RISK OF DISEASE DUE TO CONTAMINATION OF REFILL DRINKING WATER: USING QUANTITATIVE MICROBIAL RISK ASSESSMENT

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Abstract

Refill drinking water has been popular due to its low price and practicality, but the quality is still questionable. Data from the Health Office of Pariaman City stated that based on laboratory tests on the quality of drinking water from the drinking-water refill depots in Pariaman City, it showed that every year more than 50% of drinking water from the drinking-water refill depots do not meet the health requirements for drinking water. This study aimed to investigate the health risks of refill drinking water generated from 78 drinking-water refill depots spread across four sub-districts in Pariaman City. Using the Quantitative Microbial Risk Assessment calculation, the risk calculation used drinking-water refill depots laboratory examination data from the Pariaman City Health Office in 2020. It was found that there was a high risk of infection from E. coli contamination in refill drinking water, where the highest risk was in the North Pariaman District with an annual risk of disease for individuals of 5,14×10-1. This showed the ineffectiveness of drinking-water refill depots in eliminating bacteria and lousy hygiene and sanitation practices. An approach is needed for the owners and operators of drinking water refill depots to improve the tools' effectiveness and education on hygiene and sanitation for drinking-water refill depots operators to maintain patient safety and health.

Keywords: **Drinking water refill, Drinking water refill depot, E.Coli, Quantitative microbial risk assessment, Waterborne disease**

Introduction

The existence of water is vital and needed for all living things on earth because water can affect various vital activities carried out by living things. For humans, the need for water is absolute because 70% of the substances that make up the human body consist of fluids. To survive, humans always need water to do almost all daily activities. Human needs for water also vary, ranging from drinking water, bathing, helping with daily household chores such as cooking, washing, and other activities. The most important benefit of water for humans is its function as drinking water (Notoadmodjo, 2020).

The community's need for drinking water, which continues to increase along with population

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growth, is not balanced with the availability of clean water. One of the causes is the occurrence of groundwater pollution, so it is no longer safe to be used as raw materials for drinking water (WHO, 2006; WHO, 2008).

Therefore, the drinking-water refill depot (DWRD) business began to develop to meet community needs (Marsono, 2013). Around 1999, during the economic crisis in Indonesia, the DWRD business began to grow due to the demand for drinking water which was increasingly expensive. People started looking for alternatives to meet these needs at a lower cost. The DWRD business is growing rapidly, beginning in 400 existing depots and then growing to approximately 6000 DWP in 2005 spread throughout Indonesia, from densely populated areas to areas where it is difficult to access clean water (Pokja, 2009; Pemerintah Republik Indonesia, 2012; Alfian *et al*., 2021).

The community has increasingly used refill drinking water (RDW) because of a lifestyle that prefers something practical. The increasing demand for RDW by the community has resulted in more sales of drinking water refill popping up and making it easier to find in the community. With the low price of RDW offered to consumers, people are more interested in consuming RDW, but not all RDW products are guaranteed product quality, especially from the threat of biological contamination. Drinking water that is safe for consumption must meet established standards starting from the physical, chemical, microbiological, and radioactive aspects as stipulated in the Decree of the Minister of Health of the Republic of Indonesia NO 492/MENKES/PER/IV/2010 (Indrawati, 2009; Peraturan, 2010; Raksanagara *et al*., 2015).

Based on the 2010 Baseline Health Research (Riskesdas), drinking-water refill depot is the third most common source of drinking water consumed by the people of West Sumatra with a percentage of 17.2% after dug wells and piped water with a percentage of 22.1% and 20.8%. Another study conducted by Athena *et al*.; in 2004 found a relatively high number of Coliform and Escherichia coli (E. coli) bacteria in RDW from various DWRD in Jakarta, Tangerang, and Bekasi. The results of testing the quality of drinking water from 120 samples of refilled drinking water taken from 10 major cities (Jakarta. Tangerang, Bekasi, Bogor, Cikampek, Surabaya, Medan, Semarang, Yogyakarta, and Denpasar) showed variations in the quality of DWR produced by DWRD between one another. The results showed that for microbiological quality, 11 depots (28.9%) did not meet the requirements for Coliform, and seven depots (18.4%) did not meet the requirements for E. coli. Meanwhile, raw water that did not meet the requirements for Coliform was 12 depots (31.6%) and 11 depots of E. coli (28.9%) % (Widiyanti and Ristiati, 2004; Putri *et al*., 2015).

One of the diseases caused by drinking water with poor microbiological quality is diarrhea. Diarrhea is one of the ten most common diseases in Pariaman City. Based on the health profile of Pariaman City in 2020, the number of diarrhea cases was 1,049 cases (Dinas Kesehatan, 2020). Therefore, an alternative approach is needed to measure the risks associated with disease transmission from drinking water. The risk-based approach is invaluable in providing information to decision-makers regarding the water sector in improving drinking water quality to protect public health.

Materials and Methods

This study focuses on calculating the risk of disease due to the consumption of refilled drinking water containing microorganisms. The study used secondary data from laboratory tests on 78 drinking-water refill depots (DWRD) spread over four sub-districts: Central Pariaman, North Pariaman, South Pariaman, and East Pariaman Districts in Pariaman City, West Sumatra Province, Indonesia. This study used secondary data due to the Covid-19 pandemic so it was not retrieve primary data and direct laboratory testing due to the government's lockdown policy. Calculation of health risk using Quantitative Microbial Risk Assessment (QMRA) technique. QMRA has four stages in quantitative disease risk: Hazard Identification, Dose-Responses Analysis, Exposure Assessment, and Risk Characterization.

The first step is to identify the hazard. At this stage, the organisms and causes of the disease are explained, including the organisms' symptoms, severity, and mortality, to identify populations that are particularly susceptible to infection. The next step is to look at the relationship between the number of microbes received and their effect on health so that a mathematical model is produced to be able to predict dose-response. The dose-response calculation was carried out by calculating the beta-Poisson model with the formula: (Haas *et al*., 1999)

$$d = V\ x\ c \quad (1)$$

$$P_1 = 1 - \left[1 + \frac{d}{N_{50}}\right]^{-,àù} \quad (2)$$

d : ingested dose per day,
V : volume of water consumed per day
c : concentration of microorganism in drinking water.
PI : probability of infections to occur,
A : parametric slope,
N50 :average dose to cause an infection.

Escherichia coli has N50 value 8.6 × 107 and α value 0.1778 (Haas *et al*., 1999).

After the dose-response is obtained, the pathways that allow microbes to reach people and cause infection are described through the air, water, touch, etc. In determining the path of exposure, it is also possible to estimate the number of people exposed and the category of people affected. In addition, the calculation of the risk of infection in one year and the risk of the disease per year for an individual, with the formula:

$$P_{annual} = 1 - (1 - P_{infection})^{365} \quad (3)$$

$$P_{ill} = P_{inf.annual}\, x\, P_{ill/inf} \quad (4)$$

The pill is the possibility of disease due to infection per year.

Pill/inf (E. coli) = 0.35

The final step is to integrate the information from each of these steps. The last step is to produce an analysis known as Monte Carlo Analysis, the possible risk, including the worst average risk that humans will accept due to a particular exposure. The results of this analysis can also be used to make decisions by looking at the risk of something. Scientists use this to get better information. (WHO, 2001; Water, 2014) QMRA calculations are carried out to measure the magnitude of the health risk that possibly occurs due to exposure to a thing. In this case, what will be measured is the amount of health risk that can arise due to exposure to E.coli found in drinking water when consumed by the public. E.coli are believed to affect health, causing diseases known as waterborne diseases.

Results and Discussion

Hazard Identification

Several other important pathogenic microorganisms in water include Salmonella, Vibrio Cholerae, E. coli, Yersina, Campylobacter, and Leptospira (Bitton, 1990). Bacteria as sanitation indicators are bacteria whose presence indicates that human feces have contaminated the water or food. Sanitation indicator bacteria are generally bacteria that live and live in the human gut. The presence of these bacteria in water or food indicates that in one or more stages of processing, the water or food has been in contact with feces originating from the human intestine and therefore may contain other harmful pathogenic bacteria (Pemerintah Republik Indonesia, 1996).

Indonesia uses an indicator of the number of E.coli to indicate microorganisms that can cause waterborne disease. Enterotoxigenic E. coli (O157:H7) is awell-known waterborne pathogen in developed countriesand has been the cause of high-profile outbreaks of disease. However, there is only limited dose-response data for E.coli (O157:H7), the numbers of organisms required to infect 50% of people ranges between 10^2 and 10^6 CFU (Hunter, 2003). Several diseases often manifest due to microbiological contamination, such as diarrhea, cholera, dysentery, typhoid, pneumonia, tuberculosis, and leptospirosis (Cabral, 2010). There are not many pathogen outbreaks for cholera and dysentery cases in Indonesia, but diarrhea cases are classified as dangerous cases because they have a reasonably high prevalence from year to year (Nastiti, 2013). E. coli is a group of Coliform. E. coli are facultative anaerobic bacteria that are rod-shaped, not encapsulated, and can move actively. In general, E. coli normally lives in the human digestive system. E. coli are in the form of short rods with a size of 0.4-0.7 miumeter × 1.4 miumeter, so this bacterium is a kokobacil bacterium. Most E. coli have positive motility, and some strains have capsules. E. coli grows at a temperature of 10-40°C and 37°C at an optimal temperature (Peraturan, 2010; Fardiaz, 1993; Widiyanti and Ristiati, 2004). E. coli present in drinking water indicates that the drinking water has been contaminated with human feces and may contain intestinal pathogens. Drinking water standards require E. coli to be zero in 100 ml.

Table 1. Value of Dose-Response

District	Value of Pathogen Exposure (d)	Dose-Response (Pinf/day)
North Pariaman	5.76	0.180
Central Pariaman	4.85	0.1778
East Pariaman	4.19	0.1778
South Pariaman	5.17	0.1780

* Assumption of individual intake volume is 1 liter per day
* Using the average number of bacteria
* d is Dose (per day)

Dose-Responses Analysis

This stage uses the beta-Poisson model calculation. The data were analyzed to determine the possible risk of infection that would be accepted by using Equation (1) and (2), as shown in Table 1.

The possible infection caused by E. coli is more significant in refill drinking water from the drinking-water refill depots in the North Pariaman District. This is due to the high rate of E. coli contamination in refill drinking water in the North Pariaman District, so it can pose a risk of developing waterborne diseases such as diarrhea, cholera, dysentery, and various other diseases caused by consuming bacteria through contaminated drinking water.

Poor access to drinking water is associated with an increasing number of cases of the disease, especially waterborne diseases such as diarrhea, cholera, and typhoid (WHO, 2005). The incidence of diseases transmitted directly through drinking water is still in the top five. This figure contributes to poor sanitation conditions and the low public knowledge about safe drinking water, availability problems, and the deteriorating quality of water sources. Microbiological contamination, especially fecal bacteria, is a common symptom that occurs in many water sources around settlements. As an illustration, in developing countries, deaths due to diarrhea, including cholera, in 2002 reached 1.8 million, and 90% of them occurred in infants and toddlers. As many as 88% of diarrhea cases are related to unsafe water and hygiene and sanitation that does not meet health requirements (Suriawiria, 1993; United Nations Children's Fund and World Health Organization, 2011).

Exposure Assessment

Based on Government Regulations and WHO, the biological requirements for drinking water are the amount of Coliform and E. coli that cannot exceed the values of 1000 and 100 CFU/ml. If drinking water is found in one milliliter containing as many microorganisms as that threshold, then the water condition is said to be polluted (Peraturan, 2001; Peraturan, 2010; Yassi *et al*., 2011; Peraturan, 2017). The following chart illustrates the path of exposure from microorganism contamination of refill drinking water:

Based on Figure 1, contamination of refill drinking water is caused by ineffective water treatment at the drinking-water refill depots. Good and proper water treatment eliminates and reduces microorganisms present in the water. In this study, it was found that the treatment was ineffective due to the absence of maintenance and renewal of the tools used, so the effectiveness of the tools used also decreased in eliminating microorganisms present in the water. Inaddition, it is also influenced by the inadequate hygiene and sanitation practices carried out by the owner or operator of DWRD when refilling drinking water. Poor hygiene and sanitation behavior is caused by the lack of knowledge of the owner or operator of drinking-water refill depots on hygiene and sanitation. These things result in drinking water that has been processed into refill drinking water which is still contaminated with E. coli, which the people then consume through the fecal-oral route.

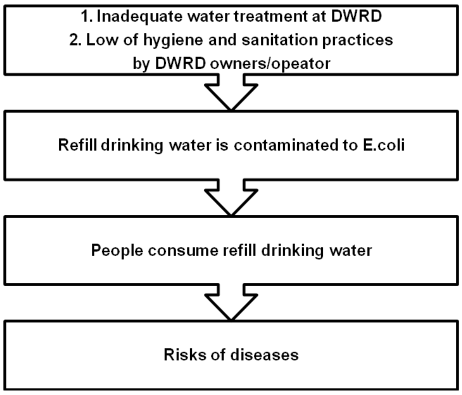

Figure 1. Path of Exposure

Coliforms in water indicate inadequate processing or sanitation conditions. So, hygiene and sanitation affect the presence or absence of bacterial coliform contamination in refilled drinking water. Hygiene and sanitation are health efforts to reduce or eliminate factors that cause contamination of drinking water and the facilities used for processing, storing, and marketing drinking water. Environmental sanitation affects the presence of coliform bacteria contamination in refilled drinking water (Pitojo, 2013). Apart from being the responsibility of the manager or owner of the refill drinking water depot, operators of supervision and hygiene development also requires support and cooperation from the government and the local health office. One of the collaborations that can be carried out by the government and the health department to change unsanitary living behavior on operators is to facilitate seminars or training related to sanitation hygiene to owners, managers, and operators of refill drinking water depots which are expected to increase knowledge and application of clean- living behavior on operators of refill drinking water depots.(Alfian *et al*., 2022)

The community's consumption of refill drinking water in Pariaman City increases because refilled drinking water is considered cheaper and more practical to obtain. Refill drinking water that still contains E. coli is certainly a risk for health problems for those who consume it. The risk value can be described in Table 2 as follows by using Equation (3) and (4):

Table 2. Value of Infection Risk

District	Annual Infection Risk (PAnnual)	Annual Individual (Pill)
North Pariaman	1	$3{,}5 \times 10^{-1}$
Central Pariaman	1	$3{,}5 \times 10^{-1}$
East Pariaman	1	$3{,}5 \times 10^{-1}$
South Pariaman	1	$3{,}5 \times 10^{-1}$

Based on table 2 above, the same risk value is obtained for four sub-districts, using a risk level; 0 means there is no risk of infection, and 1 means a particular risk of infection (WHO, 2005; WHO, 2011).

Risk Characterization

Risk characterization aims to integrate exposure information with the results of the dose-response analysis to obtain overall risk estimation information. The condition of drinking water that has been contaminated with microorganisms in high enough quantities requires appropriate action in its processing. From the results of the study, it was found that the level of risk for the four sub-districts was as follows:

Value of Pinf/day/Pill $>10^{-6}$ means high risk.
Value of Pinf/day/Pill $<10^{-6}$ means low risk.
Value of Pinf/day/Pill $=10^{-6}$ means moderate risk.

Risk Characterization calculated by using Dose Response (Pinf/day): Annual Individual (Pill)

Table 3. Risk Characteristic

District	Value of Risk Characterizion (Pinf/day/Pill)
North Pariaman	5.14×10^{-1}
Central Pariaman	5.080×10^{-1}
East Pariaman	5.080×10^{-1}
South Pariaman	5.086×10^{-1}

Table 3 shows that refilled drinking water produced by DWRD in North Pariaman District has a higher risk than the other three sub-districts in transmitting waterborne diseases transmitted through drinking water. However, overall, they are both classified as high risk. This is due to poor handling and hygiene at the time of processing. Therefore, it requires special attention. Not only affects the quality of water, but this can also result in a high incidence of illness due to infection with microorganisms consumed through drinking water. Based on Figure 2, this is also in line with the incidence of diarrhea in North Pariaman District, which continues to increase every year and is the highest of the three other districts, namely:

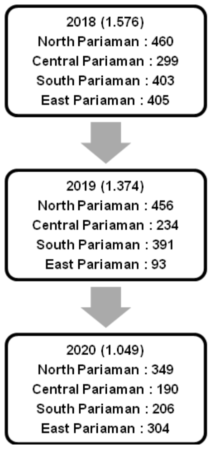

Figure 2. Diarrhea cases during 2018-2020

Conclusions

The low effectiveness of DWRD water treatment in Kota Pariaman and poor hygiene and sanitation practices have caused contamination of refill drinking water by E.coli. This is the risk of waterborne disease in the exposed population with the highest risk value for DWRD in the North Pariaman District. This shows that refill drinking water in Kota Pariaman has not provided good protection for public health. DWRD sanitation inspections need to be carried out regularly and not only by taking water samples but also by conducting education and promotion regarding good and proper water treatment tools and methods, hygiene, and sanitation education to DWRD Operators or owners and the need to form an Association of DWRD Owners who can collaborate with the Government.

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