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Effect of boiling and water storage practices on *E. coli* contamination of drinking water in the city of Bekasi (case study: Jatiluhur, Sumur Batu, and Jatirangga Villages)

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Abstract. In the city of Bekasi, a large proportion of the population uses groundwater and is at risk of *Escherichia coli* contamination. Water can remain contaminated by *E. coli* even after treatment, and it may be recontaminated through storage practices. This research aims to analyze the effect of boiling and the correlation of water storage practices to *E. coli* contamination in the drinking water of households in the villages of Jatiluhur, Sumur Batu, and Jatirangga. Among 54 randomly surveyed households, 98.1% boiled their water before drinking. The results show that 67% showed decreased *E. coli* after boiling. Boiled water with a low risk of *E. coli* made up 64.8% of the samples, a medium risk made up 25.9%, a high risk made up 7.4%, and a very high risk made up 1.9%. Observation of water storage practices showed that 51% of households store water in a jug after treatment, and 35.3% store it in a kettle or pot. Residents used a container equipped with a lid 94.1% of the time. The statistical analysis revealed no correlation between water storage practices and *E. coli* contamination in drinking water. Boiling water can be a fairly effective way to decrease *E. coli* contamination; however, other factors that can recontaminate water, such as storage hygiene and hand washing, require attention in future studies.

1. Introduction

Water is the most essential element for humans and other living things [1]. Humans need water, especially for drinking. Based on the Ministry of Health Regulation of the Republic of Indonesia Number 492 of 2010, drinking water is water that may or may not undergo treatment that meets health requirements and can be drunk directly. Water for drinking must be free from contamination and safe for consumption. In accordance with Sustainable Development Goals (SDG's) 6.1 target, water consumed by the community should be easy to access and free of contaminants. One indicator of water contamination is the presence of *Escherichia coli*. Ministry of Health Regulation 492 of 2010 states that the microbial quality standard for *E. coli* in drinking water should be 0 in 100 ml samples [2].

E. coli are commensal bacteria, intestinal pathogens, and extraintestinal pathogens that can cause urinary tract infections, meningitis, and septicemia. Pathogenic *E. coli* can cause diarrhea in humans [3]. In Indonesia, the level of diarrhea in infants reached 12.3% in 2018 [4]. In fact, during the same



year, this disease caused 4.76% of deaths in children in Indonesia [5]. Diarrhea can also cause stunting or chronic malnutrition problems due to lack of nutrition over a long period, resulting in growth disorders, or stunting, in children. In 2019, the percentage of stunting in children under five years old in Indonesia was 27.67% [6].

Diarrhea due to *E. Coli* contamination is associated with both sanitation conditions and inadequate access to sources of clean drinking water, which becomes a pathway for organisms to enter the human body [7]. Water treatment and hygienic storage can decrease the concentration of *E. coli*.

Individual households can treat water to ensure its safety through a variety of methods, such as boiling, filtration, chemical treatment, and solar disinfection [8]. Boiling is perhaps the oldest way to disinfect water and is widely used at the household level. If it is practiced properly, boiling can be one of the most effective ways to kill or deactivate the pathogens that can be transmitted through water, including bacterial spores and protozoa [9]. In Indonesia, boiling water is an easy, practical, and inexpensive way to improve water quality [10]. Boiling drinking water has become a culture for some people in Indonesia. Studies conducted at the Cikapundung riverbank area in Bandung showed that 62% of the users of protected wells treated their drinking water by boiling, and 67% of the users of unprotected wells boiled their water before drinking [11]. Boiling water can reduce the average concentration of *E. coli* by 83%; however, *E. coli* was still detected in 70.4% of the water of those who reported that they boiled their water [12]. This shows that water is not completely free from *E. coli* contamination even after treatment.

Another factor that can affect the presence of *E. coli* after boiling is the use of water storage containers. The type of container used and the availability of a lid are the aspects that should be taken into consideration [13]. When water is stored in gallons, bottles, or thermoses, it has a 42% chance of contamination, and when it is stored in dispensers, it has a 37% chance of contamination with *E. coli* [12]. In addition to these aspects, it is important to keep the storage container clean by washing it at least once a week or more often if possible [14].

Bekasi is the most populated city in the province of West Java; it has a population of 2,873,484 people. The population growth rate reached 2.64% from 2013 to 2017. The city is also densely populated, with an average density of 13,651.4 people/km² [15]. Unfortunately, the high population does not have corresponding adequate water services. In Bekasi, the Regional Drinking Water Company (PDAM) supplies piped water services, but it services only 26.8% of the population. Meanwhile, the rest of the population uses groundwater to fulfill their water needs; 2.1 million people construct boreholes or dig wells at their dwellings, in their yards, or in plots to access groundwater for their household [15]. Considering the large number of people using groundwater in Bekasi and the effect of *E. coli* contamination on drinking water, it is important to understand its extent. As mentioned above, *E. coli* is still detected after boiling, and usage of water containers can affect *E. coli* contamination. Therefore, this study will analyze the effects of boiling water and water storage practices for drinking water in Bekasi and, especially, in three urban villages: Jatiluhur, Sumur Batu, and Jatirangga.

2. Materials and methods

2.1. Study location

The study locations for this research are three urban villages in Bekasi: Jatiluhur, Sumur Batu, and Jatirangga. The study was conducted during the rainy season, from February to March 2020. These study locations were chosen for their high population density, high poverty rates, and lack of piped water connections or PDAM, which results in a high dependence on groundwater use.

Out of the 98 households sampled in this study, only 54 used groundwater as their source of drinking water (instead of bottled water, gallon water, or refill water). Since this research is focused on boiling water for drinking, and people do not boil their bottled water, gallon water, or refill water, only data from the 54 households were analyzed. The study locations are shown in Figure 1 below.

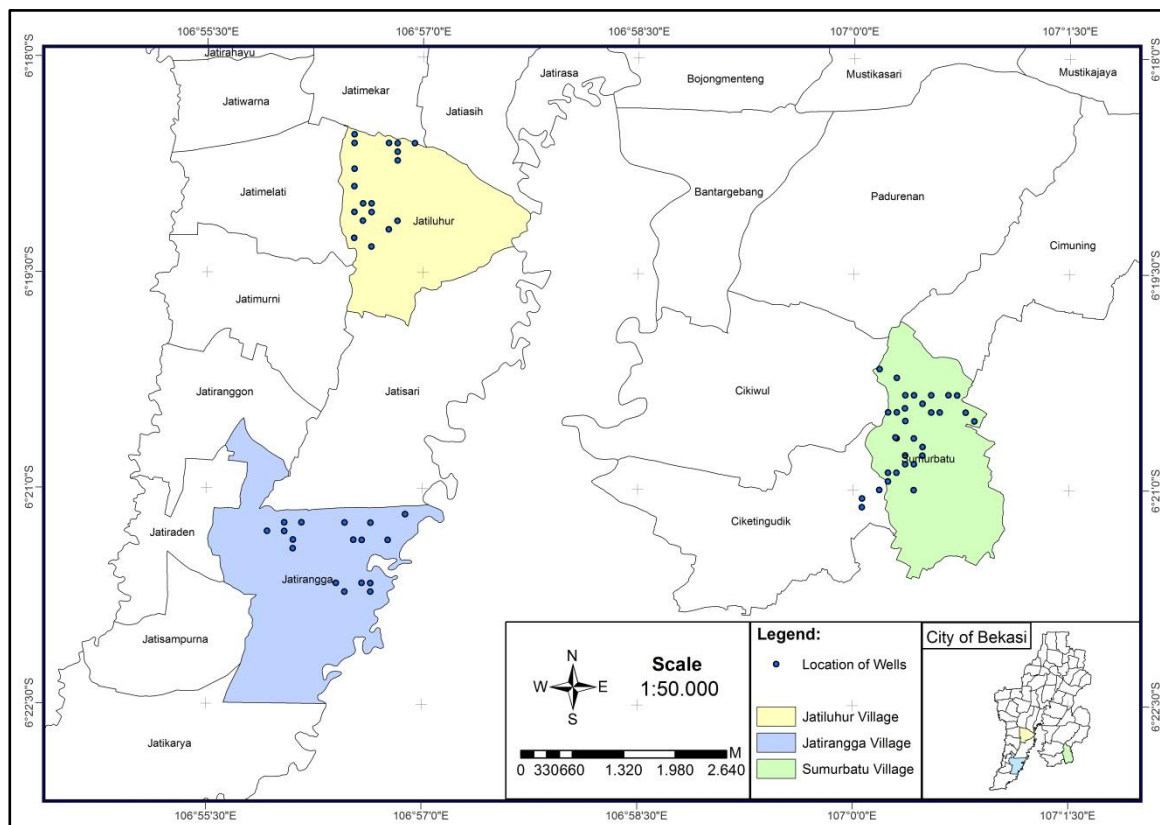


Figure 1. Study location map

2.2. Data collection

Data collection was carried out using both a questionnaire that included questions regarding how the households treat groundwater before drinking it and observations of their storage containers. The Survey Solution application was used to facilitate data collection for the interviewer. Coordinate data from the location of the research well with GPS was also collected to be mapped using the ArcGIS application. In addition to collecting data using questionnaires, water sampling was done in the groundwater source (boreholes and/or dug wells) and at the point of use (POU) for drinking water. About 100 ml of each water sample was collected in a sterile Whirl-Pak and stored in a cooler bag with a temperature of $\leq 4^{\circ}\text{C}$. The samples were taken to the laboratory and were measured for *E. coli* concentration per 100 mL using IDEXX-Colilert 18. This method uses a Quanti-tray with 49 large columns and 48 small columns to see the color changes that occur after incubation with reagents [16],[10]. The maximum storage time before testing was six hours. The *E. coli* concentration was calculated using the most probable number (MPN). To control the quality of the water samples and to ensure that they are safe from contamination, field blanks, laboratory blanks, and duplicates were taken once every day.

3. Results and discussion

3.1. Effectiveness of boiling water on *E. coli* reduction

Based on the results, households in the study location treat their groundwater by boiling it and adding chlorine to it. Data shows that 98.1% of the total samples (53 households) treated their water by boiling, and the remaining 1.89% (1 household) treated their water by adding chlorine. The majority of the population treated their water by boiling it prior to drinking.

This study also found that boiling water did not remove *E. coli* completely. Comparing the concentration of *E. coli* in the groundwater source and the concentration of *E. coli* in the drinking water after boiling revealed that *E. coli* was only removed from 67% of the samples. These results

prove that boiling is a fairly effective way to reduce the concentration of *E. coli*. While boiling decreases *E. coli* levels, it can still be detected in drinking water [12]. However, this study also found that the concentration of *E. coli* did not change in 19% of the samples and that it increased in 14% of the samples, as shown in Figure 2 below. It is possible that this is due to inadequate boiling procedures, improper water handling after boiling (leading to recontamination), or false reports of boiling [17]. Moreover, when water begins to cool after boiling, it is vulnerable to recontamination from hands and utensils, because it contains no residual disinfectant and is often stored in open vessels [9].

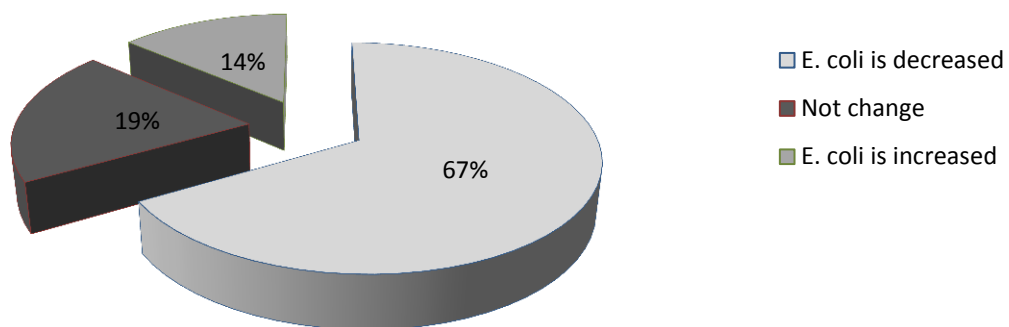


Figure 2. Effectiveness of decreasing *E. coli* by boiling

3.2. Risk assessment of *E. coli* after boiling

Although boiling water can be a fairly effective way to decrease the contamination of *E. coli*, *E. coli* remains after treatment. A risk assessment of *E. coli* is needed to determine whether water is safe for consumption. Assessing the risk of drinking water supplies can increase trust in drinking water safety [18]. Based on WHO's 2011 report, "Guidelines for Drinking-Water Quality", the risk level of *E. coli* can be divided into four categories: low, medium, high, and very high risk, which are defined as *E. coli* levels of <1, 1–10, 11–100, and >100 MPN/100ml, respectively [19]. The results showed that 64.8% of boiled water had low risk, 25.9% had medium risk, 7.4% had high risk, and 1.9% had very high risk *E. coli* contamination (Figure 3). This result indicates that drinking water has the potential to cause waterborne disease. A prior study in Aceh province, Indonesia showed that boiling water does not guarantee that it will be free from *E. coli* contamination [17]. Also, a study in Tanzania found that households that boiled drinking water had higher percentages of diarrhea (16%) than control households (9%) [7]. Therefore, it is important to discover the source of recontamination with *E. coli* after boiling in order to address the health issue caused by *E. coli* contamination. As mentioned before, water storage practices may contribute to increased *E. coli*. Observation of water storage practices by the households in the study locations is explained in the next part.

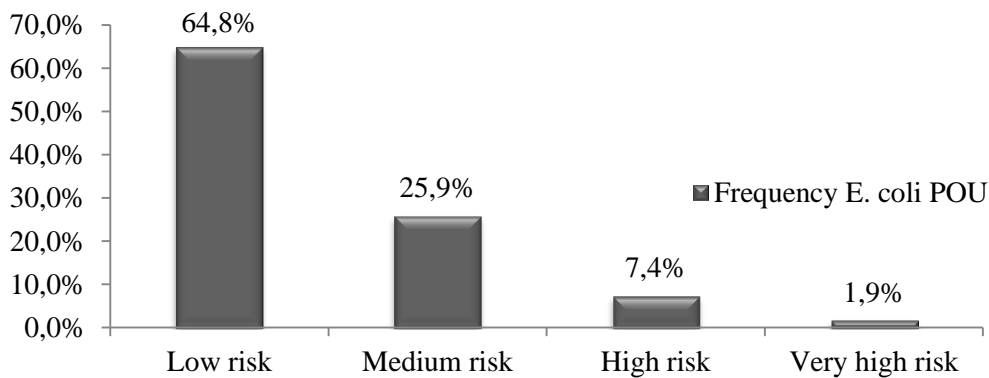


Figure 3. Groundwater treatment

3.3. Correlation of water storage practices with *E. coli* contamination

Data for water storage practices was processed for 51 out of the 54 samples and remained unknown for the other 3 samples. Based on the data, 51% of households (n=51) store boiled water in a jug, 35.3% use a kettle/teapot, and the rest use a pot, gallon, bottle, or bucket (Table 1). The households that use a cover on their water container made up 94.1% of the sample (Table 1). Covering the water container is important to protect the water from contamination. If contamination occurs, organic compounds that remained after boiling can potentially support bacterial growth [8]. Based on previous studies, about 44% of boiled water can be contaminated with *E. coli* because the container is open and easily touched by hands [10].

In addition, other factors that influence the risk of contamination are higher temperatures, length of storage time, and the presence of air or dust particulates [13]. The data shows that 39.2% of the samples kept their water for one day, and 41.2% kept their water after boiled one day ago (Table 1). People tend to boil only the quantity of water they need for a short period, so that the water does not need to be stored for a long time after boiling.

Table 1. Water storage containers (n=51)

		n	%
Type of Container	Jug	26	51.0%
	Kettle/Teapot	18	35.3%
	Bottle	1	2.0%
	Bucket	1	2.0%
	Gallon	2	3.9%
	Pot	3	5.9%
Container Cover	Yes	48	94.1%
	No	3	5.9%
Storage Time in Container (days)	0	16	31.4%
	1	20	39.2%
	2	9	17.6%
	3	5	9.8%
	7	1	2.0%
Days After Water Undergo Boiling (days)	0	17	33.3%
	1	21	41.2%
	2	9	17.6%
	3	3	5.9%
	7	1	2.0%

The correlation of *E. coli* contamination at POUs with storage containers was analyzed using the SPSS application and Spearman's correlation. Spearman's test is used to find the compatibility between the dependent variable and the independent variable using the ordinal data scale, which is changed to rank hypothesis testing using two tails to test whether the sample is larger or smaller than the range of values on both sides of the specified data range. The concentration of *E. coli* is divided into three categories: ≤ 1 MPN/100 ml, ≤ 10 MPN/100 ml, and ≤ 100 MPN/100 ml. The results showing correlation between the water quality at POUs and storage practices are shown in Table 2.

Table 2. Correlation of *E. coli* at point of use with storage practices (n=51)

	≤ 1 MPN/100 ml		≤ 100 MPN/100 ml		≤ 100 MPN/100 ml	
	<i>Correlation Coefficient</i>	<i>Sig. (two-tailed)</i>	<i>Correlation Coefficient</i>	<i>Sig. (two-tailed)</i>	<i>Correlation Coefficient</i>	<i>Sig. (two-tailed)</i>
Type of Water Storage Containers	-0.034	0.814	0.101	0.480	0.090	0.530
Container Cover	-0.146	0.306	-0.082	0.565	-0.035	0.805
Storage Time in the Container (days)	0.121	0.399	0.141	0.322	-0.005	0.972
Days After Water Undergo Boiling (days)	0.101	0.483	0.223	0.115	-0.020	0.887

Based on the results of Spearman's test, none of the variables are significant (>0.05). This indicates that there is no correlation between storage containers, container covers, storage time, or length of time after processing with *E. coli* contamination at POUs water. Furthermore, the output results above the correlation coefficient values are below number 0.25 entirely, revealed that the coefficient values indicate a very weak correlation between the independent and dependent variables [20]. The results confirm previous studies, which found no relationship between improved storage containers, storage time with *E. coli* contamination [7],[17]. That might be because the parameters of container hygiene and hand washing were not observed and included. Container hygiene is important and can be maintained by cleaning at least once a week or more often if possible [14]. Pouring water is also preferable to scooping it from a glass container because the water can be easily contaminated when the user's hands are dirty [14]. Based on previous studies, if water has been contaminated from water sources and improper boiling practices was done, then the type of water storage container will have no effect on protection from microbial contamination [17].

4. Conclusions

Boiling water is a common practice in almost all households at the study site. As many as 98.1% of households treat their groundwater by boiling. After boiling, *E. coli* was decreased in 67% of the samples, no change was detected in 19% of the samples, and *E. coli* was increased in 14% of the samples. A total of 64.8% of boiled water showed a low risk of *E. coli*, 25.9% showed a medium risk of *E. coli*, 7.4% showed a high risk of *E. coli*, and 1.9% showed a very high risk of *E. coli*. Most of the households (51%) store their boiled water in a jug, followed by 35.3%, who store it in a kettle or teapot. In addition, 94.1% of households used water containers with a lid or cover, and most of them

stored the boiled water for only one day before consuming it. The statistical analysis showed no correlation between the water storage practices (type of water container, availability of container cover, storage time in the container, days since boiling) and *E. coli* contamination at the POU for drinking. Other parameters, such as container hygiene and hand washing, are worth considering for future research.

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