Nitrate in groundwater of the west side Magelang Regency, Central Java, Indonesia

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Abstract. Nitrate (NO₃⁻) pollution in groundwater is generally caused by chemical fertilizers from the agricultural sector and wastewater from onsite sanitation. Magelang Regency, Central Java, Indonesia, is a large food estate that has 206 km² paddy fields. In addition, this area is inhabited by 1.3 million people who produce onsite sanitary waste every day. Due to the concentration and intensity of fertilization and sanitary waste, which are quite high, Magelang Regency is susceptible to groundwater pollution by nitrate. This study aims to determine the characteristics of nitrate in the groundwater of the west side Magelang Regency, Central Java, Indonesia. The research was carried out by testing groundwater samples taken from several springs, dug wells, and drilled wells used by society for their daily needs. Groundwater sampling was carried out in the wet season and tested using the ion chromatography method to determine the level of nitrate in groundwater and know the chemical characteristics to analyze dominant ions in groundwater. The results showed that the average nitrate was 3.9 mg/l; the deviation standard was 5.12; minimum nitrate was 0 mg/l; and maximum nitrate was 20.78 mg/l. The origin of nitrate content may come from feces but still in small quantities. Facies of groundwater are Ca-HCO₃ and Na-Cl. It can be concluded that the groundwater of the west side Magelang Regency is not yet polluted by nitrate. However, there is still a possibility in the future, so that necessary to apply for groundwater protection immediately.

1. Introduction
According to Bell (2007), nitrate ions may be indicative of a source of pollution, and their occurrence usually is associated with shallow groundwater sources [1, 2]. Some studies about nitrate pollution in groundwater have shown that the concentration of nitrate has a variable tendency from a point to a strip and from shallow to deep [3-6]. The sources of nitrate pollution are generally caused by inorganic fertilizer, soil nitrogen, and wastewater [7-9].

Groundwater is one of the most important sources of drinking water in many cities and rural communities, accounting for approximately 20% of the world's freshwater supply. Based on PUPR (2016), 52% of water consumption in Magelang Regency, Central Java, Indonesia was supplied by groundwater around 928.7 m³/s. This area is inhabited by 1.3 million people [3] who use groundwater to produce sanitary waste every day and has a large food estate that has 206 km² paddy fields with the
possibility of using chemical fertilizers. Due to the concentration and intensity of fertilization and sanitary waste, which are pretty high, Magelang Regency is susceptible to groundwater pollution by nitrate. On the other hand, nitrate affects human health when it is converted to nitrite in the stomach [4-13].

The study area is located on the east part slope of Sumbing Volcano. The administrative boundaries of study area is Temanggung Regency in the northern boundary, Wonosobo Regency as the western boundary, meanwhile the eastern boundary is the Progo River, and the southern boundary is the Yogyakarta Province and Borobudur sub-district of Magelang Regency. Morphologically, the study area has the minimum elevation at 235 masl and the maximum elevation at 1,625 masl. Based on regional geology (Figure 1), the research area is included on two regional geology map of Semarang-Magelang Sheet and Yogyakarta Sheet [14-20]. The lithology of the research location consists of sedimentary rocks of Old Sumbing Mountain (Qsmo), Lava and Andesite Profiri (Qpl1), Condong Volcanic Rock (Qco), Gantti Volcanic Rock (Qgi), Kekep Volcanic Rock (Quake), Telomoyo Volcanic Rock (QTe), and Young Sumbing Mountain Deposit (Qsm). The research location is dominated by the Sedimentary Rocks of Sumbing Muda Volcano (Qsm) and many fractures are found in the northwest-southeast direction and many springs seem to be correlated on this structure [18-21].

Fathmawati et al. (2017) researched the origin and distribution of nitrate in water well using comparisons of nitrate and chloride concentrations were used to determine the source of nitrate contamination [6]. Based on ARGOSS (2001), the origin of the principal chemical contaminant is on-site sanitation which is consists of nitrate and chloride. The nitrogen loading from on-site sanitation in densely populated areas can be very large indeed. Both nitrate and chloride may show significant seasonal fluctuations in shallow groundwater, although concentrations are expected to be more stable in deeper groundwater. ARGOSS (2001) experience, if the ratio of nitrate and chloride concentrations in water is from 1 to 8:1, nitrate may be originated from feces. World Health Organization (WHO)'s
The guideline for drinking water has set the maximum content of nitrate in the drinking water is 50 mg/l [22, 23].

To differentiated the origin of nitrate, understanding the hydrochemistry of water is important. Based on Mazor (2004) and Kresic and Stevanovic (2010), geochemistry is one of the analytical methods to determine groundwater facies. The major ions in the anion consist of chloride (Cl\(^-\)); nitrate (NO\(_3\)\(^-\)); sulphate (SO\(_4\)\(^2-\)); and bicarbonate (HCO\(_3\)\(^-\)). In the cation, the major components are sodium (Na\(^+\)); potassium (K\(^+\)); magnesium (Mg\(^2+\)); and calcium (Ca\(^{2+}\)). The total ions of cations and anions in each solution are the same. Deviations from these equations can be used as indicators in assessing data quality called reaction error, where the ideal value is less than 5% [12]. Facies of groundwater can be classify based on the Piper diagram. Piper diagram is used to determine the classification of hydrochemical facies based on the dominant ion in groundwater. Fetter (2001) explained that trilinear diagrams could show the percentage of the ionic composition. On the cation, there are 3 (three) groups, which are a combination of Na\(^+\) and K\(^+\); Ca\(^{2+}\); and Mg\(^{2+}\). On the anion, there are also 3 (three) combination groups of CO\(_3\)\(^2-\) and HCO\(_3\); SO\(_4\)\(^2-\); and Cl\(^-\). Trilinear charts are very commonly used in the chemical analysis of groundwater [7].

Shallow groundwater system with direct recharge from the surface is commonly representing by dominant HCO\(_3\)\(^-\) anion, meanwhile dominan concentration Cl\(^-\) in the groundwater represent deep groundwater system. As source of nitrate is commonly comes from surface, high nitrate concentration may found in the HCO\(_3\)\(^-\) rich groundwater.

Knowing the factors that affect groundwater pollution is important to prioritize measures in protecting water supplies. Nitrate that has a potential long-term impact on this contamination, therefore it should be necessary point to understand and prevent since remedial action is difficult while nitrate contamination continues to increase every year. Based on above facts, this study aims to determine the characteristics of nitrate in the groundwater of the west side Magelang Regency, Central Java, Indonesia. The research was carried out by testing groundwater samples taken from several springs, dug wells, and drilled wells used by society for their daily needs.

### 2. Method of Research

The research method is carried out by analyzing the major ions in the anion consist of chloride (Cl\(^-\)); nitrate (NO\(_3\)\(^-\)); sulphate (SO\(_4\)\(^2-\)); and bicarbonate (HCO\(_3\)\(^-\)). In the cation, the major components are sodium (Na\(^+\)); potassium (K\(^+\)); magnesium (Mg\(^{2+}\)); and calcium (Ca\(^{2+}\)) using Metro Ohm 850 Professional IC (Ion Chromatography). To ensure the data of analysis are correct, test of ion balance or reaction error (RE) was conducted and all the samples show RE less than 5%. This means all the samples can be used for further analysis and interpretation. The analysis is done to the 17 (seventeen) samples, which are consist of 11 (eleven) springs; 5 (five) deep wells; and 1 (one) dug well as shown in Figure 2.

As additional information, based on field observations, there is a scarcity of finding dug wells in Magelang Regency, so that the number of dug well is quite a bit.

The results from the laboratory are compared with the maximum standard of nitrate in drinking water according to WHO. Then by using a comparison of nitrate and chloride, the origin of nitrate content in groundwater could be carried out. Moreover, to find out the dominant ion content in the water on the west side of Magelang Regency, a geochemical analysis was carried out using a piper diagram.

### 3. Result and Discussion

The result of analysis of major anion and cation ions in the groundwater samples are shown in Table 1. The result shows that the highest nitrate content is relatively low compared to the maximum limit of nitrate content in drinking water, which is 50 mg/l. From Table 1, it can be seen clearly that the average nitrate content in the groundwater was 3.9 mg/l with deviation standard was 5.12. The smallest value was 0 mg/l and the highest value was 20.78 mg/l. It also can be recognized, groundwater sample from
deep wells and hot spring (Sta 33) contain very low concentration of Nitrate. Meanwhile other samples show relatively higher concentration.

![Figure 2. Distribution of samples groundwater in study area](image)

**Table 1.** Major ions of groundwater samples in study area

| No | Name of Sample              | Source          | NO\(^-\) (mg/l) | Cl\(^-\) (mg/l) | HCO\(_3\) (mg/l) | SO\(_4\)\(^2-\) (mg/l) | Na\(^+\) (mg/l) | K\(^+\) (mg/l) | Ca\(^2+\) (mg/l) | Mg\(^2+\) (mg/l) |
|----|-----------------------------|-----------------|-----------------|----------------|-----------------|---------------------|----------------|----------------|-----------------|---------------|
| 1  | Sta 32 Banyuroso            | Deep Well       | 0.000           | 794.540        | 366.0           | 118.140            | 482.470        | 81.110         | 123.160         | 44.420        |
| 2  | Sta 33 Kasinan              | Hot Spring      | 0.000           | 759.954        | 353.8           | 116.754            | 477.336        | 78.445         | 101.973         | 38.424        |
| 3  | Sta 36 Rejomulyo            | Spring          | 6.511           | 11.618         | 122.0           | 5.521              | 10.496         | 2.759          | 29.490          | 7.910         |
| 4  | Sta 37 Gilirejo             | Deep Well       | 0.599           | 3.540          | 183.0           | 2.428              | 15.515         | 6.788          | 34.726          | 10.476        |
| 5  | Sta 39 Johon Bandongan     | Spring          | 1.336           | 2.359          | 140.3           | 2.152              | 12.255         | 2.726          | 26.720          | 8.527         |
| 6  | Sta 40 Susangan            | Deep Well       | 4.117           | 10.316         | 79.3            | 6.864              | 11.306         | 2.394          | 18.834          | 5.876         |
| 7  | Sta 41 Geologi Nasional Well| Deep Well       | 0.000           | 3.566          | 170.8           | 1.990              | 13.174         | 5.582          | 32.852          | 10.718        |
| 8  | Sta 42 Kaliangkrik         | Spring          | 2.010           | 2.792          | 109.8           | 2.016              | 9.428          | 2.819          | 21.037          | 7.537         |
| 9  | Sta 44 Gianti               | Spring          | 7.513           | 3.486          | 115.9           | 1.615              | 9.788          | 2.490          | 21.252          | 9.558         |
| 10 | Sta 45 Kalisari             | Deep Well       | 0.127           | 3.208          | 170.8           | 2.048              | 15.089         | 6.172          | 31.644          | 9.999         |
| 11 | Sta 47 Muning               | Spring          | 0.760           | 0.867          | 97.6            | 1.187              | 7.311          | 2.140          | 18.119          | 4.284         |
| 12 | Sta 50 Sangan              | Spring          | 5.576           | 2.915          | 85.4            | 2.609              | 7.625          | 2.757          | 14.336          | 6.571         |
| 13 | Sta 51 Kalilorlo            | Spring          | 2.567           | 2.483          | 268.4           | 10.093             | 34.513         | 6.130          | 18.378          | 30.701        |
| 14 | Sta 52 Tuk Semar            | Spring          | 20.78           | 2.616          | 42.7            | 1.067              | 5.840          | 3.429          | 10.487          | 2.744         |
| 15 | Sta 53 Mosque Darul Falah  | Dug Well        | 4.516           | 10.262         | 122.0           | 8.420              | 14.007         | 19.053         | 19.655          | 7.548         |
| 16 | Sta 55 Silitin I           | Spring          | 7.809           | 2.623          | 122.0           | 0.643              | 9.702          | 3.691          | 24.801          | 7.890         |
| 17 | Sta 56 Candisari           | Spring          | 2.120           | 2.240          | 73.2            | 0.814              | 10.572         | 1.801          | 12.694          | 2.494         |
| **Average**                   |                 |                 | 3.902          | 95.258         | 154.2            | 16.727          | 67.437         | 13.546         | 32.950        | 12.68         |
According to Figure 3, based on AGROSS (2001), the distribution of nitrate-chloride concentration ratio on the west side of Magelang Regency has 1–8:1, which indicates that nitrate may originate from feces. It should be noted that the two groundwater samples, STA 32 and STA 33, were not included in plotting the nitrate-chloride concentration ratio due to significant differences in nitrate content. It is estimated those samples which have 0,000 mg/l of nitrate content, are originated from deep groundwater system which is not affected by surface pollution, while the other groundwater with detected nitrate contain are presumably comes from shallow groundwater system [19].

To prove this estimation, plotting the chemical data on Piper diagram was conducted.

**Figure 3.** Nitrate-Chloride ratio in groundwater of the study area

**Figure 4.** Piper diagram plot of groundwater samples from study area
The hydrochemical characteristics of the groundwater in the west side of Magelang Regency are shown in Figure 4. Interpretation from the diagram, the distribution groundwater ions show that facies of groundwater are classified into 2 (two) different sources, which are dominated by Ca-HCO₃; and the remainder is Na-Cl. Ca-HCO₃ water type is a common shallow groundwater water type with near recharge area, on otherside the groundwater samples from STA 32 and 33 are classify as Na-Cl water, proving that these groundwater definitely comes from deep groundwater system [15].

4. Conclusion
The results showed that the average nitrate was 3.9 mg/l and the smallest value of nitrate was 0 mg/l; and the highest value was 20.78 mg/l. It can be concluded that the groundwater in the study area is not yet polluted by nitrate. However, there is still high possibility in the future as most of groundwater comes from shallow groundwater system, so surface pollution may easily contaminated groundwater. Which is proven that the origin of nitrate content may be coming from feces but still in small quantities. Eventhough, deep groundwater system existing in the study area have non detected nitrate content, the groundwater can not be used for supplying domestic water needs due to high salinity of the water. Therefore, it is necessary to protect the shallow groundwater resources immediately for sustainable use of groundwater resources on the study area.

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