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BACTERIOLOGICAL CONTAMINATION OF GROUNDWATER AFFECTED BY SEPTIC TANKS CONDITION IN KOTO TANGAH DISTRICT, PADANG, INDONESIA

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Abstract

Introduction: *Padang City Sanitation Working Group reported that 34.32% of households in Padang City use unsafe latrines with septic tanks that still do not meet the standards which potentially causes the wastewater from the septic tanks to contaminate the water of the wells. This study was conducted to analyse the effects of the septic tank condition on the microbiological quality parameters of the well-water, namely total coliform and Escherichia coli in Koto Tengah District, Padang.* ***Methods:*** *This study uses a quantitative research method. The data were collected by questionnaires, observation, interviews, and laboratory tests. Water sampling was collected by using the purposive sampling method where the water is taken from 20 wells originating from 10 coastal and 10 non-coastal areas.* ***Results and Discussion:*** *Total coliform was found in all samples, while Escherichia coli was found in two samples from coastal and five from non-coastal regions. The septic tank condition had a strong correlation with the total coliform concentration (r= -0.531) and affected the total coliform concentration in the well-water by 30.8%. However, the Escherichia coli concentration was not related and not affected by the condition of the septic tank (p>0.05). There was no significant difference in the concentration of the microbiological parameters in the coastal and non-coastal areas.* ***Conclusion:*** *The microbiological quality of the well-water did not comply with the quality standards to be used as water sources for the community. The total coliform concentration in the well-water was shown to have a close relationship with the septic tank's condition.*

INTRODUCTION

Some communities in developing countries still depend on supplies of untreated groundwater. However, groundwater can be contaminated which causes its quality to decrease (1). One of these contaminations can be caused by the local wastewater treatment system (2). The application of a local wastewater treatment system can be a major contributor to groundwater pollution because feces can accumulate in one place so the leaching of contaminants into the environment can occur (3). This condition is also one of the challenges in the target of *Sustainable Development Goals* (SDGs) number 6 regarding universal and equitable access to safe drinking water.

Septic tanks, one of the technologies in on-site wastewater treatment systems (3), are widely used in rural and suburban areas to treat small volumes of wastewater (4). Most community septic tanks are still not up to the standard where the bottom of the tanks is generally not watertight so that the sediment that settles can seep into the ground causing wastewater contaminants including microbiological contaminants to contaminate the groundwater. This pollution will be more severe if it occurs in dense settlements where the location of the local wastewater treatment system and groundwater sources (well water) is very close (5).

Microbiological parameters used in determining the groundwater quality were total coliform and *Escherichia coli*. *Escherichia coli* has a primary habitat in the intestines of warm-blooded animals (6), and its presence in the water indicates contamination from human or animal feces (7). A study on community-dug wells in Rahaoundana Village, Kendari, Southeast Sulawesi showed high levels of microbiological contamination in well water which was indicated by the presence of *Escherichia coli* in all well water samples and there was

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a strong relationship between the construction of septic tanks (r= -0.783) for the presence of *Escherichia coli* in well water (5). It shows that wastewater from septic tanks can affect the quality of well water.

Padang is one of the cities in West Sumatra Province which also implements a local wastewater treatment system. The largest District in this city is Koto Tangah District which has the largest population in Padang and the area reaches 33.42% of the total area of Padang (8). The area of Koto Tangah District stretches widely from the border area of the Northern coastline of Padang (coastal) to highland (non-coastal) areas. The supply of clean water in Padang is sourced from the Regional Public Drinking Water Company *(Perumdam)* of Padang. However, the service coverage has only reached 83.85%. Residents who are not served by *Perumdam* get clean water from other sources such as well water. The number of households that use well water is 10.78% of which 13.64% of the total percentage comes from residents of the Koto Tangah District. In coastal areas, the excessive use of groundwater can lead to seawater intrusion (9). Seawater intrusion can affect groundwater salinity levels. At high salinity conditions, microbiological cells can be damaged by osmotic pressure (10). It leads to the hypothesis that there are possible differences in the quality of the microbiological parameters of well water in coastal and non-coastal areas.

The Padang City Sanitation Working Group reported that 65.68% of households in Padang already have safe latrines and the remaining 34.32% still do not comply with the criteria of safe latrines. Of the total percentage, 25% of the population of Koto Tangah District already has safe latrines (11). Unsafe latrines are latrines that do not have septic tanks or already have septic tanks but do not comply with the *Standard Nasional Indonesia* (SNI). Unsafe latrines can cause fecal contamination of well water which is characterized by the presence of *Escherichia coli* (6,12). These conditions indicate that the application of septic tanks as a local wastewater treatment system has the potential to affect the quality of the microbiological parameters of the well water in Padang, including in the Koto Tangah District.

This study was conducted to analyze the effect of the septic tanks application on the microbiological quality parameters of the well water in Padang with a case study in Koto Tangah District. The analysis of the septic tank application included the condition of the septic tanks. In addition, this study also analyzed the differences in concentration of microbiological parameters (total coliform and *Escherichia coli*) in different areas, namely coastal and non-coastal.

METHODS

This study was quantitative research. The study stages include collecting secondary data, preliminary surveys, distributing questionnaires provided with interviews and field observations, taking well water samples, and testing well water samples in the laboratory.

The study population was the residents of Koto Tangah District. The study location was chosen based on the purposive sampling method so for that purpose two villages in Koto Tangah District were selected, that was Pasie Nan Tigo Village (coastal) and Koto Panjang Ikua Koto Village (non-coastal). The location selection was carried out after collecting the secondary data, that was population data using dug wells and septic tanks in Padang, and conducting a preliminary survey. Secondary data were obtained from the Sanitation Working Group of Padang City.

The distribution of questionnaires provided with interviews and observations was carried out to obtain information about the existing condition of the community's septic tanks with the parameter assessed being the condition of the septic tanks. The results of the questionnaire were used as primary data for the assessment of the septic tanks that comply with the requirements according to SNI 2398:2017 (13) and as a reference for analyzing the effect of the septic tanks application on microbiological parameters of the well water. The sample of the questionnaire was taken from 45 respondents based on the Slovin method.

Water samples were taken from residents' dug wells, there were 20 samples which consist of 10 samples from coastal and 10 samples from non-coastal areas. The selection of sampling locations was carried out using the purposive sampling method. The criteria for the sample were the samples from the households that have a septic tank and use dug well water as a water source. The map of the sampling locations can be seen in Figure 1. The sampling frequency was three times a month. A sampling of well water was carried out according to SNI 6989 58:2008 (14). Samples were taken using a vertical water sampler and then put into sample bottles that had been sterilized using an autoclave. The analysis of total coliform and *Escherichia coli* concentration was carried out using the Most Probable Number (MPN) method according to SNI 01-2332.1-2006 (15).

The data analysis carried out was an analysis of the results of the questionnaire, correlation analysis, analysis of the effect of the septic tanks conditions on microbiological parameters, and analysis of differences in microbiological parameter concentrations in two different locations, namely coastal and non-coastal areas.

RESULTS

Questionnaire Analysis Concerning the Condition of the Septic Tanks

The result of the questionnaire analysis about the septic tanks condition is shown in Table 1, while the interpretation can be seen in Figure 2. Table 1 shows that the percentage of respondents' answers is in the range of 22.22%-100%. Figure 1 shows that there were three categories of interpretations obtained, they were very good (50%), sufficient (37.50%), and less (12.50%).

Table 1. Results of the Questionnaire for the Application of Septic Tanks in Koto Tangah District

	Question	Percentage (%)	Interpretation
A1	The septic tanks storage building is made of materials according to SNI 2398:2017	95.56	Very good
A2	The wall of the septic tanks is watertight	100.00	Very good
A3	The bottom floor of the septic tanks is watertight	57.78	Sufficient
A4	There is an inspection hole in the septic tanks	82.22	Very good
A5	There is an air pipe (vent pipe) in the septic tanks	88.89	Very good
A6	There is the further treatment of wastewater after it is treated in a septic tanks	24.44	Less
A7	The Septic tanks have been drained	40.00	Less
A8	Draining the septic tanks is carried out every period or period of 5 years	22.22	Less

Figure 1. The Map of the Sampling Location

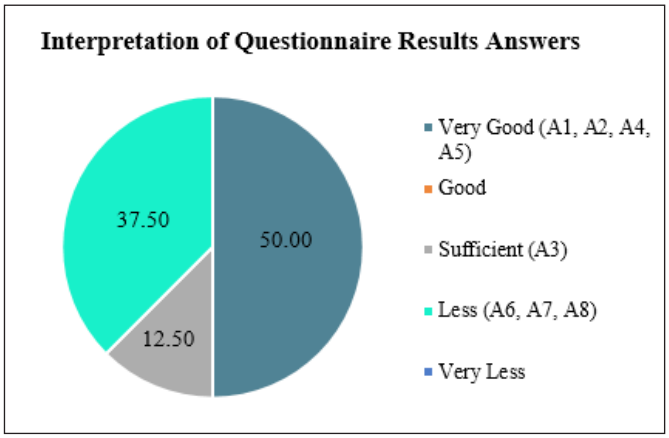

Figure 2. Interpretation of the Questionnaire Results of the Existing Condition of the Septic Tanks in Koto Tangah District

Microbiological Analysis

Coastal Area

The results of the analysis of the total coliforms and *Escherichia coli* in coastal areas can be seen in Table 2 and Table 3. Table 2 shows that all samples (100%) in coastal areas contained coliforms. Meanwhile, Table 3 shows that two samples (20%) in coastal areas, specifically at locations 1 and 6, contained *Escherichia coli*.

Table 2. Results of Analysis of Total Coliform Concentration in Coastal Areas

Location	*Total Coliform* Concentration (MPN/100 mL)	Quality Standards of Total Coliform (MPN/100 mL)		
		Regulation No. 32/2017	Regulation No. 492/ MENKES/2010	Comparison
1	31.3×10^3	50	0	Not Complied
2	38.7×10^3			
3	10.0×10^3			
4	46.0×10^3			
5	75.5×10^3			
6	4.2×10^3			
7	6.4×10^3			
8	40.9×10^3			
9	81.3×10^3			
10	75.5×10^3			

Table 3. Result of *Escherichia coli* Concentration Analysis in Coastal Areas

Location	*E. coli* Concentration (MPN/100 mL)	Quality Standars of *Escherichia coli* (MPN/100 mL)		
		Regulation No. 32/2017	Regulation No. 492/ MENKES/2010	Comparison
1	0.18 x 10^3	0	0	Not Complied
2	0			Complied
3	0			Complied
4	0			Complied
5	0			Complied
6	0.18 x 10^3			Not Complied
7	0			Complied
8	0			Complied
9	0			Complied
10	0			Complied

Non-coastal Area

The results of the analysis of total coliforms and *Escherichia coli* in non-coastal areas can be seen in Table 4 and Table 5. Table 4 shows that all samples (100%) in non-coastal areas contained total coliforms. Meanwhile, Table 5 shows that *Escherichia coli* was found in five samples (50%) in non-coastal areas, specifically at locations 1, 3, 4, 5, and 7.

Table 4. Results of Analysis of Total Coliform Concentration in Non-Coastal Areas

Location	*Total Coliform* Concentration (MPN/100 mL)	Quality Standards of Total Coliform (MPN/100 mL)		
		Regulation No. 32/2017	Regulation No. 492/ MENKES/2010	Comparison
1	88.7 x 10^3	50	0	Not Complied
2	81.3 x 10^3			
3	54.3 x 10^3			
4	24.0 x 10^3			
5	20.1 x 10^3			
6	9.0 x 10^3			
7	16.8 x 10^3			
8	4.2 x 10^3			
9	4.7 x 10^3			
10	8.2 x 10^3			

Table 5. Results of Analysis of *Escherichia coli* Concentration in Non-Coastal Areas

Location	*E. coli* Concentration (MPN/100 mL)	Quality Standars of *Escherichia coli* (MPN/100 mL)		
		Regulation No. 32/2017	Regulation No. 492/ MENKES/2010	Comparison
1	18.1 x 10^3	0	0	Not Complied
2	0			Complied
3	1.8 x 10^3			Not Complied
4	4.7 x 10^3			Not Complied
5	0.3 x 10^3			Not Complied
6	0			Complied
7	0.4 x 10^3			Not Complied
8	0			Complied
9	0			Complied
10	0			Complied

Correlation Analysis of Septic Tanks Conditions with Total Coliform and *Escherichia coli* Concentration

The correlation analysis was carried out using Spearman's Rank analysis because the data obtained did not comply with the assumption of normality. The correlation coefficient and significance value of the analysis results for total coliform and *Escherichia coli* can be seen in Table 6. The significance value obtained for the total coliform parameter is 0.016 and the correlation coefficient value is -0.531. Meanwhile, the significance value for the *Escherichia coli* parameter is 0.072 and the correlation coefficient value is -0.411.

Table 6. Correlation Analysis Results

Parameters	Significance Value (p)	r
Total Coliform	0.016	-0.531
Escherichia coli	0.072	-0.411

Analysis of the Effect of Septic Tanks Conditions on Total Coliform and *Escherichia coli* Concentration

The effect analysis of the septic tanks condition on the total coliform and *Escherichia coli* concentration was carried out using regression analysis. The significance and regression values can be seen in Table 7. The graph plot of the data is also shown in Figure 3 and Figure 4.

Table 7. Regression Analysis Results

Parameters	Significance Value (p)	R^2
Total Coliform	0.011	0.308
Escherichia coli	0.228	0.073

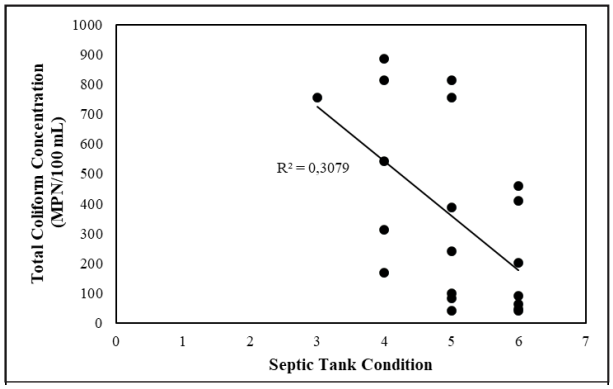

Figure 3. The Effect of Septic Tanks Conditions on Total Coliform Concentration

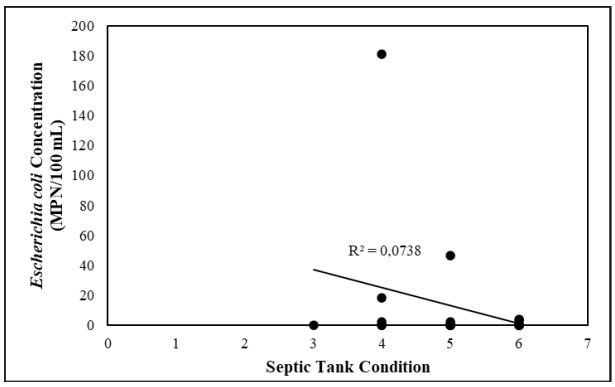

Figure 4. The Effect of Septic Tanks Conditions on *Escherichia coli* Concentration

The significance value obtained for the total coliform parameter is 0.011 and the determination coefficient value is 0.308. Meanwhile, the significance value for the *Escherichia coli* parameter is 0.228 and the determination coefficient is 0.073.

Analysis of Differences in the Concentration of Microbiological Parameters in Different Areas

The analysis used to determine the difference in total coliform and *Escherichia coli* concentration in coastal and non-coastal areas was the Mann-Whitney test because the data obtained were not normally distributed. The result of the Mann-Whitney test can be seen in Table 8. The significance value for the total coliform is 0.426 and for the *Escherichia coli* is 0.076.

Table 8. Mann Whitney Test Results

Parameters	Significance Value (p)
Total Coliform	0.426
Escherichia coli	0.076

DISCUSSION

The Existing Condition of the Septic Tanks in Koto Tangah District

The existing condition of the septic tanks in Koto Tangah District was seen based on the condition of each component of the septic tanks. The condition of the septic tanks can be seen based on the percentage of answers on the questionnaire. The highest percentage was in question A2 (100%) about the septic tanks wall which meant that all respondents already have a watertight septic tanks wall. Meanwhile, the lowest percentage was in question A8 about the septic tank draining period which meant that 22.22% of the total respondents have drained the septic tanks following SNI. This meant that the existing condition of the septic tanks structure in Koto Tangah District had not all complied with the SNI. The percentage level of answers can also generate the achievement category of each question in the questionnaire, which was very good, sufficient, and less. These categories indicated that the condition of the septic tanks in Koto Tangah District was not all in the good category.

Total Coliform and *Escherichia coli* Concentration in the Well Water

The concentration of microbiological parameters was compared with the Regulation of Ministry of Health of Republic Indonesia No. 32 year 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitary Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths (16) and Regulation of Ministry of Health of Republic Indonesia No. 492/MENKES/2010 concerning Quality of Drinking Water (17).

Coastal Area

The highest total coliform concentration in the coastal area was located at location 9 while the lowest was at location 6. High total coliform concentration at location 9 can be caused by the distance of the well location which is quite close to the septic tanks so the well water is more susceptible to pollutants from the septic tanks. Meanwhile, location 6 has a considerable distance from the septic tanks so the total coliform concentration in this location is lower. All samples were declared not to comply with the total coliform quality standard allowed in the regulations. Furthermore, the presence of *Escherichia coli* can be caused by the condition of the well without a cover which is more susceptible to contamination by microorganisms. Samples at locations 1 and 6 were declared not to comply with the quality standards of *Escherichia coli*.

Non-coastal Area

The highest total coliform concentration was at location 1 while the lowest concentration was at location 6. The high total coliform concentration at location 1 could be due to the poor sanitation conditions of the well and the proximity of the septic tank to the well location. Meanwhile, the sanitary conditions of the well at location 6 were quite good and the distance from the septic tanks location was far enough so it can led the total coliform concentration in this location to be lower. All samples were declared not to comply with the total coliform quality standard allowed in the regulations. Furthermore, the presence of *Escherichia coli* in well water could be caused by the proximity of the septic tank to the well location, poor sanitary conditions of the wells, and other factors such as the method of taking well water and domestic activities carried out around the well. Five samples containing *Escherichia coli* were declared not to comply with the quality standards. Microbiological contamination on groundwater samples can indicate the entry of feces into groundwater (18). The presence of fecal coliforms is related to fecal contamination from wastewater (19).

The Relationship of Septic Tanks Conditions with Microbiological Parameters Concentration

The significance value obtained from the correlation analysis between the condition of the septic tanks and the total coliform concentration was less than 0.05, which meant that there was a significant relationship between the condition of the septic tanks and the total coliform concentration in the well water. The correlation coefficient value obtained was -0.531 which indicated that the level of correlation between the

two variables was moderate. Moreover, the correlation value with a negative sign (-) indicated the relationship between the condition of the septic tanks and the total coliform concentration was inversely proportional. It meant that the better the condition of the septic tanks, the less the total coliform concentration in the well water, and otherwise, the worse the condition of the septic tanks, the higher the total coliform concentration in the well water. Furthermore, the significance value of the correlation analysis between the septic tank condition and the *Escherichia coli* concentration was found greater than 0.05. It meant that there was no significant relationship between the condition of the septic tanks and the *Escherichia coli* concentration in the well water.

The discovery of bacteria in well the water can also be caused by the carrying of polluted waste that settled in the soil and then seeped and flowed into water sources when it was raining. Bacterial concentration in well water can also be influenced by the construction of the well, domestic activities around the well, methods of taking well water such as dirty ropes or buckets, and well maintenance methods (20). Factors that contribute to well water pollution can also come from poor sanitation conditions of the well, poor depth of the well, the proximity of the septic tanks to the well location, and the presence of animal waste and trees near the well (12). Other factors that can also affect the quality of well water are population density (21), the type of well (ring well/ not) (22), and the septic tank density (23).

The Effect of Septic Tanks Conditions on Microbiological Parameters Concentration

The significance value obtained for the total coliform parameter was less than 0.05 which meant that there was a significant effect of the septic tanks condition on the total coliform concentration in the well water. Furthermore, the determinant coefficient value indicated that the septic tank condition affected the total coliform concentration in the well water by 30.8% and the remaining 69.2% indicated that other factors affected the total coliform concentration such as soil geohydrological conditions and well sanitation conditions. Furthermore, the significance value for the *Escherichia coli* parameter was obtained greater than 0.05 so it can be concluded that there was no significant effect between the condition of the septic tanks on the *Escherichia coli* concentration in the well water. This study showed that the septic tanks condition can affected the total coliform concentration but could not affect the concentration of *Escherichia coli* in well water. It could happen because *Escherichia coli* was found less than total coliform in the well water samples so there were differences in the results of those parameters in statistical analysis.

Septic tanks are a non-point source of groundwater contamination through infiltration. Runoff or seepage of wastewater from feces that are not treated properly will slowly penetrate underground water flows (aquifers) causing the process of groundwater pollution (5). Several factors can affect the potential of septic tanks to contaminate groundwater resources, including the distance of the septic tanks to a water source, the topography or slope of the soil, and soil characteristics. Hydrological conditions including depth of the groundwater table (21), groundwater streamline (1), piezometric level of groundwater (24), and permeability of the unsaturated zone also contribute to groundwater contamination (25).

In addition, the presence of *Escherichia coli* in the well water does not only come from septic tanks wastewater. *Escherichia coli* is a fecal indicator bacterium that has a natural habitat in the large intestine of humans and warm-blooded animals as well as a secondary habitat in the environment (26). Therefore, *Escherichia coli* is also related to animal waste (25). The occurrence of contact with feces (27) followed by a lack of hygiene and sanitation practices (28) when taking, storing, and using the well water can be the cause of the entry of *Escherichia coli* into the well water. The presence of *Escherichia coli* in the environment, whether in water, sediment, or soil, is also determined by the conditions for its growth (29). The survival of *Escherichia coli* is influenced by physical factors such as temperature, pH, nutrient availability (26), and its ability to compete with other microorganisms in the environment (6).

The Differences in Microbiological Parameters Concentration in Coastal and Non-Coastal Areas

In this analysis, the significance value was obtained greater than 0.05 for each parameter, it can be concluded that there was no significant difference in total coliform and *Escherichia coli* concentrations in coastal and non-coastal areas. The water samples in each coastal and non-coastal contained total coliform and *Escherichia coli* in different amounts. It meant that in each area there was a possibility of microbiological contamination of the well water and differences in location had no relationship with the presence of total coliform and *Escherichia coli* in the well water. A study in Bantul, Yogyakarta regarding the evaluation of microbiological contamination of groundwater in different topography found that there was no significant difference in the total coliform concentration in different topography (30).

It showed that the total coliform concentration in the well water was not related to the differences in the location. In addition, microbiological contamination in groundwater is also an indicator of the impact of surface water or surface activities (31).

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CONCLUSION

This study showed that the microbiological quality of the well water did not comply with the quality standards to be used as a water source for the community. The concentration of microbiological parameters in the well water was not different in coastal and non-coastal areas. The total coliform concentration in the well water was affected by the condition of the septic tanks, meanwhile, *Escherichia coli* concentration was not affected by the condition of the septic tanks.

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