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Analysis of Nitrogen Concentration (Nitrate, Nitrite, Ammonia) in Groundwater in Ngaglik SubDistrict, Sleman Regency, Yogyakarta Province

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ARTICLE INFO

Article History:

Received 20 April 2024

Revised 20 May 2024

Accepted 24 May 2024

Published 10 Juni 2024

Keywords:

Ammonia,
Groundwater,
Nitrate,
Nitrite,
Water quality.

ABSTRACT

Groundwater plays a critical role in supporting all forms of life on Earth. The Ngaglik sub-district has experienced continuous regional development, which has led to increased human activities. Such activities contribute to higher waste generation, which can ultimately degrade the quality of surface water and groundwater. The objective of this study is to assess the concentrations of nitrite, nitrate, and ammonia in groundwater from the Ngaglik sub-district, to analyze the spatial distribution of these pollutants, and to identify the factors influencing groundwater quality. The research was conducted in the Ngaglik sub-district, Sleman Regency, Yogyakarta Province, at 14 well locations. Nitrite, nitrate, and ammonia concentrations were determined using spectrophotometry, following the Indonesian national standard method. To evaluate the spatial distribution of water quality, a mapping analysis was conducted using Quantum Geographic Information System (QGIS) software. Laboratory analysis revealed nitrate concentrations ranging from 1.102 mg/L to 14.503 mg/L, nitrite concentrations from 0.045 mg/L to 2.175 mg/L, and ammonia concentrations from 0.208 mg/L to 4.65 mg/L. The study concludes that the concentrations of nitrite and nitrate in the groundwater met the environmental health standards set by the Ministry of Health (Regulation No. 2 of 2023), while ammonia concentrations exceeded the permissible limits.

1. Introduction

Ngaglik is a sub-district located in Sleman Regency, within the Special Region of Yogyakarta, with a total population of 109,170 residents, as reported by the [Central Statistics Agency in 2022](#). The population density of the Ngaglik sub-district is 2,772 individuals per square kilometer, making it the fourth most populous sub-district in Sleman Regency, Yogyakarta Province.

Population growth is positively correlated with increased demand for clean water. As the population expands, the community's water requirements for daily activities also rise. Ngaglik sub-district is located within the Yogyakarta-Sleman Groundwater Basin, serving as a transition zone between the groundwater recharge and discharge areas ([Purwantara, 2018](#)). Consequently, the majority of residents in Ngaglik rely on groundwater as their primary source of clean water. To access groundwater, most residents construct either dug wells or drilled wells. Dug wells are the most commonly used type of well in Yogyakarta, accounting for 35% of all wells ([Central Statistics Agency, 2020](#)). These wells are typically shallow, extending less than 50 meters below the ground surface, and draw water from aquifers located relatively close to the surface.

Yogyakarta groundwater is susceptible not only to industrial activities such as the batik industry ([Da Silva, 2023; Rahmadanti, 2023](#)) and gas stations ([Rahmawati et al, 2018; Juliani et al., 2023](#)) but also to domestic activities, such as seepage from septic tanks into wells. A study by [Ekarini et al. \(2020\)](#) in Sleman, Yogyakarta, revealed that nearly all of the groundwater samples they tested contained levels of *Escherichia coli* (E. coli) and total coliform that exceeded the quality standards set by the Regulation of Indonesian Minister of Health number 492 of the year 2010 about Drinking Water Quality Requirements. Groundwater contaminated with pathogenic bacteria poses significant health risks to the public. Additionally, research by [Brontowiyono et al. \(2022\)](#) indicated that nitrate concentrations at several locations in Yogyakarta exceeded the government quality standards.

This study, therefore, aims to evaluate the chemical quality of groundwater in the Ngaglik sub-district, Sleman Regency, Yogyakarta Province, focusing on key chemical parameters such as nitrate, nitrite, and ammonia. It also seeks to conduct a spatial analysis of groundwater quality to determine the distribution of water quality across the Ngaglik sub-district.

2. Methods

The research was conducted in Ngaglik District, Sleman Regency, Yogyakarta Province, which is subdivided into six villages: Donoharjo, Minomartani, Sardonoarjo, Sariharjo, Sinduharjo, and Sukoharjo. Groundwater samples were collected between November 2022 to February 2023 from 14 wells belonging to residents of Ngaglik District. These sampling points were categorized into two groups: locations near a communal wastewater treatment plant (WWTP or IPAL) and locations farther from the IPAL. The location of sampling points is shown in Figure 1. Groundwater sampling procedures followed the Indonesian National Standard (SNI) 6989.58: 2008, which outlines methods for groundwater sampling.

Following collection, the groundwater samples were analyzed at the Environmental Water Quality Laboratory of the Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. The water quality parameters tested in this study using Indonesian National Standards (Standar Nasional Indonesia, SNI): SNI 01-3554-2006 for nitrate (NO_3), SNI 06-6989.9-2004 for nitrite (NO_2), and SNI 6989.30-2005 for ammonia (NH_3).

The obtained water quality then being compared to the standard quality criteria based on the Regulation of the Indonesian Minister of Health number 2 of the year 2023 about Environmental Health. The results were also imported to the QGIS program to be analyzed spatially using inverse distance weighting (IDW) interpolation ([Khouni et al., 2021](#)) so it can give insight into the distribution pattern of the water quality.

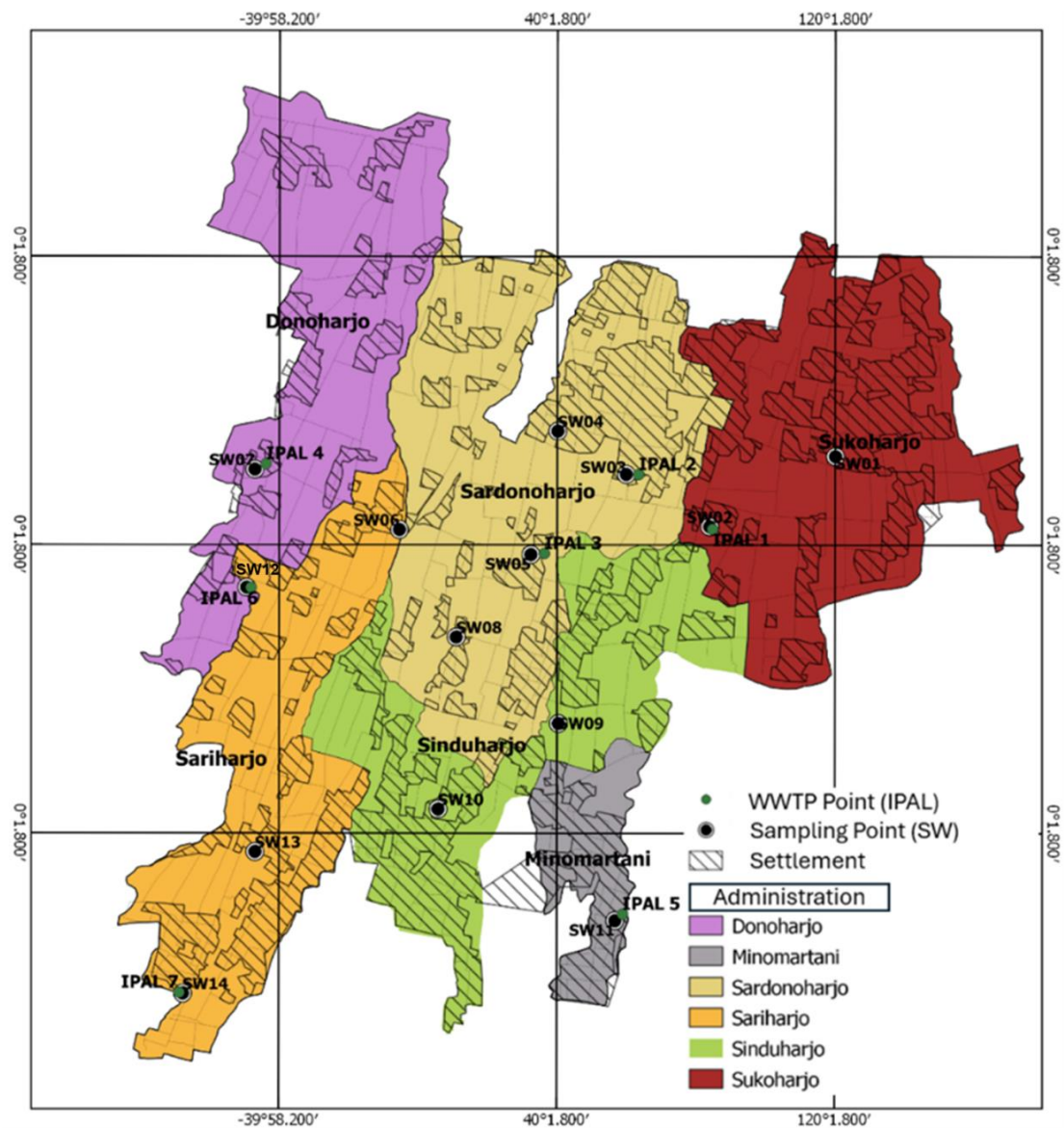


Figure 1. The location of sampling points in Ngaglik District, Sleman Regency, Yogyakarta

3. Results and Discussion

3.1 Sampling Point Conditions

Observations of the sampling point conditions were carried out through interviews with the well owners. The information gathered included well dimensions, the age of the well, sanitation systems in use, the distance between the sanitation system and the well, and the drainage conditions surrounding the well. This observational data is presented in Table 2. As shown in Table 2, nearly all of the locations use septic tank systems, except for sampling point number 14 (SW14) where domestic wastewater is directly connected to a communal wastewater treatment plant (WWTP or IPAL). Additionally, most of the wells at the study sites are over 10 years old, and all locations feature adequate drainage systems around the wells, indicating that the leaked wastewater from IPAL on the surface should be directed laterally rather than vertically infiltrated into the soil.

Table 2. Location and Condition of Sampling Point Wells

No.	Well Code	Coordinate	Well Dimension			Well Age	Sanitation System of the Well Owner	Distance between Well and Sanitation System (m)	Near/Far from WWTP (IPAL)
			Diameter (m)	Water level (m)	Depth (m)	Year			
1	SW01	-7,703536	1	5	7	20	Septic Tank	5	Far
		110,427105							
2	SW02	-7,709475	1	2	5–6	30	Septic Tank	5	Near
		110,416435							
3	SW03	-7,705034	1	3	7	2	Septic Tank	10	Near
		110,40935							
4	SW04	-7,701371	1	1	5	30	Septic Tank	10	Far
		110,403544							
5	SW05	-7,711822	1	4	12	50	Septic Tank	15	Near
		110,401262							
6	SW06	-7,709699	1	1,5	4	40	Septic Tank	7–10	Far
		110,390103							
7	SW07	-7,704578	1	2	7	10	Septic Tank	3	Near
		110,377839							
8	SW08	-7,718808	1	6	12	30	Septic Tank	10	Far
		110,394919							
9	SW09	-7,726133	1	2	6	22	Septic Tank	8–10	Far
		110,403578							
10	SW10	-7,733378	1	2,5	5	7	Septic Tank	15	Far
		110,393373							
11	SW11	-7,742841	1	3	8	15	Septic Tank	40	Near
		110,408374							
12	SW12	-7,714576	1	2	6	4	Septic Tank	10	Near
		110,377145							
13	SW13	-7,736972	1	3	6	12	Septic Tank	15	Far
		110,377833							
14	SW14	-7,748963	1	2,5	8	15	Communal WWTP	100	Near
		110,371692							

3.2 Concentration of Nitrate, Nitrite, and Ammonia in Well Water

The nitrate concentrations across all sampling points ranged from 1.102 mg/L to 14.503 mg/L, with the highest concentration observed at point SW04 (14.503 mg/L) and the lowest at point SW12 (1.102 mg/L). Nitrite concentrations varied from 0.045 mg/L to 2.175 mg/L, with the highest level recorded at point SW01 (2.175 mg/L) and the lowest at point SW11 (0.045 mg/L). According to the Regulation of the Minister of Health No. 2 of 2023, the maximum allowable concentrations for nitrate and nitrite in groundwater are 20 mg/L and 3 mg/L, respectively. Based on the test results, all sampled well points comply with the established nitrate and nitrite quality standards. A detailed comparison of nitrite concentrations across all well points is provided in Figure 2.

The concentration of ammonia (NH₃) across all sampling points ranged from 0.208 mg/L to 4.652 mg/L, with the highest concentration recorded at point SW07 (4.652 mg/L) and the lowest at point SW06 (0.208 mg/L). According to the Regulation of the Minister of Health No. 2 of 2023, ammonia is a key water quality parameter for areas designated for agriculture, plantations, or forestry, with a maximum allowable concentration of 1.5 mg/L. Based on this standard, it can be concluded that all sampling points meet the environmental health quality requirements, except for SW03 (Candi Dukuh), SW07 (Bantaran, Donoharjo), and SW13 (Jalan Bima). A comparison of ammonia concentrations across all sampling points is illustrated in Figure 2.

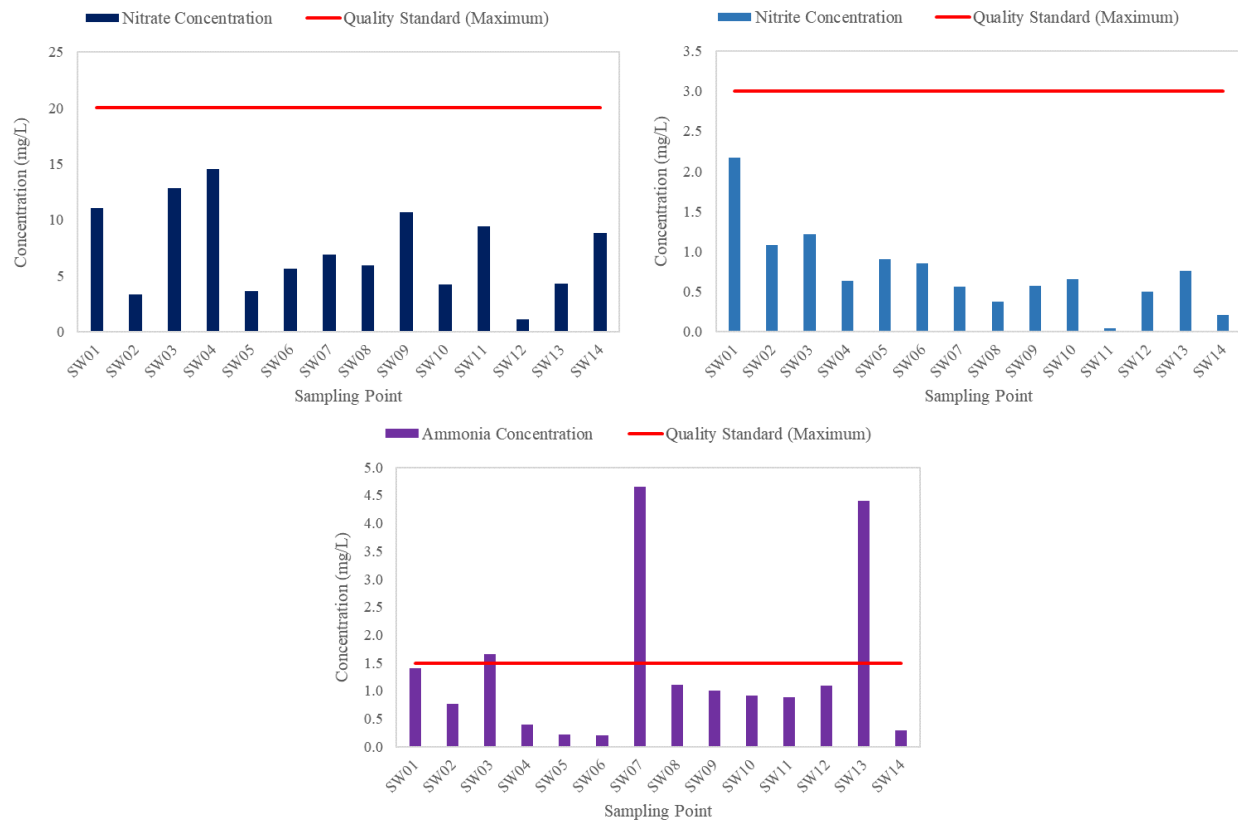


Figure 2. Nitrate, nitrite, and ammonia concentrations in all sampling points

Except for a few exceptions, all sampling points show a higher nitrate concentration than those of nitrite and ammonia. This trend occurs because ammonia is the precursor compound that undergoes oxidation first to nitrite and then to nitrate. Since nitrite is readily oxidized to nitrate, nitrate is the most commonly detected compound in both groundwater and surface water (Merian, 2016).

3.3 Spatial Analysis of Groundwater Quality

The distribution of nitrate concentration at 14 points in Ngaglik District was analyzed using the inverse distance weighting (IDW) interpolation method. This approach facilitated the visualization of concentration variations across different locations. Color gradients were applied to highlight concentration differences: darker colors represent higher nitrate concentrations, while lighter colors indicate lower concentrations. Interpolation results (Figure 5) reveal that the lowest nitrate concentration is observed near point SW12, whereas the highest concentration is near point SW04. The high nitrate levels around point SW04 are likely influenced by a nearby private vegetable garden that uses fertilizers (either organic or chemical) and proximity to a toilet. These factors are probable contributors to elevated nitrate concentrations in the area. Groundwater is a significant source of nitrate (Yu *et al.*, 2020), with common contributors including improper waste disposal, animal waste, and the application of nitrogen fertilizers (Burkholder *et al.*, 2007; Adimalla *et al.*, 2016).

Mapping of nitrite concentrations (Figure 5) shows the highest levels around point SW01 in Sukoharjo Village. Similarly, the ammonia concentration mapping (Figure 5) indicates the highest levels around points SW07 (Donoharjo) and SW13 (Jalan Bima). Elevated ammonia levels at point W07 are likely due to the well's proximity to livestock facilities, where livestock waste infiltration may

increase ammonia concentrations. Additionally, the nearby septic tank, located approximately 3 meters from the well, could contribute to these elevated levels. At point SW13, the high ammonia concentration may also be due to the well's proximity to a septic tank, about 5 meters away. Both locations (Donoharjo and Jalan Bima) exhibit ammonia concentrations that exceed the maximum threshold of quality standards.

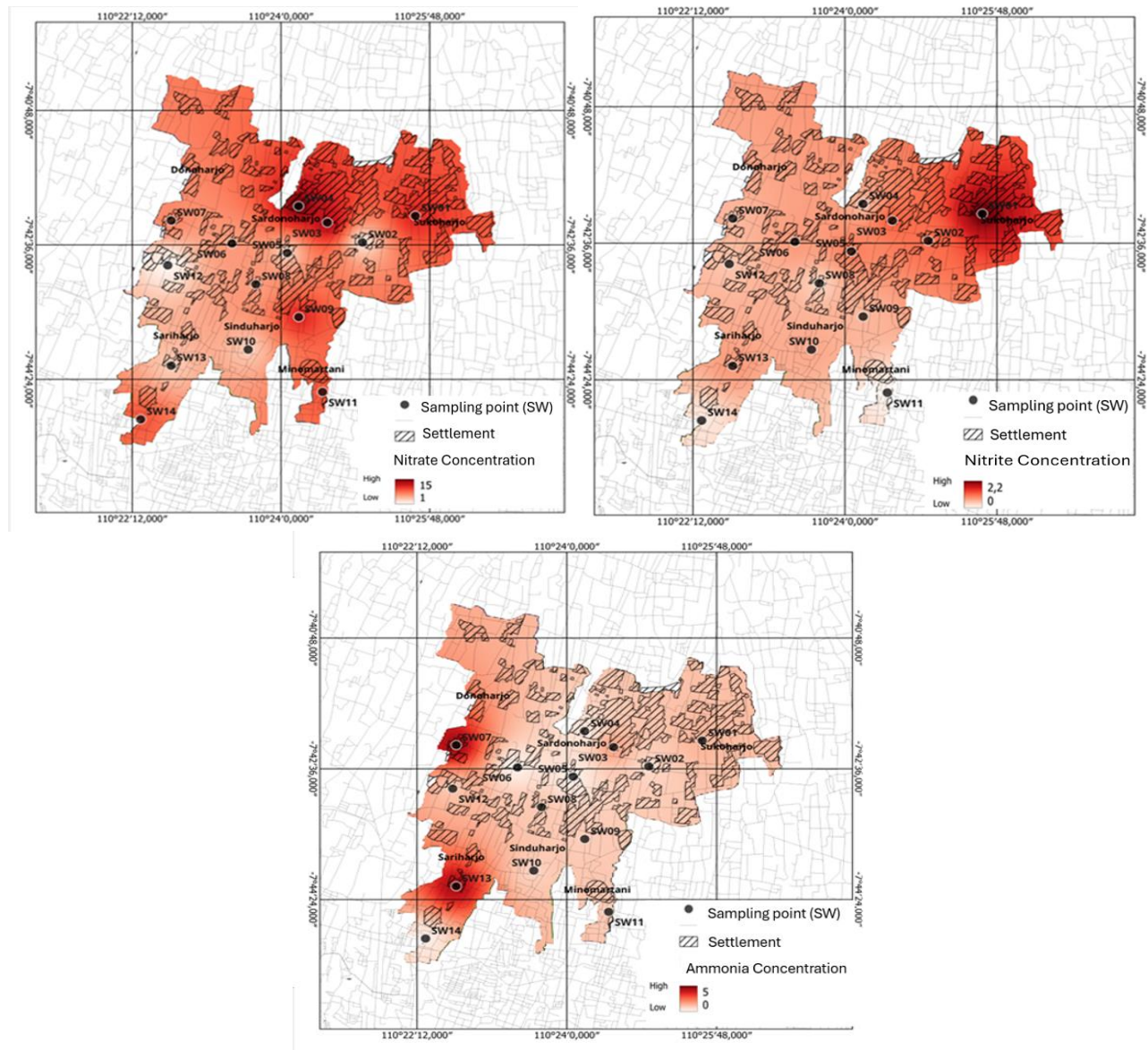


Figure 5. Distribution map of nitrate (upper-left), nitrite (upper-right), and ammonia (bottom) contamination in groundwater using inverse distance weighting interpolation in QGIS

3.4 Impact of Communal Wastewater Treatment Plant

The research indicates that the distribution of groundwater quality is largely unaffected by the presence of communal wastewater treatment plants. This conclusion is supported by the analysis of nitrate, nitrite, and ammonia concentrations, which did not exceed quality standards in monitoring

wells located both near and distant from these treatment plants. However, three samples did show elevated ammonia levels above the quality standards: SW03 (1.663 mg/L), SW07 (4.562 mg/L), and SW13 (4.404 mg/L). These elevated levels appear to be influenced by factors unrelated to the wastewater treatment plants.

At point SW03, the high ammonia concentration is likely attributable to the proximity of a poultry cage to the well. Additionally, domestic waste, such as bathroom and dishwashing water, has been disposed of near the well without adequate drainage, contributing to elevated ammonia levels.

For point SW07, the high ammonia concentration is probably due to the well's close proximity to livestock facilities, which leads to waste infiltration into the soil and subsequent groundwater contamination. The nearby septic tank, located approximately 3 meters from the well, may also contribute to the elevated ammonia levels.

At point SW13, high ammonia concentrations may result from cloudy well water and the close proximity of a neighbor's septic tank, about 5 meters away. Anthropogenic sources contributing to high ammonia levels in groundwater include fertilizer use, livestock manure disposal, and general waste disposal practices (Liang *et al.*, 2022).

3.5 Impact of Soil Types

Ngaglik subdistrict is characterized by an elevation ranging from 160 to 380 meters, with relatively gentle topography and an average slope of less than 8%. The area is situated within the geological formation of Merapi volcanic deposits. Based on its geological and topographical characteristics, Ngaglik is well-suited for settlement and agricultural development. The predominant soil type in the district is regosol, which originates from pyroclastic volcanic material. Regosol soils are known for their high porosity, which enhances water absorption and can influence the movement of pollutants (Purwantara, 2018).

4. Conclusions

In Ngaglik Subdistrict, Sleman, Yogyakarta, nitrate concentrations at all 14 sampling points ranged from 1.102 mg/L to 14.503 mg/L, and nitrite concentrations ranged from 0.045 mg/L to 2.175 mg/L, both of which met quality standards. However, ammonia concentrations, which ranged from 0.208 mg/L to 4.652 mg/L, exceeded the quality standards. The highest nitrate concentration was recorded at point SW04 in Sardonoarjo Village, measuring 14.503 mg/L. The highest nitrite concentration was observed at point SW01 in Sukoharjo Village, with a value of 2.175 mg/L. The highest ammonia concentrations were found in Donoharjo and Sariharjo Villages at points SW07 (4.562 mg/L) and SW13 (4.404 mg/L), respectively.

The distribution of groundwater quality appears largely unaffected by the presence of communal wastewater treatment facilities (IPAL). This conclusion is supported by the analysis of nitrate and nitrite levels, which were within acceptable limits even at wells located near IPALs. For ammonia, despite three sampling points meeting the quality standards, elevated concentrations are likely due to local conditions around the sampling sites rather than the IPAL.

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