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Water Quality of Unconfined Aquifer in Universitas Negeri Malang Following the Drinking Water Quality Standard of Indonesian Ministry of Health

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Abstract

The quality of groundwater is naturally determined by water-bearing rock characteristics. However, the progression of civilian activities also negatively affects the groundwater quality. Therefore, this study aims to assess groundwater's physical, chemical, and biological characteristics in Indonesia's Universitas Negeri Malang (UM) campus area and evaluate its compliance with drinking water quality standards, particularly the Class A standard. A comparative descriptive strategy was utilized in the study by involving groundwater in the campus area of UM. The focus of the research is water quality in unconfined aquifers. Through purposive sampling, 12 wells were selected to ensure appropriate spatial dispersion. Water samples were collected in sample bottles and tested for physical, biological, and chemical properties. The Perum Jasa Tirta I Malang carried out these water quality tests. Water quality data were analyzed qualitatively, descriptively, and comparatively. This study concludes that (1) the groundwater on the UM campus generally meets the physical criteria for drinking water quality standards; (2) the chemical quality of the groundwater on the UM campus still satisfies the drinking water quality standards; and (3) biologically, the free groundwater on the UM campus fails to meet drinking water quality standards. The novelty of this research is that the biggest threat to the quality of free groundwater in the campus area is bacterial contamination from sanitation activities. Accordingly, it is recommended that groundwater is boiled before being utilized for drinking water purposes to neutralize the E. coli bacteria present in all well water samples.

Keywords: Water Quality of Unconfined Aquifer; The Drinking Water; Quality Standard

INTRODUCTION

Geologically, the State University of Malang (UM) campus area occupies sedimentary rocky land, establishing an aquifer beneath the surface, allowing the discovery of free groundwater. Fallatah et al. (2023) construed that the geological features of an area significantly affect the quantity and quality of groundwater. Rocks contain cavities in pores between grains, enabling water to come and remain retained within them (Kodoatie, 1995; Utaya, 2012). Naryanto (2008) asserted that groundwater availability is limited, and its quantity relies on the geometry and distribution of the aquifer and the rock material's position, thickness, and composition (Todd and Mays, 2005).

The chemical composition of rocks determines the chemical content of groundwater through the interaction between rock material and water, resulting in rock dissolution, thereby, the groundwater contains minerals from the rocks. The interaction between rock material and water leads to rock dissolution and subsequent mineral content in groundwater (Amadi et al., 2015). Geochemical processes such as rock-water interaction, ion exchange, evaporite dissolution, and the dissolution of carbonate and silicate minerals govern groundwater chemistry (Roy et al., 2018; Narany et al., 2014; Ziani et al., 2016). The dissolution of minerals in various rock types, including silicate, carbonate, sulfate, and salt rocks, has a significant impact on the hydrochemical characteristics of groundwater (Zhai et al., 2022; Li et al., 2017; Murkute, 2023; Ganyaglo et al., 2010). A study by (Putranto et al., 2020) reported that volcanic rocks contribute to this process, resulting in groundwater with anions and mineral content of Ca2+ and Mg2+ cations. This suggests that groundwater quality can be attributed to chemical compounds and elements originating from rock dissolution in the geological formation of land on the UM campus. Jumhari (2019) uncovered that the type of lithology controls the chemical properties of water. Accordingly, the sedimentary rocks present on the UM campus determine the type and quantity of minerals contained in the rock, ultimately influencing the chemical properties of water.

In general, the groundwater in sedimentary rocks has high quality due to the chemical properties of the rocks and aquifers, which determine the mineral content of the water. Putranto et al. (2020), through their research conducted on the Kendal basin area of Central Java, uncovered that groundwater in alluvial rocks from plain areas presents high sodium (Na+) content, along with chloride (Cl-) or sulfate (SO42-) anions. Similarly, (Ramadhan, 2018) also reported the potential for geology for groundwater consumption in Ngawi, Indonesia, particularly regarding physical and chemical properties. The study concludes shallow groundwater has carbonate or hardness content below the maximum level.

Commonly, shallow groundwater quality is good, as (Safari, 2018) reported in the Gempol area of Blora, Central Java, Indonesia. The study concluded that groundwater meets drinking water standards per the Regulation of Ministry of Health No. 492, Year 2010. However, groundwater quality can be impacted by pollution resulting from human activities (Fallatah et al., 2023). The level of groundwater vulnerability is mainly determined by the nature of the rock's permeability and the distance or depth of the aquifer from the source of pollution (Sejati, 2020). Further, inappropriate human activities often increase the possibility of pollution, resulting in groundwater that is naturally resistant to pollution now becoming an easy target due to open pathways for waste to flow into groundwater bodies.

A study (Ningrum, 2018) conducted in Madiun, Indonesia, suggested a decrease in groundwater quality. Although groundwater is generally resistant to pollution due to its protection by rock layers, the quality of free groundwater on the surface of geological formations can be easily degraded (Sejati, 2020). This is attributed to various human activities that may impact the groundwater's quality (Li et al., 2021). Additionally, the type of waste polluting the groundwater determines the type of pollution that occurs, while the

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characteristics of the waste discharge depend on the type of activity of the population, such as household, industrial, mining, or agricultural activities. Accordingly, as this study was performed in the university, campus residents' effluents tend to resemble domestic effluents.

According to the wastewater quality standard, the composition of domestic waste includes nitrogen organic matter (NH_3. NO_2, NO_3), phosphorus (Total Phosphorus and PO_4), detergents, phenols, and E-coli bacteria, with key parameters, such as pH, BOD, COD, TSS, oil and fat, ammonia, and total Coliform (Permen LHK, 2016). Cheerawit et al. (2012) asserted that domestic waste contains pollutants such as BOD, COD, turbidity, fat, detergents, etc. The results of observation on groundwater in wells on the UM campus indicate the presence of pollution. Thus, evaluating the quality of groundwater used by UM residents is crucial for determining its feasibility. Besides, the evaluation is also essential to ensure the safety of groundwater consumption.

Following the discussion above, there is a need to investigate the groundwater quality in the area of the UM campus. Thus, this study examines groundwater's physical, chemical, and biological properties in the UM campus area and evaluates the quality of free groundwater based on the quality standards of drinking water class A according to Regulation of Ministry of Health No. 02, Year 2023.

RESEARCH METHODS

This groundwater quality research employed a quantitative descriptive approach. It was conducted from July to September 2023 in Malang City, Indonesia, particularly focusing on the location of the 47-ha Malang State University campus area. The subject of this research was groundwater, and groundwater samples were selected through purposive sampling on wells. The sampling was performed using the category of spatial distribution. The location of the sample wells is presented in Figure 1.

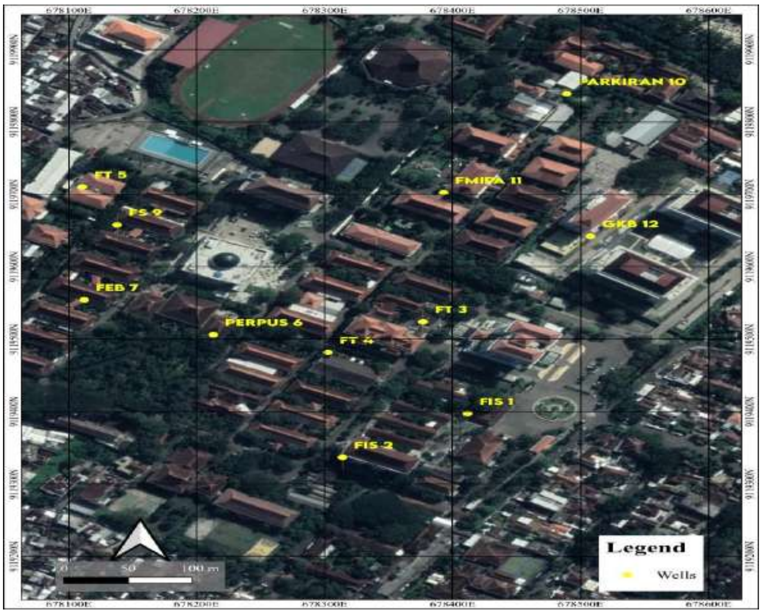

Figure 1. Location of Groundwater Sampling (Source: Field Mapping With Drone, 2023)

Groundwater quality was identified on 12 well samples in the UM campus area. The sample was garnered using the sample bottle. This groundwater sample test was conducted at the Water Quality Test Laboratory of Perum Jasa Tirta I Malang City, Indonesia. For the water quality, we adopted parameters for clean water and the Quality Standards from the Regulation of Indonesian Ministry of Health No. 02, the Year 2023, concerning the Implementation of Government Regulation No. 06 on environmental and water health requirements for sanitary hygiene. We adopted 13 physical, chemical, and biological parameters in the laboratory test. Physical parameters consist of temperature, turbidity, colour, and odour. Meanwhile, the chemical parameters comprised of pH, nitrate (NO_3^-), nitrite (NO_2^-), valence 6 chrome (Cr+6), manganese (Mn), and dissolved iron (Fe). The biological parameters examined pathogenic bacteria in the aquatic environment, particularly from the total Coliform and Escherichia Coli (E. Coli).

Groundwater quality data were analyzed through descriptive quantitative and comparative analyses. The quantitative analysis aimed to identify variations in the groundwater's physical, chemical, and biological properties, while the comparative analysis assessed the suitability of groundwater usage as a source of drinking water in the UM campus area. The analysis was completed following the drinking water quality standards, especially the group A water quality standards issued by the Ministry of Health of the Republic of Indonesia No. 02, the Year 2023.

RESULTS AND DISCUSSION

Groundwater quality was identified at 12 well points located in UM campus units. The groundwater analysis conducted at the Malang Perum Jasa Tirta I comprised physical, chemical, and biological analysis.

Physical Properties of Groundwater

The physical properties of the groundwater were analyzed using five parameters: temperature, total dissolved solids (TDS), turbidity, fragrance, and odour. The data on the physical properties of groundwater from laboratory tests are presented in Table 1.

Table 1. Results of Physical Properties Analysis on Groundwater in the UM Campus Area

Code		FIS 1	FIS 2	FT 3	FT 4	FT 5	Perpus6	FEB 7	FIP 8	FS 9	Parkiran10	FMIPA11	GKB 12
Depth of groundwater (m)		30	30	30	30	30	50	30	20	30	30	30	20
Temp	(°C)	26	26	26	26	26	26	26	26	26	26	26	26
TDS	(mg/L)	244	228.4	224	192	269.2	260	290.8	316.4	276.4	358.4	289.6	522.4
Turbidity	(NTU)	0.29	1.13	0.51	1.18	4.36	0.32	0.28	0.49	1.27	0.31	1.55	0.86
Color	(TCU)	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006	0.3006
Odor		1	1	1	1	1	1	1	1	1	1	1	1

(Sources: Primary Data, 2023)

The obtained groundwater temperature in Table 1 suggested that all water samples have an average temperature of 26°C, which falls within the acceptable range. This assessment was made following the Regulation of Indonesian Health Ministry No 02, the Year 2023, which defines the groundwater temperature suitable for consumption as ranging around ±30°C. Conformity to water temperature standards is crucial, as temperature directly impacts the harmful effects of various pollutants and the growth of microorganisms and viruses (Suryana, 2013). Besides, the local climate or water source affects the high and low temperatures of the water (Ningrum, 2018); thereby, the groundwater samples present homogeneous temperatures as they are located in the same environment. The impact of climate on groundwater temperature is apparent, as Ningrum (2018) reported, on the quality of well water in Madiun City, Indonesia, which had hot weather. The study reveals that certain temperature parameters in well water do not meet the drinking water quality standards.

In addition, the TDS parameter test results imply that three wells exceed the TDS quality standards (> 300mg/L), namely well 12 from the shared lecture building (GKB) with a level of 522.4mg/L, well 10 from the parking lot (Parkiran)with a level of 358.4mg/L, and well 8 from the faculty of education science (FIP) with TDS levels of 316.4mg/L. The remaining wells meet the TDS quality standard value threshold, indicating their sound quality. The lowest TDS value has been observed in well 4 from the faculty of engineering (FT), measuring 192 mg/L. Total dissolved solids refer to materials in water that pass through millipore filter paper with a pore size of 0.45µm. Total Dissolved Solids (TDS) impact water translucency and colour. TDS stems from inorganic ions typically present in water.

The results of the turbidity test indicate that well 5 from the Faculty of Engineering (FT) possesses the highest turbidity level, reaching 4.36 NTU, thus exceeding water turbidity quality standards. Conversely, the lowest turbidity was found in well seven from the Faculty of Economy and Business (FEB), with a value of only 0.28 NTU. Out of the 12 wells of water samples being tested, only wells from the Faculty of Engineering (FT) 5 exceeded the standard limits of drinking water quality standards. The remaining 11 well water samples have turbidity values of less than 3 NTU. Turbidity is a measure that adopts the effect of light as the basis for measuring the state of water with the NTU (Nephelometric Turbidity Unit) scale. Measuring water quality using the Nephelometric Turbidity Unit (NTU) scale can quantify turbidity in units equivalent to 1 mg/litre of silicon dioxide (SiO2). Sanitary hygiene quality standards define that turbidity should not exceed <3 NTU.

Regarding the physical characteristic of colour, laboratory tests conducted on 12 water samples revealed results that were notably below the maximum acceptable level. The water quality standard for colour is 10, while the well water samples present <0.3006 TCU, implying they meet the standard. Additionally, all sample wells had 1 score for the odour physical parameter, indicating the absence of odour in the groundwater. These laboratory test outcomes confirmed that the quality of well water in the UM campus environment satisfies the sanitary hygiene quality standards for both colour and odour parameters.

The laboratory tests comparing the physical properties of groundwater with drinking water quality standards generally suggested that the quality of free groundwater in the UM campus area meets these standards. However, the TDS from three wells shared lecture buildings (GKB), the Faculty of Mathematics and Science (FMIPA) parking lot, and the Faculty of Education Science (FIP), as well as the turbidity from the well 5 in the Faculty of Engineering (FT), exceed the drinking water quality standards and are therefore unsuitable for drinking.

High TDS content has been observed in three wells, which differs from the other nine well samples. Similarly, a study from Jumhari et al. (2019) on the area of Ceremei Mount, West Java, Indonesia, reported that the groundwater's TDS ranges from high to low. Meanwhile, for the turbidity parameter, the findings of this study align with the results of groundwater research conducted in Lahore City, Punjab, Pakistan, reporting that the water quality in the region is generally good. Still, some places have relatively high turbidity (Shahid & Iqbal, 2016).

Chemical Properties of Groundwater

This study examined the chemical properties of the 12 groundwater samples through six pH parameters: NO3, NO2, chrome, Mn, and Fe. The results of groundwater chemical properties in the UM campus areas are presented in Table 2.

Table 2. Chemical Properties of Groundwater in UM Campus Area

Sample Location		FIS 1	FIS 2	FT 3	FT 4	FT 5	Perpus 6	FEB 7	FIP 8	FS 9	Parkiran 10	FMIP A11	GKB 12
pH		7.21	7.02	7.15	7.02	7.04	7.13	7.23	7.08	7.12	7.11	7.08	7.14
NO3	Nitrat (mg/L)	18.68	0.2545	5.154	0.139	0.139	0.139	10.82	5.685	0.139	2.634	21.77	0.7717
NO2	Nitrit (mg/L)	0.0587	0.0401	0.0534	0.0383	0.0374	0.0638	0.0588	0.0471	0.0382	0.0444	0.0446	0.0384
Krom	Krom Valensi 6 (mg/L)	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Mn	Mangan terlarut (mg/L)	0.9243	0.0104	0.0104	0.0104	0.1832	0.8779	0.3739	0.0104	0.2973	0.13	0.0104	0.0104
Fe	Besi terlarut (mg/L)	0.0208	0.0208	0.0208	0.0208	0.0682	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208	0.0208

(Sources: Primary Data, 2023)

The results of the groundwater chemical parameter test presented in Table 2 indicate that the pH or acidity of all wells in the UM area tends to be neutral, as evidenced by the obtained pH around 7. Spatial variation in groundwater pH levels is discerned with reference to the highest pH in the Faculty of Economy Business (FEB) 7 well with a pH of 7.23. In contrast, the lowest pH measurements were recorded for the Faculty of Social Science (FIS) 2 and Faculty of Engineering (FT) 4 wells at pH = 7.02. Based on the Regulation of the Indonesian Ministry of Health No. 02, the Year 2023, water quality standards, the pH level of groundwater in the UM campus area meets the requirements for drinking water. The appropriate degree of acidity for drinking water ranges between 6.5 and 8.5, which is still consistent with the drinking water quality standards. Further, Harianti (2016) asserted that the pH value reflects the acidity or alkalinity of a liquid and is measured based on the concentration of hydrogen ions present.

The findings of our study differ from the study by (Sri & Riswandi, 2016) conducted in Wonogiri, Indonesia, which described that some shallow well water was acidic. Likewise, in the Banyumudal Groundwater Basin (CAT) in Kebumen Regency, Indonesia, Listyani and Putranto (2020) discovered that the pH level of the water was highly acidic. The pH of the groundwater in dug wells ranged from 5.761 to 8. The variation in pH among groundwater in Malang, Wonogiri, and Kebumen can be attributed to the geological and climatological disparities in these regions.

In addition, nitrate is the primary nitrogen form found in water, occurring in both organic and inorganic forms. Nitrate parameter laboratory test results ($NO3^-$) reveal that well 11 in the Faculty of Mathematics and Science (FMIPA) had the highest nitrate concentration at 21.77 mg/L, while wells in the Faculty of Engineering (FT) 4, FT 5, Library 6, and Faculty of Letters (FS) 9 had levels below 0.139 mg/L, indicating the lowest nitrate content. From the 12 samples of groundwater tested, most of them did not exceed the nitrate quality standard for drinking water of 20 mg/L, indicating satisfactory levels of $NO3^-$ content. However, the well water in the Faculty of Mathematics and Social Science (FMIPA) 11 surpassed the drinking water quality standard. Meanwhile, the well in Faculty of Social Science (FIS) 1 already had excess nitrate levels before the testing, totalling 18,68mg/L. Although it does not surpass the sanitary hygiene quality standard, the amount is significantly more significant than that of other wells.

The nitrate (NO2 -) is a partially oxidized form of nitrogen. Laboratory analysis of groundwater samples indicated that nitrite levels in all samples were within the quality standard. The library well 6 demonstrated the highest nitrite concentration at 0.0638mg/L, while the well in the Faculty of Letters (FS) 9 exhibited the lowest concentration at 0.0382mg/L. According to the standards for water quality in sanitation, the highest acceptable concentration of nitrite in water is 3mg/L. Nitrite compounds present in water are typically of low quality or unstable due to the impact of oxygen (O2).

The other chemical parameters analyzed in this study were valence 6 chrome (Cr^{6+}), dissolved iron (Fe), and dissolved manganese (Mn). These parameters contribute to the presence of heavy metal contamination in groundwater. According to the laboratory testing outcomes, for Cr^{6+}, all well water samples contained <0.012 mg/L, indicating that the Cr^{6+} content adheres to the maximum allowable quality standard of 0.01mg/L. Therefore, from this result, the well water quality in the UM environment is good.

Half of all wells have levels of dissolved manganese (Mn) that exceed the quality standards of the Regulation of Indonesian Health Ministry No. 02, the Year 2023, which pertains to the Implementation of Government Regulation No. 06. The well with the highest dissolved manganese content is well in the Faculty of Social Science (FIS) 1, measuring 0.9243mg/L, while the lowest content dissolved manganese is on the well located in the Faculty of Social Science (FIS) 2, Faculty of Engineering (FT) 3, FT 4, Faculty of Education Science (FIP) 8, Faculty of Mathematics and Natural Science (FMIPA) 11, and shared lecture building (GKB 12), amounting of less than <0.0104mg/L. Therefore, it can be concluded that the dissolved Fe content in all wells is within acceptable limits, as it does not exceed the quality standard of 0.2mg/L.

The study's findings indicate satisfactory levels of Mn and Fe, consistent with the study by Giffari et al. (2015) performed in the Batu Putih mountain hills region, which discovered 0.157 mg/L and 0.021 mg/L of iron (Fe) and manganese (Mn) content, respectively, in groundwater samples. These levels are within normal parameters and additional drinking water quality requirements.

The chemical composition analysis through the six parameters implies that the UM campus' groundwater remains satisfactory. Ramadhan (2018) attests that geological factors do not significantly affect these chemical parameters. Instead, shallow groundwater's carbonate content or hardness has a more dominant relationship with them. This is further supported by the study from (Sri & Riswandi, 2016) conducted in Wonogiri, Indonesia, uncovering that 50% of the groundwater in the research area exhibited secondary alkalinity in the form of carbonate hardness, with Ca+2 and Mg+2 being the dominant elements. Similarly, results from groundwater studies conducted in the Al-Jouf region of Saudi Arabia indicate that alkali metals (K+ and Na+) dominate the groundwater and are controlled by the rock-water interaction process (Alrowais, 2023). These findings align with the research from (Jumhari et al., 2019) in the southeast and southern areas around Mount Ceremei, West Java, Indonesia, revealing that the dominant geological structure largely controls the process of chemical content in groundwater. Specifically, the type of lithology and morphology have been reported to impact changes in groundwater chemical properties significantly.

Biology Properties of Groundwater

The biological properties were analysed on two parameters, namely the total Coliform and Escherichia Coli (E coli). The results of the biological property test are presented in Table 3.

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Table 3. Biology Properties of Groundwater in the UM Campus Area

Code	Unit	FIS 1	FIS 2	FT 3	FT 4	FT 5	Perpus 6	FEB 7	FIP 8	FS 9	Parkiran 10	FMIP A11	GKB 12
Location		UM Museum Well	Well in front of FIS	Behind LP3	In front of the culinary department	Civil engineering building	In front of the library	Behind the monument of akucinta FEB	Shared lecture building FIP/library FIP	Opposite the main literature building	UM busses parking lot	Near the central building FMIPA	Pool shelter
∑Coliform	Total Coliform (CFU/100ml)	184	118	139	112	240	72	218	168	185	160	168	113
E.Coli	Escherichia Coli (CFU/100ml)	1	1	19	10	1	1	24	22	15	19	1	16

(Sources: Primary Data, 2023)

The obtained biological property in Table 3 indicates the presence of Escherichia Coli (E. coli) and Total Coliform bacteria in all water samples. However, these two parameters are expected to be 0 CFU/100ml (as per the quality standards stated in the Regulation of Indonesian Ministry of Health No 02, Year 2023) since Coliform bacteria signifies other pathogenic bacteria in polluted waters. Further, the collected data demonstrated that all well water samples contained bacteria (biological parameters) above the set standards for drinking water quality. The well from the Faculty of Engineering (FT) 5 had the highest total Coliform parameter of 240 CFU/100ml, while the lowest was found in well library 6, with a Coliform level of 72 CFU/100ml. Among the Escherichia Coli bacteria parameters, the highest was observed well in the Faculty of Business (FEB) 7 at 24 CFU/100ml. At the same time, the lowest was found in five wells, namely Faculty of Social Science (FIS) 1, FIS 2, Faculty of Engineering (FT) 5, Library 6, and Faculty of Mathematics and Natural Science (FMIPA) 11, with a level of 1 CFU/100ml. From these results, the well water fails to meet the criteria for potable water regarding biological parameters, as the obtained biological parameter levels have surpassed the permissible water quality standards.

The discovery of E-Coli and total Coliform in the groundwater located in UM correlates with the analysis results proposed by (Fallatah et al., 2023) that groundwater quality is determined by the characteristics of the aquifer in regional geology and is strongly affected by both natural and anthropogenic activities. Further, Sejati (2020) asserted that natural factors play a significant role in groundwater quality. The form of aquifer types, constituent materials of the aeration zone, and the depth of the free groundwater table have the capacity to facilitate the interaction between pollutants and free groundwater from pollutant sources. Meanwhile, in relation to the influence of anthropogenic factors, Sejati's (2020) study on the southern slopes of Mount Merapi, Indonesia, reported a positive correlation between population density and the potential for groundwater pollution. Population is the central influencing factor of groundwater quality (Li et al., 2021). Consequently, an increase in population density can lead to an increment in domestic waste, potentially contaminating groundwater (Sejati, 2020). In practice, the quality of well water is impacted by various sources of pollution, such as sewage, garbage, and agricultural waste. Additionally, the quality of the water body, distance from latrines, and the presence of domestic wastewater are the primary factors that affect the quality of well water (Ningrum, 2018).

CONCLUSION

Following the analysis results, this study concludes that the physical properties of groundwater at the UM campus align with the drinking water quality standards. Regarding its chemical quality, the groundwater on the UM campus meets the drinking water quality standards. However, the groundwater at the UM campus falls biologically below the drinking water quality standards. The novelty of this research is that the biggest threat to the quality of free groundwater in the campus area is bacterial contamination from sanitation activities. Accordingly, it is advisable to avoid using groundwater for drinking water purposes. Boiling is necessary to eliminate the E. Coli bacterium present in all well water samples.

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