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Analysis of Physicochemical and Microbial Parameters in Refill Drinking Water Sources and Health Risk Assessment: A Case Study in Bandung District, Indonesia

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ABSTRACT

The decline in the quality of groundwater occurred in Bandung District, especially in three areas, namely Ciparay, Dayeuhkolot and Margaasih sub-districts. Pattern shifting in the use of drinking water occurred from groundwater sources to refill drinking water sources. Refill drinking water as a new emerging source is inseparable from contamination. Therefore, a public health risk assessment is carried out due to the use of refill drinking water. Analysis of physicochemical and microbial of refill drinking water was carried out on 45 refill drinking water sample in three areas. Risk characterization is carried out by quantitative methods of calculating the value of the Hazard Quotient (HQ), Hazard Index (HI), and Excess Cancer Risk (ECR) with Monte Carlo analysis. Quality of refill drinking water exceeds the quality standard of Indonesian Minister of Health Regulation No. 492/2010 on the parameters of *E. coli*, total coliform, and heavy metals (Fe, Al, Se). Oral exposure from refill drinking water showed an acceptable non-carcinogenic risk (HI $\leq$ 1) in all categories from three areas but adult category in Ciparay Subdistrict has maximum tolerable value for Excess Cancer Risk (ECR), 1 x 10^{-4}, shown that the use of refill drinking water in this area can affect to human health in long-term situation for adults. Reducing public health risk can conducted by improving the process in refill drinking water station, evaluate the quality regularly, and revised the land use masterplan by the government.

Keywords: Bandung district, drinking water, ECR, HI, HQ, Monte Carlo analysis.

INTRODUCTION

The decrease in the quantity and quality of clean water occurred in the Upper Citarum River Watershed area in Bandung District. In Upper Citarum River Watershed has been reported the decline in quality occurred in the subdistrict of Ciparay, Dayeuhkolot, and Margaasih, which had the lowest percentage of clean water facilities meet the requirements of clean water sources according to Regulation of Ministry of Health Indonesia No. 492/2010. In these three areas, community activities are focused on domestic, industrial, and especially agricultural activities. Based on research, almost 80% of community in Upper Citarum River Watershed using groundwater as drinking water for daily life (Oginawati & Pratama, 2016). This means with the pollution in the river, groundwater can also be affected by the physicochemical, microbial, and especially organic matter (as a residue of pesticides in agricultural areas) pollution. Therefore, pattern shifting in the use of drinking water happened in the community, which is due to the impractical use of groundwater sources because its use must be treated first to remove the contaminants, causing people to shift the consumption with refill drinking water.

Consumption of refill drinking water or known as bottled drinking water has been increasing steadily in Indonesia. From the data reported, the amount of refill drinking water station has increased 13.8% each year in urban area. This data reflects that the demand of consumption refill drinking water by the people of Indonesia has been increased (Raksanagara et al., 2018). Consumption of refill drinking water or bottled water also increase globally as reported increased steadily almost 10 billion liters per year (Aris et al., 2013). This constant behavior has associated by the benefits of the bottled drinking water, this source regarded as cleaner, tastier, and healthier compared by the other sources such as groundwater source. Although the benefits itself, this new source of drinking water that has emerged also inseparable from contamination that can decrease its quality and categorized as low quality.

Several research about quality of refill drinking water and bottled drinking water has conducted globally. In Chile, thirty-two chemical elements were analyzed, including minor and trace elements with results 30% of the analyzed samples exceed the value of arsenic (As) permitted by Chile Drinking Water Regulations (Daniele et al., 2019). In Malaysia, one of sample bottled drinking water was analyzed below the pH limit of 6.5 according to Malaysian Ministry of Health (Aris et al., 2013). Also, in Indonesia, research that has presented data regarding the low output of refill drinking water quality treatment in several cities in Indonesia, one of them in the city of Bandung noted that 50% of refill water still contains Coliform (Putri et al., 2015).

The presence of trace elements in refill drinking water or bottled water has investigated in several research to establish the guideline for drinking water, but this effort is very difficult caused by the exposure of trace element has degree of time to make an adverse health effects on human (Daniele et al., 2019). The trace element can have specific effect as reported in several publication depend on concentration, contaminant, and time of contact. The specific effect such as abdominal pain, high blood pressure, kidney damage and eventually failure, irritability, skeletal harm and degradation, cancer, nerve damage, headaches, and neurodegeneration and its consequences on the intellectual system. These specific effects, however, depend on the type of contaminant, its concentration, and the cause and span of contact (Hussain et al., 2019).

Therefore, an assessment of the health risks resulting from the use of refill drinking water needs to be carried out and is very important. Thus, the objectives of this study include: (a) to determine and analyze the contaminants in refill drinking water used for daily needs, and (b) to assess the non-carcinogenic and carcinogenic health risks to the community who are exposed by oral contact routes.

MATERIALS AND METHODS

Study area

In Figure 1 showed sampling map of three areas: Ciparay subdistrict, Margaasih subdistrict, and Dayeuhkolot subdistrict. The sample for the research taken was determined by cluster random sampling with the distance between the resident's house and the refill drinking water station at 100 m – 1 km. It is 45 water sample acquired (27 water sample from resident house and 18 water sample from water station). The selection of refill drinking water station was carried out using the transect walk method from February to March 2021. GPS plotting was carried out using Geospatial Information System Software.

Laboratory analysis

The physicochemical parameters examined in Laboratory Quality of Water, Department of Environmental Engineering, Institut Teknologi Bandung: Total Dissolve Solid (TDS), turbidity, temperature, pH, total hardness ($CaCO_3$), nitrate (NO_3^-), nitrite (NO_2^-), and heavy metal parameters examined in Central Laboratory, Universitas Padjajaran: chromium (Cr), iron (Fe), copper (Cu), aluminum (Al), zinc (Zn), arsenic (As), manganese (Mn), cadmium (Cd), selenium (Se). In addition, the microbial parameters examined in Laboratory Quality of Water, Department of Environmental Engineering, Institut Teknologi Bandung: total coliform and Escheria coli (*E. coli*). Method for collecting sample in the field and measurement based on Standard Method for the Examination of Water and Wastewater 21st Edition (APHA, 2005). Preservation method for

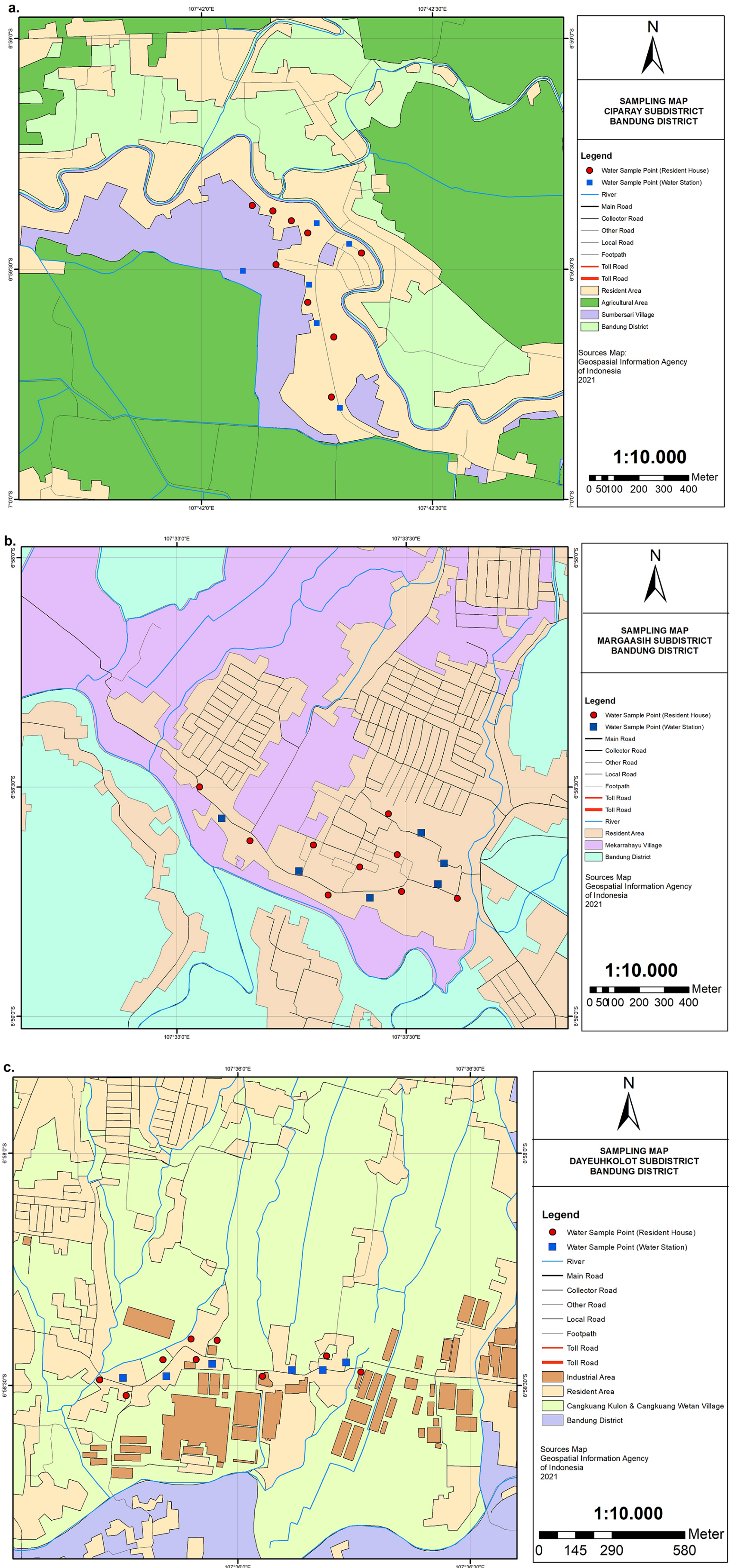

Figure 1. Sampling locations a) Ciparay Subdistrict, b) Margaasih Subdistrict, c) Dayeuhkolot Subdistrict

sample's hardness and heavy metal parameters checking are adding the HNO_3 until reaching pH level: 2 and store it in plastic bottle. Preservation method for sample's nitrate, nitrite and microbial parameters checking are store it in plastic bottle (for nitrate and nitrite parameters) and glass bottle (for microbial parameters) with temperature 4°C. Temperature, TDS and pH parameters measured in the field with water checker automatic. Hardness, nitrate, and nitrite parameters measured with combination of titration, complexometric titration for hardness parameters, *brucine-spectrophotometry* for nitrate parameters, *diazotize-spectrophotometry* for nitrite parameters and spectrometry method using Spectrometer UV-Vis with wavelength respectively 420 nm to measure nitrate parameters and 540 nm to measure nitrite parameters. Microbial parameters measured using membrane filter method with cellulose acetate membrane specification: 0.45-micron, diameter 47 mm, white plain. Heavy metals parameters measured using Inductively Coupled Plasma with Optical Emission Spectroscopy (ICP-OES) method, with ICP-OES Analyzer specification: CCD Detector, plasma flow (15 l/min), auxiliary flow (1.5 l/min), nebulizer flow (0.6 l/min), argon (80 psi), nitrogen UHP (80 psi).

Monte Carlo analysis

Data processing is done by evaluating exposure by calculating Chronic Daily Intake (CDI), calculating risk through the Hazard Quotient (HQ), Hazard Index (HI) and Excess Cancer Risk (ECR). The parameters used to calculate the intake and HQ values are taken with a probabilistic approach with Monte Carlo Simulation Analysis. First, an evaluation is carried out to assess the variability of the distribution, so each parameter is tested in the R Studio software, using the EnviroPRA package (fit_dist_parameter and fit_dist_test) available on the Comprehensive R Archive Network (CRAN) (Kaur et al., 2020). Each parameter is simulated with a random probability in the appropriate distribution, then the CDI is calculated using equation (1). Then the HQ value is iterated at 10000 iterations using the Monte Carlo Simulation spreadsheet. The results of the iteration are carried out by plotting the histogram on SPSS software, then the mean value is determined along with the percentile 95% and 5% (Saha et al., 2017; Saha & Rahman, 2020). The mean value obtained is the HQ value which is used to accumulate each parameter to produce a HI value.

Intake calculation

The CDI calculation from the source of contaminated drinking water orally can use equation (1) (He et al., 2021; Nyambura et al., 2020; Soemirat, 2013).

$$\text{CDI oral} = \frac{\text{CW x IR x EF x ED}}{\text{BW x AT}} \tag{1}$$

where: CW – concentration of contaminants in water (mg/liter);
IR – ingestion rate (liters of water/day);
EF – exposure frequency (days/years);
ED – exposure duration (years);
BW – body weight (kg);
AT – average time (days).

Risk characterization and assessment

For contaminant groups that have a threshold, the hazard index can be calculated as the Hazard Quotient (HQ). The HQ value can be calculated by equation (2) (He et al., 2021; Nyambura et al., 2020; Soemirat, 2013).

$$\text{HQ} = \frac{\text{CDI}}{\text{RfD}} \tag{2}$$

where: CDI – Chronic daily intake;
RfD – Reference dose, a figure set by the US EPA's IRIS.

After the HQ calculation, the Hazard Index (HI) is determined by equation (3). If the value of HI > 1 then a contaminant is considered to be harmful to human health. However, if HI is ≤ 1, the contaminant dose does not endanger human health (He et al., 2021; Nyambura et al., 2020; Soemirat, 2013).

$$\text{HI} = \sum_{i=1}^{n} \text{HQ} \tag{3}$$

where: HI – Hazard index; HQ – Hazard quotient.

For contaminants that do not have a threshold, the carcinogenic potential can be calculated as an Excess Cancer Risk (ECR), which is the possibility of an increase in cancer / mutase / teratoma rates during life. The ECR calculation of the consumption of contaminated drinking water can use equation (4) (He et al., 2021; Nyambura et al., 2020; Soemirat, 2013).

$$ECR = CDI \times SF \quad (4)$$

where: ECR – Excess cancer risk;
CDI – Chronic daily intake;
CSF – Cancer slope factor.

The tolerable ECR value < 1.0 x 10^{-4} (Wongsasuluk et al., 2014), where the ECR value is a value that shows the potential risk in an area which means the growth of 1 person developing cancer per 10,000 people.

RESULT AND DISCUSSION

Physicochemical and microbial analysis of refill drinking water sample

The quality of refill drinking water from water station and resident's house summarized in Table 1. These shows the quality of refill drinking water compared to the standard Regulation of Ministry of Health Indonesia No. 492/2010. The parameters that exceed the water quality standard for drinking water are heavy metals, namely Fe, Al, Se, with each having an average value for water sample on water station respectively 0.770 ± 0.730 mg/l, 0.350 ± 0.300 mg/l, and 0.034 ± 0.024 mg/l. and for water sample on resident house respectively 0.610 ± 0.550, 0.300 ± 0.300, 0.023 ± 0.026. The mineral content of iron is high enough to affect the taste of drinking water and the content in the body can cause damage to the intestinal wall. Complications of aluminums toxicity caused by gastrointestinal are neurotoxicity effects such as neuronal atrophy in locus coeruleus, substantia nigra and striatum (Jaishankar et al., 2014; Tay et al., 2019). Selenium metals which are high enough in the body can also cause nausea and can further cause rheumatism (Slamet, 2007). In addition, the average value of *E. Coli* and total coliform for water sample on water station respectively 0.220 CFU/100 mL ± 0.940, 5.280 CFU/100 mL ± 9.230 and for water sample on resident house respectively 11.330 CFU/100 mL ± 15.120, 25.590 CFU/100 mL ± 31.280. These values are also above the required quality standard, *E. coli* detection indicate other possible pathogens, pathogens risk of ingesting the contaminated water were often identified by cholera, salmonellosis and shigellosis (Cabral, 2010).

From the data in Table 1 shown that from the nine parameters heavy metal examined, the results for five parameters: Fe, Al, Cr, Zn, and Se quality from the water sample is higher in the water station than in the resident's houses. It indicates the poor processing of water in the water station. Sources of raw water also can

Table 1. Descriptive analysis for quality of refill drinking water

Parameters (Units)	Water sample on water station	Water sample on resident house	Regulation of Ministry of Health Indonesia No. 492/2010
Nitrate (mg/l)	0.060 ± 0.10	0.160 ± 0.280	50
Nitrite (mg/l)	0.070 ± 0.070	0.070 ± 0.070	3
Fe (mg/l)	0.770 ± 0.730*	0.610 ± 0.550*	0.3
Al (mg/l)	0.350 ± 0.300*	0.300 ± 0.300*	0.2
Cr (mg/l)	0.004 ± 0.004	0.003 ± 0.004	0.05
Cu (mg/l)	0.001 ± 0.004	0.004 ± 0.0071	2
Zn (mg/l)	0.143 ± 0.150	0.114 ± 0.139	3
Se (mg/l)	0.034 ± 0.024*	0.023 ± 0.026*	0.01
Mn (mg/l)	0.012 ± 0.017	0.025 ± 0.023	0.4
As (mg/l)	0.001 ± 0.002	0.002 ± 0.003	0.01
Cd (mg/l)	0.001 ± 0.001	0.002 ± 0.001	0.003
TDS (mg/l)	92.460 ± 34.750	90.610 ± 28.840	500
Turbidity (NTU)	3.910 ± 0.240	3.830 ± 0.440	5
Temperature (℃)	26.310 ± 1.130	26.880 ± 0.740	± 3
pH	7.190 ± 0.360	6.990 ± 0.44	6.5–8.5
Hardness (mg/l)	38.990 ± 14.250	36.060 ± 14.060	500
E.coli (cfu/100 mL)	0.220 ± 0.940*	11.330 ± 15.120*	0
Total Coliform (cfu/100 mL)	5.280 ± 9.230*	25.590 ± 31.280*	0

*Parameters exceeded the regulation.

affect the process in water station, mostly parameters Fe and Al degrade by aeration method (Eckenfelder, 1991). Degradation of heavy metals content in the water from resident's house can caused by the storage of the bottled water. If the bottled water stored in the right condition not exposed to high temperatures and/or sunlight, the contamination will not made (Diduch et al., 2011). Also, with the little aeration from the water dispenser can made the degradation occurred. In addition, the results for microbial parameters in resident's house water sample are higher than the water station's water sample. This microbial parameter value indicates the unhygienic storage in resident's houses as a factor for microbial pollution. Although the microbial parameters for water sample on water station low, but still exceeded the regulation. Hygiene sanitation in water station that is not accordance with regulations can result in the quality of drinking water produced not meeting the specified drinking water quality standards. The quality of drinking water does not meet the regulation especially in bacteriological quality will cause health problems as diarrhea, hepatitis, typhoid, dysentery and gastroenteritis (Khoeriyah et al., 2013).

Variability of carcinogenic and non-carcinogenic risk elements

In probabilistic approach for calculation of Hazard Index, it is necessary to analyze the variability of each element for the calculation. The calculation elements in this risk calculation are the concentration of the refill drinking water quality parameters for non-carcinogenic and carcinogenic risk calculation. The parameters in the calculation are the concentration of nitrate (NO_3^-), nitrite (NO_2^-), chromium (Cr), aluminum (Al), iron (Fe), manganese (Mn), cadmium (Cd), selenium (Se), arsenic (As), copper (Cu), and zinc (Zn). Each parameter is analyzed by fitted distribution function and goodness of fit. The selection of the fitted distribution function was based on the largest K-S Test p-value and the smallest Akaike Information Criteria (AIC) value (Kaur et al., 2020). Table 2 shows the fitted distribution function and goodness of fit for refill drinking water quality parameters.

Intake from non-carcinogenic and carcinogenic elements

Dose defined as substance available for interaction with metabolic processes after crossing the

Table 2. Fitted distribution function and goodness of fit for refill drinking water quality parameters

Parameters	Distribution function	Fitted parameter	K-S Test (p-value)	Signification K-S Test
Nitrate	Weibull	Shape: 0.621	0.053	Significant
		Scale: 0.078		
Nitrite	Weibull	Shape: 0.832	0.219	Significant
		Scale: 0.061		
Cr	Log-normal	Meanlog: -2.841	0.481	Significant
		Sdlog: 0.691		
Fe	Log-normal	Meanlog: -0.695	0.240	Significant
		Sdlog: 0.731		
Al	Weibull	Shape: 1.211	0.388	Significant
		Scale: 0.672		
Zn	Log-normal	Meanlog: -2.475	0.07	Significant
		Sdlog: 0.811		
Cu	Log-normal	Meanlog: -1.891	0.178	Significant
		Sdlog: 0.976		
Se	Weibull	Shape: 0.603	0.050	Significant
		Scale: 0.204		
Mn	Weibull	Shape: 1.219	0.740	Significant
		Scale: 0.028		
As	Log-normal	Meanlog: -4.078	0.363	Significant
		Sdlog: 1.497		
Cd	Weibull	Shape: 0.588	0.166	Significant
		Scale: 0.023		

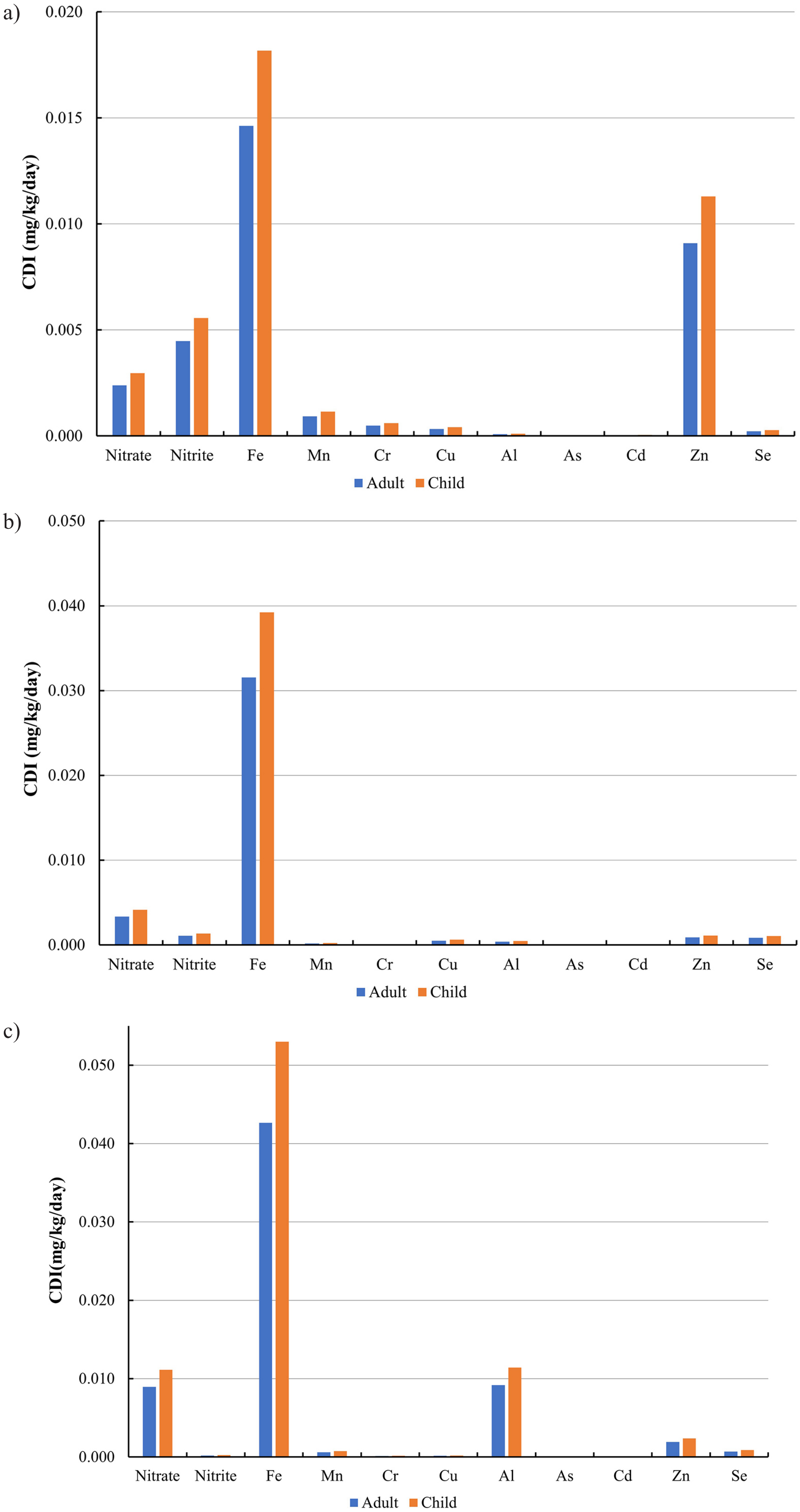

Figure 2. Chronic daily intake value from all contaminants in each area: a) Ciparay Subdistrict, b) Margaasih Subdistrict, c) Dayeuhkolot Subdistrict

boundary of an organism. In the function of time, dose can be defined as Chronic Daily Intake (CDI) with function of time daily. For taking calculations daily intake dose, calculations must be based on some toxicity standards. The calculation based on equation (1), with the value of each symbol described in Table 3. Parameters concentration of water (CW), ingestion rate (IR), Body Weight (BW) specific in this research area. The value of ingestion rate and body weight are the average based on the questionnaire sample in this research area.

Calculation of Chronic Daily Intake in this research using Monte Carlo Simulation with input concentration of water. From the data in Figure 2, in each area Ciparay, Margaasih, and Dayeuhkolot, CDI value caused by Fe contaminant consistently the highest value among contaminants. The presence of high Fe content in groundwater in the domestic area could occur due to the conversion of agricultural land used as living areas so that the Fe content is quite high in the area (Abdalla & Khalil, 2018). So, if the raw water used by the water station are from groundwater sources, it could be there is a pollution occurred either from the agricultural area or from the conversion of the agricultural area in domestic area. When compared between the CDI values in adults and children, the CDI values in children are higher for all types of contaminants. This can occur because children have different behavior and characteristics in calculations of health risk. Children have more absorption of contaminants per unit body weight than adults (WHO, 2005).

Assessment of non-carcinogenic and carcinogenic risk

From all the physicochemical and microbial quality parameters above, the parameters considered in the US EPA non-carcinogenic health risk assessment are NO_3^- (Nitrate), NO_2^- (Nitrite), Fe, Mn, Cr, Zn, As, Cd, Al, Se, and Cu. These contaminants have a reference dose (RfD) based on US EPA in Table 4, so it can be calculated as a Hazard Quotient (HQ) per contaminant with equation 2. Next, for the calculation of non-carcinogenic risk, a Monte Carlo simulation is used to determine Hazard Quotient and Hazard Index with a probabilistic distribution. The probabilistic distribution using Monte Carlo Simulation with iteration model 10000, and then it approached by the graphic percentile with the value for HQ probabilistic based on the percentile 50% shown in Table 5. Considerations for selecting the probabilistic calculation method for non-carcinogenic risks due to use of drinking water because its contaminants have seasonal variations and bioavailability fractions that quite affect the data. The application of a Monte Carlo simulation can be done to overcome this risk limitation because it applies a probability distribution that is also contained in the variation factor (He et al., 2021; Saha & Rahman, 2020). In addition, the 5% and 95% percentile values, which are low and high estimates for probabilistic and deterministic risk calculations, have a wider range in the probabilistic approach compared to the deterministic so that this shows the probabilistic approach covers all possible scenarios including extremes, which may not be encountered by a deterministic approach (Saha et al., 2017).

From the data in Table 5, the HQ value of each contaminant ordered by the contaminant's contribution to non – carcinogenic risk is obtained as follows:

- Ciparay Subdistrict – Agricultural Area: As > Cd > Se > Nitrite > Cr > Mn > Fe > Zn > Al > Cu > Nitrate.

Table 3. Standard value for exposure symbol in CDI equation

Parameters symbol (units)	Default value	References
CW (mg/L)		Research data
IR (L/days)	2.2 (Adult) 1.3 (Child)	Research data
EF (day/year)	365 (Oral)	US EPA
ED (year)	30 (Adult) 6 (Child)	US EPA
BW (kg)	61 (Adult) 29 (Child)	Research data
AT (days)	ED x 365 (non-carcinogenic) 70 x 365 (carcinogenic)	US EPA

Table 4. Reference dose for HQ equation

Contaminant	RfD (mg/kg/day)
Nitrate (NO_3)	1.6
Nitrite (NO_2)	0.1
Arsenic (As)	0.0003
Cadmium (Cd)	0.0005
Chromium (Cr)	0.003
Iron (Fe)	0.7
Mangan (Mn)	0.024
Copper (Cu)	0.04
Aluminum (Al)	1
Zinc (Zn)	0.3
Selenium (Se)	0.005

- Margaasih Subdistrict – Domestic Area: Se > Cd > As > Fe > Cr > Mn > Zn > Nitrite > Al > Cu > Nitrate.
- Dayeuhkolot Subdistrict – Industrial Area: As > Se > Cd > Cr > Fe > Mn > Zn > Al > Nitrate > Cu > Nitrite.

Heavy metals dominate the highest order in each area, which is caused by heavy metals having a smaller RfD compared to nitrate and nitrite where the smaller RfD value of a contaminant, the greater the risk. Heavy metals as As, Cd, Se are three dominant contaminants from each

Table 5. HQ probabilistic value in graphic percentile

Ciparay Subdistrict – agricultural area						
Parameters	Adult			Child		
	Percentile 5%	Percentile 50%	Percentile 95%	Percentile 5%	Percentile 50%	Percentile 95%
HQ Nitrate	-0.00215	0.00140	0.00490	-0.00259	0.00174	0.00611
HQ Nitrite	0.03980	0.05545	0.07079	0.05001	0.06872	0.08754
HQ Fe	-0.00214	0.02548	0.05381	-0.00343	0.03109	0.06599
HQ Cr	-0.04989	0.04569	0.14037	-0.05635	0.05757	0.17581
HQ Cu	-0.00623	0.00333	0.01318	-0.00798	0.00422	0.01675
HQ Al	-0.00745	0.00894	0.02503	-0.00855	0.01103	0.03043
HQ Zn	-0.01635	0.01601	0.04841	-0.02023	0.01976	0.05988
HQ As	-0.34236	0.23075	0.80846	-0.42270	0.28666	0.99413
HQ Cd	-0.27088	0.07552	0.41377	-0.34120	0.08257	0.51567
HQ Se	-0.05315	0.06910	0.19490	-0.06825	0.08861	0.24102
HQ Mn	0.00565	0.04093	0.07627	0.00526	0.04987	0.09402
Margaasih Subdistrict – domestic area						
Parameter	Adult			Child		
	Percentile 5%	Percentile 50%	Percentile 95%	Percentile 5%	Percentile 50%	Percentile 95%
HQ Nitrate	-0.00210	0.00075	0.00365	-0.00265	0.00090	0.00451
HQ Nitrite	0.00985	0.01276	0.01562	0.01232	0.01591	0.01939
HQ Fe	-0.01821	0.02919	0.07663	-0.02457	0.03641	0.09698
HQ Cr	0.00394	0.02302	0.04184	0.00436	0.02865	0.05231
HQ Cu	-0.00820	0.00160	0.01167	-0.01025	0.00221	0.01425
HQ Al	-0.00169	0.01218	0.02606	-0.00238	0.01497	0.03189
HQ Zn	-0.00734	0.01291	0.03350	-0.01009	0.01590	0.04165
HQ As	-0.26051	0.11658	0.49409	-0.31354	0.14409	0.60540
HQ Cd	0.02698	0.13905	0.25029	0.03384	0.17107	0.31232
HQ Se	0.19175	0.38311	0.57604	0.23318	0.47539	0.71773
HQ Mn	-0.04764	0.02233	0.09478	-0.05959	0.02770	0.11558
Dayeuhkolot Subdistrict – industrial area						
Parameters	Adult			Child		
	Percentile 5%	Percentile 50%	Percentile 95%	Percentile 5%	Percentile 50%	Percentile 95%
HQ Nitrate	-0.00615	0.00554	0.01758	-0.00762	0.00702	0.02167
HQ Nitrite	0.00003	0.00173	0.00341	0.00005	0.00218	0.00431
HQ Fe	-0.02169	0.04543	0.11117	-0.02269	0.05708	0.13783
HQ Cr	-0.04794	0.04723	0.14069	-0.06246	0.05615	0.17203
HQ Cu	-0.00399	0.00176	0.00739	-0.00483	0.00221	0.00927
HQ Al	-0.00860	0.01189	0.03282	-0.01090	0.01476	0.04066
HQ Zn	-0.01402	0.01435	0.04277	-0.01778	0.01739	0.05369
HQ As	0.03902	0.22963	0.41906	0.05419	0.28955	0.52896
HQ Cd	0.02292	0.06924	0.11453	0.02915	0.08658	0.14361
HQ Se	-0.10948	0.11862	0.34450	-0.13628	0.14638	0.43244
HQ Mn	-0.00944	0.02175	0.05218	-0.01168	0.02721	0.06590

area. For drinking water, exposure to sunlight, absence of filtration in the stage of packing and also the distribution of raw water from the pipe can also leached the contaminants (Ab Razak et al., 2016; Chowdhury et al., 2016; Malakootian et al., 2020). Also the nitrite has a higher value in the area of agricultural means there is a raw water from the water station have a contaminants of pesticides residue due to the transform of pesticides to nitrite form in the water (Fallahzadeh et al., 2017; Oginawati & Pratama, 2016).

In addition, hazard index calculates all of hazard quotient per contaminant to determine total of non – carcinogenic risk caused by all contaminants. Hazard Index shows the level of hazard due to the use of drinking water, if HI ≤ 1 means the safe level obtained and HI > 1 means there is a non-safe level of risk and must get the treatment. In Figure 3 show that none of community category exceeded the safe level (HI ≤ 1) means non – carcinogenic risk does not occur in the area. However, from the data category for Child-Dayeuhkolot have the highest HI value among all categories with 0.7. It means there must be a protection to the child from the consumption of refill drinking water in Dayeuhkolot Area. Efforts to improve the quality of refill drinking water need to be carried out by assessing the standard criteria for refill drinking water, especially heavy metal criteria.

Then, in this research calculate the carcinogenic risk due to the use of refill drinking water. The calculation conducted to parameters which has carcinogenic impact determined by US EPA. The parameters are arsenic, cadmium, chromium. In this research total chromium for the calculation of Excess Cancer Risk (ECR) is assumed as Cr(VI) carcinogenic parameters due to limited of segregation method. The parameters have value of Cancer Slope Factor (CSF) respectively, 1.5 $(mg/kg/day)^{-1}$, 0.38 $(mg/kg/day)^{-1}$, 0.5 $(mg/kg/day)^{-1}$. In Figure 4 show value of ECR for each community category. From the data, category for Adult - Ciparay has a maximum tolerable value 1×10^{-4} (Wongsasuluk et al., 2014). This data confirms that the risk value category in the non-carcinogenic that can still be tolerated (HI ≤ 1) can show a different interpretation for the value of carcinogenic risk. In this data, the category for Adult - Ciparay shows that this area can have a carcinogenic risk in adults due to oral exposure of refill drinking water. It shown that exposure in range of carcinogenic time can affect to human health with pollution of heavy metal in refill drinking water.

CONCLUSIONS

It may be concluded from this study, refill drinking water sample were evaluated for their quality based on Regulation of Ministry of Health Indonesia No. 492/2010. The parameters of refill drinking water exceeded the regulation are microbial parameters (Total Coliform and *E. coli*) and heavy metals (Fe, Al, and Se). All water samples were evaluated

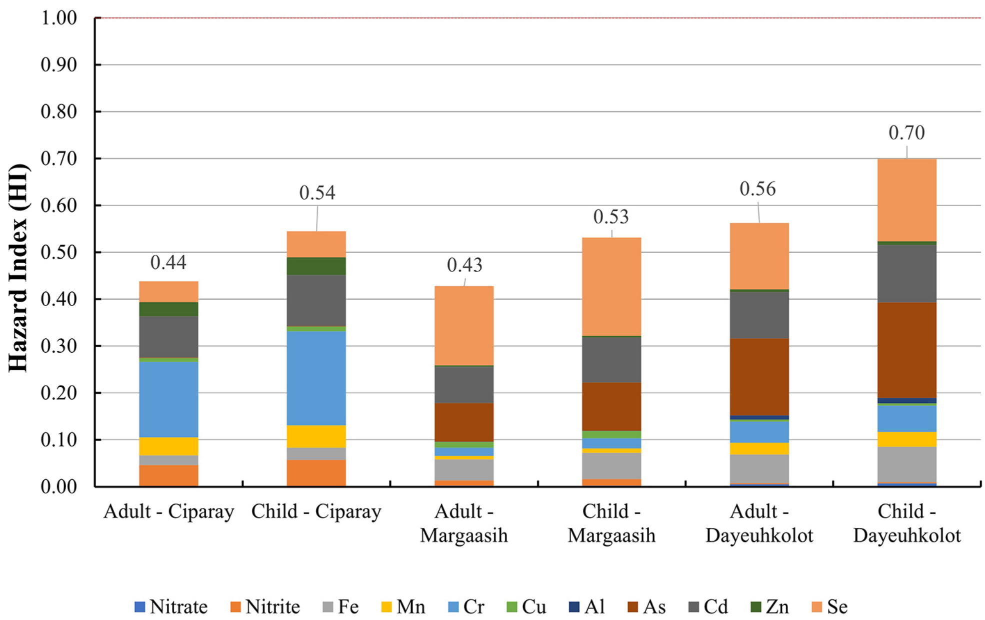

Figure 3. The value of the hazard index in each area of Ciparay Subdistrict - Agriculture Area, Margaasih Subdistrict - Domestic Area, Dayeuhkolot Subdistrict - Industrial Area

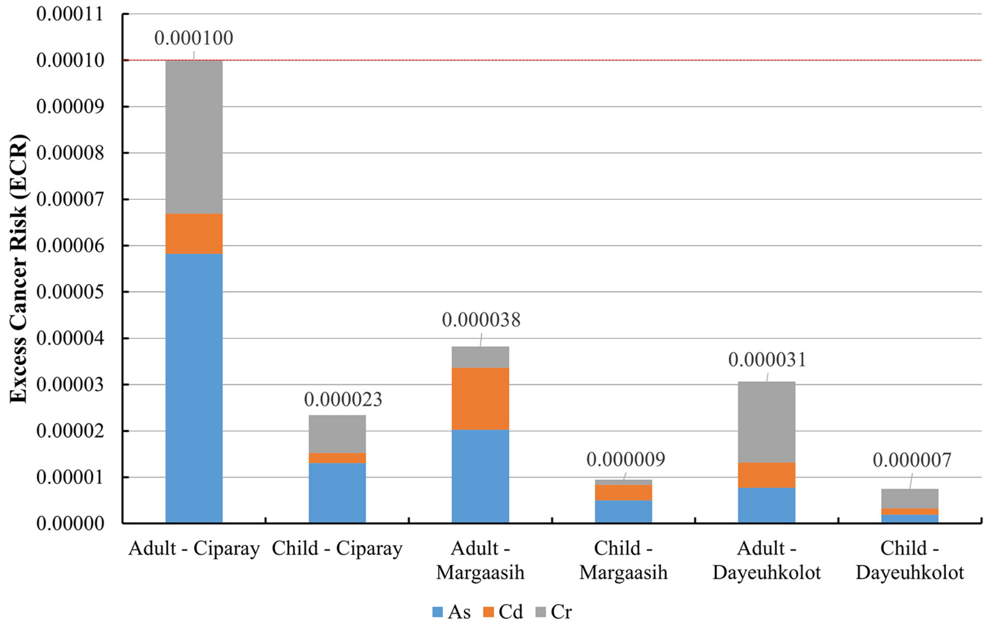

Figure 4. The value of the excess cancer risk in each area of Ciparay Subdistrict - Agriculture Area, Margaasih Subdistrict - Domestic Area, Dayeuhkolot Subdistrict - Industrial Area

for potential carcinogenic and non-carcinogenic risks. The largest contaminant for Chronic Daily Intake contribution comes from Fe with a large consistency in three areas. In all three areas, non-carcinogenic with Hazard Index value calculation shown that all areas are acceptable (HI $\leq$ 1) but adult category in Ciparay Subdistrict has maximum tolerable value for Excess Cancer Risk (ECR), 1 x 10^{-4}, shown that the use of refill drinking water in this area can affect to human health in long-term situation for adult. The evaluation on refill drinking water station need to be carried out by the government regularly and land use planning is also needed so that public health risks can be reduced.

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