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MORALITY BEFORE KNOWLEDGE

Groundwater quality analysis using the weighted arithmetic water quality index at the elementary school

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ABSTRACT
Background: Children are a vulnerable group exposed to water pollution. Elementary schools in Kapanewon Prambanan, have experienced complaints regarding water quality. Therefore, this study aims to determine the water quality in elementary schools in Kapanewon Prambanan compared to the quality standards according to PERMENKES Number 2 of 2023 and to calculate the water quality index using the Weighted Arithmatic Water Quality Index (WAWQI) method. **Method:** The parameters tested were pH, Total Dissolved Solid (TDS), turbidity, nitrate, iron, and E.Coli. Measurements were carried out directly in the field at 12 sample points and testing was carried out in the laboratory. Determination of sample points was based on land use, Groundwater Basin (CAT) areas, geology, soil type, and complaints about water quality problems. **Findings:** Based on WAWQI calculations, it can be seen that the water quality at Kapanewon Prambanan elementary school is divided into two classes, namely very good and not suitable for consumption needs. WAWQI values range from 7.51 to 3105.82. Based on a comparison of the measurement results with the PERMENKES quality standards Number 2 of 2023, there are four sample points that exceed the quality standards for turbidity parameters, two points for TDS parameters, three sample points for nitrate parameters, and ten for E.Coli parameters. **Conclusion:** The WQI value at Kapanewon Prambanan Elementary School, which is divided into two classes, namely not suitable for consumption needs and very good is directly proportional to the distance of the well to the septic tank. Schools with very good water quality have a distance that meets the standard, which is more than 10 meters. **Novelty/Originality of this article:** This study is expected to be able to increase attention regarding the study of water quality in schools, especially in Indonesia, which is currently still rarely done.

KEYWORDS: water quality; elementary school; weighted arithmetic water quality index.

1. Background

Water is a crucial environmental aspect in fulfilling the basic needs of living things, both surface water and groundwater (Zahra et al., 2022; Chakraborty, 2021). Groundwater is the main source in fulfilling daily needs such as domestic, industrial, and agricultural activities (Komalawati et al., 2024; Mishra, 2023). Seventy percent of the clean water needs of the Indonesian population are obtained from groundwater utilization, while industrial needs reach 90% (Bregasnia et al., 2020). Groundwater is water flow beneath the earth's surface layer or aquifer and undergoes an infiltration process first. Nearly 98% of water on land is stored as groundwater in the pores or cracks of rocks and soil (Rejekiningrum, 2009). Groundwater availability is influenced by geological conditions, soil type, climate, and

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anthropogenic activities (Yuan & Guo, 2023; Gautam et al., 2022). Therefore, each region has different water availability.

Water quality is a characteristic of water and the various components of living organisms and substances contained in water (Sahabuddin et al., 2014). The content of substances or pollutants in water that exceed standards can disrupt the balance of the ecosystem and cause health problems (Singh et al., 2024). Population growth, urbanization, and industrialization have implications for increasing pollution and decreasing water quality (Sarker et al., 2021). The problem of water pollution is a significant environmental issue and a concern both nationally and internationally. This aligns with goal number 6 of the Sustainable Development Goals (SDGs) regarding clean water and adequate sanitation.

Water pollution, along with waste and spatial planning, are three major environmental issues in the Special Region of Yogyakarta. Currently, population growth in the Special Region of Yogyakarta is growing quite rapidly, with a positive population growth rate between 0.67 and 0.70 between 2021 and 2023 (Ningrum & Wahyuana, 2023; Central Bureau of Statistics, 2024). Special Region of Yogyakarta is a province with a relatively small area compared to other provinces in Indonesia, covering 3,185.80 km2, or 0.17% of Indonesia's total area. However, DIY ranks fourth in population density in Indonesia after DKI Jakarta, West Java, and Banten, with a population density of 1,186 per km2 (Central Bureau of Statistics, 2024). This will undoubtedly lead to increased use of clean water and increased water pollution. According to UNICEF Indonesia (2022), nearly 70% of drinking water sources in Indonesia are contaminated with fecal waste and contribute to the spread of diarrheal diseases.

Prambanan Subdistrict is located in Sleman Regency, Yogyakarta Special Region. The subdistrict is an area with diverse topography and geology. The geology in Prambanan Subdistrict consists of silt units, medium-sized sand units, fine sand units, tuff units, lapilli units, and sandstone units, thus having poor capacity to store and transmit water (Kristanto et al., 2020). The depth of the aquifer in Prambanan Subdistrict also varies quite a lot, from shallow depths (1-5 meters) to deep depths reaching up to 100 meters below the ground surface (Sadjab et al., 2012). Research conducted by Asrifah (2012) showed that the water quality conditions in Prambanan Subdistrict in terms of TSS, phosphate, manganese, hydrogen sulfide, and coliform parameters in some areas have exceeded quality standards. Research related to water quality in Prambanan Subdistrict is still rare, especially in the last 10 years.

One of the national goals enshrined in the 1945 Constitution is to improve the lives of the nation. However, research on water quality in schools in Indonesia has not received sufficient attention, resulting in very little research. Contaminated groundwater can cause health problems if consumed continuously over a long period of time. Children are considered more vulnerable to health problems due to water pollution than adults (Rana et al., 2022). Childhood is a crucial period in the development of cognitive abilities. Most children spend their time at school, especially now that elementary schools have begun implementing a full-day school system (Novianti & Pertiwi, 2019). However, clean water facilities in school environments are often neglected and receive little attention (Kusumarini & Embon, 2020). Poor water sanitation and unsafe drinking water will result in increased disease transmission. Therefore, assessing groundwater quality in schools is crucial.

Water quality assessment can be performed by calculating the Water Quality Index/*Indeks Kualitas Air (IKA).* IKA calculations can be used to determine water quality conditions based on existing quality status (Pramaningsih et al., 2023). The resulting value is a single value resulting from the integration of water quality parameters (Ratnaningsih et al., 2018). IKA can simplify water quality data so that conditions can be analyzed quickly. One method for calculating the water quality index is the Weighted Arithmetic Water Quality Index (WAWQI). This method is suitable for calculating groundwater quality and can be adapted to the parameters used. Research related to the use of the WAWQI method in Indonesia is also still rare. This study focuses on groundwater quality in elementary schools in the Prambanan Subdistrict using the WAWQI method, which has never been used in previous studies.

2. Method

2.1 Study location

The research location is at the Prambanan Subdistrict Elementary School, Sleman Regency. Prambanan Subdistrict covers an area of 4,135 hectares and consists of six villages: Sumberharjo, Wukirharjo, Gayamharjo, Sambirejo, Madurejo, and Bokoharjo. Prambanan Subdistrict is located between -7.738540 and -7.831390 latitude and 110.465460 and 110.546572 longitude. Prambanan Subdistrict is located in a humid tropical climate with two seasons, namely the rainy season and the dry season.

The morphology in Prambanan Subdistrict can be divided into mountains and plains with three formations consisting of the Kebobutak Formation, Semilir Formation, and Alluvial Sediment Unit. In addition, Prambanan Subdistrict also has geomorphological units in the form of structural, denudational, and fluvial units. The soil types at the study site consist of three types, namely latosol, regosol, and cambisol. The thickness of the soil solum can be divided into five classes, namely very thin (0-30 cm), thin (30-60 cm), medium (60-90 cm), thick (90-150 cm), and very thick (>150 cm) with the dominance of the very thick soil solum classification of 28.35% and fast permeability with a percentage of 72.63% (Fajria, 2016). Land use in Kapanewon Prambanan is dominated by gardens, rice fields and settlements with the Southern Mountains area dominated by gardens and rice fields and settlements in the plains.

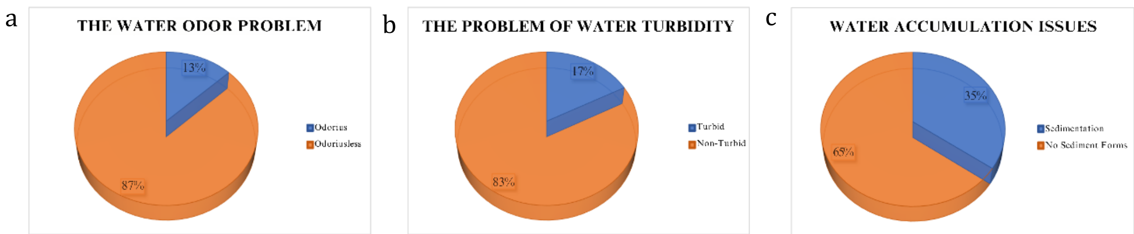

Fig. 1. May 2024 survey results

The research location is at the Prambanan Subdistrict Elementary School. The location selection was based on the results of the identification of water quality problems in elementary schools that have been quite common in Prambanan Subdistrict Elementary Schools. Based on a survey conducted by the author of schools in Prambanan Subdistrict on March 5, 2024, with a total of 22 respondents out of 29 elementary schools, 18 elementary schools in Prambanan Subdistrict utilize groundwater and 4 elementary schools utilize village PAM. A total of 95% of schools have canteens and 70% of schools use groundwater for sanitation and consumption. There are 35% of respondents who complained about the problem of sediment formation, 13% complained about smelly water, and 17% complained about colored water. Awareness regarding the importance of the quality of water consumed is also still lacking because there is one school that stated that water quality is something that does not need to be considered. In addition, based on an interview with one of the elementary school supervisors in Prambanan Subdistrict, it can be seen that there are problems with water that has a taste like irrigation water and groundwater that is colored and produces whitish sediment. Based on interviews with staff at the Kapanewon Prambanan Elementary School, school awareness regarding the quality of water used for school needs still needs to be improved. Water quality remains a secondary issue that is often overlooked, with schools tending to focus on immunizations and healthy eating.

2.2 Data collection

Water quality data collection was conducted in 12 of 29 elementary schools. Determination of sampling points was carried out using the purposive sampling method. This method is carried out by considering the sampling location according to the research objectives by using various sources to support and obtain appropriate results. Determination of sampling points in the groundwater quality analysis research in elementary schools was based on complaints about water quality problems, differences in geological conditions, water sources used, and differences in the morphology of the study area. Water quality sampling was carried out using the grab sample technique. This technique is a sampling technique that is carried out directly in the field. Sample bottles were washed with sample water three times before taking water quality samples. Water quality samples for hardness, iron, and nitrate parameters were preserved with HNO3 chemicals. Water quality samples were stored in a cooler box before being taken to the laboratory.

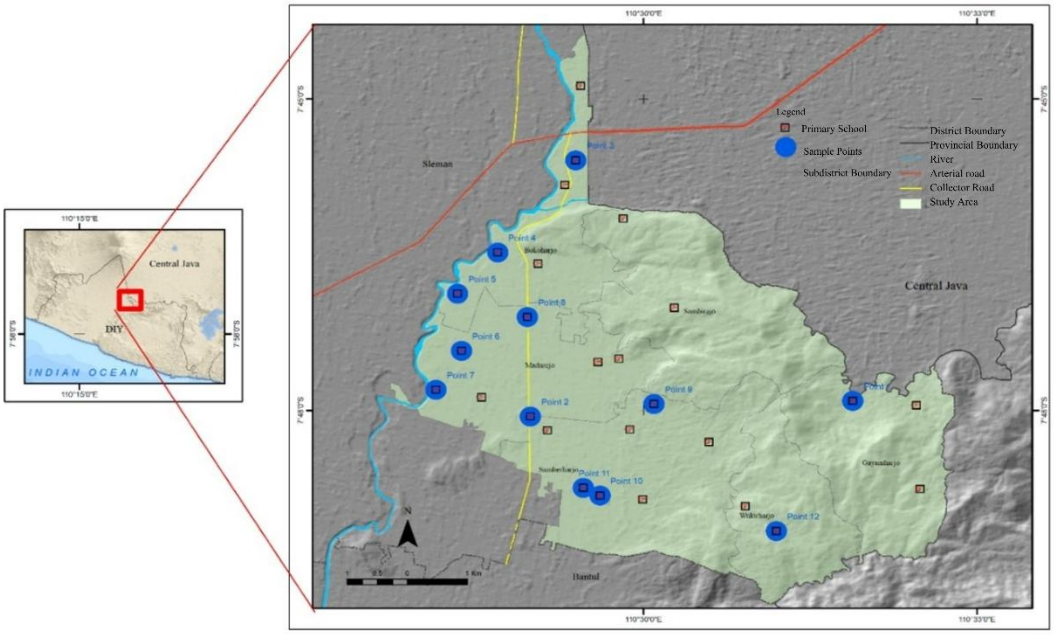

Fig. 2. Sample point map

Several water quality parameters must be measured immediately in the field to ensure representativeness. Water can change during its journey to the laboratory. These parameters include pH, which can be tested directly in the field using a water checker. Odor, taste, and color are parameters that can be measured sensorily in the field. Odor can be detected by inhaling the water's aroma using the sense of smell. Color can be observed directly using sight. Taste parameters, however, can be detected using the sense of taste, but caution is required as contaminated water can pose health risks.

Table 1. Sample point description table

No	Sample Point	Geology	Soil Type	Complaint
1	Point 1	Kebobutak Formation	Latosol	Has a white colored sediment
2	Point 2	Inseparable Volcanic Rocks	Regosol	Has sediment and water that tastes
3	Point 3	Inseparable Volcanic Rocks	Regosol	There isn't any
4	Point 4	Breezy Formation	Regosol	There isn't any
5	Point 5	Inseparable Volcanic Rocks	Regosol	Have sediment

6	Point 6	Inseparable Volcanic Rocks	Regosol	There isn't any
7	Point 7	Inseparable Volcanic Rocks	Regosol	There isn't any
8	Point 8	Inseparable Volcanic Rocks	Latosol	Turbidity and sediment
9	Point 9	Inseparable Volcanic Rocks	Latosol	There isn't any
10	Point 10	Inseparable Volcanic Rocks	Cambisol	Turbidity
11	Point 11	Inseparable Volcanic Rocks	Cambisol	There isn't any
12	Point 12	Breezy Formation	Latosol	There isn't any

Groundwater quality parameters also require laboratory testing because they require special handling and equipment to provide more accurate results. Testing is carried out in an accredited laboratory that conducts testing according to the Indonesian National Standard/*Standar Nasional Indonesia (SNI)* to guarantee water quality results. Physical parameters that require laboratory testing are TDS and turbidity, while biological parameters are E. coli, and chemical parameters include nitrate (NO3-) and iron (Fe). Nitrate and iron testing uses spectrophotometry with the principle of light absorption at certain wavelengths. Hardness and E. coli parameters require special testing methods, for hardness is measured by the titration method using EDTA reagent, while E. coli is done using the CFU (Colony Forming Unit) technique. TDS and turbidity are tested using special tools, TDS parameters are tested with a conductivity tool and turbidity using a turbidimeter.

2.3 Data processing and analysis

Based on Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 27 of 2021 concerning the Environmental Quality Index, the Water Quality Index or Water Quality Index (WQI) is a value that describes the condition of water quality. It is a composite value of water quality parameters in an area at a specific time. The WQI is one of the most widely used methods for representing water quality values (Chidiac et al., 2023). Water quality data is quantified to represent the water quality status at a location with the aim of simplifying the complexity of water quality data. The WQI value is then divided into several classes based on water quality status.

WQI calculations that are often used include the Weighted Arithmetic Water Quality Index (WAWQI), the National Sanitation Foundation Water Quality Index (NSFWQI), the Oregon Water Quality Index (OWQI), and the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) (Tyagi et al., 2013). Water quality parameters that have been measured in the field and tested in the laboratory will have certain values. These water quality values can be compared with drinking water quality standards and calculated using the Weighted Arithmetic Water Quality Index (WAWQI) method. The WAWQI method uses mathematical equations to assess water health with more flexible parameters and is suitable for the suitability of groundwater for human consumption (Tyagi et al., 2013). WQI calculations according to Tyagi (2013) can be calculated using Equation 1, with Qi calculations can be calculated using formula Equation 2, Wi values are calculated using formula Equation 3, and constant values or K are calculated using formula Equation 4.

$$WQI = \frac{\Sigma QiWi}{\Sigma Wi} \quad \text{(Eq. 1)}$$

Information Q_i represents the quality rating scale, while W_i denotes the relative weight assigned to each parameter. The value of Q_i can be calculated using the following formula as follows.

$$Qi = 100(\frac{Vi-Vo}{Si-Vo}) \quad \text{(Eq. 2)}$$

The V_i represents the measured value of parameter i, V_0 denotes the ideal value of parameter i (assumed to be 0 for all parameters except pH, for which the ideal value is 7), and S_i is the quality standard value of parameter i. The value of W_i can also be calculated using the following formula Equation 3 and 4 that K is a constant obtained.

$$Wi = \frac{K}{Si} \quad \text{(Eq. 3)}$$

$$K = \frac{1}{\Sigma(1/Si)} \quad \text{(Eq. 4)}$$

The results of WQI calculations according to Tyagi (2013) can be classified into 5 classes which can be seen in Table 2.

Table 2. WQI Classification

No	Value	Description
1.	0-25	Very good
2.	26-50	Good
3.	51-75	Bad
4.	76-100	Very bad
5.	>100	Not Fit for Consumption

(Tyagi, 2013)

Groundwater quality analysis at Kapanewon Prambanan Elementary School was conducted using a quantitative descriptive method. The results of water quality measurements, both direct field measurements and laboratory tests for pH, TDS, turbidity, nitrate, iron, and E. coli parameters, were compared with the drinking water quality standards stipulated in the Ministry of Health Regulation Number 2 of 2023. Water quality data for pH, TDS, turbidity, nitrate, iron, and E. coli parameters were also calculated using the WQI method to obtain a composite value and can be analyzed according to the WQI value classification.

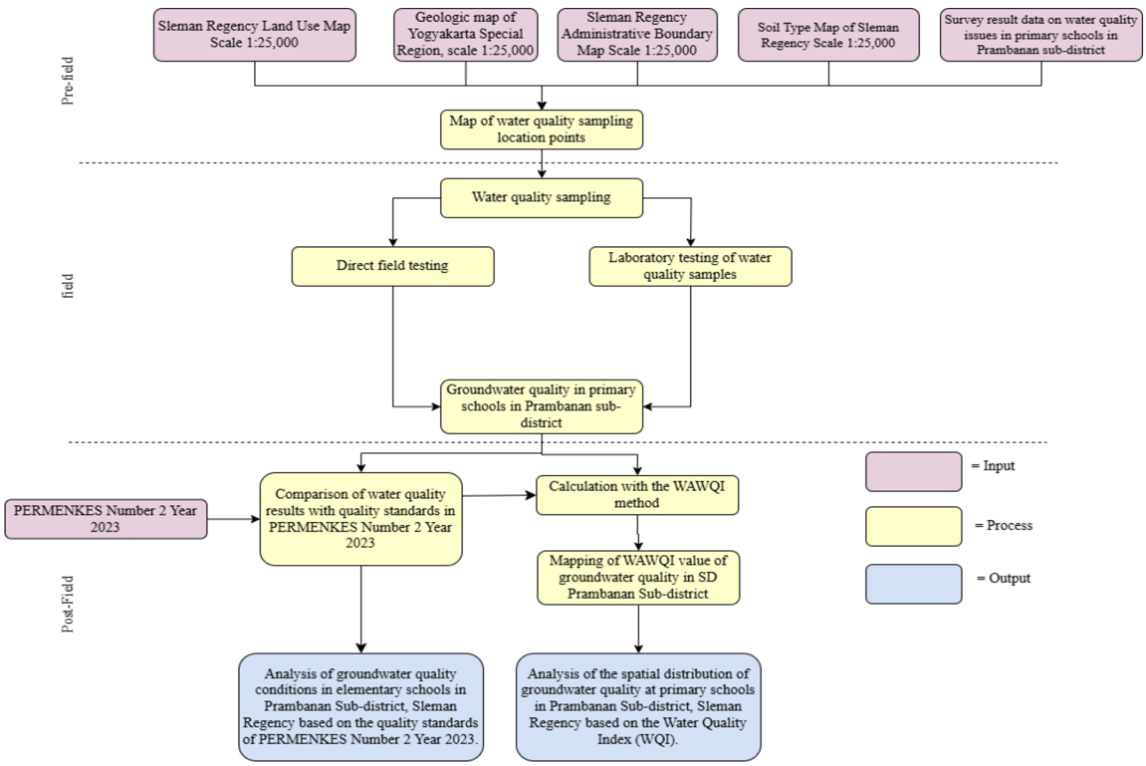

Fig. 3. Research Flowchart

3. Results and Discussion

Water quality in elementary schools in the Prambanan Subdistrict shows significant variation. Several points exceed quality standards for certain parameters. These include turbidity, TDS, Nitrate, Fe, and E. coli. For the E. coli parameter, many elementary schools exceed the quality standards based on PERMENKES Number 2 of 2023, namely ten out of twelve schools. Four schools exceed the quality standards for turbidity. Three schools exceed the quality standards for nitrate. Two schools exceed the quality standards for TDS (Total Suspended Solids). The pH and iron parameters for all elementary schools in the Prambanan Subdistrict still meet quality standards.

Table 3. Water quality measurement results

No	Sample Point	pH	Turbidity (NTU)	TDS (mg/L)	Nitrate (mg/L)	Fe (mg/L)	E.Coli (CFU/100 ml)
1	Point 1	7.99	1.3	324	26.69	0.0688	TNTC
2	Point 2	7.1	1.4	158	9.23	<0.0168	20
3	Point 3	6.72	0.9	835	140	<0.0168	10
4	Point 4	7.23	0.4	180	13.5	<0.0168	45
5	Point 5	6.68	0.9	187	17.82	<0.0168	TNTC
6	Point 6	7.12	0.6	196	20.23	<0.0168	60
7	Point 7	7.25	0.3	173	5.32	<0.0168	0
8	Point 8	7.06	3.5	218	16.26	0.0323	TNTC
9	Point 9	7.47	0.6	276	10.6	<0.0168	0
10	Point 10	7.08	3.7	246	0.32	0.1658	120
11	Point 11	6.77	5.4	199	18.04	<0.0168	TNTC
12	Point 12	7.96	5.7	204	5.74	0.0494	TNTC
Quality standards		6.5-8.5	3	300	20	0.2	0

3.1 Organoleptic properties (smell, color, taste)

The parameters of odor, color, and taste were observed sensorily with the odor parameter using the sense of smell, the color parameter using the sense of sight, and the taste parameter using the sense of taste. Based on observations at twelve sample points, it can be seen that twelve sample points are odorless and tasteless. However, in the color parameter, one sample point was found to be brownish and the other eleven sample points were clear. The elementary school with the brownish color is Point 8 which is located in the lowlands. Based on the results of interviews with teachers, there have been complaints about brown water for a long time, even blackish so that the water was only used for bathroom water and ablution until 2023. Another school that also complained about cloudy, tasteless, or smelly water is in the eastern part of the Prambanan Subdistrict which is located in the Southern Mountains series. However, the school already uses PAM water and does not use well water due to lime deposits. Point 2 complained about drinking water that tastes like rice field water. However, at the time of the study the water was tasteless.

3.2 Physical parameters: Turbidity

Turbid water is caused by high levels of suspended particles. Materials that influence turbidity include clay, mud, dissolved organic matter, plankton, and microorganisms. Turbid water reduces oxygen-holding capacity (Pati, 2022). Turbidity also impacts filtration and disinfection effectiveness, thus impacting the water purification process. Furthermore, turbid water can harbor pathogenic microbes (Aneta et al., 2021). Therefore, turbidity is one of the physical parameters of water quality considered for consumption.

Turbidity parameters in elementary school groundwater in Kapanewon Prambanan showed varying results with turbidity values ranging from 0.30 to 5.70 NTU. Four of the twelve elementary schools had turbidity values that exceeded the quality standards. These four elementary schools include Point 8 with a turbidity value of 3.50 NTU, Point 10 with a turbidity value of 3.70 NTU, Point 11 with a turbidity value of 5.40 NTU, and Point 12 with a turbidity value of 5.70 NTU. The well at Point 12 is still an open well without a well lip cover, making it easier to come into contact with processes above the ground surface and facilitating the entry of other substances or particles. All four wells have a shallow groundwater table depth, which is less than five meters. All four wells have a shallow groundwater table depth, which is less than five meters.

a b

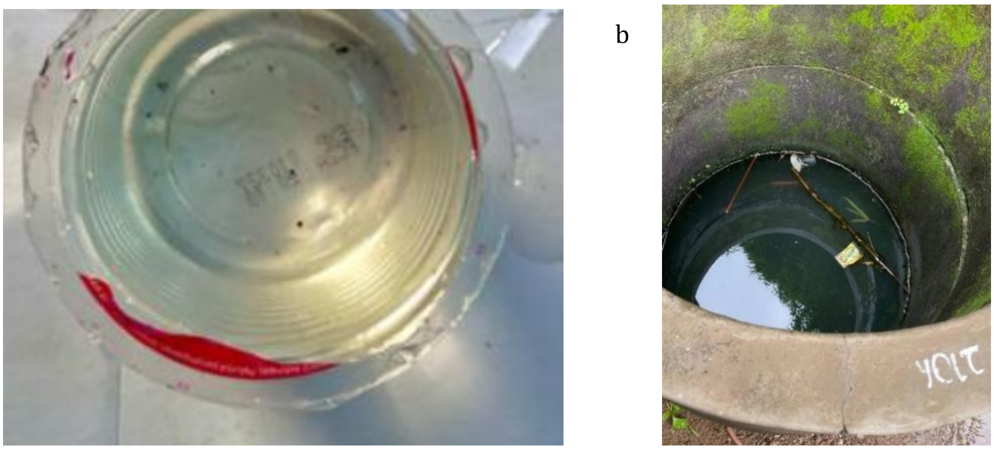

Fig. 4. (a) Water conditions at point 8; (b) Well conditions at point 12

3.3 Chemical parameters: Total dissolved solids (TDS)

Total Dissolved Solids (TDS) indicates the amount of organic and inorganic substances in water. A high TDS indicates high microbial activity in the water. TDS is an important parameter to consider for daily needs, especially for consumption, due to its impact on health. A high TDS can indicate high levels of inorganic salts or dissolved organic matter in the water, such as sodium, sulfate, chloride, magnesium, and bicarbonate. A TDS that is too low can also result in a slightly bitter taste in drinking water (Nabih et al., 2021).

The TDS parameter is one of the parameters frequently tested in groundwater quality research for drinking water. Groundwater with poor water quality can be affected by TDS concentrations that also exceed quality standards. Based on research conducted by Patel et al. (2023), the majority of schools in the southern Gujarat region have poor water quality with TDS and hardness parameters exceeding quality standards. Furthermore, research by Ahmed et al. (2020) also showed that TDS, turbidity, chloride, and hardness parameters participated in the decline in drinking water quality in one-third of schools in Sindh Providence, Pakistan. This phenomenon was also found in research by Chandra et al. (2017) where the majority of sample points had TDS exceeding quality standards and research by Rahman et al. (2016) where all sample points had TDS values exceeding quality standards.

The TDS parameters in the groundwater quality of the Prambanan Elementary School showed varying results with values ranging from 158 to 835 mg/L. These values are not much different from the TDS values in Asrifah's (2012) study, which showed TDS values in the Prambanan and Kalasan Districts ranging from 312 to 792 mg/L. Two of the twelve schools had TDS exceeding the quality standard, namely Point 1 at 324 mg/L and Point 3 with a TDS value almost three times the quality standard at 835 mg/L. Point 1 is located in the southern mountainous area in the Kebobutak Formation, which consists of alternating conglomerates, tuffaceous sandstones, shales, and silts containing various minerals that can affect the TDS value (Sutarto et al., 2020). Meanwhile, Point 3 is located in the midst of quite intense anthropogenic activity because it is close to an arterial road, so that settlements can be found around the school. Furthermore, the well at Point 1 is quite deep, approximately three to ten meters, thus increasing the likelihood of contact with rocks. High TDS values indicate a high ion content in the groundwater (Cahyadi et al., 2022).

3.4 Chemical parameters: pH

The intensity of water acidity is expressed in pH parameters. The taste of drinking water can be affected by the water's pH. A low or acidic pH will have implications for the taste of drinking water that tends to be bitter, while if the pH is too alkaline, it will cause the water to taste unpleasant and thicker (Emilia, 2019). All samples still meet the quality standards for pH parameters. There are three schools that have an acidic pH or below 7, namely Point 3 with a pH of 6.72, Point 5 with a pH value of 6.68, and Point 11 with a pH value of 6.77. All three elementary schools are located in the lowlands. Point 3 and Potrojayan 3 Elementary School are located in a fairly dense settlement and a deep groundwater depth of more than ten meters. Meanwhile, Point 11 is located near settlements and rice fields. Two schools located in the Southern Mountains have a higher pH than the other schools located in the lowlands, namely Point 1 with a pH of 7.99 and Point 12 with a pH of 7.96. The pH of groundwater in the Southern Mountains of the Semilir Formation and Kebobutak Formation has a basic pH due to contact with various higher minerals.

3.5 Chemical parameters: Nitrate (NO3-)

Nitrate is an important parameter in the quality of water used for consumption. Nitrate can originate from agricultural activities such as urea fertilizer, fish ponds, animal and human waste, and household waste (Sutardi et al., 2017; Pertiwi & Lestari, 2022). High and persistent nitrate concentrations entering the body will affect hematological and neurological conditions. Nitrate can be converted to nitrite through the denitrification process. Nitrate concentrations in the body can also be implicated in an increased risk of cancer (Ardhaneswari & Wispriyono, 2022). Nitrate is an important chemical parameter for drinking water quality, given high population growth and agricultural activity.

Nitrate parameters at elementary schools in the Prambanan Subdistrict showed highly variable values, with a low of 0.32 mg/L and a high of 140 mg/L. Three schools had nitrate levels exceeding the standard: Point 1 with a nitrate level of 26.69 mg/L, Point 3 with a value seven times the standard, at 140 mg/L, and Point 6 with a value of 20.23 mg/L. Nitrate levels are strongly influenced by organic waste or organic debris. Point 3 is located in an agricultural area near the Opak River. Some nitrate from pesticides can be absorbed into the soil, while others can be carried by surface water flow and enter water bodies. In addition, cattle breeders near the school still bathe their livestock in the river. Point 1, located near a densely populated residential area and a factory, may contribute to the high nitrate levels because nitrate can also originate from human activities such as septic systems, wastewater disposal, and garbage dumps. The three schools also have in common the proximity of wells to bathrooms and septic tanks. The well at Point 6 is also flanked by two bathrooms: the school bathroom and the market bathroom, which are located directly next to the school. Wastewater from the school bathrooms also flows near the well, potentially affecting nitrate levels.

3.6 Chemical parameters: Iron (Fe)

Iron is a heavy metal that, if ingested in excess and over a long period of time, can cause liver cirrhosis, hemochromatosis, diarrhea, coma, and irritability (Andini, 2018). Groundwater tends to have a high carbon dioxide content, making iron insoluble (Lexia & Ngibad, 2021). Groundwater containing iron can cause yellow water, a bitter taste, and stain clothing (Khaira, 2013). Even small amounts of iron exceeding drinking water quality standards can lead to health problems.

Iron parameters are still within safe limits for consumption. Water quality iron values range from <0.0168 to 0.1658 mg/L. Point 10 is the school with the highest iron content, at 0.1658 mg/L. This school has the shallowest groundwater level compared to other schools in the Prambanan Subdistrict, at less than one meter. Shallow groundwater is more susceptible to exposure to aboveground activities. Schools located in the Southern Mountains tend to show higher iron concentrations than schools in the lowlands.

3.7 Biological parameters: E.Coli

The increase in population and living standards has led to an increase in the need for new drinking water sources. Dug wells are often constructed without proper distance from septic tanks, which require a minimum distance of ten meters. E. coli in water is caused by contamination from human and animal waste. This bacterial content can lead to diarrhea, meningitis, and intestinal infections (Desiana et al., 2024).

Table 4. Distance between well and septic tank at school

No	Sample Point	Distance (m)
1	Point 1	4
2	Point 2	5
3	Point 3	3
4	Point 4	5
5	Point 5	7
6	Point 6	6
7	Point 7	15
8	Point 8	6
9	Point 9	15
10	Point 10	5
11	Point 11	5
12	Point 12	3

The majority of E.Coli parameters have exceeded the established quality standards. The majority of E.Coli parameters at elementary schools in Kapanewon Prambanan, Sleman Regency have exceeded the established quality standards. E.Coli. This is in line with research conducted by Wiyajanti et al. (2018) with one of its points in Kapanewon Prambanan which showed that E.Coli had exceeded the established quality standards. E.Coli found in water is influenced by human waste. Of the twelve schools, only two schools met the E.Coli quality standards, namely Point 7 and Point 9 with an E.Coli value of 0 CFU/100 ml. The highest E.Coli value is TNTC or more than 200 colonies which can be found at Point 1, Point 5, Point 11, Point 8, and Point 12. Points 1 and Point 12 are in the Southern Mountains, while Points 5, Point 8, and Point 11 are in the lowlands. Domestic wastewater treatment plants (WWTPs) are rare in Prambanan Subdistrict, so residents still use septic tanks. Schools with E. coli levels that meet the standard are located at a distance from their septic tanks that meets the established standards, while other schools that do not meet the E. coli standards have wells that are too close to the septic tanks and do not meet the standard.

3.8 WAWQI calculation results

Water Quality Index can be calculated using various methods, one of which is WAWQI. Based on WAWQI calculations, it can be seen that the water quality in Kapanewon Prambanan elementary school can be divided into two classes, namely very good class and class not suitable for consumption needs. The WQI value is greatly influenced by the E.Coli parameter because many sample points have E.Coli more than 200 colonies while the E.Coli quality standard itself is zero or there should be no E.Coli in the water at all. In addition, the E.Coli parameter weight ranks second highest, which is 0.15374. The highest WQI value is 3105.82 at Point 1 with parameters that exceed the quality standard are TDS, nitrate, and E.Coli. sample point 8 is a sample point with very good water quality, which is 7.51. This is indicated by no parameters exceeding the quality standard and having an E.Coli value of zero.

Besides E. coli, the parameter that contributes significantly to the WQI value is iron. The weight of the iron parameter is the highest compared to other parameters, at 0.76872.

Although none of the iron parameters exceed the quality standard, the iron quality standard is very small, so even slightly higher iron values will contribute significantly to the WQI value, namely 6 to 63 of the final WQI calculation value. This is because iron is a heavy metal that is dangerous if found in water.

Schools with good WQI scores are located in the lowlands. Both schools are also located in the southern area of the Prambanan Subdistrict. The southern region tends to have a lower population density and settlements than the northern side. The IKA score for Point 7 is 7.5052, with the iron parameter contributing the highest score, namely 6.4573 of the total IKA score. Meanwhile, the parameter that contributes the smallest IKA score is E.Coli, which is 0. In addition, the turbidity value contributes the second highest IKA score, namely 0.5125. However, the turbidity at Point 1 is the smallest turbidity value compared to other schools, namely 0. Point 9 has an IKA value that is not much different from Point 7, namely 8.5035. The iron parameter also contributes the highest score to the IKA value, namely 6.4573. Meanwhile, the E.Coli parameter also contributes the smallest score, namely 0. The turbidity parameter also ranks second in contributing the highest IKA score.

On the other hand, there are ten schools that do not meet quality standards. These ten schools are distributed across different geological conditions, with one school in the Semilir Formation, one school in the Kebobutak Formation, and eight schools in the Unbreakable Volcanic Rocks. Furthermore, the ten schools also have different soil types, consisting of three schools with latosol soil types, two schools with cambisol soil types, and five schools with regosol soil types. The five schools that complained about water quality issues are classified as unsuitable for consumption. The decline in water quality is also influenced by the presence of pollution sources, especially from anthropogenic activities such as domestic, agricultural, and industrial activities that produce waste. The higher the anthropogenic activity, the higher the potential for groundwater pollution. Residential land use and rice fields are often found in lowlands. IKA values that are unsuitable for consumption in lowland areas tend to be associated with rivers and highways.

The highest IKA value was found at Point 1 with an IKA value of 3105.82. The order of parameters contributing to the IKA score from highest to lowest is E. coli, iron, turbidity, pH, nitrate, and TDS. The E. coli parameter contributed a value of 3074.88. The concentration of iron, TDS, and nitrate at Point 1 ranked second highest, and the pH value was the most alkaline. The nitrate, TDS, and E. coli parameters at Point 1 have exceeded the quality standard. This has implications for the high IKA value.

Point 12 has the second highest IKA value with a value not much different from Point 1, namely 3105.02. The order of parameters contributing to the IKA value from highest to lowest at SD Muhammadiyah Gunungharjo 2 is E.Coli, Iron, turbidity, pH, nitrate, and TDS. The iron parameter is ranked third highest and has the highest loss value. Both schools are located in the Southern Mountains area. The water quality in the Southern Mountains area is unsuitable for consumption is influenced by geological factors. The majority of other schools in the Southern Mountains have used PAM water for their water source due to complaints of hardness from groundwater in the area. This hardness is evidenced by cooking utensils that have a whitish crust. However, both schools still use well water to meet consumption needs at school.

Schools located in lowlands with water quality unsuitable for consumption are affected by anthropogenic activities, particularly domestic and agricultural activities. Schools located in densely populated areas, particularly those on the northern side of the Prambanan Subdistrict, have higher IKA scores. This is also influenced by the fact that the majority of residents in the Prambanan Subdistrict still use septic tanks rather than communal wastewater treatment plants (WWTP). As the population increases in a location, the sources of pollutants from anthropogenic activities also increase, resulting in a decline in water quality.

Fig. 5. Crusty cooking utensil at point 1

The school with the third highest IKA score is Point 8 with an IKA score of 3094.01. The order of water quality parameters that contribute to the highest to lowest IKA score is E.Coli, iron, turbidity, pH, nitrate, and TDS. E.Coli at Point 8 is still the same as Points 1 and 12, namely TNTC FCU/100 ml. Iron concentration is ranked fourth highest compared to other schools, namely 0.0323 mg/L. The turbidity parameter value has ranked fourth highest, namely 3.5 NTU. Parameters that exceed the quality standard are E.Coli and turbidity.

Point 11 ranked fourth in terms of the highest IKA value, at 3092.12. The conditions at Point 11 were not significantly different from Point 8, with the only difference being the pH parameter, as Point 11 had a pH below neutral (7). Point 11's turbidity value was also higher, even ranking second with the highest turbidity value, at 5.4 NTU. Point 5 has an IKA value of 3084.75. This elementary school tends to have fairly good water quality because other parameters besides E. coli still meet quality standards. However, the E. coli value is very high, at TNTC FCU/100ml, which has implications for the high IKA value. TDS and turbidity values are still in the moderate range. The nitrate parameter has a fairly high value, although it does not exceed the quality standard, as it is in the third highest concentration at 20.23 mg/L. Point 10 has an IKA value of 1915.13. The E.Coli parameter still contributes the highest score but the concentration at this sample point has decreased compared to other sample points with higher IKA values, namely 120 CFU/100 ml and contributing an IKA score of 1844.92.

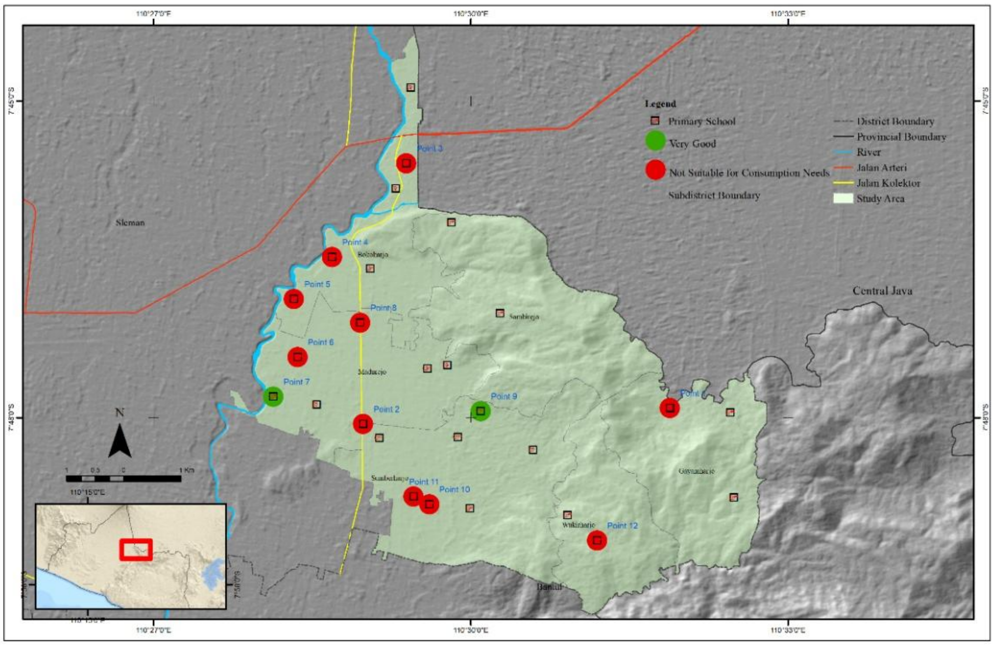

Fig. 6. Distribution of WQI values

However, the iron parameter contributes a fairly high score because the iron concentration at Point 10 is the highest even though it has not exceeded the quality standard, which contributes 63.7269. Point 6 has an IKA of 930.90. The E.Coli parameter contributes the highest IKA score with a concentration of 60 CFU/100 ml and contributes a score of 922.46. In addition to the E.Coli parameter, it shows a fairly good water quality value and does not exceed the quality standard. This phenomenon also occurs at Point 4 and Point 2 where parameters other than E.Coli have shown quite good results. Point 4 has an IKA value of 699.82 with an E.Coli parameter concentration of 45 FCU/100 ml contributing a score of 691.85. Meanwhile, Point 2 has an IKA value of 316.84 with an E.Coli parameter concentration of 20 CFU/100 ml contributing a score of 307.49. Point 3 has the lowest IKA value in the class not suitable for consumption needs, namely 168.28. The E.Coli parameter still contributes the highest score, followed by iron, nitrate, turbidity, pH, and TDS. The E.Coli concentration is 10 CFU/100ml. However, there are three parameters in this school that have exceeded the quality standard: E.Coli, nitrate, and TDS. The TDS and nitrate values at Point 3 are the highest compared to other schools.

Table 5. WAWQI calculation results

Sample Point	WQI	Classification
Point 1	3105.82	Not Fit for Consumption
Point 2	316.84	Not Fit for Consumption
Point 3	168.28	Not Fit for Consumption
Point 4	699.82	Not Fit for Consumption
Point 5	3084.75	Not Fit for Consumption
Point 6	930.90	Not Fit for Consumption
Point 7	7.51	Very good
Point 8	3094.01	Not Fit for Consumption
Point 9	8.50	Very good
Point 10	1915.13	Not Fit for Consumption
Point 11	3092.12	Not Fit for Consumption
Point 12	3105.02	Not Fit for Consumption

4. Conclusion

Elementary schools in the Prambanan Subdistrict have a Water Quality Index (IKA) value that can be divided into two categories: very good water quality and unsuitable for consumption. Points 7 and 9 have very good WQI values, while the other points have WQI values that are unsuitable for consumption. Based on a comparison of the measurement results with the PERMNEKES quality standards Number 2 of 2023, there are four sample points that exceed the quality standard for the turbidity parameter, two points for the TDS parameter, three sample points for the nitrate parameter, and ten for the E. coli parameter. The IKA value is directly proportional to the distance from the septic tank to the well.

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Author Contribution

The authors independently carried out all stages of the research. These stages included problem formulation, data collection, data processing, and the preparation of results and discussion.

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References

Ahmed, J., Wong, L. P., Chua, Y. P., & Channa, N. (2020). Drinking Water Quality Mapping Using Water Quality Index and Geospatial Analysis in Primary Schools of Pakistan. *Water, 12*(12), 3382. https://doi.org/10.3390/w12123382

Andini, A. (2018). Analysis of Fe(III) Water Levels in Tanggulangin District, Sidoarjo. *Medical Technology and Public Health Journal, 2*(1), 19-24. https://doi.org/10.33086/mtphj.v2i1.763

Asrifah, D. (2012). Evaluation of Unconfined Groundwater Potential for Water Supply in Kalasan and Prambanan. *Indonesian Geography Magazine, 27*, 56-78. https://doi.org/10.22146/mgi.13448

Central Bureau of Statistics. (2024). *Indonesian Statistics 2024.* Central Bureau of Statistics, Jakarta.

Bregasnia, W., Suwarsito, S., & Sarjanti, E. (2020). Study of groundwater flow patterns in the main campus area of Muhammadiyah University of Purwokerto. *Sainteks, 17*, 19-25. https://doi.org/10.30595/sainteks.v17i1.8507

Cahyadi, A., Haryono, E., Adji, TN, Widyastuti, M., Riyanto, IA, Acintya, R., & Qushoyyi, NF (2022). Hydrogeochemical Characteristics and Water Quality of the Selonjono Karst Springs, Gunungsewu, Special Region of Yogyakarta. *Geodika: Journal of Geographical Science and Education Studies,* 6(2), 175-185. https://doi.org/10.29408/geodika.v6i2.6100

Chandra, D. S. , Asadi, S. S., & Raju, M. V. S. (2017). Estimation of Water Quality Index by Weighted Arithmetic Water Quality Index Method: a Model Study. *International Journal of Civil Engineering and Technology,* 8(4), 1215-1222. https://iaeme.com/Home/article_id/IJCIET_08_04_136

Chakraborty, S. K. (2021). Water: Its properties, distribution, and significance. *In Riverine Ecology Volume 1: Eco-functionality of the Physical Environment of Rivers (pp. 23-55). Cham: Springer International Publishing.* https://doi.org/10.1007/978-3-030-53897-2_2

Desiana, Rusdi, & Rachman, A. (2025). Escherichia coli Bacteria Testing in Clean Water Sources from Dug Wells in the Suatang Baru Community Health Center Work Area. *Journal of Sport Science, Health and Tourism of Mandalika (Jontak), 6*(1), 6-13. https://doi.org/10.36312/jontak.v6i1.4147

Emilia, I. (2019). Analysis of Nitrate and Nitrite Content in Refilled Drinking Water Using the UV-VIS Spectrophotometry Method. *Indobiosains, 1*(1). https://doi.org/10.31851/indobiosains.v1i1.2441

Fajriah, L. (2016). *Landslide Vulnerability Level in Prambanan District, Sleman Regency Using Geographic Information System*. Universitas Negeri Yogyakarta.

Gautam, A., Rai, S. C., Rai, S. P., & Ram, K. (2022). Impact of anthropogenic and geological factors on groundwater hydrochemistry in the unconfined aquifers of the Indo-Gangetic plain. *Physics and Chemistry of the Earth, Parts A/B/C, 126*, 103109. https://doi.org/10.1016/j.pce.2022.103109

Khaira, K. (2013). Determination of Iron (Fe) Content in Well Water and PDAM Water Using Spectrophotometric Method. *Sainstek: Journal of Science and Technology, 5*(1), 17-23. http://dx.doi.org/10.31958/js.v5i1.78

Komalawati, K., Romdon, A. S., & Hidayat, Y. (2024). Community Knowledge and Perception of Groundwater Utilization and Conservation in Pekalongan City. *Pekalongan City Research and Development Journal, 22*, 14-27. https://doi.org/10.54911/litbang.v22i1.294

Kristanto, W. A. D., Astuti, F. A., Nugroho, N. E., & Febriyanti, S. V. (2020). Distribution of Groundwater-Scarce Areas Based on Geological Conditions of the Prambanan Sub-district Hilly Area, Sleman, Yogyakarta. *Journal of Environmental Science & Technology, 12,* 68-83. https://doi.org/10.20885/jstl.vol12.iss1.art6

Kusumarini, E., & Embon, S. (2020). The Importance of Providing Clean Water Facilities in School Environments to Create a Clean and Healthy Environment at SDN 020 North Samarinda. *Pendas Mahakam: Journal of Elementary School Education and Learning, 5*, 87-92. https://doi.org/10.24903/pm.v5i1.1089

Lexia, N., & Ngibad, K. (2021). Application of Spectrophotometry to Quantitatively Determine Iron Content in Water Samples. *Jurnal Pijar Mipa, 16*(2), 242-246. https://doi.org / 10.29303/jpm.v16i2.1908

Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies, 4* (3), 1-78. https://doi.org/10.29303/jpm.v16i2.1908

Nabih, F. N., Takwanto, A., & Rahayu, M. (2021). The Effect of Ozone Concentration on the pH and Total Dissolved Solids (TDS) of Bottled Drinking Water (AMDK). *Distillate: Journal of Separation Technology, 7*(2), 347-352. https://doi.org/10.33795/distilat.v7i2.239

Ningrum, A. D. R., & Wahyuhana, R. T. (2023). Analysis of the Suitability of the Implementation of Inclusive Settlement Development in Blunyahrejo Village, Karangwaru Subdistrict, Yogyakarta City. *Journal of Regional and Rural Development Planning, 7*, 235-249. https://doi.org/10.29244/jp2wd.2023.7.2.235-249

Nipu, L. P. (2022). Determination of Groundwater Quality as Drinking Water Using the Pollution Index Method. *Magnetic: Research Journal of Physics and Its Application, 2,* 106-111. https://doi.org/10.59632/magnetic.v2i1.150

Novianti, D., & Pertiwi, W. E. (2019). Implementation of Environmental Sanitation in Elementary Schools: 2018 Inspection Report from Kapanewon Kramatwatu, Serang Regency, Banten Province. *Journal of Environmental Health, 11*, 175-186. https://doi.org/10.20473/jkl.v11i3.2019.175-188

Patel, D. D., Mehta, D. J., Azamathulla, H. M., Shaikh, M. M., Jha, S., & Rathnayake, U. (2023). Application of the Weighted Arithmetic Water Quality Index in Assessing Groundwater Quality: A Case Study of the South Gujarat region. *Water, 15*(19), 3512. https://doi.org/10.3390/w15193512

Pati, D. U. (2022). Effectiveness of Slow Sand Filters (Downflow) in Measuring Water Quality as an Impact of Reducing River Water Turbidity as Clean Water in East Sumba Regency. *Journal of Citizenship, 6*(3), 6326-6334. https://doi.org/10.31316/jk.v6i3.4138

Pertiwi, K. D, & Lestari, I. P. (2022). Water Quality of the Kaligarang River Sub-Watershed, Gogik Village Reviewed from Nitrate, BOD, COD, and DO Parameters. *Pro Health Scientific Journal of Health, 4*(2), 274-279. https://doi.org/10.35473/prohealth.v4i2.1816

Pramaningsih, V., Yuliawati, R., Sukisman, S., Hansen, H., Suhelmi, R., & Daramusseng, A. (2023). Water Quality Index and Impact on Public Health Around the Karang Mumus River, Samarinda. *Indonesian Journal of Environmental Health, 22*, 313-319. https://doi.org/10.14710/jkli.22.3.313-319

Rahman, A., Hashem, A., & Nur-A-Tomal, S. (2016). Potable Water Quality Monitoring of Primary Schools in Magura District, Bangladesh: Children's Health Risk Assessment. *Environmental Monitoring and Assessment, 188*, 1-10. https://doi.org/10.1007/s10661-016-5692-6

Rana, M. S., Alam, M. J., Musa, M. A., Kumar, S., & Rahman, M. A. (2022). Groundwater arsenic poisoning in a primary educational institution: health risks to school-going children. *Acta Geochimica, 41*, 1069-1082. https://doi.org/10.1007/s11631-022-00563-w

Ratnaningsih, D., Lestari, R. P., Nazir, E., Pitalokasari, O. D., & Fauzi, R. (2018). Development of a Water Quality Index as an Alternative for River Water Quality Assessment. *Ecolab, 12*, 53-61. https://doi.org/10.20886/JKLH.2018.12.2.53-61

Rejekiningrum, P. (2009). Opportunities for utilizing groundwater for sustainable water resources. *Journal of Land Resources, 3*(2). ISSN 1907-0799

Sadjab, B. A., As'ari, & Tanauma, A. (2012). Mapping of Groundwater Aquifers Around Prambanan Temple, Sleman Regency, Yogyakarta Special Region Using the Geoelectric Resistivity Method. *Jurnal MIPA, 1*, 37-44. https://doi.org/10.35799/jm.1.1.2012.432

Sahabuddin, H., Harisuseno, D., & Yuliani, E. (2014). Analysis of water quality status and pollution load capacity of the Wanggu River, Kendari City. *Journal of Water Resources Engineering, 5*, 19-28. https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/201

Sarker, B., Keya, K. N., Mahir, F. I., Nahiun, K. M., Shahida, S., & Khan, R. A. (2021). Surface and ground water pollution: causes and effects of urbanization and industrialization in South Asia. Scientific Review, *7*(3), 32-41. https://doi.org/10.32861/sr.73.32.41

Singh, P. K., Kumar, U., Kumar, I., Dwivedi, A., Singh, P., Mishra, S.,... & Sharma, R. K. (2024). Critical review on toxic contaminants in surface water ecosystems: sources, monitoring, and their impact on human health. *Environmental Science and Pollution Research, 31*(45), 56428-56462. https://doi.org/10.1007/s11356-024-34932-0

Sutardi, A., Suprayogi, S., & Adji, TN (2017). Study of Unconfined Groundwater Quality between the Kuning River and the Tepus River in Ngemplak District, Yogyakarta, Indonesia. *Indonesian Geography Magazine, 31*(1), 31-38. ISSN 2540-945X

Sutarto, S. (2020). Characteristics and Formation of Igneous Rocks in the Jiwo Mountains, Bayat, Central Java. *Journal of Minerals, Energy, and the Environment, 4*(2), 18-31. https://doi.org/10.31315/jmel.v4i2.3235

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of water quality index. *American Journal of Water Resources, 1*, 34-38. https://doi.org/10.12691/ajwr-1-3-3

UNICEF Indonesia. (2022). *Indonesia: Nearly 70 percent of household drinking water sources are contaminated with fecal waste*. UNICEF. https://www.unicef.org/indonesia/id/siaran-pers/indonesia-hampir-70-persen-sumber-air-minum-rumah-tangga-tercemar-limbah-tinja

Yuan, R., Li, Z., & Guo, S. (2023). Health risks of shallow groundwater in the five basins of Shanxi, China: Geographical, geological and human activity roles. *Environmental Pollution, 316*, 120524. https://doi.org/10.1016/j.envpol.2022.120524

Zahra, F. S., Putranto, T. T., & Muhammad, F. (2021). Groundwater quality assessment for drinking water and irrigation water in Banjarbaru City and its surroundings. *Journal of Geoscience and Technology, 4*, 57-71. https://doi.org/10.14710/jgt.4.2.2021.57-71

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