

The Analysis of Groundwater Quality for Drinking Purposes: A Case Study of Universitas Muhammadiyah Makassar Area

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ABSTRACT The use of groundwater for drinking purposes is increasing along with population growth and the wider range of human activities that require water. Groundwater is used more often because it is more accessible than surface water. The quality of groundwater suitable for consumption as drinking water must pass physical, chemical and biological parameter tests. This study aims to analyze the comparison of groundwater quality at depths of 30 and 100 meters in the area of the Universitas Muhammadiyah Makassar and determine its suitability as drinking water based on physical, chemical, and biological parameters. This research is an experimental study with water sampling collected at two different locations: 30-meter and 100-meter depth wells. In each well, sampling was carried out three times so that there were six total water samples analyzed in total. Data collection was carried out by observation and laboratory tests. Observations were made by looking directly at groundwater conditions to measure parameters such as odor, color, temperature, and pH, while other parameters were tested in the laboratory. The data analysis results showed differences in the values of the physical, chemical, and biological parameters of groundwater taken at a depth of 30 meters and 100 meters. However, the two samples are still within the standard's allowable range of values. This study concluded that groundwater at a depth of 100 meters in the Universitas Muhammadiyah Makassar area has better water quality than groundwater at a depth of 30 meters. Therefore, if groundwater at a depth of 30 meters is to be used as drinking water with good quality, it must undergo specific treatment.

KEYWORDS Drinking water; Groundwater; Quality control; Water quality; Well water

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1 INTRODUCTION

The purpose of this research is to evaluate the quality of groundwater for drinking purposes in the area of the Universitas Muhammadiyah Makassar, South Sulawesi Province, Indonesia. Rainwater that reaches the soil surface and is absorbed by the soil layer is referred to as groundwater (Li et al., 2017). The rainwater penetrates various layers of the soil, causing water hardness (HO and SA, 2014). The process of entering the water from the surface into the soil is called infiltration, while the movement of water in the soil due to gravity is called percolation (Rakhim et al., 2019; Nanda et al., 2020). The use of groundwater is increasing along with the increasing demand due to population growth and the increasing scope of human activities that require water. Groundwa-

ter is more often used since it is easier to access than surface water (Shamshedenova et al., 2019; Li et al., 2020). It is estimated that one-third of the world's population depends on groundwater for drinking water (Adimalla and Li, 2019; He and Wu, 2019). The limited source of surface water is caused by the decrease in vegetation density and the opening of the land surface due to land use for agricultural needs (Arsyad et al., 2014; Adimalla and Li, 2019; Nanda et al., 2020). The quality of groundwater that is suitable for consumption as drinking water must be tested for physical, chemical, and biological parameters (Putranto et al., 2017; Naili et al., 2018; Ibrahim, 2019; Syafrudin et al., 2021; Shakya et al., 2022). The quality of drinking water is an important concern, especially

in urban areas where the population mainly relies on groundwater for drinking. Therefore, assessment and monitoring of groundwater quality in the area of the Universitas Muhammadiyah Makassar, which is located in the middle of Makassar city, South Sulawesi Province, Indonesia, is required to test its suitability as a source of drinking water.

A number of studies have been conducted to determine the quality of groundwater as a source of drinking water in several regions in Indonesia (Ibrahim, 2017; Permana et al., 2020; Ronny et al., 2019; Hamzar et al., 2021; Tangahu et al., 2021; Vina et al., 2021). The results of research by analyzing the quality of groundwater at a depth of 2.8 to 4 m based on physical parameters (color, odor, taste, and TDS) concluded that the quality of groundwater at that depth did not meet the requirements for drinking water (Permana et al., 2020). The composition of infiltration water, the interaction between water and soil, and the rocks in contact with it in the unsaturated zone all have a significant impact on groundwater quality (Batabyal and Chakraborty, 2015; Gil-Doménech et al., 2018). Groundwater quality is also influenced by topography, lithology, hydrology, and climate (Zhao et al., 2022). Another researcher examined the drinking water quality of shallow groundwater in Gowa Regency, South Sulawesi Province. Based on laboratory testing, they judged that three of the five samples were unsafe for human consumption because they did not fulfill the requirements for drinking water quality standards set by the Minister of Health of the Republic of Indonesia (Hamzar et al., 2021). A study with 18 groundwater sampling locations in Pangkep Regency, South Sulawesi Province, also shows that the quality of groundwater in each location is not always the same because it is influenced by climatic factors and human activities (Ronny et al., 2019).

However, no research has been conducted so far on the quality of groundwater for drinking purposes in the area of the Universitas Muhammadiyah Makassar, Makassar City, South Sulawesi Province, Indonesia. In fact, some citizens who live around campus use groundwater for their daily needs, including drinking water. Water quality is a major concern in urban areas where the population relies mainly on groundwater for drinking.

Moreover, the Universitas Muhammadiyah Makassar has the capacity to develop the need for clean water, particularly drinking water, for the campus and the surrounding area. A previous research has shown that the parameters of pH, BOD, COD, and TSS of groundwater in community settlements in Makassar city mostly exceed the environmental quality standard threshold (Ibrahim, 2017).

Based on the problem mentioned above, it is required to conduct research to assess the quality of groundwater for drinking purposes in the area of the Universitas Muhammadiyah Makassar. This study investigates differences in water quality at different depths. The groundwater quality evaluation for drinking water is based on the parameters of the World Health Organization's groundwater quality index released in 2011 (WHO, 2011), Regulation of the Minister of Health (Permenkes) of the Republic of Indonesia No.492/MENKES/PER/IV/2010 (Kementerian Kesehatan RI, 2010), and Government of Indonesia Regulation regarding water standard class 1, number 22 the year 2021 (Pemerintah Republik Indonesia, 2021). Thus, the goal of this study was to examine (1) the comparison of groundwater quality at depths of 30 m and 100 m in the University of Muhammadiyah Makassar area; (2) the feasibility of groundwater for drinking water based on physical, chemical, and biological parameters in the area of the Universitas Muhammadiyah Makassar.

2 METHODS

This is an experimental study conducted at Universitas Muhammadiyah Makassar, Makassar City, South Sulawesi Province, Indonesia, by taking water samples at two different depths in different locations. The samples were collected three times at each location to have a total of six water samples for analysis. Moreover, each water sample was tested 3 times and this led to a total of 18 sample tests. The independent variable was the groundwater at depths of 30 and 100 m while the dependent variable was the water quality determined through the physical, chemical, and microbiological parameters. The study location and sample collection sites are indicated in the following Figure 1.

The equipment used for the water sampling is a 1.5-liter bottle while a dark glass bottle was used

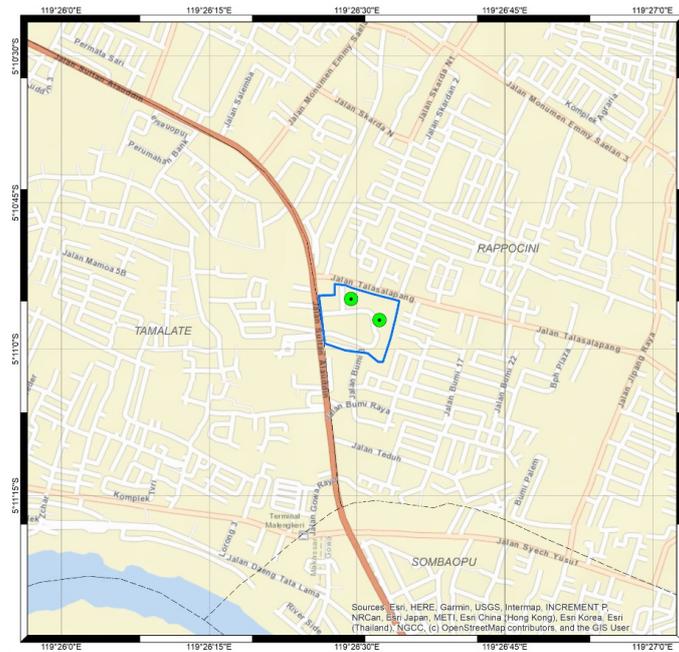


Figure 1. Study location and water sampling site

for the storage. A cool box was also utilized as a sample bottle container, GPS (Global Positioning System) to determine the coordinates of the sampling area, Bunsen to sterilize the glass bottles used, writing utensils to record observations, label paper to provide sample bottles names, and a camera for documentation. Meanwhile, the main materials used include alcohol for hand sterilization, ice crystals for sample preservation, and water samples.

This study tested 20 parameters which are focused on the physical, chemical, and biological aspects. These include color, temperature, TDS, odor, taste, pH, sulfate (SO_4), chloride (Cl^-), total hardness, nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), Arsenic (As), Iron (Fe), Cadmium (Cd), Manganese (Mn), Zinc (Zn), Total Chromium (Cr), Escherichia coli, and Total Coliform. The standard for the assessment was based on the Indonesian Government Regulation Number 22 of 2021 concerning the class 1 water quality standard for drinking water feasibility (Pemerintah Republik Indonesia, 2021).

Data were collected using observation and laboratory tests. The observations involved looking at the direct condition of groundwater in drilled wells at the 2 selection locations around the Universitas Muhammadiyah Makassar. It is important to note that several parameters were measured di-

rectly in the field such as odor, color, temperature, and pH using smell, colorimetry, thermometer, and pH meter, respectively. Furthermore, water samples were collected in a 1.5-liter sample bottle and a dark bottle for bacterial analysis while the other parameters were tested at the Water Productivity and Quality Laboratory, Faculty of Marine and Fisheries Sciences, Hasanuddin University.

The Scoring Sturges approach was used to analyze the data related to the feasibility of drinking water quality (Chatterjee et al., 2017). The parameter value at or above the maximum allowable limit is provided with a value of 1 and a bad rating while those at or below the maximum allowable limit are provided with a value of 2 and a good rating. The drinking water quality assessment was conducted to classify the score obtained from the scoring technique using the following formula:

$$K = \frac{a - b}{u} \quad (1)$$

Where K is the constant, a is the total number of highest scores, b is the total number of lowest scores, and u is the number of classes. Water quality was classified into two categories in this study which include appropriate for drinking and unfit for drinking with two interval classes in between. The maximum possible score (a) is = $20 \times 2 = 40$ while the lowest possible score (b) is = $20 \times 1 = 20$.

Table 1. Comparison of the physical parameters results of groundwater quality at depths of 30 and 100 m

| Physical parameters | Unit | Water quality standard | Sample code | | | | | |
|---------------------|-------------------|------------------------|-------------|-----|-----|-------|-----|-----|
| | | | 30 m | | | 100 m | | |
| | | | A1 | A2 | A3 | B1 | B2 | B3 |
| Color | TCU | 15 | 15 | 17 | 20 | 5 | 5 | 5 |
| Temperature | C | 3 | 28 | 26 | 26 | 27 | 28 | 27 |
| TDS | mgL ⁻¹ | 1000 | 168 | 173 | 156 | 215 | 197 | 188 |
| Odor | - | - | Yes | Yes | Yes | No | No | No |
| Taste | - | - | Yes | Yes | Yes | No | No | No |

Table 2. Comparison of the chemical parameters results of groundwater quality at depths of 30 and 100 m

| Chemical parameters | Unit | Water quality standard | Sample code | | | | | |
|---------------------|-------------------|------------------------|-------------|--------|--------|--------|--------|--------|
| | | | 30 m | | | 100 m | | |
| | | | A1 | A2 | A3 | B1 | B2 | B3 |
| pH | - | 6-9 | 6.75 | 6.65 | 6.71 | 6.56 | 6.70 | 6.57 |
| Sulfate | mgL ⁻¹ | 300 | 15.7 | 16.25 | 15.6 | 17.54 | 16.89 | 17.02 |
| Chloride | mgL ⁻¹ | 300 | 46.15 | 47.3 | 46.23 | 54.23 | 49.5 | 50.78 |
| Total Hardness | mgL ⁻¹ | - | 125.56 | 232.54 | 156.78 | 22.022 | 21.023 | 21.675 |
| Nitrate | mgL ⁻¹ | 10 | 1.537 | 2.531 | 2.662 | 0.314 | 0.211 | 0.231 |
| Nitrite | mgL ⁻¹ | 0.06 | 0.060 | 0.068 | 0.065 | 0.011 | 0.012 | 0.031 |
| Ammonia | mgL ⁻¹ | 0.1 | 0.007 | 0.006 | 0.008 | 0.001 | 0.002 | 0.001 |
| Arsenic | mgL ⁻¹ | 0.05 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| Iron | mgL ⁻¹ | 0.3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cadmium | mgL ⁻¹ | 0.01 | 0.005 | 0.005 | 0.005 | 0.00 | 0.00 | 0.00 |
| Manganese | mgL ⁻¹ | 0.1 | 0.06 | 0.05 | 0.06 | 0.00 | 0.00 | 0.00 |
| Zinc | mgL ⁻¹ | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 |
| Total Chromium | mgL ⁻¹ | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 |

The class interval was computed as follows:

$$K = \frac{40 - 20}{2} \quad (2)$$

$$K = 10 \quad (3)$$

This result led to the classification of water quality as follows:

- Groundwater quality is unfit for drinking when the score is ≤ 30 .
- The groundwater quality is fit for drinking when the score is ≥ 31 .

This means the Sturges method was used by classifying the highest score (≤ 30) and the lowest score (≥ 31) from the scoring technique to categorize the feasibility of the groundwater quality (Soltani et al., 2020).

3 RESULTS

The water quality was assessed in this study based on the standards provided by the Indonesian Government Regulation No. 22 of 2021 concerning water quality standards for class 1 drinking water. It is important to note that drinking water is defined as processed or unprocessed water that meets health requirements and can be consumed exclusively (Prayoga et al., 2021; WHO, 2011). Water with high quality is required to satisfy physical, chemical, and bacteriological standards (Naily et al., 2018; Syafrudin et al., 2021; Shakya et al., 2022). The physical parameters analyzed were color, temperature, TDS, odor, and taste and the results showed variations based on the 30 m and 100 m depth. It was discovered in Table 2 that the samples obtained from 30 m smell and taste while those from 100 m do not have any aroma or taste. This means the groundwater at a depth of 100 m in the study area has better quality in terms of the

physical requirements for drinking water. However, the TDS level at a depth of 30 m was found to be lower than at 100 m but the values are in the normal range required for drinking water requirements at <500 mg/L (Kementerian Kesehatan RI, 2010; National Standardization Agency of Indonesia, 2015). Table 1 compares the results of the groundwater physical parameter data at 30 and 100 m depths.

The chemical parameters analyzed are thirteen and the results showed significant differences in the two depths. The samples from 30 m depth were observed to contain arsenic, cadmium, manganese, zinc, and chromium, while they are not present in 100 m depth. However, it was discovered that the amount of the chemical components in the samples from 30 m depth meets the criterion for safe drinking water as indicated in Table 2.

E.coli and total coliform were the biological parameters tested in this study and the results showed some differences in their contents in the two different depths. It was discovered that the average number of *E.coli* in 30 m was 84 while 100 m had only 47 and a similar trend was observed for the average total coliform with 920 and 733 recorded, respectively, as indicated in Table 3. Meanwhile, these values satisfy the class 1 water quality criteria for drinking water according to the Indonesian government regulation No. 22 of 2021.

Table 4 shows the calculation for the feasibility of using groundwater for drinking purposes based on all the parameters. It was discovered that the mean score at a depth of 30 m was 29.0 while 100 m depth had 37.7. The categorization criteria previously stated showed that a score ≤ 30 indicates that the groundwater quality is unfit for drinking while a score ≥ 31 means it is feasible for drinking. Therefore, it was concluded that the groundwater at 100 m depth in Universitas Muhammadiyah Makassar area meets the requirements to be used

for drinking purposes while those at 30 m need to be treated specially before they can be consumed.

4 DISCUSSION

The results showed certain differences between the quality of groundwater quality at a depth of 30 m and 100 m in Universitas Muhammadiyah Makassar area. Water with good quality is physically required to be tasteless, odorless, colorless, not cloudy, and of normal temperature (Pemerintah Republik Indonesia, 2021; Kementerian Kesehatan RI, 2010; WHO, 2011). The three repetitions of water samples obtained at a depth of 100 m were physically observed to have a color value of 5 TCU which is less than the 15 TCU standard required in class 1 Number 22 of 2021. This means the samples from this depth are suitable for drinking. Meanwhile, those retrieved from 30 m depth had values greater than 15 TCU and this means the water is not clean, contaminated, and has the potential to interfere with human health. The temperature of all the six samples tested was found to be between 26°C and 28°C, and this is within the Indonesian government's standard temperature interval of $\pm 3^\circ\text{C}$, indicating all the samples are suitable for consumption based on their temperature. The water with a temperature higher or lower than the air temperature is believed to contain certain dissolved compounds or undergo a harmful process of organic materials breakdown by microorganisms (Wijayanti et al., 2018; Ibrahim, 2017; Surya et al., 2020).

The TDS for all types of water samples meets the class 1 water standard set by the Indonesian Government of 1000 mgL⁻¹. The groundwater was categorized based on the amount of dissolved solids such that soft water has < 100 mgL⁻¹, clean water between 100 and 500 mgL⁻¹, carbonate hard water between 500 and 1,000 mgL⁻¹, non-carbonate hard water between 1,000 and 2,000 mgL⁻¹, brackish water between 2,000 and 10,000 mgL⁻¹, brine water between 10,000 and 100,000 mgL⁻¹, and

Table 3. Comparison of the biological parameters results of groundwater quality at depths of 30 and 100 meters

| Biological parameters | Unit | Water quality standard | Sample code | | | | | |
|-----------------------|---------------|------------------------|-------------|-----|-----|-------|-----|-----|
| | | | 30 m | | | 100 m | | |
| | | | A1 | A2 | A3 | B1 | B2 | B3 |
| <i>E.coli</i> | colony/100 mL | 100 | 89 | 78 | 85 | 47 | 48 | 46 |
| Total Coliform | colony/100 mL | 1000 | 920 | 900 | 940 | 720 | 700 | 780 |

Table 4. Calculation results of the feasibility of groundwater for drinking water based on all parameters (physical, chemical, and biological)

| Parameters | Unit | Water quality standard | Sample code | | | | | |
|----------------|-------------------|------------------------|-------------|----|----|-------|----|----|
| | | | 30 m | | | 100 m | | |
| | | | A1 | A2 | A3 | B1 | B2 | B3 |
| Color | TCU | 15 | 1 | 1 | 1 | 2 | 2 | 2 |
| Temperature | C | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| TDS | mgL ⁻¹ | 1000 | 2 | 2 | 2 | 2 | 2 | 2 |
| Odor | - | - | 1 | 1 | 1 | 2 | 2 | 1 |
| Taste | - | - | 1 | 1 | 1 | 2 | 2 | 2 |
| pH | mgL ⁻¹ | 6-9 | 2 | 2 | 2 | 2 | 2 | 2 |
| Sulfate | mgL ⁻¹ | 300 | 2 | 2 | 2 | 2 | 2 | 2 |
| Chloride | mgL ⁻¹ | 300 | 2 | 2 | 2 | 2 | 2 | 2 |
| Total Hardness | mgL ⁻¹ | - | 2 | 2 | 2 | 2 | 2 | 2 |
| Nitrate | mgL ⁻¹ | 10 | 2 | 2 | 2 | 2 | 2 | 2 |
| Nitrite | mgL ⁻¹ | 0.06 | 1 | 1 | 1 | 2 | 2 | 2 |
| Ammonia | mgL ⁻¹ | 0.1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Arsenic | mgL ⁻¹ | 0.05 | 2 | 2 | 2 | 2 | 2 | 2 |
| Iron | mgL ⁻¹ | 0.3 | 2 | 2 | 2 | 2 | 2 | 2 |
| Cadmium | mgL ⁻¹ | 0.01 | 1 | 1 | 1 | 2 | 2 | 2 |
| Manganese | mgL ⁻¹ | 0.1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Zinc | mgL ⁻¹ | 0.05 | 1 | 1 | 1 | 2 | 2 | 2 |
| Total Chromium | mgL ⁻¹ | 0.05 | 1 | 1 | 1 | 2 | 2 | 2 |
| <i>E.coli</i> | colony/100mL | 100 | 1 | 1 | 1 | 1 | 1 | 1 |
| Total Coliform | colony/100mL | 1000 | 1 | 1 | 1 | 1 | 1 | 1 |
| Total score | | | 29 | 29 | 29 | 38 | 38 | 37 |

saltwater >100,000 mgL⁻¹ (Djuhariningrum, 2005). It was discovered that the groundwater in the study area has sufficient quality to be consumed as drinking water based on the TDS value. Moreover, the test conducted on the odor and taste indicated that the samples at a depth of 30 m had a slight odor and taste while those at 100 m had no odor and taste. The difference is possibly associated with the presence of bacteria in the groundwater at a depth of 30 m which led to the slight odor and taste perceived.

The chemical parameters were also analyzed and the pH for the six water samples was observed to meet the predetermined standard with values ranging from 6.56 to 6.75. This is due to the fact that good drinking water is expected to range between 6 and 9 (WHO, 2011; Zhao et al., 2022) with those having less than 6 or greater than 9 perceived to be containing different chemical components that are detrimental to health. This is consistent with the opinion of Islam et al. (2017) that drinking water needs to have a pH

range of 6.5-8.5 in order to meet Environmental Protection Agency (EPA) standards. It was also observed that the sulfate and chloride values were below the required standard of <300 mgL⁻¹. Moreover, the content of Nitrate (NO₃⁻), Nitrite (NO₂⁻), Ammonia (NH₃), Arsenic (As), Iron (Fe), Cadmium (Cd), Manganese (Mn), Zinc (Zn), and Total Chromium (Cr) is in accordance with the quality standards set by the Minister of Health of Indonesia through Minister of Health Regulation No. 492/MENKES/PER/IV/2010 concerning requirements for good drinking water quality. Meanwhile, the total hardness of the samples from 30 m depth was found to be higher than those from 100 m. It was also discovered that the nitrate (NO₃⁻) concentration of the samples at 30 m was higher ranging between 1.5 mgL⁻¹ and 2.6 mgL⁻¹ compared to those from 100 m with 0.2 mgL⁻¹ to 0.3 mgL⁻¹. Fortunately, all the samples do not have iron (Fe) content and this means all water samples at Universitas Muhammadiyah Makassar area satisfied the requirements for drinkable water at both 30 m and 100 m depth.

The bacterial content was also analyzed in the form of *E.coli* and total Coliform and the results showed that the samples from 100 m depth had lower bacterial content with 47 *E.coli* colonies per 100 mL and a total Coliform count of 733 colonies per 100 mL than those at 30 m 84 colonies/100 mL and 920 colonies/100 mL, respectively. This means the water samples have been contaminated by bacteria due to the leak in the piping that flows through the water which has not been replaced for ten years. It allows the microorganisms to easily enter the water and cause a decrease in microbiological quality. According to Kuroda et al. (2012), water can be accidentally contaminated due to dilapidated water channel networks, thereby leading to the detection of *E.coli* at a depth of < 30 m and 500 m. It is important to note that the bacterial concentration at the two depths is below the values in the Indonesian Government's class 1 water quality standard number 22 of 2021. The field observations also indicated that the soil texture in the area has a high water absorption capacity, particularly during the rainy season, which can lead to an increment in the contamination of water sources.

The groundwater with many Coliform bacteria is not suitable for drinking (WHO, 2011; Pal, 2014) and can also present a severe health risk when not handled properly (Amanah et al., 2019; Bu et al., 2020). Indonesian Minister of Health Regulation No. 492 of 2010 requires that the maximum concentration of Coliform bacteria in non-piped and piped drinking and clean water is 1000 colonies/100 mL. It is important to state that the Coliform bacteria are organisms considered to be highly resistant to natural water purification processes. The identification of these bacteria in water samples indicates the presence of different pathogens, even in trace concentrations (He and Wu, 2019; Shamshedenova et al., 2019). Moreover, previous studies showed that the depth of groundwater can be the cause for the presence of bacteria in water (Armah, 2014; Tangahu et al., 2021) such that a shallow well is expected to have a greater potential to have bacteria. However, it is possible to remove these microorganisms through several treatments to ensure the water meets the required standards for drinking water.

5 CONCLUSION

The results showed that groundwater at a depth of 100 m in Universitas Muhammadiyah Makassar area of South Sulawesi Province, Indonesia, has better water quality than at 30 m. This was indicated by the physical, chemical, and biological parameters which were found to be in the range of values permitted by Indonesian government regulations regarding class 1 water standards, number 22 of 2021. It was also observed that the groundwater from 30 meters needs to be treated specially to be used as drinking water. There is a need for further study with a more significant number of samples at the study location to obtain accurate data.

DISCLAIMER

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

All data are available from the author.

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