Environmental health risks (EHR) and *E. coli* concentration in refilled drinking water stations in Palembang (a cross-sectional study)

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Abstract. This study aims to determine the relationship between environmental health risk (EHR) consisting of external area, building design and facilities, refilled station operators, equipment, and raw water, and the concentration of *Escherichia coli (E. coli)* in drinking water produced by the refilled drinking water station (RDWS). This cross-sectional study was conducted in 106 RDWS in Palembang City, Indonesia. The EHR checklist used a sanitation inspection and the concentration of *E. coli* obtained from water sample examinations using the membrane filter method. The average concentrations of *E. coli* (SD) in raw water and treated drinking water that is ready to distribute to the consumer, were 82 CFU/100 mL (121 CFU/100 mL) and 18 CFU/100 mL (45 CFU/100 mL), respectively. There was a significant difference in the average *E. coli* concentration between the raw water used and the treated drinking water ($Z = -6.260$; $p < 0.001$). There was a weak relationship between the outdoor area variable ($r = -0.265$) and equipment ($r = -0.336$) with the concentration of *E. coli* in the produced drinking water. Enforcement of regulations related to monitoring and reporting of drinking water quality needs to be carried out consistently to maintain the safety of refilled drinking water.

1 Introduction

Water is a basic thing that humans need for a healthy community, whether intended as clean water, drinking water, or other purposes. Globally, the use of bottled drinking water is increasing. It is estimated that there will be an increase in consumption of bottled drinking water by 513 billion liters by 2025 [1]. In Indonesia, population growth and high urbanization in urban areas have led to an increase in demand for water. Water supply services in urban areas are also carried out by non-public providers such as providing various bottled drinking water products ranging from multinational brands to refilled drinking water stations (RDWS) [2]. The number of RDWS in urban areas in Indonesia increases by 13.8% every year [3]. This increase

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could occur because refilled drinking water is the main type of drinking water facility for 31.1% of urban households for practical reasons [4].

Based on the 2021 Indonesian Health Profile, South Sumatra has only reached 50% of food processing places that meet health requirements. Palembang, the capital of South Sumatra Province, has the highest number of RDWS but has 29,1% RDWS that meets the health requirements [5]. Based on monitoring the quality of drinking water at RDWS in Palembang, it is known that 77.06% of samples do not meet health requirements with 11.45% of them not meeting requirements for microbiological parameters [6]. The microbiological requirement that must be met is the absence of Escherichia coli (E. coli) in the drinking water produced. The presence of this bacteria in the water indicates that the water has been contaminated by dirt or poor hygiene conditions in the food processing area [7]. There are many strains of Escherichia identified and cause diseases ranging from mild gastroenteritis to kidney failure and septic shock [8]. People with inadequate drinking water quality have a 4.2 times higher risk of being infected with diarrhea [9]. Furthermore, approximately 2 – 7% of infections from E. coli in humans can cause complications, namely the destruction of red blood cells and kidney failure called hemolytic uremic syndrome [10].

People consume refilled drinking water (RDW) without processing it first, so it is necessary to guarantee the safety of the drinking water [11]. World Health Organization (WHO) recommends a system of risk assessment, monitoring, and management as well as consistent risk communication from source to consumption by the community to ensure the safety of drinking water in the community. One of the approaches for risk assessment is by using sanitation inspection and water quality testing [12]. To assess sanitation hygiene in RDWS, WHO has a kiosk sanitation inspection form intended for drinking water providers who have the same principle as RDWS, namely selling water that has been treated at a certain rate [13]. Meanwhile, the RDWS sanitation hygiene inspection in Indonesia refers to the form published in the Minister of Health's regulations in Risk-Based Food Sanitation Hygiene Supervision Guidelines. The use of a combination of these two forms is expected to provide a more comprehensive picture of environmental health risks in RDWS.

Based on the description above, it is necessary to understand the potential public health risk of RDW in Palembang. We estimated the risk by analyzing the concentration of *E. coli* and assessing the potential sources of contamination using the sanitary inspection forms.

2 Materials and methods

2.1 Participant

There are 739 RDWS registered with the Palembang City Health Office. After calculating the number of samples, 106 RDWS were obtained which were selected using probability proportional to size represent all sub-districts in Palembang City, namely 18 sub-district. The RDWS selected were those that process drinking water using methods other than boiling. During the visit, we took unprocessed water, namely raw water, after processing ready to be distributed to the consumers, namely drinking water, and assessed the potential source of contamination using sanitary inspections (SI).

2.2 Methods

This research is an analytical observational study with a cross-sectional study design. The dependent variable is the *E. coli* concentration in drinking water and the independent variables are the outdoor area, building design and facilities, refill station operator, equipment, and raw water. Environmental health risk is obtained from the average of independent variables.

The RDWS that was sampled recorded its coordinates using a global positioning system (GPS) device. Sample collection of raw water was conducted either at the outlet pipe or by submerging the sample bottle into the raw water. Drinking water samples were taken at the outlet tap used for filling drinking water. The samples were transported to the laboratory using a cooler box equipped with cooling materials [14]. In this study, the transportation of samples took approximately 6 hours then examined using the membrane filter method, where the water samples were passed through a 0.45 µm membrane filter paper and placed onto chromocult coliform agar medium that had been prepared in a petri dish, then incubated for 24 hours (Figure 1). Environmental health risk observation utilized an SI form adapted from the Guidelines for Food Hygiene and Sanitation Risk-Based Surveillance by the Ministry of Health and the WHO's 2021 sanitation inspection for kiosks. The statements in the form are conformity statements, thus the higher the score obtained, the better.

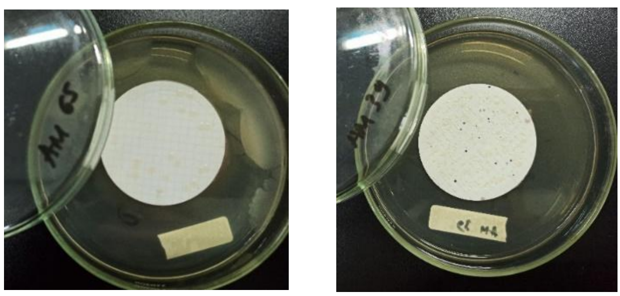

Fig 1. Results of drinking water sample examination using the membrane filter method.

Priority areas are determined using the WHO methodology by comparing SI scores and *E. coli* concentrations. The results categorize the risk as low, intermediate, high, or very high. These categories then guide the level of priority for actions: no action required, low action priority, higher action priority, or urgent action required.

2.3 Statistical analysis

We compiled the *E. coli* concentration and the results of the SI forms in Microsoft Excel and imported the data into SPSS 27 for statistical analysis. Since the data did not meet the assumptions of normality or linearity, we applied nonparametric tests to analyze the potential relationship between *E. coli* concentration and the risk scores, (e.g., Kruskal-Wallis (H), the Spearman rank–order correlation (r_s) and Wilcoxon signed-rank (Z). The statistical significance is at a 95% probability level.

3 Result and discussion

3.1 Sanitary Inspection

Sanitary inspection is an on-site evaluation to see the compliance of all conditions, devices, and practices in the water supply system that pose an actual or potential hazard to the health and welfare of consumers [15]. The frequency distributions of each variable and common issues found during the sanitation assessment of RDWS can be seen in Table 1. The mean of outdoor area is 45.1%, the lowest average compared to other variables. In contrast, the mean of equipment is 67.3%. The problems frequently found in RDWS based on checklist observation results are presented in Table 2 in percentage units of the total RDWS.

In the outdoor area variable, which is the poorest variable with the lowest average score, there is a lack of qualified sink and the presence of a hole from the outdoor area to the indoor area. The lack of a qualified sink can reduce the opportunity for operators to wash their hands properly. Another problem is the presence of open holes that can be accessed for vectors and pests to enter the production area. Vector and pest control must be done physically, for example by repairing buildings, using partitions, and the outdoor environment around the production site [16,17].

Table 1. Frequency Distribution of Environmental Health Risk of Refill Drinking Water Stations (%) (n =106).

Variable	Min ; Max	Mean (SD)
Outdoor area	11.8 ; 88.2	45.1 (13.3)
Building design and facilities	30.8 ; 96.2	64.3 (13.0)
Refill station operators	30.0 ; 70.0	49.0 (7.6)
Equipment	35.7 ; 89.3	67.3 (10.8)
Raw water	50.0 ; 100.0	63.4 (22.1)
Environmental health risk of refill station	33.7 ; 88.7	57.9 (7.9)

3.2 *E. coli* concentration

Most of the raw water used by RDWS is purchased from water providers. The source of the raw water was drilled well water (75%), local municipal waterworks (24%), and the rest used a mixture of both (1%). The concentration of *E. coli* in raw water does not vary significantly between sources obtained from local municipal waterworks and other sources ($H(1) = 1.033$; $p > 0.05$). This could be because the raw water samples were collected from the RDWS, rather than directly from the source. One factor influencing raw water quality is its treatment and distribution processes. Inadequate treatment in local municipal waterworks, caused by suboptimal unit operation or insufficient maintenance, as well as leaks in the distribution network, can lead to a decline in water quality [18]. For borehole water purchased from suppliers, careful attention must be paid to the transportation time and the condition of the storage tanks. The use of unclean tanks and transportation exceeding 12 hours can facilitate the growth of harmful microorganisms [19,20].

The average concentration of *E. coli* in the raw water before processing or treatment was 82 CFU/100 mL (median = 21 CFU/100 mL; SD = 121 CFU/100 mL). Meanwhile, the average concentration of *E. coli* in treated drinking water was 18 CFU/100 mL (median = 0 CFU/100 mL; SD = 45 CFU/100 mL). The Wilcoxon signed-rank test revealed a significant difference between the concentrations of *E. coli* in the raw water used and the treated drinking water ($Z = -6.260$; $p < 0.001$), with *E. coli* concentrations in the treated water being better than the raw water. However, 42.5% of RDWS still produce drinking water containing *E. coli.* The presence of *E. coli* in water indicates that the water is contaminated with feces and can affect public health such as diarrhea (7,9,21–24). Although this is important to note, the problem of refilled drinking water containing *E. coli* is still widely found in RDWS [19,20,25–28].

Table 2. List of Most Common Problems Found at Refill Drinking Water Stations (n =106)

No	Assessment criteria		%*
1	Outdoor area		
	a.	There are no holes/cracks that open into areas inside the building	29.2
	b.	Have a sink that meets the requirements	0
2	Building design and facilities		
	a.	Have clean walls (no dirt, mold, or peeling paint)	17.9
	b.	Have a trash can that meets the requirements	4.7
	c.	Have access to a bathroom or latrine	14.2
3	Refill station operators		
	a.	Wear work clothes that are only used at work	1.9
	b.	Always do wash their hands with soap and running water before and periodically when processing food	1.9
	c.	Carry out regular health checks	0
	d.	Have a certificate of having attended drinking water depot sanitation hygiene training	18.9
4	Equipment		
	a.	The microfilter is in its service life/not expired and there is a microfilter replacement schedule	0.9
	b.	Documentation of the use of sterilization equipment by manufacturer standards	0
	c.	The raw water reservoir is in good condition, without cracks, and clean.	38.7
	d.	There were no signs of possible contamination in the raw water reservoir	21.7
	e.	Brushing the inside of the gallon for about 30 seconds before filling,	8.5
	f.	Rinsing before filling is done by spraying the product for 10 seconds	15.1
5	Raw water		
	a.	There is written proof of the raw water purchase receipt from the water transportation company/water source certificate	27.4

Note: *) Percentage of RDWS

3.3 Relationship between Environmental Health Risk of Refill Drinking Water Station Score and *E. coli* Concentration and Recommendations for Improvement

The drinking water produced by RDWS can be influenced by the practices carried out by the water providers. Interventions targeting the water providers can result in safer water [13]. One of the intervention efforts that can be made is to pay attention to the hygiene and sanitation of RDWS. Several studies have shown that the hygiene and sanitation of RDWS are related to the bacteriological quality of the drinking water produced [19,29–31]. We found a significant negative relationship between the outdoor area variable (r_s = -0.265) and equipment (r_s = -0.336) with the concentration of *E. coli* in the produced drinking water. The result shows that the higher the score in outdoor areas and equipment, the lower the *E. coli* concentration.

A critical issue in the outdoor area is the presence of holes in the building that can serve as entry points for vectors and pests into the production area. These pests may leave droppings in the production area, which if not regularly cleaned, can become a source of contamination. In addition, another problem is the lack of a sink that meets the requirements. Without an adequate hand washing sink, the potential for disproportionate RDWS handler's engagement in hygienic behaviors is inherently diminished. Poor washing of hands with soap and running water is the major cause of hand contamination in RDWS handlers, which can contribute to product contamination and thus compromise public health [32].

Health-compliant equipment plays a crucial role in the processing of raw water into drinking water that meets health standards [33]. Issues identified in the equipment include cleanliness and documentation. In several raw water tanks at RDWS, dirt was observed on the water surface, the water appears cloudy, and sediment is present at the bottom. These tanks need to be cleaned regularly to reduce the potential for cross-contamination and ensure the production of safe drinking water [34–36]. Algae growth was found on the filling taps and some RDWS were found to fill gallons using hoses was a problem found in the drinking water filling process. Drinking water filling should be conducted in a closed and hygienic environment to prevent contamination by microorganisms, which are small, lightweight, and easily carried by air [37].

The equipment used for drinking water processing must have its usage time documented to monitor its lifespan. It was found that 21.7% of RDWS have functioning UV lamps but still produce non-compliant drinking water. This may occur because the UV lamps used have exceeded their lifespan. The effective wavelength for killing germs is 254 nm. If the UV lamp has surpassed its lifespan, the produced wavelength will decrease and become less effective [37].

Table 3. Distribution Frequency of combining sanitary inspection and *E. coli* concentration (n = 106).

	Sanitary Inspection Score			
E. coli count	8-10	5-7	2-4	0-1
>100	0	5	1	0
11-100	0	14	6	0
1-10	0	16	3	0
0	1	55	5	0

Risk Category:	Low Risk	Intermediate Risk	High Risk	Very High Risk
	0.9%	67.0%	26.4%	5.7%

The number of RDWS meeting the priority determination criteria can be seen in Table 3. Meanwhile, the distribution of RDWS based on its risk category can be seen in Figure 2. This mapping was carried out only to provide an overview of the distribution of RDWS risk categories in Palembang City.

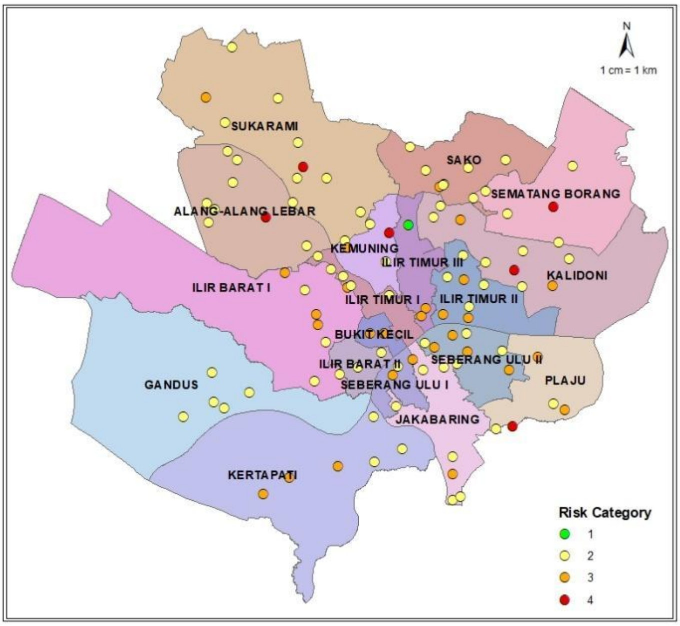

Fig 2. Distribution of RDWS risk in Palembang City.

Many RDWS fall into the intermediate risk category. The risk is seen from the concentration of E. coli in drinking water and the results of RDWS sanitation inspections. 6 RDWS are classified as very high risk and are spread across various sub-districts as seen in Figure 2. Of the several sub-districts, Kemuning and Plaju have RDWS with a very high-risk category of 25% and 20%, and RDWS with a high-risk category of 25% and 40%. These two categories indicate that the RDWS in the sub-district requires immediate improvements.

The RDWS in this sub-district has environmental conditions that can cause contamination of RDW, such as sources of pollution in the form of garbage and puddles near the RDWS and unclean buildings. After all, the RDWS is a drinking water treatment unit whose quality is the responsibility of the RDWS owner. Health officers in each sub-district are tasked with monitoring and providing input on any deviations found. However, no decisive action has been taken when deviations are found, nor has there been effective risk communication to the community regarding the RDWS. This problem is even more important to note because the number of RDWS in the area is relatively small. Residents may have limited choices and inadvertently use unsafe water sources due to the lack of information on the RDWS risk category.

Corrective actions on high-risk RDWS need to be taken immediately. Consistent enforcement of rules and regulations on monitoring and reporting drinking water quality is vital to ensure the safety of RDW. It is crucial to sensitize RDWS owners about the significance of proper sanitation hygiene practices and carrying out private water quality testing.

4 Conclusion

This study found that the score of the outdoor area variable was the poorest in environmental health risk assessment. Otherwise, the equipment variable has the best but also has the highest number of problem items compared to other variables. These two variables are significantly related to the concentration of *E. coli* in the drinking water produced. The concentration of *E. coli* in drinking water is better than in raw water. However, *E. coli* was found in 42.5% of samples. The combination of SI assessments and *E. coli* concentrations indicates that many RDWS fall into the intermediate risk category and need urgent intervention to protect consumers' health. This study emphasizes the urgency to increase the knowledge and awareness of RDWS owners or managers regarding the importance of fulfilling RDWS environmental hygiene and sanitation requirements as an effort to improve the bacteriological quality of the drinking water produced.

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