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Groundwater and indoor air quality of urban village housing: study in Janturan, Warungboto, Yogyakarta

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ABSTRACT

Water and air are important elements for life. The presence of pathogenic bacteria in the surrounding environment can cause health problems resulting from the low quality of water and air. The purpose of this study is to measure the quality of groundwater and air based on microbiological parameters in urban village housing. This research was conducted in a descriptive survey, and a purposive sampling technique was carried out. Groundwater and air samples were taken from six residents' houses located in the Janturan area. The water quality test used the most probable number (MPN) method and the air quality test used the agar filter method using a microbiological air sampler (MAS) to trap microbes. The results of the MPN test for total coliform bacteria from six samples of groundwater showed that three samples were positive for coliform bacteria which exceeded the threshold according to Indonesian standard<50 MPN/100 ml. Assay of *E. coli* bacteria showed that all samples of groundwater positively contained *E. coli* bacteria which exceeded the threshold of 0 MPN/100 ml. The results of indoor air quality measurements from 6 residents' houses showed that five houses have air quality did not meet the standard for indoor air germ numbers based on Indonesian standard, less than 700 CFU/m3 (colony forming units per metres cubic) and 1 house that got the number of airborne germs, in the normal range, namely 356 CFU/m3. It was concluded that the water quality and air quality in the urban village did not meet health requirements.

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1. INTRODUCTION

Water is a chemical substance that is abundant in the human body and plays a central role in regulating the transport of nutrients, disposal of toxic wastes, regulation of body temperature and digestion, organ function, and metabolic activity. Various bacteria, parasites, and viruses that are known to be pathogenic have the potential to cause health problems if enter the human body [1]. The environmental protection agency (EPA) considers total coliform and *E. coli* useful as indicators of pathogens in water quality measurements [2].

While air is a vital element for the survival of various types of individu, its composition and quality must be managed. Thel low quality of air could be transmission media of disease-causing microorganisms. Previous research stated that in developed countries, indoor air pollution is estimated to contribute to 67% of the annual death rate in rural areas and 23% of the annual death rate in urban areas, while in developing countries, indoor air pollution is estimated to contribute to 9% of annual deaths in urban areas and 1% of the annual death rate in rural areas. Based on these results it is said that the impact of the presence of air pollutants in the home space on health can occur both directly and indirectly [3].

The economic gaps between population in the city give some problems in the community. This poverty and rapid urbanization have led to the expansion of urban neighborhoods known as kampungs which are densely populated with substandard housing quality and a lack of infrastructure. On the other hand, Indonesia is a tropical area with daily maximum temperatures always exceeding 30 °C which can trigger global warming. Furthermore, human activities such as rapid urbanization and industrialization can negatively impact water and air quality such as increased spread of microbial pollutants. Groundwater quality and low air quality can have long-term impacts on the environment [4].

Human activity is a source of decreasing water and air quality. The higher population density affected the urban air pollution, including nitrogen oxides, particulate matter, ozone, and an aggregate index [5]. The high rate of population growth is a potential problem for some big cities in Indonesia, including Yogyakarta. The increasing population has implications for the high demand for the environment such as water and air. With a certain area, increasing population and rapid urbanization can put greater pressure on environmental pollution and will produce waste that leads to a decrease in the quality of water and air in the surrounding area [6].

The focus of this research is observing the water and air quality according to microbiological parameters in the urban village housing area of Yogyakarta city. The microbiological parameter that is used is the total bacterial number, the presence of coliform bacteria and pathogenic bacteria. Coliform naturally occurs in the environment, but fecal coliform and *E. coli* come from human and animal feces [7]. Thus, the presence of fecal coliform and *E. coli* in a substance or water indicates that the water is polluted by human or animal feces [8].

2. METHOD

The type of research used is observational (survey) with a qualitative and quantitative descriptive approach to test the quality of water and air in the Warungboto village community. The sampling location was carried out in six residents' houses in the Janturan Area, Warungboto Village, Yogyakarta City. The research has received permission from the head of village. Determining the number of sampling points through purposive sampling technique. The sample inclusion criteria in the study are: i) The sampling water was found from drilled well or dug well used by the community. ii) The selected houses were located on the side of the road and the other are in the alley. iii) The selected house is the living house and not be used for business.

The sampling of water was carried out aseptically according to water sampling protocol [9]. The sampling of indoor air was carried out by air sampler in the centre of house. The parameter which analyzed for water were total bacterial count, total coliform and the presence of *E. coli*. While the parameter which analyzed for air quality were total bacterial counts. The data was analysis descriptively and compared the requirements on Permenkes RI 416/MEN.KES/PER/IX/1990 for water quality and the quality standards for air and indoor spaces according to Permenkes No. 1077/MENKES/PER/V/2011.

3. RESULTS AND DISCUSSION

Urban development has an impact on environmental sustainability, including a decrease in water quality. Monitoring the quality of well water in urban settlements is an effort to determine the condition of well water quality in that environment from the presence of contaminants [10]. Well water is the main source used by the people in the Janturan Warungboto area for daily needs such as bathing, washing, cooking and other household needs.

The house criteria used in this study were presented in the Table 1. The three houses on the side of the road and other three houses in the alley. The next criterion is the number of occupants in the house, indoor activities (activities such as washing, cleaning the house, cooking and heating the vehicle), the distance between houses, the distance between the house and the road in front of the house, the distance from the well to sources of environmental pollution or disposal of organic and inorganic waste and the distance between the septic tank and the well.

Table 1. The criteria and the physical condition of the sample houses

Characteristics of the physical condition of the house	House A	House B	House C	House D	House E	House F
Building classification	1 floor house, non-AC	2 storey houses, non-AC	1 floor non-AC house	1 floor house, with AC	1 floor house, non-AC	1 floor house, non-AC
Building floor area	432 m^2	183 m^2	135 m^2	126 m^2	156 m^2	156 m^2
Building wall area	127 m^2	38.5 m^2	17.5 m^2	20.15 m^2	25.02 m^2	28.80 m^2
Window area	15 m^2	12.46 m^2	3.4 m^2	4.16 m^2	3.4 m^2	11.9 m^2
Distance to main street	5 m	1 m	200 m	1 m	1 m	150 m
Distance between well and the septic tank	5 m	10 m	200 m	15 m	14 m	9 m
Window opening activity	12 hours	6 hours	12 hours	7 hours	0 hours	12 hours

3.1. The total coliform bacteria in ground water

The urban community in Yogyakarta have well for water sources. They dug well by themselves when they build housing. The control from government is very limited, so the quality of water becoming some problems. In this study, measurements of the total amount of coliform were carried out to investigate and analyze water quality by taking a number of six samples of well water (groundwater) from households living in the Janturan Warungboto area. The results of laboratory examinations for testing total coliform bacteria samples of well water with codes A-F in the Janturan area, Warungboto can be seen in Table 2.

Table 2. Total coliform bacteria of groundwater sources in the Janturan Area, Warungboto, Yogyakarta City

No	Sample code homes	Home location	Test results (MPN/100 ml)	Quality requirements (MPN/100 ml)	Category water quality	Information
1.	Code A	Side of the road	1600*	50	Very bad	TMS
2.	Code B	Side of the road	2	50	Good	MS
3.	Code C	In an alley	130*	50	Bad	TMS
4.	Code D	Side of the road	<1.8	50	Good	MS
5.	Code E	In an alley	46	50	Good	MS
6.	Code F	In an alley	>1,600*	50	Very bad	TMS

Information:
MS = meet the standard
TMS = Do Not meet the standard

Based on Table 1, the results of microbiological examination of total coliform bacteria in 6 well water samples from six residents' houses in the Janturan Warungboto area of Yogyakarta City are in accordance with the Regulation of the Minister of Health of the Republic of Indonesia No. RI No: 416/MENKES/PER/IX/1990 concerning terms and conditions Monitoring of water quality showed that of the six samples of well water with sample codes A-F, there were three samples of well water, of which samples with codes A, C and F did not meet the requirements according to Minister of Health Regulation No. 32 of 2017 or Minister of Health RI No:416/MENKES/PER/IX/1990 Concerning Terms and Conditions for Water Quality Control because the total coliform content in it is >50 MPN/100 ml. Meanwhile, three well water samples with sample codes B, D and E met the requirements because the total coliform content in the samples did not exceed the quality standard [11].

Based on the parameter results, the total number of bacteria in the well water samples as shown in Table 1 illustrates that the quality of groundwater (well water) at the homes of residents in the Janturan Warungboto area exceeds the normal threshold. From the test results, it was found that houses with sample codes B, D and E had a total coliform content of <1.8 MPN/100 ml and 46 MPN/100 ml respectively, meaning that they entered the class "A" clean water category, where the water quality was said to be "good water quality" because it contains total coliform less than 50 MPN/100 ml, then houses with sample code C have data on total coliform test results, namely >130 MPN/100 ml, including clean water quality category class C or "poor water quality" because it contains coliform >101-1000 MPN/100 ml, while the data from the home water sample test with sample codes A and F show a total coliform number of >1,600 MPN/100 ml and belongs to the class D clean water category with "very poor water quality" because it contains >1,001-2,400 total coliform per 100 ml sample water. This is based on quality standards, namely decree of the Director General of PPM and PLP No.1/PO.03.04.PA.91 and guidelines for water quality 2000/2001 and based on PERMENKES RI No.492/Menkes/Per/IV/2010 [12].

Human activities near water sources contribute to the prevalence of coliform bacteria in these areas. From the test results the total number of bacteria obtained exceeded the set standard, this indicated that the well water in the research area used for daily needs by residents had been contaminated by the presence of coliform bacteria. On average, wells from residents' houses in 4 areas in the Janturan Warungboto area, namely area 16, 17, 18 and 19 are located in the densely populated settlements which may contribute to the quality of water [13]. The previous study found that there are four other factors that influence the level of bacterial content in groundwater, namely the gradient of the groundwater table, the depth of groundwater, the velocity of groundwater flow and the sewage system [14]. Besides that, rapid population growth in the Janturan Warungboto area can be another factor causing disruption to the quality of clean water in this area. The water quality assessment includes physical, chemical and biological parameters can be environmental information needed to assess the long term water supply in rural and urban areas [15].

3.2. Presence of *Eschericia coli*

E. coli is a pathogenic bacterium which is often found in the drinking water. The presence of *E.coli* is associated with many disease incidence [16]. The presence of *E. coli* for evaluation of drinking water quality is very important. The result of presence of *E. coli* in the well water of sample houses was presented in Table 3.

Table 3. Results of examination of total *E.Coli* bacteria from well water sources in the Janturan Area, Warungboto, Yogyakarta City

No	Sample code homes	Home location	Test results (MPN/100 ml)	Quality requirements (MPN/100 ml)	Information	Water sources
1.	Code A	Side of the road	79	0	TMS	Well water
2.	Code B	Side of the road	<1.8	0	TMS	Well water
3.	Code C	In an alley	7,8	0	TMS	Well water
4.	Code D	Side of the road	<1.8	0	TMS	Well water
5.	Code E	In an alley	13	0	TMS	Well water
6.	Code F	In an alley	920	0	TMS	Well water

TMS: Do not meet the standard

The results of laboratory examinations for the total Escherechia coli test for well water samples in the Warungboto area of Yogyakarta City can be seen in Table 3. Based on Table 3 it is stated that the results of the microbiological examination for total *E. coli* in well water samples (codes A-F) in six residents' houses in the Warungboto Janturan Area all were exceeded the total *E. coli* bacteria accordance with the regulation of the Minister of Health of the Republic of Indonesia No: 416/MENKES/PER/IX/1990. Concerning Requirements and Monitoring of Water Quality which stated that the total content of *E. coli* in clean water is 0/100 ml [11].

From the results of the total number of *E. coli* bacteria above, one of the factors that affect groundwater pollution is the type of well. In research [17] stated that overall 94.4% of unprotected dug wells in urban villages had high concentrations of *E. coli* because *E. coli* contamination could be affected by the diameter of the borehole where shallow wells (<5 meters) were more susceptible to contamination due to proximity to the ground surface. In addition, another factor that causes the quality of well water to deteriorate is because the septic tank is too close to the dug well and the structure of the well is not strong enough to facilitate the penetration of solvents and contaminants into the well. The depth of the well also affects the speed at which the contaminant solution mixes with the well water. Therefore, water sanitation facilities that meet health requirements can be one of the activities or initiatives to improve environmental health [18].

The previous study explained that there is a relationship between the quality of well water and the incidence of diarrheal diseases. The bad quality of the water were related to the incidence of diarrhea [19]. There are three factors that dominate it, namely clean water treatment plants, sewage and feces disposal. If the environment is unhealthy or contaminated with *E. coli* and supported by unhealthy human patterns or behavior through food and drink from that environment, it can cause diarrheal disease. Based on the results of this study, it was found that the amount of *E. coli* contained in the water samples did not meet the standard requirements for water quality, so well water (groundwater) in the Janturan Warungboto area was not suitable for direct consumption.

In some areas of the world, groundwater is the only source of drinking water for the human population; this depends on a combination of natural and anthropogenic factors [20]. Groundwater is generally of good quality because it is better protected, but this quality can deteriorate due to inadequate protection and poor resource management [21]. In a study conducted by Keuman *et al.* [22] showing the

quality of groundwater in the Outskirt Village of the Municipality of Jacqueville in Ivory Coast, West Africa, the calculation of the fecal contamination index of well water in the area was divided into three bacteriological quality classes, namely uncontaminated wells, wells moderately contaminated and heavily contaminated wells. This study showed that most of the wells studied had warm and turbid water with a high population of pathogenic microorganisms. The well water pollution is caused by very high turbidity values and microbiological parameters that exceed WHO standards. In line with the results of this study, the high levels of coliform and *E. coli* bacteria, it is necessary to implement them to avoid possible serious health risks such as the application of hygienic measures, including periodic chlorination of well water at water levels for household or family use. This is highly recommended for the Janturan Warungboto Residents of the City of Yogyakarta. The well water pollution is caused by very high turbidity values and microbiological parameters that exceed WHO standards.

The high contamination of *E. coli* should be avoided to the possibility of serious health risks [23]. Most of people in Janturan village use water container, and the water container condition affected the *E. coli* contamination of drinking water. The periodic decontamination such as the application of hygienic measures, including periodic chlorination of well water for household or family use [24].

3.3. Correlation of coliform bacteria and *Escherichia coli* content

Based on the results of research on six samples of well water from the residents of Janturan Warungboto, it showed the content of coliform and *E. coli* bacteria with varying levels of contamination, ranging from high levels of contamination to the lowest levels of contamination. The highest levels of coliform and *E. coli* contamination were found in samples with sample codes A, C, and F and the lowest levels found in samples with sample codes B, D and E. Corelations between the correlation of total coliform and *E. coli* in the well water samples obtained are shown in the Figure 1.

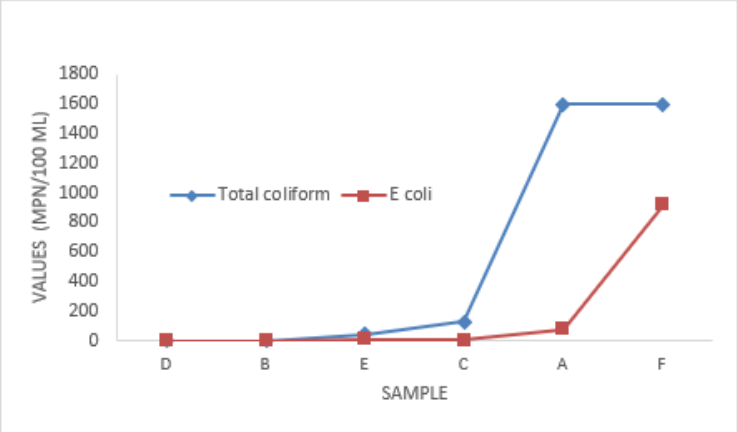

Figure 1. Correlation between the number of total coliform and *E. coli* contamination

The amount of coliform and *E. coli* in Figure 1 shows that there is a relationship between the amount of coliform and *E. coli* where in water samples with a high content of coliform bacteria also produce a high content of *E. coli* bacteria, meaning that more coliform can be cause high content of *E. coli* in water samples. *E. coli* bacteria are a group of coliform bacteria, the higher the level of contamination of coliform bacteria, the higher the risk of the presence of *E. coli* bacteria [25].

3.4. Description of the distance between the septic tank and the source of clean water

The present study also observes that almost each of house has the septic tank. The distance of septic tank with the water sourece were various as showed in Table 4. Based on the data in Table 4, it describes the distance between the location of the well and the septic tank that 33.33% (2 wells) were obtained from houses with codes A and F having a septic tank distance of less than 10 meters so that it is categorized as not fulfilling health requirements and 66.67% (4 wells) of houses with codes B, C, D, and E have a distance between the septic tank and the location of the well which is more than 10 meters which is categorized as fulfilling health requirements according to the Indonesian National Standard (SNI-03-2398-2002), it is possible that the septic tank factor can affect the content or amount of bacteria.

Table 4. Description of the distance of the septic tank with the well water source

Distance between septic tank and clean water source	Number of houses	Percentage (%)	Information
Distance≥10 meters	4	66.67%	Meet requirement
Distance<10 meters	2	33.33%	Not meet requirement
Total	6	100%	

From the results of observations, the distance between the septic tank and the drinking water source that does not meet the requirements may be due to the limited land area which allows the distance between the septic tank and the well as a source of drinking water. The previous study states that increasing population density can affect the feasibility of groundwater. Other factor such as the direction of groundwater flow, width of well lip, availability of well cover and other sanitary parameters were also affect the quality of water [26].

3.5. Air quality parameters and air germicidal numbers

The most important environmental component that supports life is air. Without oxygen from the air, metabolism in living bodies cannot take place. In addition to oxygen, air also contains mold, viruses, formaldehyde, carbon monoxide and carbon dioxide [27]. The increase in the concentration of these substances in the air can be caused by human activities, such as the density of activities in a room or house. Previous study reported that human activity around 90% spend more time indoors than outdoors. One of the top five pollution risks to health in modern society is indoor air pollution, which can have levels two to five times higher than outdoor pollution. The total of air germ number in the sample houses was presented in Table 5.

Table 5. Air quality test examination results in the Janturan Area, Warungboto, Yogyakarta City

No.	Sample code and location of residents' houses	Test type	Number of bacteria	
			Test Result (CFU/m3)	Quality Standard (CFU/m3)
1.	Code A (Side of the road)	Total air germ numbers	1430 CFU/m3	<700 CFU/m3
		Floor wipe	3 CFU/m2	-
		Wall wipe	0-1 CFU/m2	-
2.	Code B (Side of the road)	Total air germ numbers	1610 CFU/m3	<700 CFU/m3
		Floor wipe	3.9x103 CFU/m2	-
		Wall wipe	0-1 CFU/m2	-
3.	Code C (In the alley)	Total air germ numbers	760 CFU/m3	<700 CFU/m3
		Floor wipe	4.1x101 CFU/m2	-
		Wall wipe	0-1 CFU/m2	-
4.	Code D (Side of the road)	Total air germ numbers	770 CFU/m3	<700 CFU/m3
		Floor wipe	2.2x101 CFU/m2	-
		Wall wipe	0-1 CFU/m2	-
5.	Code E (In the alley)	Total air germ numbers	356 CFU/m3	<700 CFU/m3
		Floor wipe	5.6x103 CFU/m2	-
		Wall wipe	3.0x101 CFU/m2	-
6.	Code F (In the alley)	Total air germ numbers	870 CFU/m3	<700 CFU/m3
		Floor wipe	2.4x103 CFU/m2	-
		Wall wipe	0-1 CFU/m2	

After conducting research on airborne microorganisms in six residents' houses in the Janturan Warungboto area, the research data were obtained in Table 5. It is known that the number of total airgerms in residents' house spaces with sample code A; B; C; D and F exceed normal limits, where the number/number of airborne germs ranges from 760 CFU/m3-1610 CFU/m3 and one sample of a house room with code E shows that the number of airborne germs in the house is in the normal range of 356 CFU/m3 <700 CFU/m3. The measurement results show that each house, whether it is located on the side of the road or a house in an alley, has a different number of germs according to the level of activity indoors and outdoors. The results of the air quality test in this study indicate that the air quality of most residents' houses in Janturan Warungboto still does not meet health requirements. The number of air germ in the study was not meet the requirement according to Permenkes Number 1077 of 2011 concerning guidelines for air conditioning in home rooms. It is suggested that ventilation area requirements are at least 10% of the floor area by using a cross ventilation system [28].

Ventilation functions to keep the air in the house fresh, freeing room air from bacteria, especially pathogenic bacteria. Lack of ventilation will cause a lack of oxygen levels and increase in air humidity in the room [29]. The low quality of indoor air also related with the incidence of respiratory tract infection and also

other respiratory diseases [30]. The results of the study regarding the characteristics of the ventilation area of six sample houses have a ventilation area of less than 10% of the floor area, this is because the windows of the house are made of wood with very small vents so that the airflow in the house is not smooth which results in air not being able to carry bacteria out. The previous research shows that the cleanliness of air vents can affect room air quality because air vents are a medium for air circulation in the house. Apart from ventilation, the habit of opening windows also affects the air quality in the house because dust that accumulates on windows can be carried in when air circulation occurs and can contaminate the air in the room [31]. Most of the occupants of the six houses in the research sample had the habit of opening windows because the air would feel hot if the windows were not opened. However, there are some residents who do not open the windows of their homes for reasons such as disease-carrying vectors such as insects that can enter through windows. The longer the windows are open, the higher the potential for ambient air to enter the house. If the residential window is in an area with low ambient air quality, then the harmful pollutants contained in the air can enter and pollute the indoor air.

4. CONCLUSION

The quality of well water in the Janturan Warungboto area of Yogyakarta City contained coliform and *E. coli* which exceeded the water quality standard threshold according to the Minister of Health of the Republic of Indonesia No.416/MENKES/PER/IX/1990. From an air quality inspection based on the total number of airborne germs, the average airborne germ rate for each house exceeds the standard or quality standard threshold for the number of airborne germs in the home space according to RI Minister of Health No. 1077/MENKES/PER/V/2011.

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