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IDENTIFICATION OF FACTORS INFLUENCING THE PRESENCE OF FECAL COLIFORMS IN DENSELY POPULATED AREAS WITH CENTRALIZED WASTEWATER TREATMENT SYSTEMS

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Abstract

Introduction: *Tegal Panggung is a high population density sub-district of 26,326 inhabitants/km^2. Most residents utilize wells to meet their water demands, but fecal coliform bacteria were found in several wells at Tegal Panggung. This type of contamination source is typically from on-site wastewater treatments. However, wastewater from Tegal Panggung is treated at a centralized wastewater treatment plant. This study is aimed at identifying the factors leading to the presence of fecal coliform bacteria in Tegal Panggung.* ***Methods:*** *Factors reviewed in this study were the amount of waste, drainage, cattle pens, toilets, types of wells, and building density. Statistical methods and GIS were applied to determine the influence of the factors on the presence of fecal coliform and to map its distribution along with potential sources of pollution. The number of wells tested was 32, with a research period from September to October 2021. The statistical methods used are the Kolmogorov-Smirnov Normality Test, the Spearman Correlation Test, and the spatial analysis method, which was carried out using QGIS. The statistical tests were conducted to determine the correlation value between fecal coliform and pollutant.* ***Results and Discussion:*** *The study showed that only 40.62% met the standard requirements when there should be no fecal coliform contents in well water.* ***Conclusion:*** *Based on the Spearman Correlation Test, it can be deduced that the factors affecting the presence of fecal coliform within 10 meters radius are garbage and of 30 meters radius are toilets and building density.*

INTRODUCTION

In line with the development of industry to meet the increasing demands of modern society, the decline in the quality of the environment occurs rapidly. Water is one of the most vital factors for all living things' lives. Decreasing the quality and quantity of water on a small or large scale can have a fatal impact on human life.

According to the Indonesian Government Regulation Number 20/1990 on Water Pollution Control (1), water pollution is defined as the input or inclusion of living things, substances, energy, and/or other components into the water by human activities such that the quality of the water is reduced to a certain limit, hence making the water unusable according to its allocation. Coliform is a group of bacteria that can be used to indicate dirt pollution and bad salinity of water (2). Total coliforms are divided into two groups, include fecal coliform such as *E. coli,* which comes from human feces, and non-fecal coliform, which does not come from human feces but from dead plants and animals (3).

Following this, with a population, based on the monographic data for the first half of 2021, of 9,206 people (4,506 men and 4,700 women) and a total of 3,141 families, Tegal Panggung village has an area of approximately 0.35 km^2. Thus, the Tegal Panggung village has a population density of 26,326 inhabitants/km^2. This number is high compared to Yogyakarta, which has a population density of 12,781 inhabitants/km^2 (4). According to village records, it can be seen that the Tegal Panggung Village has a registered number of Family Cards of 2,501 families.

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Dense category settlements are often associated with the term slums (5-6). In this type of settlement, infrastructures are generally in poor conditions. These infrastructures include substandard roads, sanitation, and drainage, poor water quality, and improperly disposed wastes (7). Furthermore, poor sanitation can potentially be a cause of contamination of local water sources. Fecal coliform contamination is common in low-income areas (8). Often, septic tanks are not designed up to the required standard then contaminating the wells nearby, and resulting in high concentrations of fecal coliforms. The higher the level of coliform bacteria contamination, the greater the risk of childhood diarrhea (9). The fact is that Fecal Sludge Management (FSM) is not yet recognized as a priority for sanitation (10).

Following this, the community in Tegal Panggung village does not use septic tanks, rather, they dispose of their household wastes directly into the city's sewerage which is then channeled to a centralized Wastewater Treatment Plant (WWTP). To date, there has been no study on the source of fecal coliform pollution in wells situated in densely populated settlements that do not have local wastewater treatment. To provide their water demand, almost all islands have dug wells to obtain groundwater to meet daily needs (11). In this regard, the results of community service activities in Tegal Panggung Village show that many wells in the area have been contaminated with fecal coliform bacteria. This study aims to examine the factors influencing the presence of this bacteria in the wells located in the target area.

From this study we can determine the concentration of fecal coliform in the well water used by the community and also its contamination, determine the distribution of fecal coliform concentrations, and determine the relationship between potential pollutant sources and the presence of fecal coliform in the Tegal Panggung Village wells.

METHODS

Study Area

This study was conducted in Tegal Panggung Village, which is located in the east of Malioboro, one of the busiest tourist attractions in Yogyakarta. In the western part, this village is bordered by Suryatmajan Village, Danurejan District, which is separated by the Code River. In the northern, eastern, and southern parts, the area borders Kotabaru Village, Gondokusuman District, Bausasran Village, Danurejan District, and Purwokinanti Village, Pakualaman District respectively.

The Code River is one of the most important rivers that hold significant meaning for the residents of the province of Yogyakarta. Furthermore, there are springs located in one of the most active mountains in the world. These springs are used to irrigate paddy fields in Sleman and Bantul and as a drinking water source. Furthermore, most of the Code River watershed area in the Sleman Regency accounts for 71.44% of the entire Code River drainage basin (12). This river empties into the Opak River.

Tegal Panggung village, Danurejan District, as shown in Figure 1, is located in the Code River Watershed, which is the boundary between Suryatmajan and Tegal Panggung. Furthermore, the Danurejan District is an area that is often flooded by cold lava from the overflow of Mount Merapi in Sleman Regency every rainy season.

Figure 1. Study Locations in Tegal Panggung, DIY

Based on SNI 2398: 2017 regarding procedures for planning septic tanks with advanced treatment (infiltration wells, infiltration fields, up flow filters, sanitary ponds) (13), the distance between the well and the septic tank is at least 10 meters. With limited land in densely populated areas, sanitation development cannot follow the applicable standards. From direct observation, it is known that the majority of houses still need a septic tank or on-site treatment because the wastewater generated flows directly into the municipal wastewater network.

Fecal Coliform

Fecal coliforms are coliform bacteria that can be found in human or animal feces (14). An indicator of water pollution is the total presence of coliforms and *Escherichia coli*bacteria (15). Fecal contamination is usually indicated by the presence of a group of organisms called coliforms (16).

Subsequently, the presence of coliforms in foods or drinks indicates the possibility of harmful enteropathogenic and/or toxigenic microbes. Total coliforms are divided into two groups, include fecal coliform such as *E. coli,* which comes from human feces, and non-fecal coliform, which does not come from human feces but from dead plants and animals (3).

The number of coliform bacteria can be referred to by the method of most significant estimated number, which is commonly known as the Most Probable Number (MPN) (17). Also, the existence of coliform bacteria, especially *Escherichia coli*, is considered a representative of biological pollution in an aquatic environment (18).

Following this, based on the quality standard of Health Minister regulation No. 492 of 2010 on the requirements for drinking water quality (19), which states that the parameters of coliform bacteria and *Escherichia coli*are not allowed to be present in drinking water, a research was conducted to examine the bacteriological groundwater quality in relation to the environmental hygienic status and the measurement of the distribution pattern of fecal coliform bacteria.

Water for Daily Use

According to Health Minister regulation No. 492 of 2010 on drinking water quality requirements (19), water is used for sanitary hygiene purposes to maintain personal hygiene such as bathing and teeth brushing, as well as for washing foodstuffs, tableware, and clothes. In addition, water for sanitary hygiene purposes can be consumed.

Table 1 lists the mandatory biological parameters that must be checked for sanitary hygiene purposes which include all coliforms and *Escherichia coli* with colony-forming units in a 100 mL water sample.

Table 1. Biological Parameters for Sanitary Hygiene Purposes

Mandatory Requirements	Units	Quality Standard (Maximum Rate)
Total coliform	CFU/100 mL	50
E. coli	CFU/100 mL	0

Source: Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017

Slovin Analysis

Along with sampling, the team collected data in a questionnaire to residents of the Tegal Panggung Village. The data obtained from the literature study is used as a reference used to determine the number of respondents using the Slovin method. The Slovin method was used to calculate the number of respondents based on the number of families with an absolute precision value of 5%. The formula for calculating the Slovin method is as follows (20):

$$n = \frac{N}{NE^2 + 1}$$

Explanation:

n = Respondent

N = Population

E = Absolute Precision

It is known that the number of families in the Tegal Panggung Village is 2,501 families and the absolute precision value is 5 so the results of the Slovin analysis obtained that the minimum number of respondents was 345 respondents, however, the results of the data in the field were 357 respondents.

According to the results of a questionnaire conducted on 345 respondents, the social condition in the Tegal Panggung Village was that in this sub-district, on average, there were 4 people in one house, with 11 people being the highest and 1 person being the lowest. The majority of respondents' last education was High School as many as 200 or 56.02% of respondents. The number of respondents with a master's or doctoral degree is the least, namely 1 respondent. These results indicate that Tegal Panggung Village's education level is relatively high.

The most widely used water source by the community is wells, with 282 or 79% of the respondents and the rest use the services of the Tirtamarta Regional Drinking Water Company, Yogyakarta. With wells as a source of water for the majority of the community, it shows that if there is pollution to the quality of well water, this can cause problems for public health. This can be strengthened by data showing that the most used water is for daily consumption as many as 341 respondents, and the second is for bathing. The use of water for consumption and bathing activities, which is usually also used for brushing teeth, allows substances dissolved in water to enter the body without being processed thereby affecting health.

Procedure

The research was conducted in September 2021-June 2022. Sampling was carried out in September-October 2021 and June 2022 in normal weather and not on rainy days. The thing that must be done before the research is to survey the research location and prepare the equipment used for water sampling. Samples that have been taken and collected are then taken to the Yogyakarta Health and Calibration Laboratory Center for testing. The stages of the study were carried out according to the flow chart presented in Figure 2.

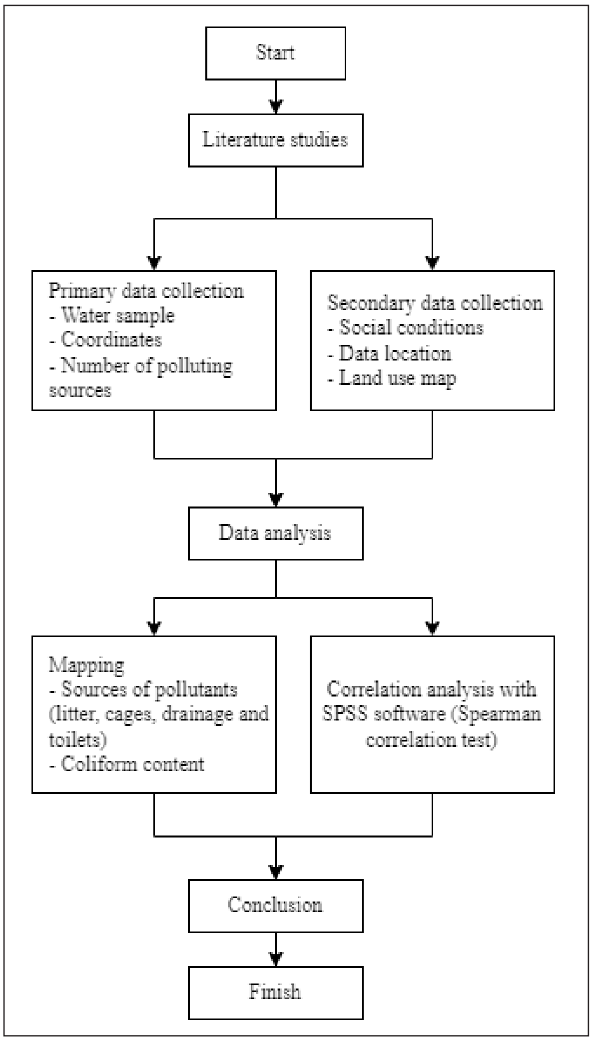


Figure 2. Study Locations in Tegal Panggung, DIY

Mapping and Spatial Analysis

Spatial analysis was conducted to map the data of the laboratory test results used for the distribution of fecal coliform in well water in Tegal Panggung Village. This spatial analysis was carried out by the Quantum Geographic Information System (QGIS) software using the Inverse Distance Weighted (IDW) method. The IDW interpolation method is used more often because it is simpler and easier to understand in the calculation process, unlike the statistical geographic Kriging method which requires a variation pattern modeling step before the main Kriging calculation process (21). The following is the IDW formula (22).

$$(X) = \sum_{i=0}^{N} \frac{w_i(X)u_i}{\sum_{j=0}^{N} w_j(X)}$$

$$w_i(X) = \frac{1}{d(x,x_i)^p}$$

Explanation :

$u_i = u(x_i)$, for I = 0, 1, …, N
X = point to be interpolated
X_i = known point
d = the distance from point x to x_i
N = number of points
p = power, real number, positive

Correlation Analysis Between Water Quality and Pollutants

The factors observed for the correlation analysis between water quality and the presence of fecal coliform are presented in Table 2. This analysis was conducted to determine which polluting factors most affect the presence of fecal coliforms. At this stage, the program employed was the SPSS program and the tests performed were Kolmogorov-Smirnov normality test and Spearman correlation tests.

Table 2. Factors Polluting Well Water

Factors	Sources
Pile of garbage Drainage or ditch Toilet	The characteristics of slum settlements include poor infrastructure conditions (roads, clean water, sanitation, drainage, and solid waste) (7)
Animal cage	Fecal coliform is a coliform bacteria derived from human or animal feces, while non-fecal coliform is a coliform bacteria found in dead plants and animals or plants (14)
Wells Construction	The top wall of the well should be built 80 cm above the surface with masonry/brick/slab, also, both inside and outside of the well should be plastered (Guidelines of the Ministry of Public Works and Public Housing)
Type of wells	Several studies say that the water from drilled wells in the area has better quality than dug well water (29)
Building density	The denser the building around the water source, the more waste is produced. This makes the possibility of pollution that occurs even higher.

RESULTS

Fecal Coliform Bacteria

Well water quality tests were conducted in the Yogyakarta Health and Calibration Laboratory to analyze the fecal coliform levels. The processed data are presented in Table 3.

Table 3. Fecal Coliform Test Results

Code	Fecal Coliform (MPN)	Coordinates	
		x	y
S 1 hamlet 1	33	110.3688146	-7.7907232
S 2 hamlet 1	33	110.3690361	-7.7911188
S 1 hamlet 2	140	110.3692098	-7.7928301
S 2 hamlet 2	1.8	110.3692226	-7.7930207
S 1 hamlet 7	13	110.3721519	-7.7896646
S 1 hamlet 8	130	110.3731095	-7.7909998
S 2 hamlet 8	1,600	110.3730007	-7.7907783
S 1 hamlet 9	170	110.3729348	-7.7911283
S 1 hamlet 10	1.8	110.3723056	-7.7927823
S 1 hamlet 11	240	110.3719366	-7.7941683
S 1 hamlet 3	1,600	110.3699514	-7.7935015
S 2 hamlet 3	1.8	110.3701681	-7.7934272
S 1 hamlet 14	33	110.3702784	-7.7963547
S 1 hamlet 6	1,600	110.3701817	-7.7911995

Code	Fecal Coliform (MPN)	Coordinates	
		x	y
S 2 hamlet 6	79	110.3703116	-7.7911182
S 1 hamlet 4	350	110.3707223	-7.7921134
S 2 hamlet 4	110	110.3705972	-7.7925568
S 1 hamlet 5	540	110.3711708	-7.7920422
S 2 hamlet 5	1.8	110.3711835	-7.7921011
S 1 hamlet 13	1.8	110.3701273	-7.7942022
S 1 hamlet 12	49	110.3717186	-7.7942209
S 1 hamlet 15	1.8	110.371746	-7.7948867
S 2 hamlet 15	13	110.3720543	-7.7948724
S 1 hamlet 16	1.8	110.3718498	-7.7960068
S 2 hamlet 13	1.8	110.3701293	-7.7943278
S 2 hamlet 7	1.8	110.3714047	-7.7902525
S 2 hamlet 9	1.8	110.372585	-7.7922686
S 2 hamlet 10	1.8	110.3728535	-7.7926908
S 2 hamlet 11	49	110.3722857	-7.7942132
S 2 hamlet 12	1,600	110.3714279	-7.7941019
S 2 hamlet 14	540	110.3705138	-7.796076
S 2 hamlet 16	1.8	110.3715377	-7.7960453

In Table 3, it can be seen that only 12 (twelve) of the 32 (thirty-two) sample locations had fecal coliform content close to 0 (zero), namely samples with codes S 2 hamlet 2, S 1 hamlet 10, S 2 hamlet 3, S 2 hamlet 5, S 1 hamlet 13, S 1 hamlet 15, S 1 hamlet 16, S 2 hamlet 13, S 2 hamlet 7, S 2 hamlet 9, S 2 hamlet 10, and S 2 hamlet 16. Some samples tested to have a very high fecal coliform, which is more than 1,600/100 mL.

The method used to test the water sample is IKM/5.4.2.M/BLK-Y which is regulated in the Decree of the Governor of the Special Region of Yogyakarta Number 96/KEP/2014 concerning the Appointment of the Health Laboratory Office of the Yogyakarta Special Region of Health as an Environmental Laboratory.

Identification of Polluting Sources

Table 4 shows that for a 10-meter radius, the most polluting waste was found in S 1 hamlet 8, the cattle pens in S 2 hamlet 11, and the largest number of toilets is 4. Meanwhile, for a 30-meter radius, the most polluting wastes were situated at two sample locations namely hamlet 16, cattle pens in S 2 hamlet 14, and toilets in S 2 hamlet 11.

Table 4. Amount of Pollutants in 10-Meter and 30-Meter Radius

Code	Garbage (spots)		Drainage (spots)		Animal cage (spots)		Toilet (spots)	
	10 m	30 m	10 m	30 m	10 m	30 m	10 m	30 m
S 1 hamlet 1	2	4	1	3	3	4	2	4
S 2 hamlet 1	3	7	2	2	0	2	2	6
S 1 hamlet 2	2	5	0	2	0	1	4	6
S 2 hamlet 2	3	4	0	2	0	3	4	7
S 1 hamlet 7	3	3	2	2	0	1	0	3
S 1 hamlet 8	5	6	1	2	0	2	3	5
S 2 hamlet 8	2	5	1	1	1	3	2	6
S 1 hamlet 9	2	2	1	2	0	2	0	3
S 1 hamlet 10	1	3	1	2	0	2	2	3
S 1 hamlet 11	3	5	2	2	2	7	4	5
S 1 hamlet 3	2	5	1	2	1	8	2	6
S 2 hamlet 3	2	4	1	2	3	4	1	3
S 1 hamlet 14	2	6	0	2	1	5	2	7
S 1 hamlet 6	4	7	1	2	0	6	3	4
S 2 hamlet 6	2	4	1	2	0	3	2	5
S 1 hamlet 4	3	4	2	3	0	3	1	4
S 2 hamlet 4	2	3	1	2	2	5	2	4
S 1 hamlet 5	1	3	1	2	0	2	1	5
S 2 hamlet 5	2	4	1	2	0	3	0	3
S 1 hamlet 13	0	2	0	2	0	4	2	4
S 1 hamlet 12	2	5	1	1	1	5	3	5
S 1 hamlet 15	1	3	1	1	0	4	2	3
S 2 hamlet 15	2	4	1	2	0	3	1	5
S 1 hamlet 16	2	8	1	3	0	7	1	6
S 2 hamlet 13	0	3	1	2	0	5	2	3
S 2 hamlet 7	0	3	1	2	0	2	2	3
S 2 hamlet 9	2	5	1	2	1	3	2	4
S 2 hamlet 10	1	3	0	2	0	2	1	4
S 2 hamlet 11	3	7	1	3	5	9	4	8
S 2 hamlet 12	2	4	1	2	3	6	1	6
S 2 hamlet 14	1	6	1	4	4	15	1	5
S 2 hamlet 16	2	8	1	3	2	7	3	6

Fecal Coliform Distribution and Potential Polluting Sources

By the research objective, namely to map the distribution of substances contained in the Tegal Panggung Village well water, the mapping was carried out using the QGIS software with the Inverse Distance Weighted (IDW) method. This method is usually used in the mining industry because it is easier to use and more accurate than the Kriging method.

The distribution of fecal coliform bacteria and potential sources of pollutants including garbage, drainage, cages, and toilets, can be seen in Figure 3 to Figure 7.

Figure 3 shows that the distribution of fecal coliform is quite varied. hamlet 6, hamlet 3, hamlet 8, and hamlet 12 indicate that in two adjacent places the water quality can be very different. Therefore, an analysis is needed to find out what pollutant sources are the factors that influence the fecal coliform number.

Figure 4 shows that the areas with the densest piles of garbage pollutant are hamlet 16 and the least common are hamlet 13. Several sample locations are public places such as public toilets and prayer rooms, so it can be seen from the map that at a radius of 10 meters the waste is denser than if observed with a radius of 30 meters.

Based on Figure 4 it can be seen that the average sampling location has the same amount of observed drainage. This is because some of the samples taken are located in public places which are on the side of roads that are used for the public. So that there are several gutters around the location of the sampling wells

In Figure 6 it can be seen that not all hamlets have many livestock pens. The fewest number of cages was in hamlet 7 and the most crowded was hamlet 14. The cages observed included chicken cages, bird cages, cow or goat cages, and rabbit cages. The majority of residents who have cages put them in front of the house.

Based on Figure 7 it can be seen that the number of toilets in the observation radius is quite dense. This is because the well at the sampling location is generally used and becomes a public toilet. While at several points the well is located in the mosque which also has several toilets in it.

Building Density

Furthermore, the land map shown in Figure 8 shows that 45% of the overall Tegal Panggung area is categorized as dense settlements, 15% are sparse settlements, and the rest are offices, workshops, schools, markets, public facilities, and others.

Table 5 presents data on the density of buildings on land having a radius of 10 and 30 meters. The building density was calculated using QGIS and Microsoft Excel software.

Table 5. The Ratio of Building Area and Land Area in 10-Meter and 30-Meter Radius

Code	Fecal Coliform (MPN)	r = 10 m			r = 30 m		
		Building area LB (m^2)	Land area LL (m^2)	Ratio (LB/LL)	Building area LB (m^2)	Land area LL (m^2)	Ratio (LB/LL)
S 1 hamlet 1	33	19.965	314.16	0.064	161.45	2827.43	0.057
S 2 hamlet 1	33	90.792	314.16	0.289	869.53	2827.43	0.308
S 1 hamlet 2	140	108.080	314.16	0.344	914.77	2827.43	0.324
S 2 hamlet 2	1.8	112.061	314.16	0.357	530.43	2827.43	0.188
S 1 hamlet 7	13	97.938	314.16	0.312	476.10	2827.43	0.168
S 1 hamlet 8	130	60.157	314.16	0.191	833.21	2827.43	0.295
S 2 hamlet 8	1,600	153.705	314.16	0.489	879.32	2827.43	0.311
S 1 hamlet 9	170	121.955	314.16	0.388	947.10	2827.43	0.335
S 1 hamlet 10	1.8	40.965	314.16	0.130	407.34	2827.43	0.144
S 1 hamlet 11	240	90.855	314.16	0.289	746.43	2827.43	0.264
S 1 hamlet 3	1,600	95.070	314.16	0.303	653.04	2827.43	0.231
S 2 hamlet 3	1.8	53.299	314.16	0.170	580.73	2827.43	0.205
S 1 hamlet 14	33	21.230	314.16	0.068	395.51	2827.43	0.140
S 1 hamlet 6	1,600	109.093	314.16	0.347	1052.98	2827.43	0.372
S 2 hamlet 6	79	108.831	314.16	0.346	1122.18	2827.43	0.397
S 1 hamlet 4	350	66.882	314.16	0.213	689.43	2827.43	0.244
S 2 hamlet 4	110	7.610	314.16	0.024	489.76	2827.43	0.173
S 1 hamlet 5	540	75.370	314.16	0.240	728.64	2827.43	0.258
S 2 hamlet 5	1.8	67.307	314.16	0.214	688.87	2827.43	0.244
S 1 hamlet 13	1.8	83.576	314.16	0.266	613.54	2827.43	0.217
S 1 hamlet 12	49	40.425	314.16	0.129	576.10	2827.43	0.204
S 1 hamlet 15	1.8	75.625	314.16	0.241	731.42	2827.43	0.259
S 2 hamlet 15	13	56.665	314.16	0.180	534.33	2827.43	0.189
S 1 hamlet 16	1.8	80.101	314.16	0.255	605.14	2827.43	0.214
S 2 hamlet 13	1.8	65.558	314.16	0.209	631.33	2827.43	0.223
S 2 hamlet 7	1.8	59.577	314.16	0.190	381.97	2827.43	0.135
S 2 hamlet 9	1.8	111.651	314.16	0.355	1063.163	2827.43	0.376
S 2 hamlet 10	1.8	102.68	314.16	0.327	815.609	2827.43	0.288
S 2 hamlet 11	49	109.162	314.16	0.347	882.023	2827.43	0.312
S 2 hamlet 12	1,600	82.295	314.16	0.262	805.644	2827.43	0.285
S 2 hamlet 14	540	118.627	314.16	0.378	853.556	2827.43	0.302
S 2 hamlet 16	1.8	130.651	314.16	0.416	662.911	2827.43	0.234

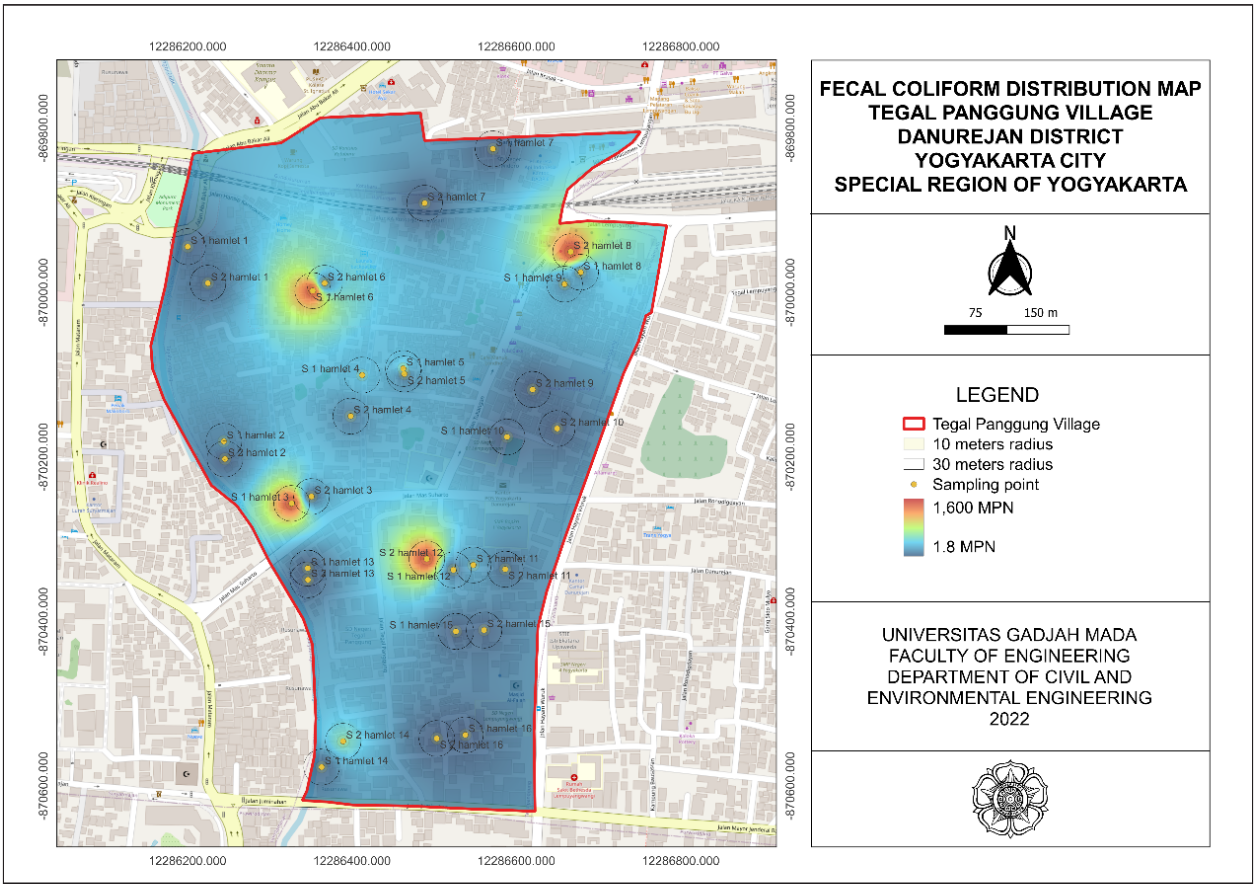


Figure 3. Fecal Coliform Distribution Map

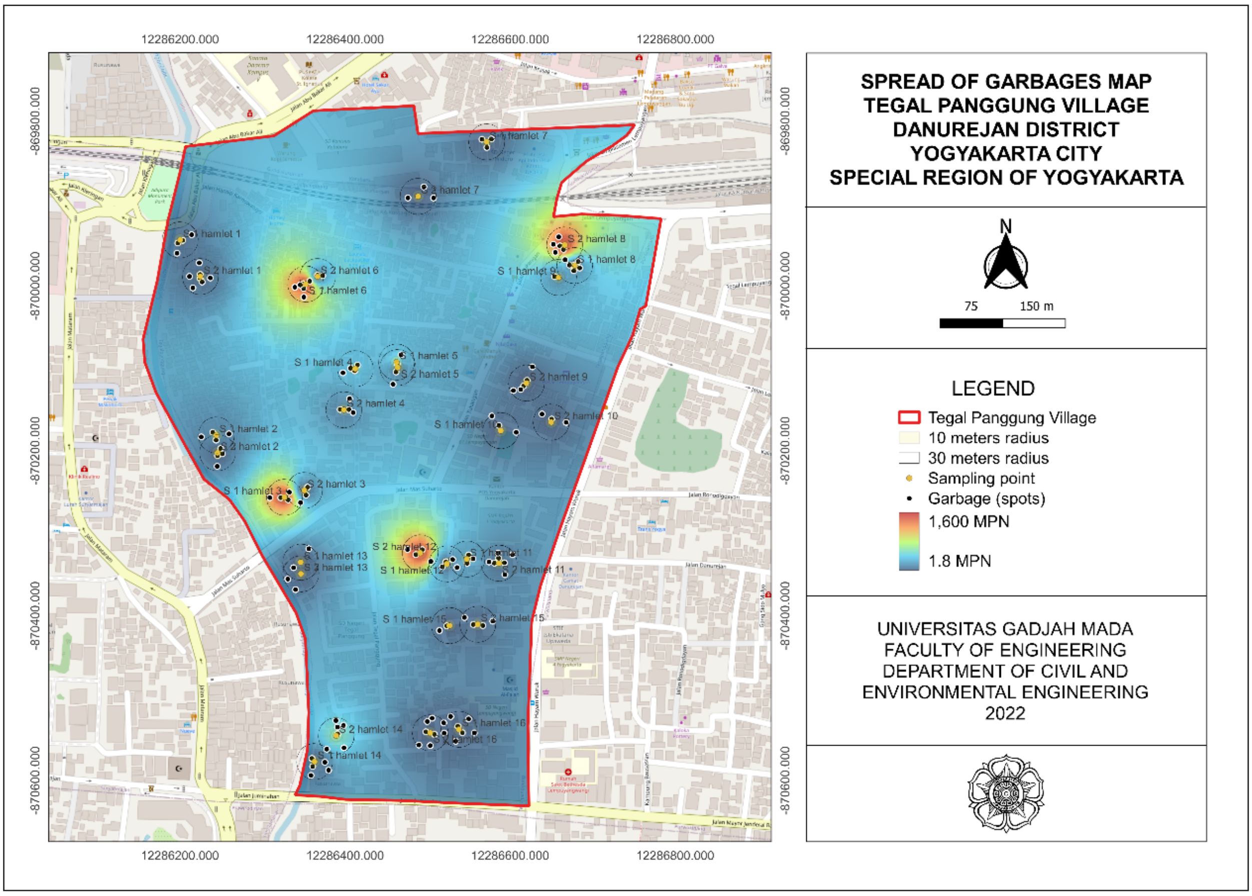


Figure 4. Spread of Garbage Against Fecal Coliform Map

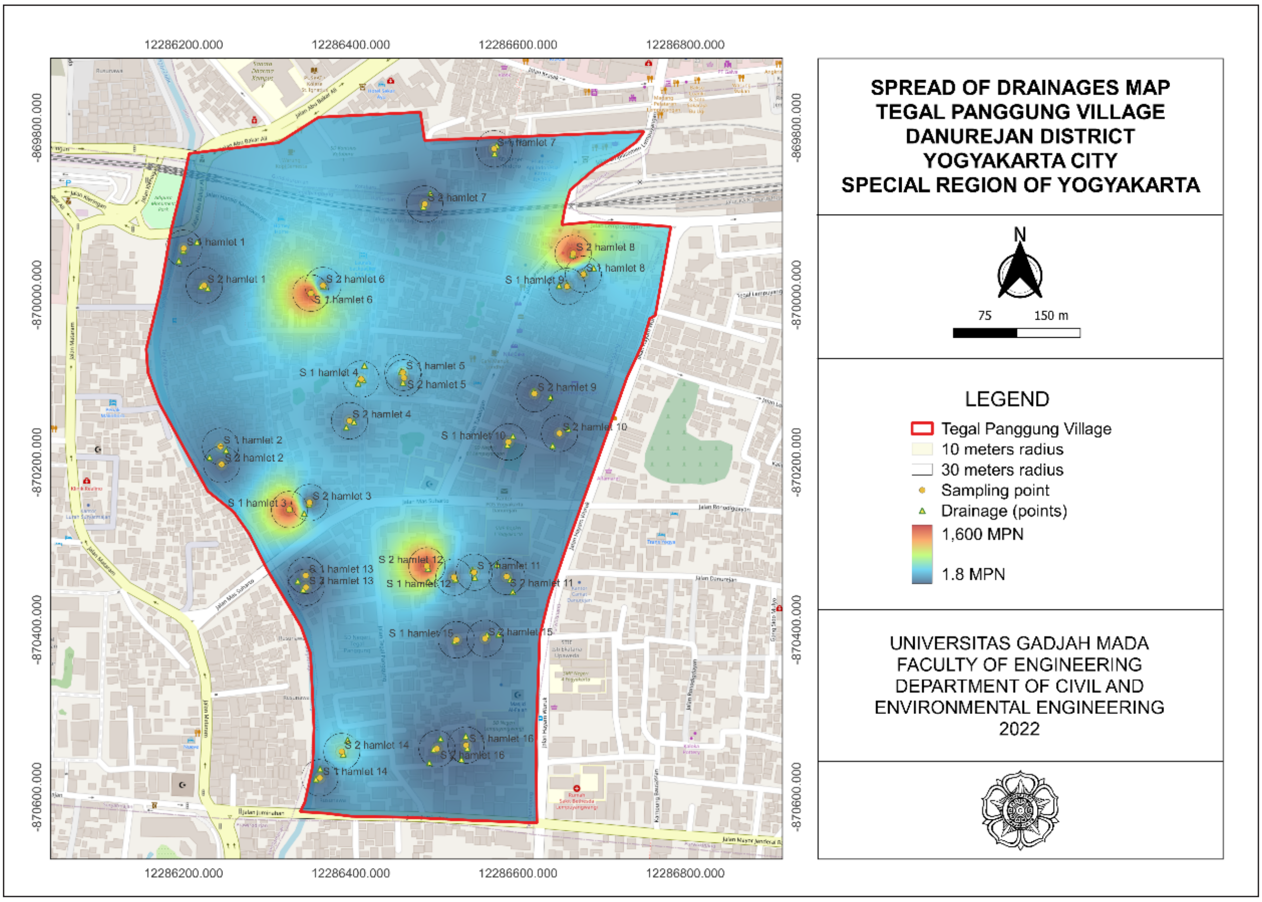


Figure 5. Spread of Drainages Against Fecal Coliform Map

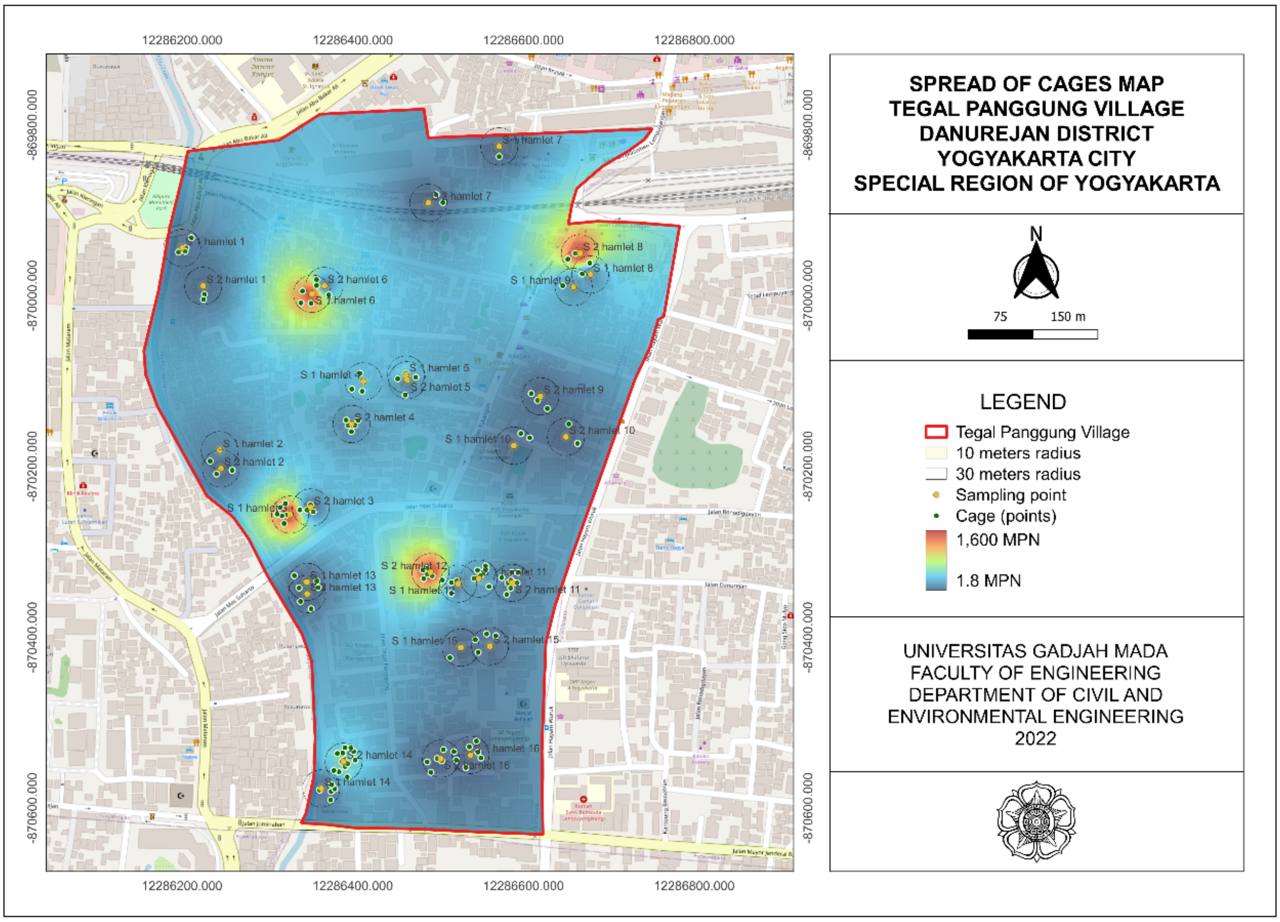


Figure 6. Spread of Cages Against Fecal Coliform Map

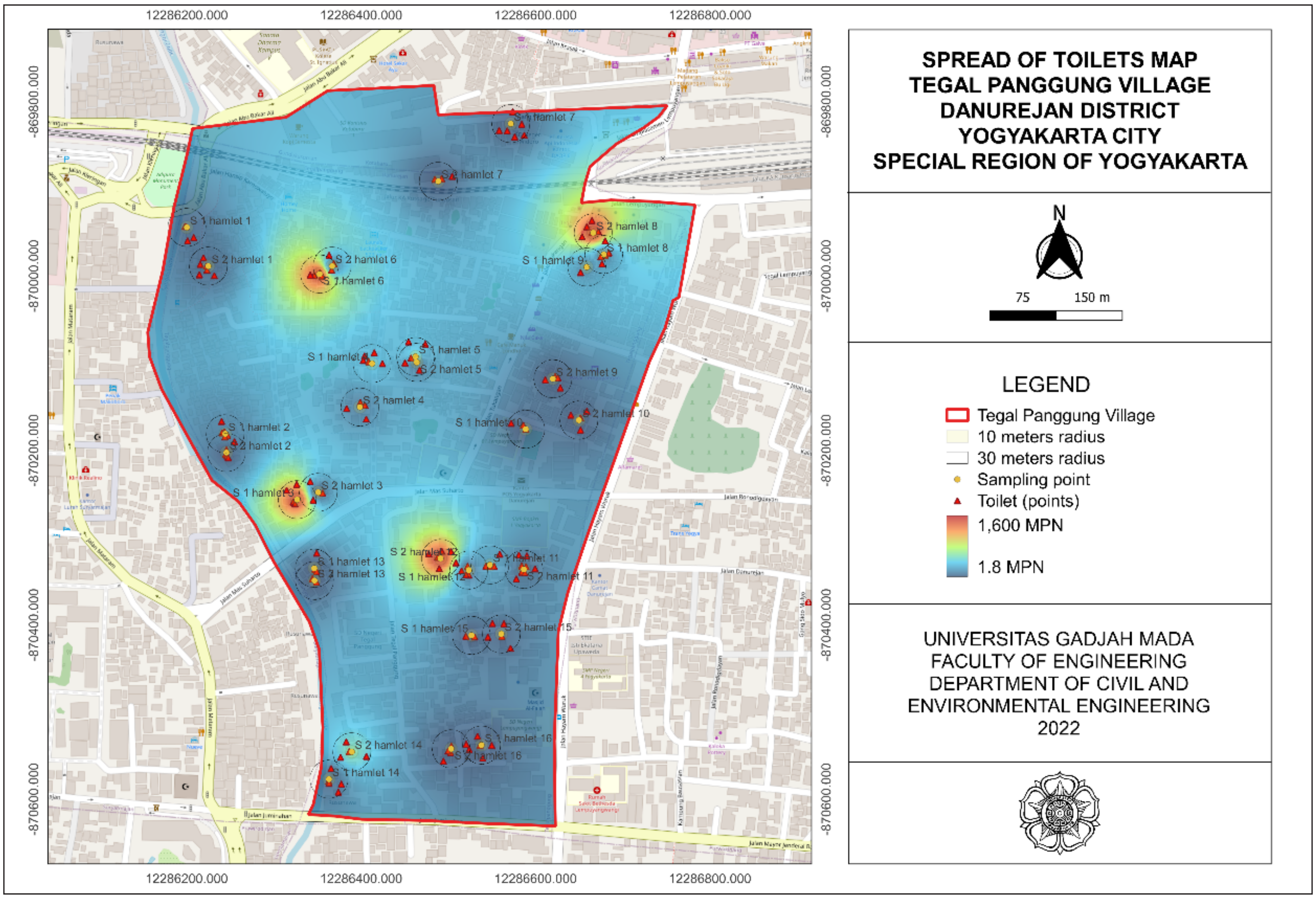
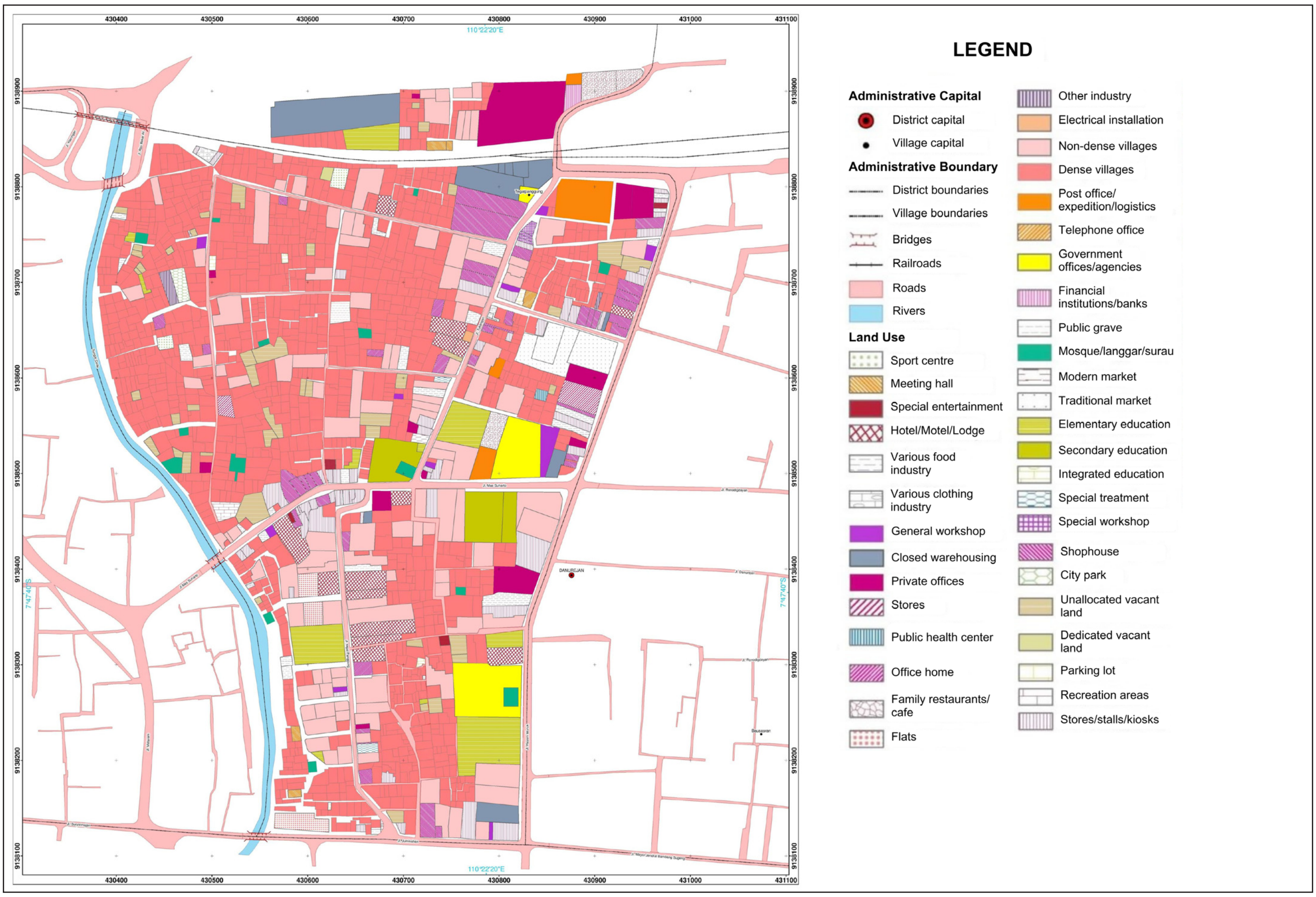


Figure 7. Spread of Toilets Against Fecal Coliform Map



source: Land and Spatial Planning Department of Yogyakarta City

Figure 8. Land use map of Tegal Panggung

Types and Construction of Wells

Generally, there are two types of wells: deep wells (drill) and shallow wells (dig). Of the 32 (thirty-two) samples collected, only 46.9% used drilled wells while the remainder utilized dug wells. Table 6 shows the types of wells and their construction.

Table 6. Types of Wells and Their Construction

Code	Fecal Coliform (MPN)	Types of wells	Construction of wells
S 1 hamlet 1	33	Drilling wells	-
S 2 hamlet 1	33	Drilling wells	-
S 1 hamlet 2	140	Dug wells	with upper wall, without lid
S 2 hamlet 2	1.8	Dug wells	with upper wall, without lid
S 1 hamlet 7	13	Dug wells	with upper wall, with lid
S 1 hamlet 8	130	Drilling wells	-
S 2 hamlet 8	1,600	Dug wells	with upper wall, with lid
S 1 hamlet 9	170	Drilling wells	-
S 1 hamlet 10	1.8	Drilling wells	-
S 1 hamlet 11	240	Drilling wells	-
S 1 hamlet 3	1,600	Dug wells	with upper wall, without lid
S 2 hamlet 3	1.8	Dug wells	with upper wall, without lid
S 1 hamlet 14	33	Dug wells	with upper wall, without lid
S 1 hamlet 6	1,600	Drilling wells	-
S 2 hamlet 6	79	Dug wells	with upper wall, without lid
S 1 hamlet 4	350	Drilling wells	-
S 2 hamlet 4	110	Dug wells	with upper wall, with lid
S 1 hamlet 5	540	Drilling wells	-
S 2 hamlet 5	1.8	Drilling wells	-
S 1 hamlet 13	1.8	Dug wells	with upper wall, without lid
S 1 hamlet 12	49	Dug wells	with upper wall, with lid
S 1 hamlet 15	1.8	Dug wells	with upper wall, with lid
S 2 hamlet 15	13	Drilling wells	-
S 1 hamlet 16	1.8	Dug wells	with upper wall, with lid
S 2 hamlet 13	1.8	Dug wells	with upper wall, without lid
S 2 hamlet 7	1.8	Drilling wells	-
S 2 hamlet 9	1.8	Drilling wells	-
S 2 hamlet 10	1.8	Drilling wells	-
S 2 hamlet 11	49	Dug wells	with upper wall, without lid
S 2 hamlet 12	1,600	Drilling wells	-
S 2 hamlet 14	540	Drilling wells	-
S 2 hamlet 16	1.8	Drilling wells	-

Results of Correlation Analysis with SPSS

Using the SPSS program, the correlation between each factor and the number of fecal coliforms was calculated. Table 8 shows the results of the Spearman correlation test analysis performed with the program. From these results, it can be seen that the factors influencing the presence of fecal coliform within a 10-meter radius are garbage and that of the 30-meter radius are toilets and building density.

Table 7. Spearman Rank Correlation Coefficient

Coefficient	Correlation strength
0.00	No correlation
0.01 – 0.09	Non-significant correlation
0.10 – 0.29	Weak correlation
0.30 – 0.49	Moderate correlation
0.50 – 0.69	Strong correlation
0.70 – 0.89	Very strong correlation
>0.90	Almost perfect correlation

Table 8. Spearman Correlation Test Results with the SPSS Program

Variable in Radius (m)	Spearman-rho value	Description
Pile of Garbage		
10	0.405	Moderate correlation
30	0.250	Weak correlation
Drainages		
10	0.231	Weak correlation
30	-0.015	Less meaningful correlation
Animal Cages		
10	0.290	Weak correlation
30	0.173	Weak correlation
Toilets		
10	0.070	Less meaningful correlation
30	0.377	Moderate correlation
Building Density		
10	0.212	Weak correlation
30	0.396	Moderate correlation
Type of Wells	0.079	Less meaningful correlation

DISCUSSION

The results of this study were compared with the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 regarding the parameters of coliform bacteria and *E. Coli* (23). Based on that its presence is not allowed in drinking water. So from the samples collected only 40.62% met the quality standards. Fecal coliform bacteria are strongly influenced by the amount of stool produced by humans and animals. The dense settlement indicates that the distance between houses is relatively small, thus, making the toilets' density high. It is known that densely populated settlements can facilitate the transmission of diarrhea caused by fecal coliform (24).

The most basic definition of potable water is 1) the main source of proper drinking water, 2) the distance to the sewage/waste collection is more than 10 meters, and 3) the round trip time to collect water (including queuing time) is less than 30 minutes. Meanwhile, indicators of safe water include 1) a proper water source, 2) the distance to the collection of dirt/waste is more than 10 meters, 3) the location of the source is in or on the home page, 4) available whenever needed, and 5) meet drinking water quality (25).

The method was based on previous studies conducted in East Lombok in 2020 (26) and Yogyakarta in 2021 (27). Determination of the amount of pollutant is carried out by taking a radius of 10 (ten) and 30 (thirty) meters from the water source as the limit. The radius of 10 meters is obtained from the Guidelines for Housing and Settlement Development by the Ministry of Public Works and Public Housing in 2016 which states that the minimum distance of dug wells from pollutant sources such as pits, septic tanks, garbage disposal, etc. is

10 meters (28). As for the 30 meter radius, it is based on research in 2018 (24) which analyzed a resolution of 30 meters according to the 2011 National Land Cover Database (NLCD) land use data. The number of pollutants is determined by field observation.

According to a study conducted in Padang, in which the quality of water from boreholes and dug wells was compared, it was stated all dug well water contains bacteria while that from drilled wells does not entirely contain bacteria and this result was by the samples collected in the study. Several studies say that the water from drilled wells in the area has better quality than dug well water (29). Furthermore, according to the guidelines for the construction of housing and rural settlements (28), when constructing a well, the upper wall should be made of masonry or split stone plastered on the outside and inside at a height of 80 cm from the floor level.

In this study, in addition to using QGIS software as a mapping medium, SPSS software is also used to determine the pollutant factors that most influence the presence of fecal coliform. The analysis performed on the SPSS program is a single parameter. The elements used as the basis for the analysis were obtained from various sources. Based on the obtained results, it can be seen from thirty-two samples that the value of significance at a radius of both 10 and 30 meters is sequentially worth 0.001 and 0.000, thus, the two data were distributed abnormally. Each value of the correlation coefficient has its meaning. The value 0.00 means that there is no correlation between the two calculated variables. When the value is within the range of 0.01 to 0.09, it means that the correlation is less significant. However, when it falls between 0.10 and 0.29, it connotes that the correlation is weak. For the ranges of 0.30 – 0.69, and 0.70-0.89, the correlation is considered moderate and very strong respectively, while for values above 0.90, the correlation is close to perfect (30). The presence of fecal coliform bacteria comes from pollutants around well water. In this study, the correlation of the presence of fecal coliform with the amount of waste, drainage, cages, toilets, or control tubs, building density, and the type of well was considered. Furthermore, the determination of the factors influencing the presence of fecal coliform bacteria was carried out using the SPSS program. The tests performed were the Kolmogorov-Smirnov normality Test and the Spearman-rho correlation test. The normality test is a test performed to assess the distribution of data across a set of variables, regardless of whether the distribution of data is normal or not. Based on the practical experience of statisticians, when the number of data is greater than 30 (n>30), the distribution can be assumed to be normal. Therefore, the normality test was used to provide certainty about whether the data has a normal distribution. Figure 9 shows the results of the Kolmogorov-Smirnov normality test conducted using the SPSS program in this study.

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		32
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	474.8927756
Most Extreme Differences	Absolute	.210
	Positive	.210
	Negative	-.118
Test Statistic		.210
Asymp. Sig. (2-tailed)		.001[c]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

(a)

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		32
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	448.6739747
Most Extreme Differences	Absolute	.241
	Positive	.241
	Negative	-.103
Test Statistic		.241
Asymp. Sig. (2-tailed)		.000[c]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

(b)

Figure 9. Results of the Kolmogorov-Smirnov Normality Test for a Radius of 10 Meters *(a)* and 30 Meters *(b)*

This study still has several shortcomings, including not considering the distance of the pollutant from the water source as a variable in the analysis. The benefits of this research are as a literature review on the analysis of fecal coliform bacteria in Tegal Panggung Village and the use of GIS (Geographic Information System) software to present data, especially to present analysis results. This data is presented to determine the correlation between pollutant factors and fecal coliform content and facilitate analysis of results.

Furthermore, this research is useful as input for the government, community, and the private sector in establishing policies related to good environmental management and achievement of the six Sustainable Development Goals (SDGs) number 6, namely clean water and proper sanitation in Tegal Panggung Village.

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CONCLUSION

From the results of the tests and analyses that have been carried out, only 40.62% of the samples collected met the quality standard requirements. Furthermore, the distribution of fecal coliform content in Tegal Panggung Village varies greatly due to several factors such as community activities, pollution, and poor sanitation. Of the 32 (thirty-two) samples collected, only 46.9% used drilled wells while the rest utilized dug wells.

Following this, based on the results obtained from the Spearman correlation test, it can be seen that the factors influencing the presence of fecal coliform in a 10-meter radius are garbage, while that of a 30-meter radius includes toilets and building density.

It is therefore recommended that the residents of Tegal Panggung treat their water before it is used by the community for daily needs, and routine water testing should be carried out to maintain the water quality.

REFERENCES

1. President of the Republic of Indonesia. Republic of Indonesia Government Regulation Number 20 of 1990 about Water Pollution Control. Jakarta: President of the Republic of Indonesia; 1990.
2. Saputri ET, Efendy M. Kepadatan Bakteri Coliform Sebagai Indikator Pencemaran Biologis di Perairan Pesisir Sepuluh Kabupaten Bangkalan. *Juvenil.* 2020;1(2):243–249. https://doi.org/10.21107/juvenil.v1i2.7579
3. Bambang AG. Analisis Cemaran Bakteri Coliform dan Identifikasi *Escherichia Coli* pada Air Isi Ulang dari Depot di Kota Manado. *Pharmacon*. 2014;3(3):325-334. https://doi.org/10.35799/pha.3.2014.5450
4. Central Statistic Agent of Yogyakarta. Danurejan Subdistrict in Figures 2021. Yogyakarta: Central Statistic Agent of Yogyakarta; 2021.
5. Friesen J, Friesen V, Dietrich I, Pelz PF. Slums, Space, and State of Health—A Link between Settlement Morphology and Health Data. *Int J Environ Res Public Health*. 2020;17(6):2022. https://doi.org/10.3390/ijerph17062022
6. Legarias TM, Nurhasana R, Irwansyah E. Building Density Level of Urban Slum Area in Jakarta. *Geosfera Indonesia*. 2020;5(2):268-287. https://doi.org/10.19184/geosi.v5i2.18547
7. Nursyahbani R, Pigawati B. Kajian Karakteristik Kawasan Pemukiman Kumuh di Kampung Kota (Studi Kasus: Kampung Gandekan Semarang). 2015;4(2):267-281. https://doi.org/10.14710/tpwk.2015.8463`
8. Díaz-Alcaide S, Martínez-Santos P. Mapping Fecal Pollution in Rural Groundwater Supplies by Means of Artificial Intelligence Classifiers. *Journal of Hydrology*. 2019;577(124006):1-14. https://doi.org/10.1016/j.jhydrol.2019.124006
9. Wagari S, Girma H, Geremew A. Water, Sanitation, and Hygiene Service Ladders and Childhood Diarrhea in Haramaya Demographic and Health Surveillance Site, Eastern Ethiopia. *Environ Health Insights*. 2022;16(1):1-13. https://doi.org/10.1177/11786302221091416
10. Verhagen J, Scott P. Safely Managed Sanitation in High-Density Rural Areas. Washington DC: World Bank; 2019. http://hdl.handle.net/10986/32385
11. Seizarwati W, Rengganis H, Syahidah M, Hatmoko W. Water Supply Scheme in Morotai Island. *J Civ Eng Forum*. 2020;6(2):123-134. https://doi.org/10.22146/jcef.51516
12. Pratama MA, Immanuel YD, Marthanty DR. A Multivariate and Spatiotemporal Analysis of Water Quality in Code River, Indonesia. *Sci World J*. 2020;1(8897029):1–11. https://doi.org/10.1155/2020/8897029
13. National Standardization Agency of Indonesia. Procedure for Planning a Septic Tank with Advanced Treatment (Infiltration Wells, Infiltration Areas, Up Flow Filters, Sanitary Ponds). Jakarta: National Standardization Agency of Indonesia; 2017.
14. Fardiaz S. Analisis Mikrobiologi Pangan. Jakarta: Raja Grafindo Persada; 1993.
15. Sastrawijaya AT. Pencemaran Lingkungan. Jakarta: Rineka Cipta; 2009.
16. Edzwald JK. Water Quality & Treatment: A Handbook on Drinking Water. 6th ed. New York: McGraw-Hill; 2011.
17. Eaton AD. Standard Methods for the Examination of Water & Wastewater. 21st ed. Washington DC: American Public Health Association; 2006.

18. Bartram J, Ballance R. Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. 1st ed. New York: E & FN Spon; 1996. 383 p.
19. Ministry of Health Republic of Indonesia. Regulation of Ministry of Health Republic Indonesia No. 492/ MENKES/2010 about Quality Requirements of Drinking Water. Jakarta: Ministry of Health Republic of Indonesia; 2010.
20. Umar H. Metode Penelitian untuk Skripsi dan Tesis Bisnis. Jakarta: Raja Grafindo Persada; 2008.
21. Purnomo H. Aplikasi Metode Interpolasi Inverse Distance Weighting dalam Penaksiran Sumberdaya Laterit Nikel (Studi kasus di Blok R, Kabupaten Konawe-Sulawesi Tenggara). *Angkasa Jurnal Ilmiah Bidang Teknologi*. 2018;10(1):49-60. http://dx.doi.org/10.28989/angkasa.v10i1.221
22. Shepard D. A Two-Dimensional Interpolation Function for Irregularly-Spaced Data. In: Proceedings of the 1968 23rd ACM National Conference On. New York: ACM Press; 1968. p. 517–524. http://portal.acm.org/citation.cfm?doid=800186.810616
23. Ministry of Health Republic of Indonesia. Regulation of Minstry of Health Republic Indonesia No. 32 of 2017 about Environmental Health Quality Standards and Water Health Requirements for Sanitation Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths. Jakarta: Ministry of Health Republic of Indonesia; 2017.
24. Wijayanti SPM, Sidik M, Iqbal A. The Determinants of Diarrhea Disease Incidence in Densely Populated Area of West Nusa Tenggara, Indonesia. *Jurnal Kesehatan Lingkungan*. 2020;12(2):107-114. https://doi.org/10.20473/jkl.v12i2.2020.107-114
25. Directorate of Urban, Housing and Settlements Deputy for Regional Development of the Ministry of National Development Planning. Pedoman Pengukuran Capaian Pembangunan Perumahan dan Permukiman Berbasis Hasil (Outcome) Upaya Integrasi Sustainable Development Goals dalam Dokumen Perencanaan Pusat dan Daerah. Jakarta: Directorate of Urban, Housing and Settlements Deputy for Regional Development of the Ministry of National Development Planning; 2019.
26. Majdi M, Sholehah H. Pemetaan Kandungan *Escherichia Coli* pada Sumur Gali Menggunakan Geographic Information System (GIS) di Wilayah Kerja Puskesmas Masbagik Baru Kabupaten Lombok Timur. *Jurnal Sanitasi dan Lingkungan*. 2020;1(2):78-89. https://e-journal.sttl-mataram.ac.id/index.php/jsl/article/view/23
27. Wacano D, Isna L, Bsa MF. Analisa Kualitas Airtanah dan Air Permukaan berdasarkan Kandungan Bakteri *Escherichia coli (E.Coli)* di Kawasan Gumuk Pasir, Bantul, Yogyakarta. Thesis. Yogyakarta: Universitas Islam Indonesia. 2021;. https://dspace.uii.ac.id/handle/123456789/16323
28. Ministry of Public Works and Public Housing of the Republic of Indonesia. Housing Development and Rural Settlements Guide: Dug Wells. Jakarta: Ministry of Public Works and Public Housing of the Republic of Indonesia; 2016.
29. Lestari IL, Singkam AR, Agustin F, Miftahussalimah PL, Maharani AY, Lingga R. Perbandingan Kualitas Air Sumur Galian dan Bor Berdasarkan Parameter Kimia dan Parameter Fisika. *Jurnal Pendidik Biologi dan Sains*. 2021;4(2):155–165. https://doi.org/10.31539/bioedusains.v4i2.2346
30. De Vaus DA. Surveys in Social Research. 5th ed. Crows Nest, NSW: Allen & Unwin; 2002. 379 p.