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The Occurrence of *Escherichia coli* in Groundwater of Bekasi City (Case Study: Jatiluhur, Sumur Batu, and Jatirangga Urban Villages)

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Abstract. The self-supply of groundwater at the household level, and especially in densely populated areas, is vulnerable to fecal contamination. The aim of this study was to assess the level of fecal contamination in groundwater of three urban villages in Bekasi City that depend greatly on groundwater: Jatiluhur, Sumur Batu, and Jatirangga. Water samples were taken from 255 households with various types of water sources in the rainy season from February-March 2020. *Escherichia coli* (*E. coli*) concentration was quantified with Colilert-18 using IDEXX Quanti-Tray/2000 based on Most Probable Number (MPN) method. *E. coli* levels were beyond the WHO standard and found in 60% of the sources; 24% were above 100 MPN/100 mL. The presence of *E. coli* in groundwater indicated a requirement for further treatment prior to the point of consumption and an urgent need to replace the water supply infrastructure for improved water sources.

1. Introduction

Water is a human right, and the demand for clean water increases along with increasing population growth. Providing access to safe water are challenges for developing countries, especially for urban areas [1], [2]. Many urban areas in developing countries, such as Dili, Beijing, New Delhi, Bangkok, Jakarta, and Bekasi, depend on groundwater as their source of water [2]. There, the groundwater at the household level is commonly provided by self-supply [3], drawn directly from stand-alone wells (dug wells or boreholes). Generally, these water sources are unregulated and the populace lacks the skills needed to investigate potential risks to water sources, leading to poor water quality [4].

Groundwater sources are also very susceptible to microbiological pollutants [2]. For example, research conducted by Khan, et al. [5] in Swat, Pakistan, detected high levels of fecal contamination in densely populated urban areas. *E. coli* in water samples taken from springs, dug wells, and boreholes

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had Most Probable Number (MPN) values more than 100 MPN/100 mL. The results of multivariate and univariate analysis have revealed that risk factors of groundwater contamination include nearby sanitation facilities, population density, and agricultural runoff in the form of human and animal waste.

Eschericia coli (*E. coli*) is the recommended measure for fecal contamination by WHO. The occurrence of *E. coli* in water is widely accepted as an indicator of fecal contamination [1]. Fecal contamination in drinking water is a key driver of diarrheal disease. Previous research has confirmed that diarrhea is one of the key causes of mortality in children in developing countries [6]. Data from the Ministry of Health of Indonesia in 2016 have indicated that diarrhea in Indonesia has reached 7 million cases annually, with the highest number of cases of diarrhea, at 1 million, occurring in West Java Province.

Bekasi City is one of the most populous cities in Indonesia with a population of 2.8 million [7]. Providing clean water for a population this size is a challenge for the Bekasi City Government. Based on data from the Tirta Patriot Regional Water Company and Tirta Bhagasasi Regional Water Company in 2018, these companies are only able to serve 21.76% of the City of Bekasi. This inadequate supply of clean water has forced people to look for other sources. Census data for the Central Bureau of Statistic (BPS) in 2010 indicated that more than 50% of people in several sub-districts of Bekasi City, including Jatisampurna, Bantargebang, and Jatiasih, depend on groundwater as their clean water source.

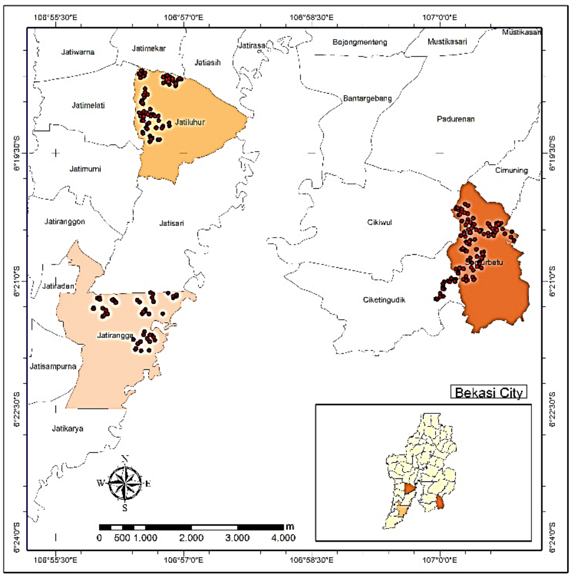
Providing safe and clean water is a priority for Bekasi City's government. The absence of research on groundwater quality at the household level in Bekasi City prompted the present water quality testing study to assess the level of *E. coli* contamination in the city's groundwater sources.

2. Tools and Methods

2.1 Study Site

The urban villages of Jatiluhur, Sumur Batu, and Jatirangga are located in the southern part of Bekasi City. Jatiluhur has a population of 30,734 people with a population density of 7,759.25 persons per km^2, Sumur Batu has a population of 20,183 inhabitants with a population density of 3,547.38 persons per km^2, and Jatirangga has a population of 13,596 people with a population density of 2,728 persons per km^2. These three urban villages were chosen as our study sites based on several considerations, including the lack of a water supply from the Bekasi City's Local Water Supply Utility (PDAM), high groundwater usage, high poverty rates, high population density, and the availability of hydrogeological data, such as aquifer type, soil, and aquifer productivity. The study was conducted in the rainy season from February to March 2020. A total of 255 water samples were collected from households in the urban villages Jatiluhur (87), Sumur Batu (108) and Jatirangga (60) (Figure 1).

Figure 1. Location map of the study area



2.2 Water Quality Analysis
A total of 255 source water samples originating from 1 artesian well, 14 protected dug wells, 233 drilled wells, and 14 protected unprotected dug wells in the three urban villages were collected for analysis of *E. coli*, pH, and temperature. The only artesian well is found in the Sumur Batu and arose from a grant from the DKI Jakarta government as a form of compensation for poor groundwater quality due to the Bantar Gebang landfill. Water sampling was performed using a 100 mL sterile whirl-pack for *E. coli* analysis and 500 mL polypropylene bottles for pH and temperature analysis. pH measurement was carried out directly in the field using a Hanna HI 9813-5 multiparameter probe, and temperature measurements were measured using a digital thermometer. Samples for microbial analysis were stored at 2-8 °C for transport and processed within six hours in the field laboratory. *E. coli* quantification was performed with Colilert-18 using the IDEXX Quanti-Tray/2000 MPN method (IDEXX, SA) and enumeration of *E. coli* using the Most Probable Number. The testing procedures and enumeration of *E. coli* have been explained previously [8].

2.3 Quality Control
Quality control of microbiological analysis was done using field blank, laboratory blanks, and duplicates. Field blank, lab blank and duplicate samples were taken every day once every day. This procedure was conducted to ensure the samples were safe from contamination.

3. Results
3.1 Groundwater Quality Test Results
Based on the test results, water quality in Bekasi City (specifically in the three urban villages) showed an average level of *E. coli* of 276.48 MPN/100 mL (95% CI 170.2–613.1), the average pH level was 5.47, and the average temperature level was 28.94 °C (Table 1). These results illustrate that the water quality for the *E. coli* parameter exceeds the World Health Organization (WHO) quality standard for drinking water, set at 0 MPN/100 mL, and had a pH below the WHO standard quality standard, which is pH 6.5–8.5.

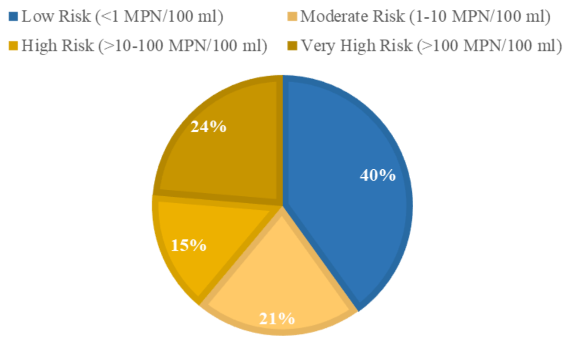
Table 1. Results of Groundwater Quality Testing in Bekasi City

Parameter	Range	Mean	SD	WHO Standards
Temperature ° C	22.6–38.6	28.94	1.73	-
pH	3–8.3	5.47	0.77	6.5–8.5
E. coli MPN/100 mL	0.5–2420*	276.48 (95% CI 170.2–613.1)	688.64	0

*Lower and upper limits of detection for IDEXX/2000 are 1 MPN and 2420 MPN respectively (so in fact the true range of *E. coli* concentrations may be greater than the value in presented table.

3.2 Levels of Fecal Pollution in Groundwater in Bekasi City
The WHO guidelines contain 4 categories of risk of fecal contamination: (i) <1 MPN/100 mL, (ii) 1–10 MPN/100 mL, (iii) 10–100 MPN/100 mL, and (iv)> 100 MPN/100 mL. Figure 2 shows that as much as 40% of groundwater sources are in a safe condition i.e., <1 MPN/100 mL; however, 24% of the groundwater sources are categorized as having a very high risk of fecal contamination, at > 100 MPN/100 ml.

Figure 2. Risk category of fecal contamination in Bekasi City groundwater based on WHO Standards



3.3 Relationship between Wells Types and Fecal Contamination Risk Categories

Table 2 shows the fecal contamination in various types of wells in the three urban villages in Bekasi City. The borehole is the most widely used type of well for groundwater sources. Boreholes and protected dug wells are the types of wells considered improved water sources (WHO, 2011). Nevertheless, both well types are still vulnerable to fecal contamination. This can be seen in Table 2, which shows that 126 drilled wells and 9 protected dug wells had fecal contamination. Likewise, with unprotected dug wells, 99%, or 17 unprotected dug wells, were contaminated with fecal microbes.

Table 2. Fecal contamination in various types of wells in Bekasi city

Type of Well	<1 MPN/100 mL		≥1-10 MPN/100 mL		> 10-100 MPN/100 mL		> 100 MPN/100 mL	
	n	%	n	%	n	%	n	%
PW (n = 11)	2	18.2%	3	27.3%	3	27.3%	3	27.3%
UW (n = 18)	1	5.6%	6	33.3%	2	11.1%	9	50.0%
BH (n = 225)	99	44.0%	42	18.7%	35	15.6%	49	21.8%
ART (n = 1)			-	-	-	-	1	100%

*PW = Protected Wells; UW= Unprotected Wells; BH = Boreholes; ART= Arthesian Wells

4. Discussion

This research is the first population-based household drinking water quality study conducted in Bekasi City. Water samples were collected from the urban villages of Jatiluhur, Sumur Batu, and Jatirangga for measurement of pH, temperature, and *E. coli* to monitor groundwater quality. The average concentration of *E. coli* in groundwater samples was 276.48 MPN/100 mL (95% CI 170.2–613.1), (Table 1), a level that exceeds the quality standards recommended by WHO (2011). These findings indicate that the water sources are unsafe for food processing and drinking. Consumption of contaminated groundwater can be a major cause of diarrheal disease and death [1]; therefore, water treatment prior to drinking is needed to reduce risk of contamination from fecal pathogens and make it safer for human consumption.

The pH levels were also below the WHO quality standards. Overall, pH levels of 7 or lower indicate an increase in acidity [9]. Fluctuations in pH affect the mucous membranes, produce a bitter taste, and can cause corrosion of household plumbing [10] [5] [11]. Low pH can cause leaks in pipes, thereby allowing contaminants to enter boreholes [11]. The pH can also affect human health indirectly by bringing about changes to other water parameters, such as metal solubility and survival of pathogens including fecal coliforms [5].

The temperature of the water samples ranged from 22.6–38.6 ° C, a result that is influenced by the tropical climate. According to WHO (2011), high temperatures can increase the risk of microbial growth and corrosion. In addition, high temperatures can increase the rate of inactivation of *E. coli* [11].

One factor affecting groundwater contamination is the type of well. Overall, 94.4% of the typical unprotected dug wells in the urban villages had a high concentration of *E. coli* (**Table 2**). This agreed with the findings of similar research conducted by Maran, et al. [12], who found that *E. coli* contamination was influenced by the borehole diameter, contact bucket, submerged motor pumps, and anthropogenic activities. In addition, shallow wells (<5 meters) were more susceptible to contamination because of their proximity to the ground surface [12]

5. Conclusion

This study assessed the level of fecal contamination in Bekasi City's groundwater, based on samples collected at study locations in the urban villages of Jatiluhur, Sumur Batu, and Jatirangga. Contamination by *E. coli* was detected in 60% of the sources. Overall, 24% of the sources had *E. coli* concentrations that exceeded 100 MPN/100 mL and were categorized as having a very high risk of fecal contamination. This result illustrates that the groundwater in Bekasi City is not safe for drinking and needs further treatment before it is consumed. High *E. coli* concentrations were found mostly in unprotected wells, indicating that the condition of the self-supply water infrastructure might affect the degree of *E. coli* contamination. Replacement of the existing water supply infrastructure is therefore recommended to improve the water source.

References

[1] Onyango, AE, Okoth, MW, Kunyanga, CN and Aliwa, BO 2018. Microbiological quality and contamination level of water sources in Isiolo County in Kenya. *J. Environ. Res. Public Health* **2018**:2139867

[2] Brindha, K and Schneider, M 2019. Impact of urbanization on groundwater quality. *GIS and Geostatistical Techniques for Groundwater Science*, (Amsterdam: Elsevier) pp 179–186

[3] Carrard, N, Foster, T and Willetts, J 2019. Groundwater as a source of drinking water in southeast Asia and the Pacific: A multi-country review of current reliance and resource concerns. *Water (Switzerland)*, **11** (8): 1605.

[4] Grönwall, JT, Mulenga, M and Mcgranahan, G 2010. *Groundwater, self-supply and poor urban dwellers A review with case studies of Bangalore and Lusaka Human Settlements Working Paper Series Water and Sanitation -26*.

[5] Khan, K, Lu, Y, Saeed, MA, Bilal, H, Sher, H, Khan, H, Ali, J, Wang, P, Uwizeyimana, H, Baninla, Y., Li, Q., Liu, Z., Nawab, J., Zhou, Y., Su, C. and Liang, R. 2018. Prevalent fecal contamination in drinking water resources and potential health risks in Swat, Pakistan. *J. Environ. Sci. (China)*, **72**: 1–12.

[6] Kirby, M.A., Nagel, C.L., Rosa, G., Iyakaremye, L., Zambrano, L.D. and Clasen, T.F. 2016. Faecal contamination of household drinking water in Rwanda: A national cross-sectional study. *Sci. Total Environ.*, **571**: 426–434.

[7] Kota Bekasi Dalam Angka 2019. Badan Pusat Statistik

[8] Abia, A.L.K., Ubomba-Jaswa, E., Genthe, B. and Momba, M.N.B. 2016. Quantitative microbial risk assessment (QMRA) shows increased public health risk associated with exposure to river water under conditions of riverbed sediment resuspension. *Sci. Total Environ*, **566–567**: 1143–1151.

[9] Ahmad, MM and Mustapha, A 2018. Assessment of the water quality from hand dug wells and boreholes water in Rogo Local Government Kano State , Nigeria. **103**(August): 257–264.

[10] Patil, P.N., Sawant, D. V and Deshmukh, R.N 2012. Physico-chemical parameters for testing of water – A review. **3**(3): 1194–1207.

[11] Engström, E., Balfors, B., Mörtberg, U., Thunvik, R., Gaily, T. and Mangold, M. 2015. Prevalence of microbiological contaminants in groundwater sources and risk factor assessment in Juba, South Sudan. *Sci. Total Environ.*, **515–516**: 181–187

[12] Maran, N.H., Crispim, A., Iahnn, S.R., Araújo, R.P. De, Grisolia, A.B., Mari, K. and Oliveira, P. 2016. Depth and well type related to groundwater microbiological contamination. *Int. J. Environ. Res. Public Health* **13** (10):1036

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