SG 10	-7.05247	111.67001
SG 4	-7.04750	111.65967	SG 11	-7.05347	111.66943
SG 5	-7.05009	111.66560	SG 12	-7.05385	111.67034
SG 6	-7.05014	111.66627	SG 13	-7.05431	111.67065
SG 7	-7.04653	111.66896	SG 14	-7.05419	111.67004

The pH analysis (Acidity Level) aims to measure the acidity and alkalinity of the healthy water [17]. The pH test results from the 14 research locations range from 6 to 8 (Table 2). Therefore, the pH measurement values meet the quality standards set by the Indonesian Ministry of Health Regulation No. 32 of 2017, which is 6.5 to 8.5. A pH value below 7 indicates an acidic condition, while a pH value above 7 indicates an alkaline condition. The pH values at the research locations are predominantly neutral. Thus, the groundwater quality in Wonocolo Village is considered neutral, as the average pH value ranges from 6 to 8.

The dissolved sulfate (SO_4) content is a key parameter used to determine the presence of sulfide mineral oxidation processes in the chemical composition of groundwater. The test results indicate that the sulfate (SO_4) levels range from 14 to 291 mg/l (Table 2). The highest sulfate concentration was found in sample code SG 1, with a value of 291 mg/l, while the lowest sulfate concentration was found in sample code SG 13, at 14 mg/l. These results indicate that the sulfate content in the groundwater of Wonocolo Village remains below the standard requirements for water media used for hygiene and sanitation, as stipulated by the Indonesian Ministry of Health Regulation No. 32 of 2017.

The maximum allowable sulfate level for groundwater is 400 mg/l, meaning the sulfate concentration still meets the standards for hygiene and sanitation purposes. The presence of cadmium in nature is relatively low. Human exposure to cadmium in the environment, particularly through the combustion of fossil fuels, can lead to contamination of water and food. Cadmium (Cd) is a metal that has a white-silver color, similar to aluminum, and is heat-resistant and corrosion-resistant [18]. The test results show that the cadmium concentration ranges from 0.059 to

0.156 mg/l. These results indicate that the cadmium levels in all the groundwater samples collected do not meet the standard requirements for water media used for hygiene and sanitation, which is 0.005 mg/l, as stated in the Indonesian Ministry of Health Regulation No. 32 of 2017.

In Figures 3 and 4, the results of the water quality tests, which have been interpolated, are shown, including physical parameters (temperature) and chemical parameters (pH, sulfate, and cadmium). The mapping results can be observed based on the color representation, where low contamination is indicated by lighter colors, and high contamination is represented by darker colors.

The test results for temperature parameters indicate that the southern part is represented by a dark red color. Points marked in dark red indicate that the temperature measurements at these locations are high. It can be concluded that the temperature parameter at four points—SG 9, SG 10, SG 13, and SG 14—exceeds the established quality standards. The temperature parameter has a deviation of 3°C from the ambient air temperature. If the normal water temperature (T) is 25°C, the water temperature is expected to range from 22°C to 28°C [19].

Pratiwi et al. [20] temperature increases or changes do not significantly affect water pollution. The rise in temperature does not impact water quality values and is not influenced by other parameters; however, it is affected by environmental conditions during water sampling and measurement in the field. Warmer groundwater temperatures indicate signs of increased mineral weathering and higher concentrations of elements relevant to drinking water, such as manganese.

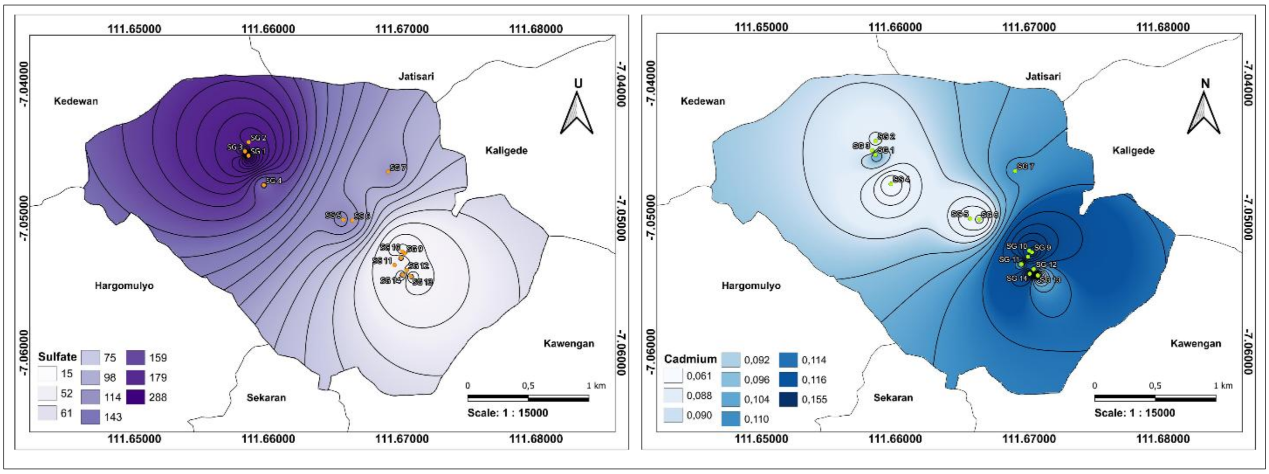

Figure 1. Results of Inverse Distance Weighted (IDW) Method Interpolation: (a) Temperature, (b) pH

TABLE 2.
GROUNDWATER QUALITY TEST RESULTS

NO	Sample	Parameters							
		Temperature	Requirement	pH	Requirement	Sulfate	Requirement	Cadmium	Requirement
1	SG 1	30		7		291		0.104	
2	SG 2	30		8		220		0.081	
3	SG 3	29		7		157		0.083	
4	SG 4	31		7		149		0.066	
5	SG 5	30		7		127		0.073	
6	SG 6	30		6		112		0.070	
7	SG 7	30	Deviasi 3°C	6	6,5-8,5	110	400mg/L	0.109	0,005mg/L
8	SG 8	32		7		58		0.144	
9	SG 9	34		7		21		0.156	
10	SG 10	34		8		23		0.141	
11	SG 11	32		7		40		0.100	
12	SG 12	30		8		37		0.118	
13	SG 13	35		7		14		0.059	
14	SG 14	34		7		67		0.154	

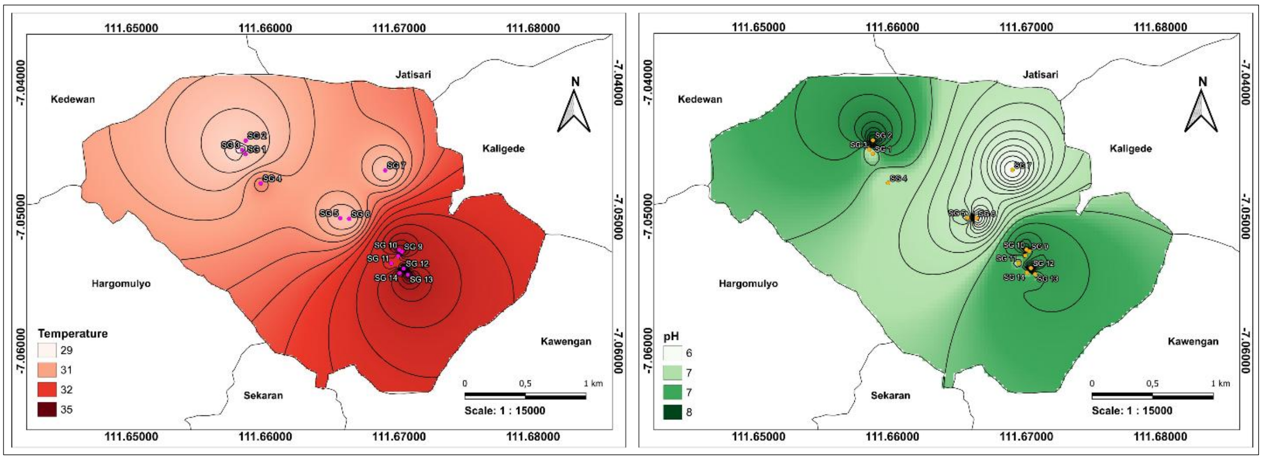

Figure 2. Results of Inverse Distance Weighted (IDW) Method Interpolation: (c) Sulfate, (d) Cadmium

The test results for the pH parameter indicate that the western and southern regions have a pH level of dark green. In the mapping results, all groundwater sample points for the pH parameter show values between 6 and 8, meaning the measurement results meet the established quality standards. The pH value of water can indicate the degree of corrosivity; the lower the pH value, the higher the water's corrosive properties [21]. Groundwater pH is influenced by the rocks and chemicals it comes into contact with underground, as well as the quality of water that is recharged or percolates into the aquifer from the surface. Acidic pH values may be influenced by the materials forming the aquifer or the surrounding lithology. According to Lesmana et al [22] acidic water (pH < 7) is usually found in areas with volcanic deposits. Alkaline pH values are influenced by the presence of bicarbonate ions (HCO3), which are alkaline. The more bicarbonate ions (HCO3) the groundwater contains, the more alkaline the groundwater's pH becomes [23].

The test results for the sulfate parameter show that the western region is represented by a dark purple color. In the mapping results, all groundwater sample points for the sulfate parameter fall within the range of 14-291 mg/l, which does not exceed the established quality standard of 400 mg/l as specified in the Indonesian Ministry of Health Regulation No. 32 of 2017. Sulfate is a compound that is chemically inert, non-volatile, and non-toxic; however, high sulfate concentrations can have negative environmental impacts and disrupt ecosystem stability [24]. According to Sharma & Kumar [25], high sulfate concentrations in groundwater can be caused by dissolution, atmospheric deposition, and anthropogenic sources, including mining activities. Issues caused by the presence of sulfate in water include scale formation, corrosion in pipelines, and the production of unpleasant odors [26].

The test results for the cadmium parameter show that the southern region is represented by a dark blue color. In the mapping results, all groundwater sample points for the cadmium parameter have values ranging from 0.059 to 0.156 mg/L, which exceed the quality standard of 0.005 mg/L as specified in the Indonesian Ministry of Health Regulation No. 32 of 2017. The natural source of cadmium release into water bodies occurs due to the weathering of rocks, which releases cadmium into the soil and subsequently into the water. According to research by Khan [27]The primary sources of cadmium include mining, metallurgy industries, pigments and plastic stabilizers, and nickel-cadmium battery factories. Kuntyasturi [28] stated that cadmium contamination levels are generally higher in industrial areas, regions with intensive agricultural activities, and densely populated areas compared to regions with less intensive agricultural activities and fewer industries and people. At point SG 9, the cadmium concentration is relatively high compared to the other 13 sample points because it is located in a densely populated area. The high cadmium levels at this residential area are due to domestic and household waste being discharged into water bodies, either directly or indirectly [29].

According to Wang et al. [30], another major source of cadmium contamination in groundwater is agricultural activities. A study in southern China showed that rice-producing areas with a double-cropping rice system, irrigation, atmospheric deposition, and the use of organic and phosphate fertilizers contributed to the increase of cadmium levels in soil and water. Heavy metals entering water bodies from mining activities also cause cadmium to be released into water bodies and groundwater through the precipitation process [31]. Hoareau et al. [32] stated that acid rain, which has become more common in industrial areas, facilitates the transportation of these heavy metals into rivers and groundwater. Atmospheric cadmium deposition can be caused by both anthropogenic and natural sources. Many reports have discussed that higher cadmium deposition originates from anthropogenic sources. However, more recent studies have shown that natural cadmium deposition exceeds anthropogenic sources by 93%, primarily from soil particles and forest fires. The concentration of cadmium in groundwater depends on the groundwater environment. Cadmium release from limestone systems and its transportation in groundwater can only occur in acidic waters. Acidification can be attributed to both natural influences, such as forests and wetlands, and anthropogenic sources, including acid mine drainage [33]. In Changsha, the capital of Hunan in southern China, the primary sources of cadmium contamination are mining and non-ferrous smelting activities near the Xiangjiang River. The increased demand for ferrous and non-ferrous metals has placed significant pressure on mining and smelting operations. Acid drainage and wastewater from mines, atmospheric deposition, and toxic slag are often the primary sources of cadmium in surrounding soils and water [34].

Distance Between Sample Points and Pollution Sources

Pollutants from mining activities can affect the water quality of sources based on distance. The closer the dug well is to the pollution source, the higher the likelihood of contamination. Dug wells should be located far from pollution sources. If the pollution source is too close to the well, it can lead to a decline in water quality, as groundwater flow is likely to carry contaminants into the well [35]. The closest distance to a pollution source, which is traditional oil mining, is at SG 2, located 0.25 km away, while the farthest distance is at SG 13, located 1.99 km from the pollution source. Both SG 2 and SG 13 share the same pollution source, namely traditional oil mining. At SG 2, the sulfate concentration in the groundwater is 220 mg/l, which is due to the proximity of the sample point to the pollution source. However, the sulfate level is still within the safe limit for groundwater. Meanwhile, at SG 13, the groundwater temperature is 35°C.

The study in Ledok Blora [36] found that groundwater pollution was caused by the proximity of residential wells to mining sites and the underground water flow, which carried oil mixed with water, contaminating the residents' well water. Other factors contributing to groundwater quality deterioration from pollution sources include porosity, permeability, and the direction of groundwater flow. Porosity and permeability can affect water absorption, allowing water to seep into the groundwater, such as in dug wells. Groundwater naturally flows due to differences in pressure and elevation. Water flows from higher to lower areas. This can have an impact if the well is located beneath the pollution source, as the contaminants, along with the underground water flow, will travel to the dug well. Determining the location of dug wells far from pollution sources is a measure to prevent and reduce the risk of contamination [37].

TABLE 3.
DISTANCE BETWEEN SAMPLE POINTS AND POLLUTION SOURCES

Sample	Coordinate		Distance (Km)	Sample	Coordinate		Distance (Km)
	X	Y			X	Y	
SG 1	-7.04532	111.65853	0,34	SG 8	-7.05292	111.66992	1,83
SG 2	-7.04431	111.65854	0,25	SG 9	-7.05259	111.67021	1,83
SG 3	-7.04500	111.65827	0,3	SG 10	-7.05247	111.67001	1,8
SG 4	-7.04750	111.65967	0,61	SG 11	-7.05347	111.66943	1,82
SG 5	-7.05009	111.66560	1,26	SG 12	-7.05385	111.67034	1,93
SG 6	-7.05014	111.66627	1,32	SG 13	-7.05431	111.67065	1,99
SG 7	-7.04653	111.66896	1,39	SG 14	-7.05419	111.67004	1,93

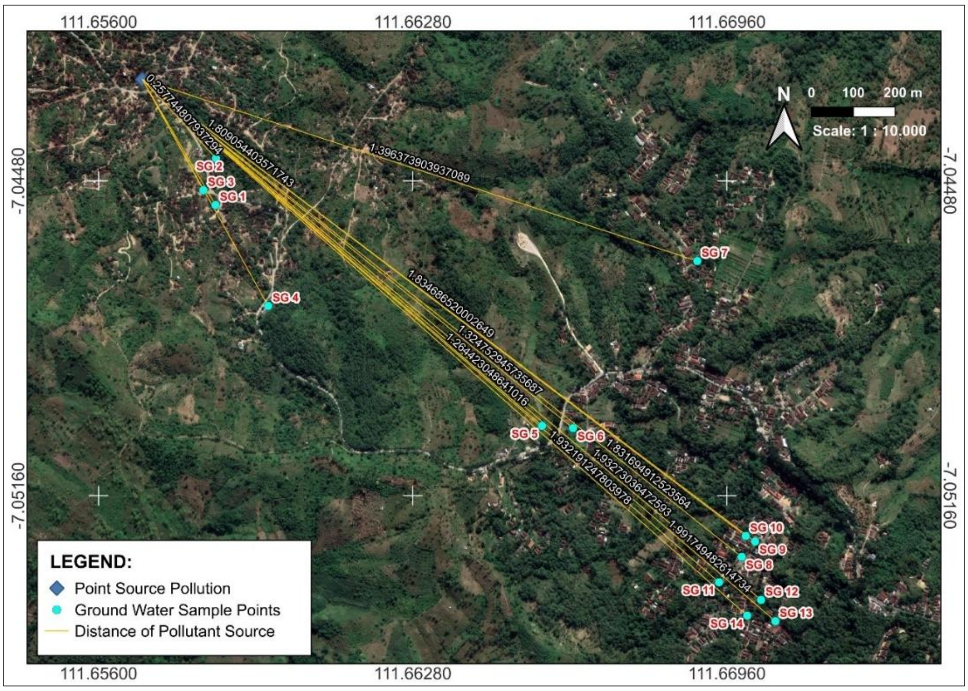

Figure 5. Distance Between Sample Point and Pollution Sources

V. CONCLUSION

Based on the groundwater quality testing results from community-owned dug wells in Wonocolo Village, the parameters of pH and sulfate still meet the established quality standards. However, the results for temperature and cadmium do not comply with the quality standards set by the Indonesian Ministry of Health Regulation No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene and Sanitation, Swimming Pools, Solus Per Aqua, and Public Baths. The groundwater temperature ranged between 34°C and 35°C, while cadmium levels ranged from 0.059 to 0.156 mg/l. The distribution of contamination shows that temperature and cadmium levels are higher in the southern area, which is predominantly a residential zone. This is likely due to anthropogenic activities surrounding the groundwater, such as mining, residential settlements, and agricultural practices.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to all those who contributed to the completion of this research. Special thanks are extended to the supervising lecturers of the Environmental Science Study Program, University of Bojonegoro, for their invaluable guidance and support throughout the research process. The author also wishes to thank the residents of Wonocolo Village for their cooperation, as well as friends and all other individuals who have provided assistance, directly or indirectly, and whose names cannot be mentioned individually. Their contributions have been essential to the successful completion of this study.

REFERENCES

[1] Nurhakim, A., Firdaus, M. (2022). Peluang Pemanfaatan Air Tanah Untuk Mendukung Keberlanjutan Sumber Daya Air di Kota Pare-Pare. 15.

[2] Muhardi, M., Perdhana, R., Nasharuddin, N. (2020). Identifikasi Keberadaan Air Tanah Menggunakan Metode Geolistrik Resistivitas Konfigurasi Schlumberger (Studi Kasus: Desa Clapar Kabupaten Banjarnegara). *Prisma Fisika*, 7(3): 331. https://doi.org/10.26418/Pf.V7i3.39441

[3] Nugroho, J. T., Sari, C. N., Nugraha, A. L. (2022). Identifikasi Zona Potensi Air Tanah Berbasis Sistem Informasi Geografis Dan Analytical Hierarchy Process (Studi Kasus: Provinsi Daerah Istimewa Yogyakarta). *Elipsoida : Jurnal Geodesi Dan Geomatika*, 5(1): 9–15. Https://doi.org/10.14710/Elipsoida.2022.16641;

[4] Bregasnia, W., Suwarsito, Sarjanti, E. (2020). Kajian Pola Aliran Air Tanah Di Area Kampus Utama Universitas Muhammadiyah Purwokerto. *Sainteks*, 17(1): 19. https://doi.org/10.30595/Sainteks.V17i1.8507;

[5] Rezky, B., Mandang, I., & Lepong, P. (2019). Identifikasi Lapisan Akuifer Air Tanah Dengan Menggunakan Metode Geoelektrisitas

Konfigurasi Schlumberger Di Taman Salma Shofa Samarinda, Kalimantan Timur. *Jurnal Geosains Kutai Basin*, 2(2).

[6] Akbar, M., Setiawan, B. (2021). Analisis Pengaruh Endapan Litologi Aquifer Terhadap Kualitas Air Tanah Dangkal Studi Kasus Pada Daerah Indralaya Utara Kabupaten Ogan Ilir. *Prosiding Seminar Nasional Hari Air Dunia*, 3;

[7] Ripo, M. K., Hasan, M. H., & Sunimbar. (2023). Pemanfaatan Air Tanah (Sumur Gali) Dan Kualitasnya Untuk Keperluan Air Minum Di Desa Oelnasi Kecamatan Kupang Tengah Kabupaten Kupang. *Jurnal Pangea: Wahana Informasi Pengembangan Profesi Dan Ilmu Geografi*, *5*(2), 69-77.

[8] Harnani. (2018). Kajian Tingkat Pencemaran Minyak Bumi Akibat Pengeboran Ilegal Berdasarkan Pemetaan Sungai Sumur Dan Fisika-Kimia Air Studi Kasus: Kecamatan Keluang Kabupaten Musi Banyuasin Sumatera Selatan. *Promine*, *6*(2): 16–23. https://doi.org/10.33019/Promine.V6i2.779;

[9] Irawan, A. B., & Waisnawa, I. P. G. B. (2022). Kajian Kualitas Air Terproduksi Minyak Bumi Dan Dampaknya Terhadap Pencemaran Air Sungai Dong Rupit Di Kawasan Sumur Tua Minyak Bumi Desa Wonocolo, Bojonegoro, Jawa Timur. *J. Ilmiah Lingkungan Kebumian*, 4(2): 2. Https://doi.org/10.31315/Jilk.V4i2.6871

[10] Setyaningrum, D., Harjono, H., & Rizqiyah, Z. (2020). Analisis Kualitas Air Terproduksi Desa Kedewan Kecamatan Wonocolo Kabupaten Bojonegoro. *Science Tech: Jurnal Ilmu Pengetahuan Dan Teknologi*, 6(1): 1–9. Https://doi.org/10.30738/Jst.V6i1.6283

[11] Jati, K. P., Sugiyanto, H., & Muryani, C. (2017). Dampak Penambangan Minyak Tradisional Terhadap Kondisi Sosial Ekonomi Dan Lingkungan Hidup (Studi Kasus Desa Ledok Kecamatan Sambong Kabupaten Blora). *Jurnal Geoeco*, 3(1): 58–67.

[12] Bahtiar, L. A., & Hidayat, J. W. (2019). Pengaruh Bioremediasi Tanaman Eceng Gondok (Eichornia Crassipes) Terhadap Penurunan Amoniak, Ph, Minyak dan Lemak Pada Limbah Minyak Mentah Wonocolo Bojonegoro. *Prosiding Sentikuin (Seminar Nasional Teknologi Industri, Lingkungan Dan Infrastruktur)*, 2, A1.1-A1.7.

[13] Subariswanti, Hakim, A., & Suprayogi, D. (2021). Analisis Pola Persebaran Pencemaran Air Tanah Di Sekitar Penambangan Sumur Minyak Tua Desa Wonocolo, Kedewan, Bojonegoro: Analysis Of Groundwater Pollution Distribution Patterns Around The Mining Of Old Oil Wells Wonocolo Village, Kedewan, Bojonegoro. *Jurnal Teknik Sipil Dan Lingkungan*, 6(2), 133-142. Https://doi.org/10.29244/Jsil.6.2.133-142.

[14] SNI (Standar Nasional Indonesia). (2010). *Sni 7644;2010 Basis Data Spasial Oseanografi: Suhu, Salinitas, Oksigen Terlarut, Derajat Keasaman, Turbiditas, Dan Kecerahan*. Badan Standar Nasional (BSN). https://Drive.Google.Com/File/U/0/D/1xtyfmhongq0ae4aopvdbv_Hygzsylc6m/View?Usp=Embed_Facebook;

[15] Yasrebi, J., Saffari, M., Fathi, H., Karimian, N., Moazallahi, M., & Gazni, R. (2009). Evaluation And Comparison Of Ordinary Kriging and Inverse Distance Weighting Method For Prediction of Spatial Variability of Some Soil Chemical Parameters. *Research Journal of Biological Science*, 4(1), 93–102.

[16] Mairizki, F. (2017). Analisa Kualitas Air Minum Isi Ulang di Sekitar Kampus Universitas Islam Riau. *Jurnal Katalisator*, *2*(1), 9. https://doi.org/10.22216/Jk.V2i1.1585;

[17] Nurhajawarsi, N., & Haryanti, T. (2023). Analisis Kualitas Air Sumur Sekitar Kawasan Industri Bantaeng (Kiba). *Sebatik*, *27*(1), 43–51. https://doi.org/10.46984/Sebatik.V27i1.2258;

[18] Lukmanulhakim, R. C., Hidayati, N. V., & Baedowi, M. (2023). Analisis Kandungan Logam Berat Kadmium (Cd) Dan Kromium (Cr) Pada Matriks Air Di Sungai Pelus Kabupaten Banyumas, Jawa Tengah. *Maiyah*, *2*(1), 41. https://10.20884/1.Maiyah.2023.2.1.8295

[19] Rosdiansyah, H. (2019). Analisis Kualitas Air Dan Daya Tampung Beban Pencemaran Kali Surabaya Di Kecamatan Driyorejo [Skripsi]. Universitas Islam Negeri Sunan Ampel.;

[20] Pratiwi, I. N. T., Yushardi, Y., Kurnianto, F. A., Astutik, S., & Apriyanto, B. (2022). Evaluasi Dan Sebaran Kualitas Air Tanah Berdasarkan Parameter Litologi, Tekstur Tanah, Dan Limbah Di Kecamatan Kaliwates Kabupaten Jember. *Majalah Pembelajaran Geografi*, *5*(2), 82. https://doi.org/10.19184/Pgeo.V5i2.34379;

[21] Lestari, I. L., Singkam, A. R., Agustin, F., Miftahussalimah, P. L., Maharani, A. Y., & Lingga, R. (2021). Perbandingan Kualitas Air Sumur Galian Dan Bor Berdasarkan Parameter Kimia Dan Parameter Fisika. *Bioedusains:Jurnal Pendidikan Biologi Dan Sains*, *4*(2), 155–165. https://Doi.Org/10.31539/Bioedusains.V4i2.2346

[22] Lesmana, A., Csssa, B. Y., & Iskandarsyah, T. Y. W. M. (2021). Karakteristik Hidrokimia Air Tanah

Pada Bagian Timur Cekungan Air Tanah Bandung-Soreang: Studi Kasus Sebagian Kecamatan Cicalengka Dan Kecamatan Cimanggung, Provinsi Jawa Barat. 5(6): 546–562;

[23] Agustiani, E., Triastuti, W. E., Zahrah, H. F., Tyas, S. R. C., Fitria, Y. D., Rahmawati, A. M., Martasari, A., & Wintara, E. S. (2023). Penentuan Kadar Sulfat Pada Air Sumur Di Wilayah Surabaya Menggunakan Spektrofotometer. *Prosiding Seminar Nasional Teknik Kimia "Kejuangan."*

[24] Ni, A. A., Ernawati, R., Cahyadi, T. A., Nursanto, E., & Amri, N. A. (2022). Overview Metode Pengelolaan Air Asam Tambang Menggunakan Bakteri Pereduksi Sulfat. *Prosiding Seminar Nasional: "40 Tahun Pandu Berbakti."*

[25] Sharma, M. K., & Kumar, M. (2020). Sulphate Contamination In Groundwater and Its Remediation: an Overview. *Environmental Monitoring and Assessment*, 192(2): 74. https://Doi.Org/10.1007/S10661-019-8051-6;

[26] Sahwilaksa, J. (2014). Pengaruh Air Laut Terhadap Kualitas Air Tanah Dangkal di Kawasan Pantai Kota Surabaya. *Rekayasa Teknik Sipil*, 3(3): 241–247.

[27] Khan, Z., Elahi, A., Bukhari, D. A., & Rehman, A. (2022). Cadmium Sources, Toxicity, Resistance, And Removal By Microorganisms: A Potential Strategy For Cadmium Eradication. *Journal Of Saudi Chemical Society*, 26(6): 101569. https://doi.org/10.1016/J.Jscs.2022.101569;

[28] Kuntyastuti, H., & Sutrisno, S. (2015). Pengelolaan Cemaran Kadmium Pada Lahan Pertanian di Indonesia. *Buletin Palawija*, *13*(1);

[29] Pratiwi, D. F., Hidayat, D., & Pratama, D. S. (2016). Tingkat Pencemaran Logam Kadmium (Cd) Dan Kobalt (Co) Pada Sedimen Di Sekitar Pesisir Bandar Lampung. 1(01);

[30] Wang, P., Chen, H., Kopittke, P. M., & Zhao, F.-J. (2019). Cadmium Contamination in Agricultural Soils of China and Its Impact on Food Safety. *Environmental Pollution*, 249: 1038–1048. https://doi.org/10.1016/J.Envpol.2019.03.063.

[31] Putri, A., Cahyadi, D. F., Rudi, M. (2023). Analisis Kandungan Logam Kadmium Dan Timbal Pada Kerang Hijau (Perna Viridis) di Cilincing, Jakarta Utara. *Fish Scientiae*, 13(1): 5-21. https://doi.org/10.20527/Fishscientiae.V13i1.200;

[32] Hoareau, C. E., Hadibarata, T., & Yılmaz, M. (2022). Occurrence Of Cadmium In Groundwater In China: A Review. *Arabian Journal Of Geosciences*, *15*(17), 1455. Https://Doi.Org/10.1007/S12517-022-10734-X;

[33] Kubier, A., Wilkin, R. T., & Pichler, T. (2019). Cadmium In Soils and Groundwater: A Review. *Journal of The International Association of Geochemistry and Cosmochemistry*, 108:1–16. https://doi.org/10.1016/J.Apgeochem.2019.104388

[34] Du, P., Zhang, L., Ma, Y., Li, X., Wang, Z., Mao, K., Wang, N., Li, Y., He, J., Zhang, X., Hao, F., Li, X., Liu, M., & Wang, X. (2020). Occurrence And Fate of Heavy Metals in Municipal Wastewater in Heilongjiang Province, China: A Monthly Reconnaissance From 2015 To 2017. *Water*, 12(3): 728. https://doi.org/10.3390/W12030728;

[35] Rohmania, S. Y., & Eri, I. R. (2022). Jarak Tempat Pembuangan Sampah Dan Kondisi Fisik Sumur Gali Terhadap Kualitas Air Sumur Di Wilayah Kelurahan Cemengkalang Sidoarjo. *Jurnal Kesehatan Lingkungan*, 12(1): 110–115;

[36] Rintayati, P. (2017). Persepsi Dampak Pertambangan Minyak Tradisional Terhadap Kondisi Lingkungan Hidup Di Daerah Cepu (Survei Pada Masyarakat Desa Ledok Kecamatansambong, Kabupaten Blora). *Prosiding Snpbs (Seminar Nasional Pendidikan Biologi Dan Saintek)*, 141–155. https://Publikasiilmiah.Ums.Ac.Id/Handle/11617/9323;

[37] Rahayu, P., Joko, T., & Dangiran, H. L. (2019). Hubungan Faktor Risiko Pencemaran Sumur Gali Dengan Kualitas Bakteriologis Di Lingkungan Pemukiman RW IV Kelurahan Jabungan Kota Semarang. *Jurnal Kesehatan Masyarakat*, 7.