Spatial analysis of coliform bacteria contained in phreatic water in colomadu sub-district karanganyar

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Abstract: The objective of this study is to determine (1) the distance of septic tank with phreatic well at Colomadu Sub District; (2) the distribution of coliform bacteria in phreatic well at Colomadu Sub District; (3) the correlation of septic tank and phreatic well to the content of coliform bacteria. The population in this study was all villages in Colomadu Sub District. The Sample was using simple random sampling. Data collection was carried out by using field measurement for the flow of phreatic water data and septic tank distance with wells and laboratory tests for coliform bacteria content data on phreatic water. The analysis used spatial analis and descriptive quantitative with statistical test was a correlation test. The result (1) the distance of septic tank with phreatic well the 11 samples are more than 11 meters 10 samples at 9–11 meters 22 samples at 6–8 and 27 samples below 5 meters (2) coliform contains in phreatic wells the 25 samples are more than clean water quality standard and 45 samples under clean water quality standard (3) there is negative relationship of linear correlation (r = -0.27) between the content of septic tank distance with coliform bacteria in phreatic wells.

1. Introduction

Water is the basic major needs in life as all living things on earth need water to grow and develop well. Water covers about 75% of the earth's surface. Water is very pivotal for the human body because it covers 50-70% of all body weight [1].

As the population grows, water becomes a basic need that demanded serious concern in accordance with the increase in the needs of water[15]. To meet the needs of human life, water can be obtained from various sources such as rain water, surface water, ground water and seawater [2]. The water cannot be directly used since it is mixed with certain impurities of various pollutant sources (industry, household, agriculture and others).

In Indonesia, shallow wells are the common clean water sources used by the people, both urban and rural areas. It is due to the fact that building shallow wells are relatively easy and inexpensive. Nonetheless, shallow wells have a very high risk of pollution in the form of physical, chemical and biological pollution [3].

In meeting the need of lean water, most importantly the drinking water, the provision of drinking water must meet the requirements that is subject to the Regulation of the Minister of Health of the Republic of Indonesia No 416 / MENKES / PER / XI / 1990. To achieve the existing quality standards, raw water must be processed and managed according to the characteristics of the water [4]. In mountainous areas, raw water is obtained from springs, while rural areas usually use well water/groundwater that the quality still meets standards. On the other hand, densely populated areas are lack of available sources of clean water from nature. The water obtained by people in urban areas is
from Regional Water Company (PDAM). The need for consumed water should have general requirements such as tasteless, colorless, odorless and do not contain heavy metals. According to the requirement of WHO (World Health Organization) and APHA (American Public Health Association), water quality is determined by the presence of bacteria and the number of bacteria contained in the water [5].

In an effort to get rid of the pollution, wells need to be ensured based on factors, such as the distance of the wells with latrines, excavation holes for waste water, and other sources of contamination and are must be closed [12]. The well distance is at least 11 meters and needs to be higher than pollution sources such as latrines, livestock pens, trash bins, etc. [6]. In certain soil conditions, the distances are varied based on the profile of the sands, for instance, sandy clay must be 12 meters, sandy loam must be 8 meter, clay must be 6.5 meter, sandy soils must be 16-22 meters in order to keep in the safe distance to avoid bacteriologic [8].

2. Methodology

2.1 Distance of Septic Tank from Well
Measuring the distance of well from a septic tank used a roll meter. Measurements can be done by asking residents and taking direct measurements.

2.2 Depth of shallow groundwater

Formula of groundwater level = t-(d-h)

Description:

- **t**: Ground level (m. dpal)
- **d**: Depth of Groundwater from the top to the upper edge of the well (m)
- **h**: Height of the upper edge of the well from the ground (m)

**Figure 1.** Measurement of Height of Shallow Groundwater

2.3 Correlation between Distance and Coliform Content

By using a correlation test, the effect of the distance of septic tank and Coliform bacteria in shallow groundwater can be determined. Determining the influence of the distance of septic tank and the well was done suing the correlation test as follows:

\[
    r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x)^2)(n\sum y^2 - (\sum y)^2)}}
\]

Description:

- **x**: Distance of septic tanks with wells
- **y**: content of Coliform bacteria
- **r**: the influence of the distance between septic tank and the content of Coliform bacteria in the well in which the value of \( r \) is classified as follows
3. Results

3.1 Distance between Septic tank and well

Most of the residents in Colomadu Sub-district have septic tanks as feces storage. Placement of septic tanks and adjacent wells can cause pollution in shallow groundwater through fecal water with the presence of coliform bacteria in well water.

The distance between the septic tank and the well of the residents must meet the safe boundary conditions of more than 10 meters. The purpose of building septic tanks and wells is to reduce the potential for groundwater pollution through coliform bacteria.

The following is a Table 1 of measurement results of 70 samples regarding the distance between the septic tank and wells owned by the residents in Colomadu District which obtained the data as follows:

| Distance (meter) | Total | (%)  | Description |
|------------------|-------|------|-------------|
| >2 – 5           | 27    | 38.6 | close       |
| >5 – 8           | 22    | 31.4 | moderate    |
| >8 – 11          | 10    | 14.3 | far         |
| >11              | 11    | 15.7 | safe        |

Source: Primary Data

Data obtained from the measurement results of 70 field samples shows that 27 (38.6%) the distance between septic tanks and wells is at 2-5 meters which is classified into the near category. There were 22 (31.4%) samples classified into the medium category with a distance of 6-8, meters. Meanwhile, there were 10 (14.3%) samples in the distant category with a distance of 9-11 meters and there were 11 (15.7%) samples which are in accordance with the safe distance (>11 meters).

3.1.1 Distance between septic tank and the well of the densely populated villages.

In densely populated villages, 37 samples to collect the data of the distance between septic tanks and shallow groundwater wells. The following is a table 2 measuring the distance between a septic tank and with shallow groundwater wells:

| Distance (meter) | Total | (%)  | Description |
|------------------|-------|------|-------------|
| >2 – 5           | 11    | 15.7 | close       |
| >5 – 8           | 10    | 14.3 | moderate    |
| >8 – 11          | 8     | 11.4 | far         |
| >11              | 6     | 8.6  | safe        |

Source: Primary Data

Data obtained from the measurements of 35 samples in densely populated areas show that 11 (15.7%) samples are included in the near category as the distance was 2-5 meters. There were 10 (14.3%) samples in the medium category with a distance of 6-8 meters. There were 8 (11.4%) samples in the distant category with a distance of 9-11 meters and 6 (8.6%) in the category according to the safe distance with a distance of more than 11 meters.
3.1.2 **Distance between septic tank and wells of the less populated regions.** In less densely populated villages, 35 samples regarding the distance between septic tanks and shallow groundwater were carried out. The following is a Table 3 measuring the distance of a septic tank with shallow groundwater wells:

| Distance (meter) | Total | (%) | Description |
|------------------|-------|-----|-------------|
| 2 – 5            | 16    | 22.9| close       |
| >5 – 8           | 12    | 17.1| moderate    |
| >8 – 11          | 2     | 2.9 | far         |
| >11              | 5     | 7.1 | safe        |

Source: Primary Data

The data obtained from the field measurement show that 16 (22.9%) samples were classified into near category at the distance of 2-5 factors. There were 12 (17.1) samples classified into moderate category at the distance of 6-8 meters. There were 2 (2.9%) samples classified into 9-11 meters and 5 (7.1%) samples classified into safe boundary condition at more than 11 meters.

Comparison between the distance of septic tanks with shallow groundwater wells in densely populated villages and less densely populated villages is in the adjacent category which was at <5 meters 15.7% and 22.9%, in the medium category at distances of 6-8 meters 14.3% and 17.1%, in the far category at the distance of 9 - 11 meters 11.4% and 2.9% and in the safe boundary condition at the distance of 8.6% and 7.1%.

3.2 **Distribution of Coliform bacteria Content**

Most of Colomadu sub-districts already have drinking water companies, yet some residents in Colomadu Sub-District remain using well water for their daily needs. Coliform bacteria is an indicator of water pollution. Thus, if the well water of residents in Colomadu Sub-district is contaminated by these bacteria, it will damage their health. Laboratory tests were carried out to find out whether or not well water is contaminated by coliform bacteria.

Laboratory tests of well water to find out the contents of coliform bacteria were carried out at the well water laboratory to find out the contents of coliform bacteria carried out at UPT Surakarta Health Laboratory. Test of this water sample used the Most Probable Number (MPN) method or Indonesian terminology, the Estimated Amount (JPT). This method is a standard of the World Health Organization (WHO) in identifying coliform in water, milk, and certain foods. The MPN method consists of three stages, namely the estimation test (presumptive test), confirmation test (confirmed test), and completeness test (completed test).

The following is a Table 4 of results of the amount of coliform bacteria content in 70 well samples that have been taken. From the results of laboratory tests, 70 samples of well water of residents in Colomadu District generated the data as follows:

| Coliform (/100ml) | Total | (%) | Description |
|-------------------|-------|-----|-------------|
| 4 – 19            | 16    | 22.9| Low         |
| >19 – 35          | 15    | 21.4| Moderate    |
| >35 – 50          | 14    | 20.0| Hight       |
| >50               | 25    | 35.7| out of the standard |

Source: 2017 Laboratory Test Results
The results of laboratory test data to 70 water samples in shallow groundwater wells showed that 25 (35%) samples are above the quality standard at more than 50/100ml. There are 14 (20%) high samples with 36-50/100ml coliform content, medium category totaling 15 (21.4%) samples with coliform content of 20-35/100ml, and low category 16 (22.9%) samples with coliform content <19/100ml.

3.2.1 Coliform Content in densely populated village. The results of laboratory test from Table 5 data contained 13 (18.5%) samples with categories above the quality standard of 50/100 ml. There are 7 (10%) samples in the high category with coliform values of 36-50/100ml, 7 (10%) samples having coliform values of 20-35 / 100ml and 8 (11.5%) samples in the low category with a coliform value of 4-19 / 100ml. In densely populated villages covering Ngasem Village, Malangjawan Village and Gawan Village, there are at least 2 samples of well water in each village contaminated with coliform bacteria which is over the quality standard.

Table 5. Content of Coliform Bacteria in the Population of Dense Population Villages in Colomadu District

| Coliform (/100ml) | Total | (%) | description |
|------------------|-------|-----|-------------|
| 4 – 19           | 8     | 11.5| Low         |
| >19 – 35         | 7     | 10  | Moderate    |
| >35 – 50         | 7     | 10  | High        |
| >50              | 13    | 18.5| Out of standart |

Source: 2017 Laboratory Test Results

3.2.2 Coliform content of densely populated villages. The results of laboratory test Table 6 data contained 12 (17%) samples with categories above the quality standard of 50/100 ml. There are 4 (150%) samples in the high category with a coliform value of 36-50 / 100ml, 8 (11.4%) samples having coliform values of 20-35 / 100ml and 8 (11.4%) samples in the low category with a coliform value of 4-19 / 100ml. In less densely populated villages including Bolon Village, Paulan Village and Gajahan Village, there are 2 samples of well water in each village contaminated with coliform bacteria which is over the quality standard.

Table 6. The content of the number of Coliform Bacteria in the densely populated villages in the District of Colomadu

| Coliform (/100ml) | Total | (%) | description |
|------------------|-------|-----|-------------|
| 4 – 19           | 8     | 11.5| Low         |
| >19 – 35         | 8     | 11.5| Moderate    |
| >35 – 50         | 7     | 10  | High        |
| >50              | 12    | 17  | Out of standart |

Source: 2017 Laboratory Test Results

Based on the diagram diagram of coliform bacteria content in Colomadu Sub-district, it can be seen that there are comparisons on the number of samples of shallow groundwater wells with coliform content which is above the quality standards in densely populated villages containing 12 samples and less densely populated villages containing 13 samples.

3.3 Distribution of Coliform Bacteria
The presence of a number of coliform bacteria in the water indicates that the water is biologically experiencing pollution. Polluted water, when it is consumed, can damage health.
Table 7 to find out the relationship between coliform bacterial content of residents' wells and the proximity of residents' septic tanks, a statistical test was carried out in the form of a correlation between the coliform content in well water and the distance of the well to septic tanks as follows:

**Table 7. Correlation Test**

| No | Wilayah               | Nilai r | Description |
|----|-----------------------|---------|-------------|
| 1  | High density area     | -0.21   | Low         |
| 2  | Moderate density area | -0.33   | intermediate|
| 3  | population            | -0.27   | good        |

Data Sources : Analysis Result in 2017

After r is known, matching is done based on the strength criteria of table r. From these results, it is known that the correlation between the content of coliform bacteria in well water and the distance between wells and septic tanks is included in the negative linear correlation. Changes to one of the variable values are followed by changes in the value of the other variables regularly in the opposite direction. If the variable value of coliform content increases, the variable distance of the septic tank will decrease. If the value of the coliform variable decreases, the variable value of the distance of the septic tank will increase.

3.3.1 Correlation between Septic Tank and the well in highly populated village. Water issues are interrelated, interdependent, and must be handled systematically, consistently and globally by the public and private stakeholders as well as business and financial resources in order to encourage sustainable development [7].

![Figure 2. Correlation diagram of Distance and Coliderm Content in the densely populated village](image)

From Figure 2 the significance value of r in the densely populated village shows ‘poor negative correlation’ with the value of r = -0.21.

3.3.2 Correlation between the Distance of Septic Tank and Well in Less Densely Populated village. From Figure 3 in the less densely populated village, the correlation is stated ‘sufficient negative correlation’ with r value = -0.33.
4. Discussion

4.1 Distance between septic tank and well

Based on the obtained results, it is determined that 84% of the people in Colomadu-Sub-district masyarakat in densely populated villages and less densely populated villages have not taken into account the minimum length between septic tank and adjacent shallow groundwater. Keeping the safe distance toward the waste, sanitation, and the protection of the water and sand serves becomes important.

The community builds septic tanks adjacent to wells in densely populated villages is due to limited land as the settlement has been even denser. The close proximity of septic tanks and wells in less densely populated areas is caused by a pattern of settlements that collecting and are close together. In some measurement samples, in less densely populated villages, the distance between septic tanks and wells was found in one of the houses far apart. Water wells with a distance of at least 2.74 m were found containing high amounts of coliform and Escherichia coli, despite the fact that the well was always closed [12].

The distance between septic tanks and adjacent wells is found in differences in ownership of wells and septic tanks. The number of 59 samples of shallow groundwater and measurements indicated that it can be contaminated by coliform bacteria by a close relationship with the septic tank. Safe distance on a clay profile of at least 12 meters, in 8 meters of sandy loam, on a 6.5 meter clay, in sandy soils 16-22 meters is a safe distance that must be maintained to avoid bacteriological [8].

4.2 Content of Coliform Bacteria

Coliform bacteria are bacteria that are indicators of water pollution. Coliform content in shallow ground well water in Colomadu Sub-District shows 25 (35.7%) samples of shallow groundwater contaminated. The number of polluted samples contained 13 shallow groundwater samples in less densely villages and 12 shallow groundwater samples in densely populated villages. Highest pollution > 2400 in densely populated villages was in sample 5 in Ngasem Village and less densely populated villages had sample 17 in Bolon Village, sample 57 was in Paulan Village and sample 66 was in Gajahan Village. The lowest pollution <3 in densely populated villages was in the sample 42 and 45 in the village of Gadirian and the less densely populated villages has the sample 21 in Bolon Village and sample 67 in the Gajahan Village.

The results of testing data for shallow groundwater samples show that every village in Colomadu Sub-district has at least 2 samples contaminated with coliform bacteria. The highest distribution of coliform bacteria in densely populated villages is in Malangjiwan Village with the highest population...
density (5998 jiwa/km²). In less densely populated villages, the highest distribution of coliform bacteria was in Gajahan Village with the lowest population density (3095 people/km²).

It can be concluded that there is a correlation between the distribution of coliform bacteria and population density in densely populated villages. This is closely related to the availability of land to build septic tanks far from wells. There is no correlation between the distribution of coliform bacteria and the population density in less densely populated villages. The distribution of coliform bacteria that occurs in Gajahan Village is due to the presence of E. coli in treated water which is still considered to indicate fecal pollution and remains a major verification tool [9]. There is a content of coliform bacteria in wells dug in the study area that exceeds the WHO provisions [11].

4.3 Distance and Coliform Content
Samples 1 and 5 the distance of septic tanks with wells does not affect the content of bacteria coliform in well water. This shows that the variable distance of septic tanks with wells does not have a significant effect on the content of bacteria coliform in Colomadu District. By testing the statistics of the distance between septic tanks and wells to coliform content in Colomadu Subdistrict, it shows a negative linear correlation relationship (changes in one of the distance values followed changes in values coliform by regular in opposite directions) with sufficient categories (r = -0.27). The correlation between the distance between septic tanks and coliform content in groundwater shallow with sufficient categories can be seen that there are other factors that influence the content of bacteria coliform in shallow groundwater. The relationship between distance and permeability of the soil with coliform content showed a strong negative correlation [8]. The biggest concentration of E. coli contamination is 3000 in 100 ml. This is due to the distance of the dug wells to septic tanks that do not meet the standards, starting from a distance of 7-9 meters [16]. The presence of micro-biologics in groundwater has an impact on decreasing water quality. [10]. Coliform bacteria cause serious public health problems for residents of this area if consumed. Boil water to remove fecal coliform [11]. The relationship between the distance of septic tanks and coliform bacteria has the effect of periodic measurements to monitor the quality of water consumption in the community [13]. Pollution problems due to the current distance between wells and septic tanks coupled with the level of cleanliness of these wells is not enough to prevent groundwater contamination [14].

5. Conclusion
Based on the results of the study, the following conclusions can be formulated: Distance of septic tanks in densely populated villages shows 11 well samples (15.7%) in the adjacent category, 10 well samples (14.3%) in the medium category, 8 well samples (11.4%) in the distant category and 6 well samples (8.6%) in the safe boundary condition category according. In less densely populated villages, there were 16 well samples (22.9%) in the adjacent category, 12 well samples (17.1%) in the medium category, 2 well samples (2.9%) in the far category and 5 well samples (7.1%) in the distant category.

Feasibility of the quality of well water in Colomadu Sub-district in 2017 shows that well water samples have 78.6% of wells samples suitable for use as clean water sources and 21.4% well samples exceed clean water quality standards. The content of coliform bacteria in densely populated villages showed that 8 well samples (11.5%) with a low category. There were 7 well samples (10%) with moderate categories and 7 well samples (10%) in the high category and 13 well samples (18.5%) have clean water quality standard coliform content (50/100ml). Coliform bacteria contained in less densely populated villages showed 8 well samples (11.8%) with a low category. 8 well samples (11.8%) with medium categories and 7 well samples (10%) in the high category. There were the 12 well samples (17%) stating about the condition of the coliform content above the clean water quality standard (50 100ml).

The overall correlation between the distance of the septic tank and the content of coliform bacteria in shallow groundwater shows a negative linear correlation between the increase in the distance of septic tank distances and the decrease in the amount of coliform bacteria in shallow groundwater. Thus, the decrease in the distance of septic tanks with wells increases the amount of coliform bacteria in shallow...
groundwater. The strength of the correlation is very weak (r = -0.21) in densely populated villages. The correlation of negative linear correlation with sufficient correlation strength (r = -0.33) in less densely populated villages.

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