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Groundwater Quality Study Based on the Existence of *Escherichia coli* as Bioindicator

A Rinanti^{1*}, M F Fachrul¹, D I Hendrawan¹, U Anisah¹, N K Alreekabi²

¹Environmental Engineering Department, Faculty of Architecture Landscape and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia

²Center of Urban & Regional Planning for Post Graduate Studies, University of Baghdad, Iraq

*Email: astririnanti@trisakti.ac.id

Abstract. The research aim was to observe the distribution pattern of *Escherichia coli* as groundwater pollution indicator in the most populous area, Matraman Sub-District Area in Jakarta, Indonesia (106°49'35" EL and 06°10'37" SL) consists of six (6) Urban Villages. The existence of *Escherichia coli* was measured with Most Probable Number (MPN) method as mentioned in Indonesian Standard Number 01-2332.1-2006. This research was also measure pollution parameter of Dissolved Oxygen (DO) and pH, and topography analyses used as well to determine groundwater flow direction. Groundwater sampling was conducted in several housings that have low, middle, and high income as indicator of sanitation quality which causes groundwater pollution by *Escherichia coli* bacteria. The research result showed that the level of average *Escherichia coli* was 345,9778, 310,0556, and 727,1389 MPN/100 mL. *Escherichia coli* distribution pattern was headed from southeastern to northwestern area, in correspondence with Matraman Sub-District topography. The average pH level, temperature and DO₀ in whole area respectively were 6.3, 24.7°C and 2.238 mg/L, that exceeded minimum water quality standards in Indonesian Minister of Health Regulation Number 492/MENKES/PER/IV/2010 regarding drinking water quality requirements. This study could be a reference for daily groundwater utilization in Matraman Sub-District and to provide information for further research.

Keywords: Groundwater Quality, *Escherichia coli*, Bioindicator, Indonesia

1. Introduction

Based on the data published by UNICEF [1] and WHO [2], Indonesia is categorized as one of 10 countries where one third of its population does not have adequate access to clean water. Generally, the citizen of Jakarta utilizes two types of water sources which are groundwater and processed water produced by Regional Drinking Water Company (or as commonly known as PDAM). However, the quality of groundwater in Jakarta area is on a critical condition.

The consumed drinking water as regulated in the Regulation of Indonesian Ministry of Health Number 492 Year 2010 Regarding Drinking Water Requirements, explains that the permitted healthy drinking water should not contain E-Coli or 0 MPN (Most Probable Number)/100 ml [3]. Also, the permitted temperature of the drinking water should be at $\pm 30^{\circ}\text{C}$ with pH levels of 6.5 – 8.5. The consumption of low quality drinking water that could not fulfill the standard quality criteria according to its designation would leads to health problems caused by pathogen microorganism, toxic chemical compound, and radioactive compounds [4].

The existence of fecal coliform bacteria (FCB) or *Escherichia coli* on groundwater can be used as one of pollution indicators since the bacterium is commonly living underground. The existence of fecal coliform in well water or groundwater can indicate that the groundwater is polluted with human feces



[5]. Besides its utilization as pollutant determining factor, the bacterium can also cause diarrhea, due to the unavailability of clean water access or a decent sanitation facility. Diarrhea is a disease commonly marked with an escalated frequency of defecation up to 3 times a day, and a change of feces consistency and shape. Diarrhea is generally caused by *Escherichia coli* infection in the digestive tract [3].

Groundwater quality monitoring result conducted by Ministry of Energy and Mineral Resources' Groundwater Conservation Center on a groundwater basin (GWB) in 2015 shows that out of the 85 monitored wells on their free aquifer layer, there are only 16 locations that fulfill the quality standards as regulated by the Regulation of Indonesian Ministry of Health Number 492 Year 2010 Regarding Drinking Water Requirements. Based on the finding, we can also assume that similar situation happens in other areas of Jakarta, especially Matraman District that is densely populated. Based on that specific reason, this research will be conducted to analyze groundwater quality based on its biological parameter, which is the existence of *Escherichia coli* and the bacterium's distribution pattern in Matraman District, supported by physical parameters such as temperature, pH and chemical parameter such as Dissolved Oxygen (DO).

2. Literature review

2.1 Research Area

This research is conducted in Matraman District, East Jakarta, Indonesia, which consists of 6 (six) Sub-Districts namely Kebon Manggis, Pal Meriam, Pisangan Baru, Kayu Manis, South Utan Kayu, and North Utan Kayu Sub Districts (Figure 1A) that are located between 106°49'35" East Longitude and 06°10'37" South Latitude, with area coverage of 4.85 km². Based on statistical data released on 2016, Matraman District has an area of 488 Ha with 171,249 people (consists of 86,257 men and 84,992 women), with 59,230 families and population density of 12,137 family/Km², as detailed in Table 1.

Table 1. Number of Neighbors (RT and RW) in Matraman District, 2015

No.	Sub-Districts	Area (Km ²)	Number of Families	RW	RT
1.	Kebon Manggis	0.78	6,561	4	64
2.	Pal Meriam	0.65	8,120	10	128
3.	Pisangan Baru	0.68	12,175	15	166
4.	Kayu Manis	0.57	9,949	9	133
5.	Utan Kayu Selatan	1.12	12,097	14	173
6.	Utan Kayu Utara	1.05	10,328	10	132
Total		4.85	59,230	796	

2.2. Sampling Point Determination

Sample point is chosen based on the Regulation of Indonesian Minister of Public Housing of the Republic of Indonesia No.10 of 2012 regarding Implementation of Housing and Settlement Areas with Balanced Occupancy, which states that sampling in an area needs to be carried out in 3 (three) household categories, namely high-income, medium-income and low-income households with a ratio of 1: 2: 3. Based on this, the research was carried out at 18 sampling points (Figure 1B) consisting of 3 houses with high-income economic status, 6 (six) houses with medium-income economic status and 9 houses with low-income economic status. More complete information is shown in Table 2.

The sampling point is determined by the stratified random sampling technique while the sampling is carried out three times over 3 periods, in accordance with the working procedure for water sampling based on Indonesian National Standard 6989.58: 2008 regarding water and wastewater - part 58 is the groundwater sampling method. Temperature was measured *in situ* with a thermometer [6]. The chemical parameters measured were Dissolved Oxygen (DO) and pH, both pH of sample and soil. Biological parameters are determined based on the presence of *Escherichia coli* as an indicator of groundwater contamination by human and warm-blooded animal feces [7].

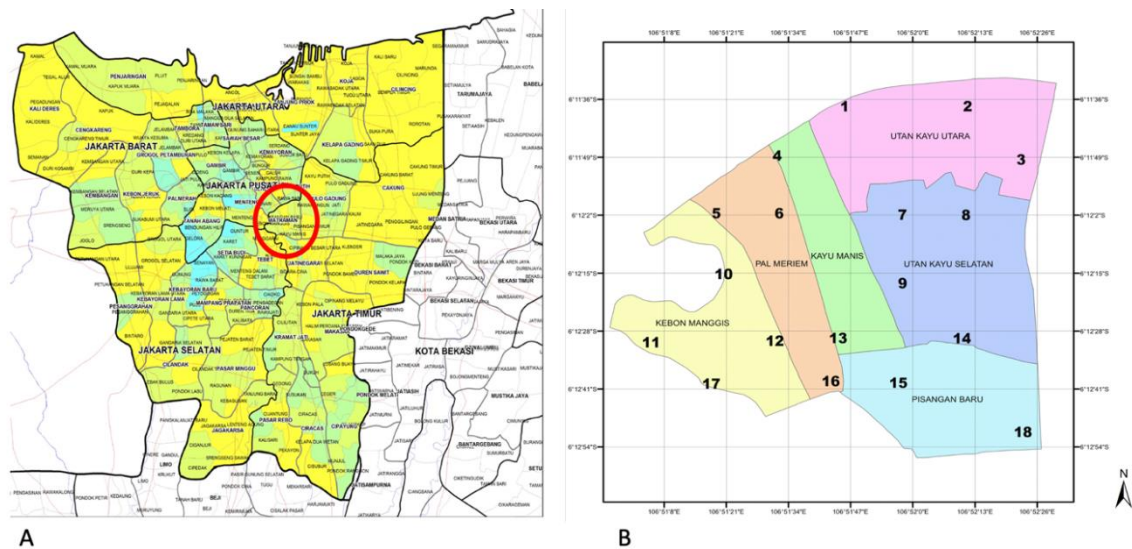


Figure 1. A) Matraman District, Jakarta, Indonesia; B) 18 sampling points in Matraman District.

The calculation of *Escherichia coli* presence is qualitatively carried out in stages based on SNI (Indonesian National Standard) 01-2332.1-2006 regarding Microbiological Test Methods-Part 1, namely Determination of Coliform & *Escherichia coli* which include Presumptive Test, Confirmative Test, and Complete Test [8], [9].

Table 2. Economic Status Based on Income or Ownership of Goods

Sub-Districts	Sample Points	Economic Status
South Utan Kayu	14	Medium Income
	7	Low Income
	8	Medium Income
	9	Low Income
North Utan Kayu	1	Low Income
	2	Medium Income
	3	Low Income
Kebon Manggis	10	Medium Income
	11	Low Income
	17	Low Income
Pisangan Baru	15	High Income
	18	High Income
Palmeriem	5	Medium Income
	6	High Income
	12	Low Income
	16	Low Income
Kayu Manis	4	Medium Income
	13	Low Income

2.3 Plotting Data into Surfer 13 Software

The software used is surfer 13 to plot the irregular XYZ tabular data. The grid is a series of vertical and horizontal lines in which the surfer forms a rectangular plane, so that it can be used as a basis for forming

three-dimensional contours and surfaces. In this case the X and Y axes determine the location, where the X axis is longitudinal and the Y axis is latitude, while Z is the data that you want to distribute. Then the data processing is carried out with a contour map, by making a distribution pattern and altitude or topography of the area. The resulted file can be exported with a jpg file and then put into the legend.

3. Result and Discussion

3.1 Well Depth and Well Distance to Septic Tank

The results of well depth measurements and the distance between the well and the septic tank at 18 sampling points in Matraman District, East Jakarta can be seen in Table 3.

Table 3. The well depth and the distance between the well and the septic tank

Sampling point	1	2	3	4	5	6	7	8	9
Depth (m)	25	12	25	10	15	15	14	15	22
Distance (m)	5	3	2	13	3	10	1.5	10	9
Sampling point	10	11	12	13	14	15	16	17	18
Depth (m)	14	20	14	12	14	15	15	10	30
Distance (m)	20	5	8	1.2	2	10	15	5	11.5

Based on Table 3, we can see the impact of high population density on several sampling points. Wells as clean water sources are closely located to septic tanks, which is not fulfill the suggested distance of 10 meters based on Indonesian National Standard 03-2398-2002 regarding Septic Tank Planning Procedures with Infiltration Systems. Besides that, based on the Regulation of Minister of Public Works and Public Housing Number 27/PRT/M/2016 regarding Implementation of Drinking Water Supply Systems, well distance to pollutant sources such as closets, ponds, garbage pits, and dirty dug hole should longer than 10 meters. The increasing population density in Matraman District can affect groundwater appropriateness, although there are several other factors such as flow pattern that can be used to determine groundwater flow direction, the width of the wells' lips, wells covers availability, and other sanitation parameters. Population density factor in the settlement causes land narrowing as main cause of groundwater pollution due to the increasing number of bacteria and septic tank that can move in any media, especially on a very short distance [10], [11].

Sanitation illustrates the people's daily activity in conducting their basic washing activities (bath, wash, and toilet). These routine activities are highly affecting groundwater quality. Based on the survey results on Matraman District, washing activities are generally individually conducted in each of the houses, although there are several areas that share their activities. This condition is caused by high population density that makes it difficult for the households to build proper septic tanks. This situation is also confirmed by the map of access to defecation facilities issued by Ministry of Public Works, Directorate General of Human Settlements, Directorate of Settlement Development, which shows that there are a number of households that has no available defecation facilities.

Technical geology map shows soil type classification in Jakarta, Bogor, Depok, Tangerang, Bekasi, Puncak, and Cianjur (Jabodetabekpunjur). Based the classification, the soil in Matraman area consists of sandy clay, loam sand, silt clay and sandy silt [9]. The porosity of clay is at 45% with 0.0005 Darcy's permeability. High porosity is not always showing that an aquifer will produce high volume of water on a well. The only water produced from an aquifer consists of water that flows through the land due to gravity. The flowing water can cause water pollution by *Escherichia coli* because the higher the porosity and land permeability, the easier it would be to distribute water [12].

3.2 Groundwater Quality

If we connect physical and chemical parameters with the existence of *Escherichia coli*, we can produce software surfer 13 as pictured in Figure 3. Based on Figure 3C, we can see that the red zone is located at sampling number 1, 6, 9, 12, and 13, which are all located in densely populated areas. On the specific

sampling points, we discover that *Escherichia coli* density is higher than 1100 MPN (Most Probable Number) per 100 ml. Based on the data shown in Table 3, well distance to septic tanks are unable to fulfill the applicable requirements as mentioned in the regulation, and increase the probability of groundwater pollution by *Escherichia coli* from the septic tanks.

The high density of *Escherichia coli* is also supported by pH data that shows pH level of 5 that included as an optimum pH for *Escherichia coli* bacterial growth (Figure 2A). DO value of 0.8 mg/l shows oxygen availability on the water sample (Figure 2B). There is no similarity on *Escherichia coli* distribution pattern and pH pattern but there is a similarity of DO distribution pattern based on the DO concentration.

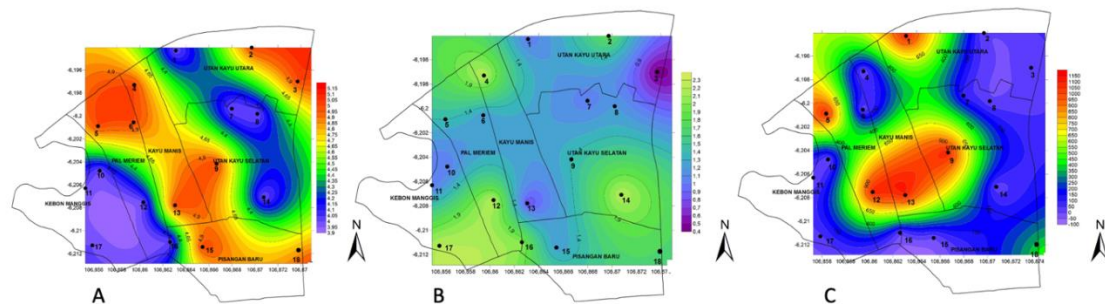


Figure 2. A) pH; B) Dissolved Oxygen; C) *Escherichia coli* Distribution.

The availability of Dissolved Oxygen is at 0.4027 mg/l to 2.2148 mg/l with average DO value of 1.443 mg/l indicates that there are *Escherichia coli* that conducts respiration and living in the groundwater. The temperature during this research was at 24-29 °C with average temperature of 27 °C [12].

Measurement result shows pH value at 4-5 with average value of 4.5. Based on [12], there is a strong relationship between pH and *Escherichia coli* growth, where *Escherichia coli* is highly sensitive on pH level changes to optimally grow. *Escherichia coli* are unable to tolerate highly alkaline or acidic environment. At the event of pH changes, enzyme in *Escherichia coli* will experience denaturation which can slow or even stop the bacterium performance and die. Ideal environment for *Escherichia coli* to optimally grow is at 7-7.5 degrees temperature with pH minimum of 4 and maximum of 9.

4. Conclusions

1. The quality of ground water in the Matraman District, East Jakarta is not suitable for use as drinking water because it does not meet the standards of the Regulation of the Minister of Health of the Republic of Indonesia No.492/2010 concerning Drinking Water Quality Requirements based on biological parameter of *Escherichia coli* existence. Even though the installation of 7 meter well pump has already fulfilled the required facility, well distance to septic tank is unable to fulfill both Indonesian National Standard 03-2398-2002 and Regulation of the Minister of Public Works and Public Housing Number 27/PRT/M/2016 requirements.
2. The pattern of *Escherichia coli* flow direction spreads from the Southeast to the Northwest. This happens due to the topographic map of Matraman District with higher elevation on southern part when compared to the North, East and West. The distribution pattern of *Escherichia coli* is not influenced by the depth of the well and the distance of the septic tank from the well but is influenced by other factors, which indicates that further research is required.

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