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*Regional Case Study*

# Analysis of Lithology Influence on the Coliform Distribution in Semarang City

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## Abstract
The amount of available water is becoming more scarce due to increased human demand. As a result, people are now obtaining their water from limited aquifers or deep groundwater from artesian water sources. Nonetheless, the varied properties of the soil and rocks within it do not ensure that the groundwater's quality remains safe from microorganisms or germs. Coliform, one of the bacteria or microorganisms that can increase in groundwater due to variations in the rock lithologies found in different regions. Analysis of coliform bacteria distribution was carried out in 30 drilled wells from confined aquifers spread across the city of Semarang. This research identified total coliforms using the Most Probable Numbers (MPN) method. The presence of coliform bacteria in certain wells was compared with the characteristics of rocks, where in this study area there are several rock lithologies such as volcanic breccia, andesite, pyroclastic breccia, lava, and clay. As for the results of this analysis, it was found that 10% of the samples contained total coliforms that exceeded the maximum limit of 50 CFU/100 ml, where the lithology with the highest total coliform content was found in the basalt area with the highest results, namely TNTC (Too Numerous to Count).

**Keywords**: Coliform; lithology; confined aquifer; semarang

## 1. Introduction

Groundwater is water in the aquifer layer, which is located below the soil's surface. This groundwater density is becoming a major source of raw water to meet needs such as households, industry, drinking water, irrigation, etc. The use of this groundwater reaches 80% of the population and industrial water needs in Indonesia (Inayati, 2008).

Semarang City is known as a city with a fairly high population density, coupled with the large number of industries operating, which means that the need for groundwater is increasing every year (Novianti, 2022). Groundwater, a component of the hydrological cycle, is largely determined by the geological conditions and some components of the surrounding habitat. (Singh et al., 2015). The quality of groundwater can be influenced by the surrounding environment, such as industrial buildings, dense settlements, sanitation, and others. The existence of structures and geology around the groundwater environment is also assessed to have an impact on the quality of groundwater. The parameters that can categorize water quality can be judged from the physical, chemical, and biological indicators (Inayati, 2008). These parameters can be assessed from physical properties such as smell, color, flavor, and stiffness, chemical properties can be seen from the stiffness, pH, DHS, TDL, and isotopes as well as on biological factors can be evaluated from microbiological distribution values; one of which is total coliform. The presence of coliform bacteria contained in groundwater may indicate that the water is contaminated with pathogenic stools. The presence of coliform bacteria contained in groundwater can indicate that the water is contaminated by pathogenic feces. The coliform bacteria can cause various diseases such as diarrhea, typhus and bacillary dysentery (Kumalasari et al., 2018). WHO estimates that the main causes of diarrhea in developing countries are Rotavirus and Escherichia coli bacteria. Both agents are closely related to environmental factors such as sanitation hygiene, adequate clean water and drinking water facilities, and food hygiene and safety. Based on SIMPUS in the Semarang City Health Profile in 2018, diarrhea is in the top 10 diseases that are widely suffered by the people of Semarang City. Diarrhea sufferers from 2013 - 2016 tended to decrease but increased in 2017 with a total of 38,766 diarrhea cases in that year. Based on data from the Padangsari Health Center Profile in 2018, it is known that diarrhea is one of the top 10 diseases that occur in the Health Center's work area. With a trend of increasing cases, namely from 50 cases in 2016, 58 cases in 2017 and 69 cases in 2018.

According to the Regulation of the Minister of Health of RI No. 2 Year 2023, clean water is water whose quality meets health requirements and can be drunk when cooked. The condition of this clean groundwater is non-sensitive, odorless, colorless, and free of chemical and microbiological contamination, one of which is coliform bacteria. Coliform, an essential indicator of fecal contamination in the groundwater content, has a maximum content of 50 CFU/100 ml, while E. coli bacteria have a tolerance of 0 CFU/100 ml. In this study, field data collection activities were carried out including lithology, rock structure, and groundwater sampling. Field data processing such as lithology and rock structure using ArcGIS software, groundwater sample processing by calculating physical parameter values in the form of TDS, DHL, Hardness, pH, and stable isotopes. Data processing related to microbiological parameters was carried out at the Semarang City Health Laboratory UPT. From the research that has been carried out in Semarang City on 30 points of samples of drilling wells, as much as 26% of points contain coliforms in varying quantities. The study uses field data collection methods or observations that are then analyzed in laboratory tests using the Most Probable Numbers (MPN) method to determine the number of Total Coliform bacteria contained in each sample.

This research aims to determine the relationship between rock lithology and Total Coliform bacterial contamination in confined aquifers. Artesian water, which is considered to have better quality than shallow well water, is not necessarily free from the presence of Total Coliform bacteria.From this, it is necessary to carry out further research related to the quality of groundwater in Semarang City on drilling wells assessed from the contents of coliform bacteria. This research is expected to be a public measure in the construction of drilling wells by paying attention to the geological conditions of the surrounding environment to annihilate the discovery of Total Coliform bacteria.

## 2. Methods

This research was conducted using primary data collection methods in the field, precisely in Semarang Highland City, which includes several sub-districts, such as Tembalang, Banyumanik, Mijen, Gunungpati, Pudakpayung, Candisari, Pedurungan, Gajahmungkur, and Ngaliyan. Samples of groundwater are taken at 30 well points that are spread in Semarang City and produce parameters of physics, chemistry, and biology. The method of field data collection in this study uses the method of data collection field (observation) and method of field analysis data. Methods of field data acquisition, such as geological and hydrogeological data, are carried out directly at the site of the research, such as surface mapping and sampling of groundwater.

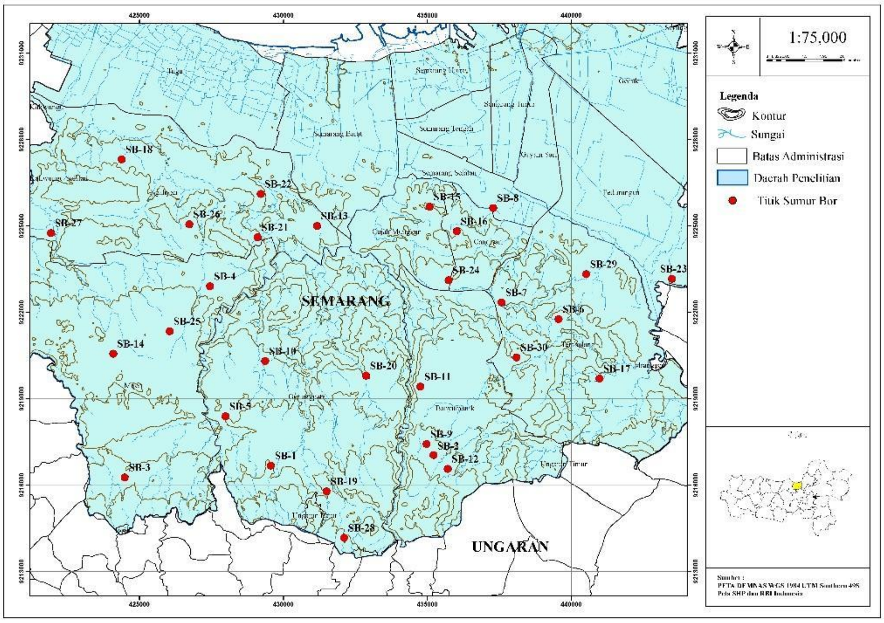


**Figure 1.** Drilled well map of Semarang City

Geological and hydrogeological data collection was carried out by mapping the research area. Hydrogeological aspects were taken from groundwater samples in drilled wells spread across Semarang. When taking groundwater samples, information about the sample is also recorded, such as chemical conditions (pH, DHL, TDS, salinity), isotopes, and drilled well coordinates (Todd, 1980).

## 2.1 Groundwater

Water is one of the crucial needs for humans. Along with the increasing population in the world, the need for water utilization for daily needs, such as drinking water, cooking, washing, and so on, is also increasing. This water requirement can be met from several water sources, one of which is groundwater.

The utilization of groundwater is obtained from the construction of wells to take water from the soil layer. The construction of this well is divided into two, namely dug wells and drilled wells. Dug wells are the most common and easy well construction in construction. This well has a depth of 7-10 meters from the ground surface. Dug wells provide water that comes from soil layers that are relatively close to the ground surface, which makes it easy to be contaminated through cracks and seepage that can come from sanitation or human and animal waste disposal sites, well waste, incorrect well construction, and other surrounding influences. In addition to dug wells, there are also drilled well constructions that have better quality. Drilled wells have a maximum depth and the pipes used are also of better quality, making drilled wells the most efficient choice for optimally utilizing groundwater (Manurung et al., 2017).

In addition to the use of wells, groundwater quality can also be affected by the location of the aquifer of the groundwater. An aquifer is a formation that can contain large amounts of water. This aquifer has a high permeability that can transmit significant amounts of water to wells and springs. The layers that can contain this are permeable layers, such as sand or gravel, in addition, there are several layers of rock that are considered impermeable such as clay layers. The function of the aquifer as a water storage and distributor is assisted by the presence of pores or cavities in the rock (porosity) and the type of rock (specific yield) found in the aquifer.

Groundwater has chemical properties that include characteristics related to the chemical composition and reactivity of water. According to Todd (1980), some of the chemical properties of groundwater include:

1. pH

The degree of acidity can measure the level of acidity or alkalinity of water which has a pH scale ranging from 0 to 14 with pH 7 considered neutral. Stable or good groundwater for consumption usually has a pH ranging from 6 - 8.5.

2. Hardness

Measures the concentration of calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) ions in water. Water with high hardness can cause scale buildup on pipes and equipment, while soft water has low hardness.

3. Total Dissolve Solid (TDS)

Total Dissolved Solids (TDS) are dissolved solids, either in the form of ions, compounds, colloids in water (Nicola, 2015)

**Table 1.** TDS Assessment Criteria (Effendi, 2003)

| TDS Value (mg/L) | Salinity Level |
|---|---|
| 0 – 1.000 | Fresh Water |
| 1.000 – 3.000 | Slightly salty/brackish |
| 3.000 – 10.000 | Moderate/brackish |
| 10.000 – 100.000 | Salty |
| >100.000 | Very salty |

4. Electrical Conductivity (EDC)

Electrical Conductivity (EDC) is a substance value that states that the substance can conduct electric current at a certain temperature expressed in units of micromhos per centimeter (μmhos/cm) or micromosiemens per centimeter (μS/cm).

**Table 2.** Water Classification based on DHL (Suharyadi, 1984)

| EDC (μmhos/cm) | Water Type |
|---|---|
| 0,055 | Fresh Water |
| 0,5 – 5 | Slightly salty/brackish |
| 5 – 30 | Moderate/brackish |
| 30 – 2.000 | Salty |
| 35.000 – 45.000 | Very salty |

As for stable isotopes in groundwater, this is a method used to determine the origin of groundwater. The stable isotope method 18O and 2H are used as groundwater fingerprints to distinguish various water sources such as rainwater, groundwater, seawater, magmatic water and connate water. From the 18O and 2H values, it can also be used to determine whether water has contamination or contact with surface water by calculating the d-excess value. The d-excess value (differential excess or deuterium excess) is a parameter in stable isotopes that is used to determine the difference between the ratio of hydrogen and oxygen isotopes in water. The d-excess value is calculated using the following equation.

$$d\text{–}excess = \delta^2H - 8 \times \delta^{18}O$$

Keterangan:

$\delta^2H$ : Deuterium isotope deviation

$\delta^{18}O$ : Oxygen-18 isotope deviation

With the d-excess value, the condition of groundwater can be known whether the flow of the water is in contact with surface water or not, where groundwater that has a d-excess value of less than 10 can be indicated to have been in contact or affected by the condition of surface water and groundwater that has a d-excess value of more than 10 has no influence from surface water.

### 2.2 Geological Mapping

The written coordinates are then entered into ArcGIS 10.8 software to create a map of the distribution of drilled wells, which will be used for geological mapping. This coordinate map serves as a reference for taking rock lithology samples where the existing samples have different rock conditions. After that, it is necessary to obtain information regarding the regional geology of the research area, which is obtained through the Regional Geological Map of Semarang (Thanden, 1996), which is also digitized using ArcGIS software. Regional geological maps can help find out rock formations or clumps in the city of Semarang. After the regional geological map and well-drilled coordinates are available, the next step is geological mapping by recording the physical condition of the rocks around the drilled well. This aims to look at the physical condition of the rock and its effect on Total Coliform bacterial contamination. Regional geological maps and well coordinates were imported into Avenza Map tracking software. This software can make it easier to read real-time coordinates on regional geological maps entered into the software storagep.

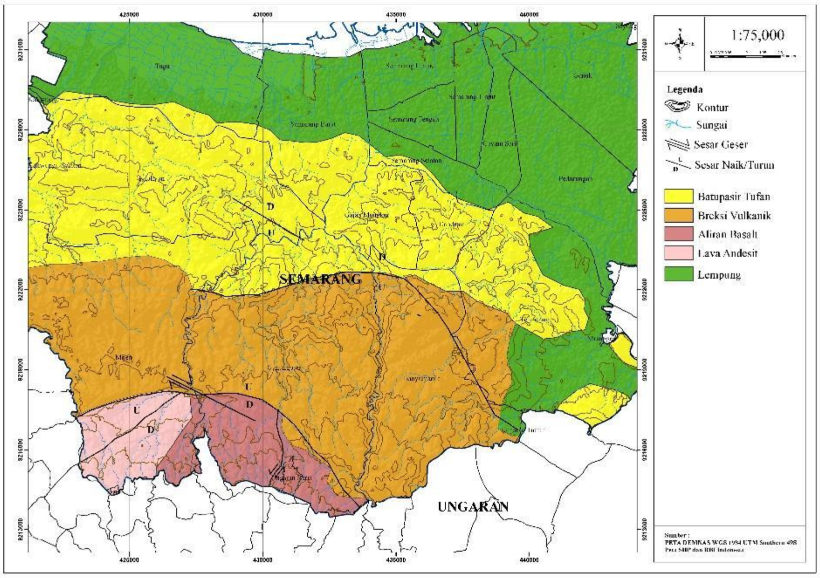


**Figure 2.** Geological map of Semarang City

The data collection of geology and hydrogeology is done to find out the geological conditions working in the research area, such as formation, lithology of rocks, geomorphology of surfaces, and geological structures, whereas for hydrogeological data the aim is to know the conditions of existing soil water, starting from the physical, chemical and biological aspects. The data obtained from geological mapping is then processed into ArcGIS 10.8 software by digitizing locations mapped in coordinates and physical rock conditions using regional geological maps as a reference. The lithology data obtained is layered with a regional geological map to get the distribution of rocks according to the physical condition and age of each rock based on the existing formation.

### 2.3 Most Probable Numbers Methode (MPN Methode)

The next stage is the groundwater sample data analysis, which uses quantitative analysis methods. Quantitative analysis is a method of analysis of data obtained and processed in numerical form, such as microbiological parameters obtained from groundwater samples taken at the well point. This method of quantitative data analysis is performed using the Most Probable Numbers (MPN) method, which is a microbiologic test to find out the distribution or spread of Total Coliform bacteria, which is the reference of biological parameters. From the methods of analysis and data collection available, results were obtained, such as the spread value of Total Coliform bacteria at each point of the drill well, surface lithology, and spread of the pressure aquifer in the area of Semarang City.The coliform test consists of three stages, namely, a presumptive test, a confirmed test, and a complete test (Martani, 2020).

1. Presumptive Test

In this test, a groundwater sample is prepared for dilution of the sample with Lactose Broth media. The water dilution in this test was carried out in 3 types of dilution, namely 10-1; 10-2; and 10-3.

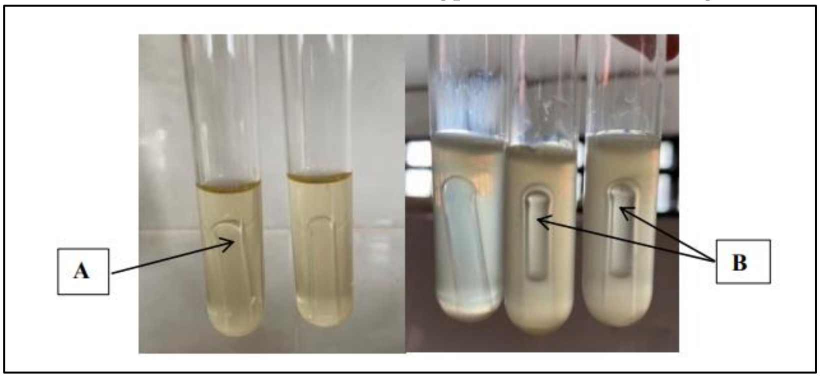


**Figure 3.** MPN Method Estimation Test Results (Ervina, 2022)

Description:

A. Negative result without gas bubbles

B. Positive result with gas bubbles and cloudy color

For each dilution sample, the sample was divided into 3 Durham tubes with Lactose Broth as the medium. Lactose media is used because coliform bacteria can ferment lactose by changing the color of the media.

With a total of 9 Durham tubes in 1 groundwater sample obtained, incubation was carried out for 24-48 hours at a temperature of 37°C to see whether there were bacteria suspected to be coliform. Positive samples will form bubbles in the Durham tube with a cloudy color. These positive samples will undergo further testing at the confirmation test stage, while for negative samples, that's enough for now.

2. Confirmation Test (Confirmed Test)

This confirmation test was carried out using selective media BGLB (Brilliant Green Lactose Broth) which contains brilliant green which inhibits the growth of gram bacteria which can ferment lactose like coliforms (Martani, 2020).

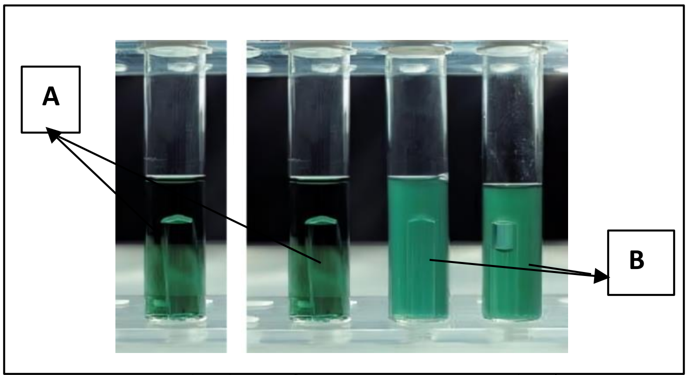


**Figure 4.** MPN Method Confirmation Test Results (Purwono, 2015)

Description:

A. Negative Result without Bubbles

B. Positive Result with Bubbles and Cloudy Color

The samples used in this sample are positive samples obtained from the estimator test. The sample was taken and placed in 3 Durham tubes with BGLB media for a total of 9 Durham tubes for dilutions 10-1, 10-2, and 10-3. After grouping the samples, carry out the incubation stage at 44°C for 24-48 hours to determine the presence of coliform bacteria which are characterized by a cloudy green color with the presence of gas bubbles.

3. Complementary Test (Completed Test)

The final test of this analysis aims to detect the presence of coliform bacteria using the gram-staining method on colonies (Martani, 2020). In this test, testing is carried out using Mac-Conkey or Nutrient Agar media where the sample from the confirmation test is inoculated or transfers microorganisms from a Durham tube into a petri dish. After transfer, the sample was incubated for 24-48 hours at a temperature of 37°C. Coliform positive samples will be marked by the presence of purple and prominent spots.

From the results of geological mapping and analysis using the MPN method, merging was carried out on the geological map with the distribution of Total Coliform values using ArcGIS to determine the distribution of bacteria in Semarang City. The Total Coliform value in each sample was entered into MS Excel, and then the data was imported into ArcGIS by layering the coordinate data. The results of merging this data showed a map of the distribution of total coliform bacteria in Semarang City.

## 3. Result and Discussion

### 3.1. Geological Setting

In this study, a lithological identification was carried out at some point in Semarang City. It aims to find out the geological conditions in the City of Semarang, especially around the groundwater sampling point. The lithology of the area of research consists of five units of rocks (from old to young) namely, volcanic brexits, andesit brexes, basalt streams, and aluvial reservoirs.

#### 3.1.1. Tuffaceous sandstone

**Figure 5.** Lithology Documentation of Tuffaceous Sandstone (Coordinate 430302, 9224520)

Tuff sandstone lithology is found in the central part of Semarang City, precisely in the Damar Formation. This sandstone has a brownish color with a gray matrix. This rock has a rounded grain shape with compact properties, tuff-lapilli grain size and massive structure. This rock has a fairly fine tuffaceous fragment size (1-5 mm) with a grayish white color with a rounded grain shape. From the shape of the rock grains, it is likely that this rock has undergone a fairly long transport process which is also seen from the fragments that have undergone weathering. Quite good sorting with good packing, with fine to medium sand grain sizes.

#### 3.1.2. Volcanic Breccia

**Figure 6.** Lithology documentation of volcanic breccia (Coordinate 435790, 9222271)

This volcanic breccia lithology is found in the central to western part of Semarang City, precisely in the Kaligetas Formation. This rock has a blackish gray color with gray fragments. As for the grain size, it has a medium size. This rock has a fragment size of around 4-64 mm or in the form of gravel that has poor sorting and poor packing with a matrix in the form of tuff and volcanic sand with angular grain shapes. Tuff matrix with a medium grain size of 0.5 - 1 mm. The petrogenesis of this rock is formed due to an exclusive eruption with fallout sedimentation and when viewed from its poor sorting.

### 3.1.3. Basalt flow unit

**Figure 7.** Lithology Documentation of BasaltFlow Unit (Camera Faces North) (Coordinate 427417, 9218372)

This basalt lithology has a dark gray color with moderate permeability. This rock has a fine grain shape with compact properties. This rock has a medium grain size. The gravel to boulder components have massive and compact properties, angular to rounded with a tuffaceous base mass. For the sorting of this rock, it has moderate to good sorting. There is also a dark gray lava flow with fine grains. From the existing appearance, this rock was found at the Kaligesik Volcanic Rock location. Judging from the condition of this rock, the possibility of petrogenesis that occurs in this rock from an extrusive eruption that passes through a river with a fairly long transport process is evidenced by fairly good sorting.

### 3.1.4. Andesite Lava

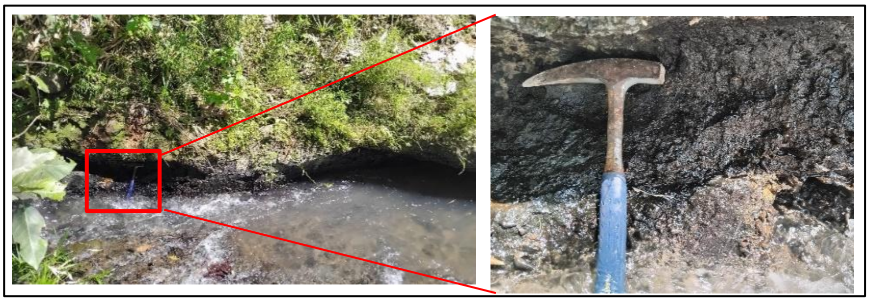

**Figure 8.** Lithology Documentation of Andesite Lava (The camera faces East) (Coordinate 426648, 9218011)

This rock unit is composed of andesite lava, holocrystalline with a blackish gray color with a lapilli grain size of 4-32 mm which is hard and compact. This rock has a fine grain size. This rock has a fairly good packing with a massive structure. As for the sorting of this rock is quite good. Judging from the condition of the rock with a blackish color, it is interpreted that the iron and magnesium content is quite dominant which is added to the dark minerals or phenocrysts in it. With good sorting of this rock, it is likely that the transport process has been quite far from the formation area or the magma formation area. This rock is found in the Gajahmungkur Volcanic Rock area.

#### 3.1.5. Clay

**Figure 9.** Lithology documentation of clay (Coordinate 441297, 9219858)

Alluvial sediment units are mostly located in the northern part of the research area with fairly bright physical characteristics and fine grains with a size of >1 mm found on the banks of rivers and swamps. From the condition of the rock, this sediment has experienced quite a long transportation of material following the water flow and eroding or sorting fragments that make this sediment have quite good sorting. Fine particles of this sediment in the form of clay are transported in suspension or floating in water in slow water flow. In the sediment sorting process, the water flow decreases so that coarser and heavier particles are deposited first, while particles with this clay size are transported further which makes the sorting more monotonous. Alluvial deposits in the form of clay can be found in the northern part of Semarang City.

### 3.2 Sample Testing using the MPN (Most Probable Number) Method

After taking groundwater samples in the confined aquifer, Total Coliform distribution testing was carried out using the MPN Method. Tests were carried out on 30 water samples in Semarang City.

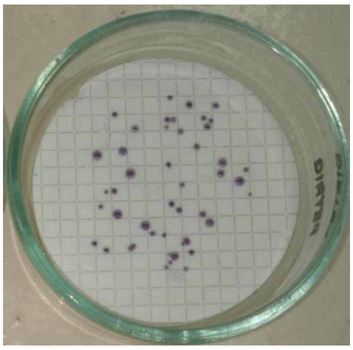

**Figure 10.** Positive sample with total coliform bacteria (SB-4)

From the results of this MPN test, it was found that Total Coliform bacteria were present in numbers that exceeded the maximum limit (Table 3), according to the Republic of Indonesia Minister of Health Regulation No. 416/MEN. KES/PER/IX/1990 concerning Raw Water, where clean water has a maximum limit for bacterial coliforms for raw water of 50 CFU/100ml and for e-coli bacteria of 0 CFU/100ml.

**Table 3.** Distribution value of total coliform in drilled well

| Sampel Number | Code | TC (CFU/100 ml) |
|---|---|---|
| 564/C/AT/VII/2023 | SB-1 | TNCT* |
| 565/C/AT/VII/2023 | SB-2 | 1 |

| Sampel Number | Code | TC (CFU/100 ml) |
|---|---|---|
| 567/C/AT/VII/2023 | SB-4 | 43 |
| 568/C/AT/VII/2023 | SB-5 | 15 |
| 573/C/AT/VII/2023 | SB-10 | 7 |
| 575/C/AT/VII/2023 | SB-12 | 69 |
| 577/C/AT/VII/2023 | SB-14 | 6 |
| 589/C/AT/VII/2023 | SB-26 | 2 |
| 591/C/AT/VII/2023 | SB-28 | 88 |

*TNTC = Too Nomerous Too Count (>250 CFU)

After analyzing using the MPN method, several wells were found to have Total Coliform bacterial contamination. The results of the analysis of bacterial contamination in drilled wells (Table 2) show that of the 30 drilled well points, 9 wells were categorized as contaminated with bacteria, and 21 other wells were safe from bacteria.

### 3.3 Distribution Map of *Total Coliform* bacteria in Semarang City

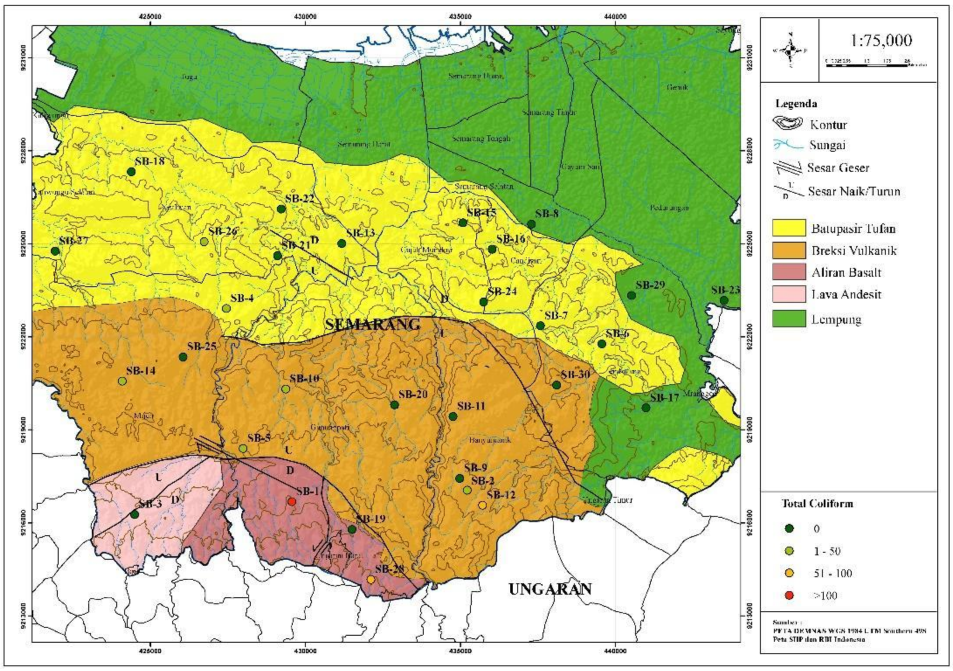


**Figure 11.** Map distribution of total coliform in Semarang City

From the results of the MPN parameter analysis, the Total Coliform value was obtained from groundwater samples taken in Semarang City. After obtaining values at each drilled well point, these results were correlated with the drilled well coordinates and the distribution of rock lithology in Semarang City (Figure 6). It can be seen that the drilled well with the highest Total Coliform bacteria is in the Basalt Unit lithology. Basalt lithology, which is known as a massive rock condition, makes it difficult for groundwater to flow. The compact and impermeable nature of rocks can make it difficult for groundwater to flow, which can indicate the high development of Total Coliform bacteria.

Based on the results of the MPN analysis that has been carried out, there are several wells that have Total Coliform content, including in Gunungpati District, namely SB-1; SB-5; SB-10; and SB-28, in Banyumanik District, namely SB-2 and SB-12, Mijen District at SB-4 and SB-14, and Ngaliyan District at SB-26. It is known that the area with the highest Total Coliform bacterial contamination is in Gunungpati District with a total of 4 wells, 2 of which exceed the maximum CFU level.

In the geological mapping and geological structure in Semarang City, 5 types of lithology were found, from old to young in the form of tuffaceous sandstone, volcanic breccia, basalt units, andesite lava, and clay deposits. In the southern part of Semarang City, an oblique fault was also found, namely a fault that overlaps between a normal fault and a shear fault. Normal faults are found along the Promasan River from Mijen District to Banyumanik District. As for the colliding shear faults, they are in the Purwosari area, Gunungpati District.

In addition, from the analysis of drilled well data, several physical parameters of groundwater in Semarang City were found, such as pH, TDS, DHL, and Hardness. These parameters were collected to determine the influence on the development of Total Coliform bacteria. Groundwater in Semarang City tends to have a pH of 6-8 which can be said to be normal, for TDS and DHL of groundwater are also still tolerable and still fall into the category of fresh water that can be consumed. These physical parameters are used to determine the possibility of influence on the distribution of Total Coliform bacteria.

**Table 4.** Groundwater parameter and Total Coliform Distribution

| Location | Sample Code | TC (CFU/100 ml) | pH | EDC | TDS | Salinity | *d-excess* |
|---|---|---|---|---|---|---|---|
| Gunungpati | SB-1 | TNTC* | 7,66 | 334 | 200.4 | 133.1 | 10.80 |
| Banyumanik | SB-2 | 1 | 6,75 | 234 | 140.4 | 94.2 | 11.50 |
| Mijen | SB-4 | 43 | 7,01 | 270 | 162 | 127.8 | 9.86 |
| Gunungpati | SB-5 | 15 | 6,79 | 273 | 163.8 | 113.6 | 11.62 |
| Gunungpati | SB-10 | 7 | 7,12 | 310 | 186 | 155.3 | 11.02 |
| Banyumanik | SB-12 | 69 | 7,96 | 434 | 260.4 | 127.1 | 12.02 |
| Mijen | SB-14 | 6 | 7,98 | 259 | 155.4 | 131.2 | 8.38 |
| Ngaliyan | SB-26 | 2 | 7,27 | 385 | 231 | 158.3 | 10.82 |
| Gunungpati | SB-28 | 88 | 7,08 | 266 | 159.6 | 110.5 | 10.72 |

In the analysis of Total Coliform values using the MPN method, several boreholes were found to be contaminated with bacteria. There were a total of 9 boreholes that had Total Coliform bacterial contamination with 3 of them exceeding the maximum limit according to the Regulation of the Minister of Health of the Republic of Indonesia. As is known, Total Coliform bacteria can grow anywhere, with several factors, such as warm temperatures, pH 6-8, and nutrients such as glucose and predation from other bacteria. When viewed from the results of the analysis of existing physical parameters, a correlation was carried out between pH, TDS, DHL, and groundwater hardness. From the correlation using the table above, it can be seen that the boreholes with the most Total Coliform contamination have pH, TDS, DHL, and hardness that are not much different from wells that have much less bacterial contamination. From this, we can further explore other influences that cause bacteria to grow so much in groundwater, especially in the city of Semarang.

In addition, high levels of Coliform bacteria at certain wellbore points were found in parts of Semarang City with faults working. The presence of geological structure symptoms in the form of faults or fractures can accumulate groundwater where there is a watertight layer that appears and then becomes a boundary plane for the water-bearing layer to flow. At the SB-1 wellbore point with a tuffaceous sandstone aquifer, it is blocked by a layer of claystone. In addition, by having a dynamic water flow, it can facilitate the filtration process by sediments around the aquifer and there is a possibility that Total Coliform bacteria are predated by other bacteria during the water transport process.

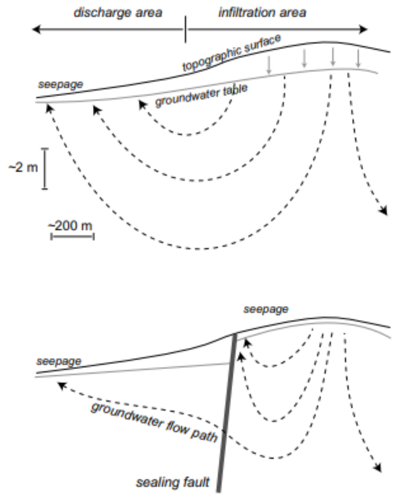


**Figure 12.** Differences in hydrological systems with the presence or absence of faults.
Source: (Bense, 2004)

The role of faults in groundwater flow is to bind the porosity of rocks containing water and form a barrier to water accumulation (Bense, 2004). Subsurface conditions around the fault cause forces or pressure on the rocks and will tend to harden and cannot release water.

In addition to the nature of the rocks that make up the aquifer, the nature of the aquifer flow that is disturbed by faults can also have an impact on the quality of the existing groundwater. Rocks with impermeable properties such as claystone, basalt and so on can be strategic breeding grounds for Total Coliform bacteria. TC bacteria can grow more easily in rocks that have a low level of permeability because the water conditions do not flow, making TC bacteria unpredated by other bacteria (James and Neal, 2001).

The high contamination of Total Coliform bacteria in SB-1 and SB-28 is indicated because it is influenced by the presence of normal faults that stretch across Mijen District and Gunungpati District, especially in SB-1 which not only has one fault, but there are also two shear faults around the area. The aquifer that should flow groundwater must be hampered by the fault process that makes this groundwater not flow and causes high bacterial growth.

From the results of this study, it can be said that the lithology conditions in an aquifer can affect the quality of groundwater, in this case, on the biological parameters seen from the Total Coliform bacterial contamination. The bacteria found grew rapidly due to the compression of the aquifer by massive rocks so that the water flow became sedimented and there was no predation that made these bacteria grow rapidly.

In some conditions, wells were also found to have less bacterial contamination than other wells that were also close to or around the fault area. This can be indicated because of differences in water flow sources. When viewed at SB-14 which has a MAT ranging from 20-30 m only has a Total Coliform bacterial contamination of 6 CFU/100ml, whereas when viewed at the location of this drilled well it is located around the shear fault in Mijen District. This is because SB-14 has a shallower MAT height than SB-1 and SB-28 which have a MAT of more than 30 m.

## 4. Conclusions

From the results of the analysis, it was found that there was a correlation between geological conditions and the distribution of Total Coliform bacteria. In the research area there are 5 types of rock lithology spread, from the oldest to the youngest, namely tuffaceous sandstone, volcanic breccia, basalt units, andesite lava, and clay deposits. The distribution value of Total Coliform bacteria in Semarang City where the area with the highest bacterial value is in SB-1 located in Gunungpati District. In the analysis conducted using the MPN method, the SB-1 borehole is indicated to have a very high Total Coliform bacteria value with a TNCT value where the number cannot be counted because it is very large. In addition to SB-1, boreholes that have high TC bacterial contamination are also found in SB-12 located in Banyumanik District and SB-28 located in Gunungpati District. The three wells found with the highest amount of Total Coliform contamination are in areas with massive lithology that causes the aquifer to be blocked and the groundwater in it does not come into contact with sedimentary rocks that work as a filter for microorganisms so that the growth of Total Coliform bacteria cannot be stopped. From this, consideration is needed in the installation of drilled wells by looking at the lithology of rocks in the local area, by means of geoelectric observations, or drilling. As for the lithology of rocks with the best composition and properties to be used as an aquifer is sandstone which is considered to be able to drain water easily and can also be a filtration of groundwater from bacteria.

With the knowledge of Total Coliform bacterial contamination in a number of drilled wells in Semarang City, analysis related to lithology and geological structure plays an important role in determining well construction. The existence of several other supporting parameters, such as data related to sanitation, distance of the well to the toilet, cement condition in the septic tank, use of land use around the well can support further research on whether several of these indicators have an effect on Total Coliform bacterial contamination. In areas where Total Coliform bacterial contamination is found with high values, such as in the Gunungpati and Banyumanik areas, further raw water treatment can be carried out, such as heating or boiling water, filtering, and so on to avoid bacterial contamination entering the body.

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