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Regional Case Study

Analysis of the Water Quality of the River in West Java as the Raw Water for Drinking Water

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Abstract
The quantity of raw water from springs, groundwaters, and rainwaters has been decreasing nowadays. This has mostly made river water to be used as the raw water to be treated for drinking water by PDAMs. However, in 2020, 52 rivers in Indonesia were polluted. Therefore, it is necessary to analyze the quality of the river water to ensure that the water conforms with the standards of the Indonesian Government Regulation Number 22 of 2021 (class 1). This study was done to study the water quality i.e. DO, TSS, and total coliform in 9 sampling points in Citarum, Cimanggu, Cibogo, Citonjong, Ciwayang, and Cigugur Rivers in West Java. Grab samples were collected and were analyzed in the laboratory. The results were then compared with the standards. DO in the Citarum River (= 3.66 mg/L) and Cimanggu River (= 3.64 mg/L) samples were below the standard which might result from the domestic waste generated by the housing settlements, schools, and hospital existed around the sampling points. Total coliform in the upstream of the Cibogo River sample was above the standard; which could be caused by the domestic waste produced by the housing settlements and the fishing area located around the sampling point.

Keywords: River water quality; raw water for drinking water; DO; TSS; total coliform

1. Introduction

The drinking water supply in Indonesia is mostly sourced from the rivers. This happens as the existence of the springs, the groundwaters, and the rainwaters has been decreasing resulted from the high development of the settlements and the industries in the conservation areas; which has led to the water crisis (Sabihi et al., 2022). However, the quantity and the continuity of the river waters are also depended on the season; the amount of the waters and their availabilities will be higher during the rainy season than in the dry season (Djoko, 2016). Research showed that there were 52 polluted rivers in Indonesia. Most of these rivers were located on Java Island, such as those in West Java i.e., the Ciliwung and Citarum Rivers (WWF, 2020). There were 13.3% of the Indonesian sub-districts that were traversed by heavily polluted rivers in West Java (Riza et al., 2020). This pollution was caused by the disposal of the industrial liquid waste and the domestic solid waste (garbage) into the rivers that in turns led to the decrease in the dissolved oxygen concentrations and the high concentrations of the dissolved solids (Christiana et al., 2020). Based on the data from the West Java Province Environmental Service in 2023, the pH and the nitrate parameters in the West Java rivers generally conformed with the quality standards; pH was of 6-9; and nitrate was of 1-4 mg/L. However, the Total Suspended Solid (TSS), the Biochemical Oxygen Demand (BOD), the Chemical Oxygen Demand (COD), and the Dissolved Oxygen (DO) parameters at several monitoring points did not meet the standards. TSS, BOD, COD and DO could reach up to 145, 20, 75, and 3 mg/L respectively (DLH, 2023). To make it worse, 70% of the drinking water sources in Indonesia were polluted by fecal waste resulted from the open defecation. The high pollution of these water sources has been leading to the higher difficulty level of the Public Water Supply Company (PDAM) to treat the waters. Therefore, PDAMs have been struggling to provide safe water to the community. The unsafe water had been causing many people contracting diarrheal diseases (UNICEF, 2022).

Given the very poor qualities of the river waters, this study was conducted to check the qualities of the river water, so that it can be used as the source for the drinking water. The water samples from six West Java River waters i.e., the Citarum River, Cimanggu River, Ciwayang River, Cigugur River, Citonjong River, and Cibogo River were tested and analyzed for their physical (TSS), chemical (DO), and microbiological (total coliform) parameters.

Previous researches had studied the qualities of the river waters worldwide, i.e., in Indonesia (Yohannes et al., 2019, Yuniarti and Biyatmoko, 2019, Christiana et al., 2020), in India (Bora and Goswami, 2017) and China (Wu et al., 2018). However, they all only analyzed one river each. Therefore, this research that examined six rivers aims to give a more worldwide thorough picture of the qualities of the river water that was used as the source for the drinking water.

2. Materials and Methods

2.1 Study Location and Research Time

The water samples from the rivers were analyzed at the accredited laboratory of Perumda Tirtawening Bandung. This research was conducted from July 4 to August 15, 2022. **Table 1** lists the sampling locations and the water parameters that were tested in each river. Not all three parameters were analyzed in each location due to the time limitation experienced. Additionally, the location of the river is depicted in Error! Reference source not found..

Table 1. The location of the rivers, their samples parameters and measurement methods

No	River	Location	Parameters	Measurement Method
1	Citarum	West Java	DO and TSS	Potentiometric and Gravimetry
2	Cimanggu	Bojong Koneng, Babakan Madang, Bogor, West Java	DO	Potentiometric
3	Ciwayang (midstream and downstream)	Cimindi Village, Cigugur, Pangandaran, West Java	TSS	Gravimetry
4	Cigugur (midstream)	Campaka Village, Cigugur, Pangandaran, West Java	TSS	Gravimetry
5	Citonjong (upstream and downstream)	Sukaresik, Sidamulih, Pangandaran, West Java	TSS	Gravimetry
6	Cibogo (upstream and downstream)	Sindanggalih, Cimanggung, Sumedang, West Java	Total coliform	Most Probable Number (MPN)

2.2. Sampling Method

In this research, sampling was carried out using grab sampling; and was referred to the Indonesian National Standard (SNI). A simple sampling tool, in the form of a plastic bucket equipped with a rope and a long-stemmed dipper was employed. The sample containers used were made of glass or plastic (poly ethylene (PE), poly propylene (PP), and polytetrafluoroethylene (PTFE)). The containers were made clean from the contaminants, and were not interacted with the sample. During the sampling process the samples were stored in a cooler of 4°C ± 2°C (BSN, 2008).

2.3. River Water Quality Testing

2.3.1 Dissolved Oxygen (DO)

The DO analysis was done in accordance with the American Public Health Association (APHA). The DO measurements were carried out using the potentiometric or membrane electrode method (Baird et al., 2017). The principle of this method is that ions in solution are measured quantitatively by electrochemistry through a combined electrode (work and comparison) (Suheryanto et al., 2019). The methods, tools, and materials for measuring the DO in the samples are presented in **Table 2**. A DO meter was used to measure the DO concentration. The DO was detected through electrodes that had an electrochemical potential. When the electrode was dipped into the river water sample, the electrode would generate a cell potential to determine the redox reaction (Suheryanto et al., 2019). Before measurement, the DO meter was calibrated so as the results obtained were more accurate (Androva and Harjanto, 2017). The DO was tested on the water samples from one sampling point each of the Citarum River and the Cimanggu River. The approximate location of the sampling points can be viewed in Error! Reference source not found..

Table 2. The methods, tools, and materials for measuring DO

Parameter	Measurement Method	Tool	Materials
DO	Potentiometric/membrane electrode (APHA)	DO meter	• Aquades • OX 921 solution for calibration • Citarum and Cimanggu River water samples

Figure 1. The rivers and sampling points locations

2.3.2 Total Suspended Solid (TSS)

The methods, tools, and materials used in the TSS measurement are revealed in **Table 3**. Initially, the filter paper was poured with distilled water (aquades), then dried to make it free from ash. The weighing process produced the initial weight of the filter (Wo) (Jappolie, 2022). The samples were then filtered using this filter paper in a vacuum gooch cup, so that the sediment separated from the water

(Widodo, 2017). After all the water samples were filtered, the filter paper was moved into a petri dish and was dried in an oven, at 103-105°C for 1 hour (BSN, 2019). The samples were then taken from the oven and were cooled in a desiccator; to make the temperature of the sample and its environment were in balance, and to avoid the absorption of water vapor by the sediment in the dish. After that, the residue in the filter paper was weighed using an analytical balance, so that the final weight (W1) was obtained (Waode, 2022). The TSS was tested on the water samples from 1 sampling point of the Citarum River, 2 sampling points (the midstream and downstream) of the Ciwayang River, 1 sampling point (the midstream) of the Cigugur River, and 2 sampling points (the upstream and downstream) of the Citonjong River. The approximate locations of the sampling points were displayed on Error! Reference source not found..

Table 3. The methods, tools, and materials for measuring TSS

Parameter	Measurement Method	Tools	Materials
TSS	Gravimetry (SNI 6989.3 2019)	• Desiccator • Oven • Analytical balance • Volumetric pipette • Measuring cup • Petri and gooch dishes • Vacuum system • Wood tongs	• Aquades • 0.7-1.5 μm filter paper • Water samples of the mid and downstream part of Ciwayang River, midstream part of Cigugur River, up and downstream of Citonjong River, and Citarum River

2.3.3 Total Coliform

The total coliform measurements were conducted using the Most Probably Number (MPN) method based on APHA, with the presumptive test to detect the presence of gram-negative bacteria; and the confirmation test to confirm the positive reaction results of the presumptive test regarding the presence of the coliform bacteria in the water (Baird et al., 2017). The methods, the tools, and the materials used in the measurement of the total coliform are presented in **Table 4**. The MPN method in this test used the variety pattern II, which consisted of 5 tubes measuring 10 mL samples, 5 tubes of 1 mL samples, and 5 tubes of 0.1 mL samples; each tube contained 10 mL lauryl tryptose broth (Sulistiawati, 2021). The presumptive test was carried out using the lauryl tryptose broth media (Fitri et al., 2021). The confirmation test used BGLB media, which contained bile salts and lactose. The water samples were put into the test tube, which already contained the lauryl tryptose broth media and the inverted durham tubes (for collecting gas), then were incubated for 24 hours at 35 ± 0.5°C (Finiarti et al., 2022). The tubes that showed a positive reaction in the presumptive test were then confirmed to ensure the presence of the coliform bacteria in the sample. The bacterial cultures on the positive tubes in the presumptive test were thus inoculated into BGLB media using a wire ose. After that, the sample was incubated for 48 hours at 35 ± 0.5°C (Baird et al., 2017). The onset of turbidity and gas in the durham tube after incubation, indicated the presence of the coliform bacteria broth (Sulistiawati, 2021). The total coliform concentration in the positive tube in the confirmation test then was calculated through the MPN table (Baird et al., 2017). The total coliform was tested on the water samples from 2 sampling points (the upstream and downstream) of the Cibogo River. The approximate locations of the sampling points can be seen in Error! Reference source not found..

Table 4. The methods, tools, and materials for measuring total coliform

Parameter	Measurement Method	Tools	Materials
Total coliform	MPN (APHA)	• Autoclave • Incubator • Test tube • Durham tube • Sterile measuring pipette • Ose wire • Bunsen	• Aquades • Lauryl tryptose broth medium • Brilliant green lactose bile broth (BGLB) medium • 70% alcohol • Water samples of up and downstream part of Cibogo River

2.4. Data Processing Procedures

The DO parameter test results were already in the form of the final results that show the DO concentration in the water sample. Meanwhile, the results of the TSS and the total coliform must be processed first to get the their concentrations. For the TSS, the data obtained were of the initial weight (Wo), the final weight (W1), and the sample volume (V). The TSS concentration was then calculated through Equation (1) (BSN, 2019).

$$TSS\left(\frac{mg}{L}\right) = \frac{(W_1\text{-}W_0)x\ 1.000}{V} \tag{1}$$

For the total coliform, the data collected were of the number of the tubes that indicated the presenced of the microbes in the samples. The total coliform concentration was determined based on the MPN table in APHA 9221 (Baird et al., 2017).

2.5. Data Analysis Procedures

The analysis was carried out using the comparative method by comparing the concentration of each parameter with the quality standards of Indonesian Government Regulation (Number 22 of 2021, appendix VI for class 1. The parameters that did not conform with the standard were then analyzed below by identifying the possible factors that may cause the un-conformity of these parameters.

3. Results and Discussion

3.1 River Water Quality Based on DO Parameter

The DO results are appeared in **Table 5**. Based on **Table 5**, the DO concentrations in both samples were low and below the standard (3.64 and 3.66 mg/L). This might be due to the high temperatures in both samples. High temperature would reduce the ability of water to absorb oxygen (Dewi et al., 2022). As the temperature increases by 1°C, the oxygen consumption will increase by 10% and the DO will decrease (Hariani et al., 2021). In addition, the low DO in both samples might be related to the sampling locations of the Citarum River and Cimanggu River. The estimated locations of the sampling points in the Citarum River were close to the settlements, the schools, and the hospital. Meanwhile, for the Cimanggu River, the sampling points were roughly close to the fishing grounds, the stalls, and the shops. These activities could produce the domestic waste that would affect the concentration of the DO, the COD, and the coliform of the water (Arnop et al., 2019). The domestic waste generation in both rivers might make the level of the organic matter in the river waters to be high, so that the activity of the microorganisms in decomposing and oxidizing the organic substances increased. This might cause the microorganisms to require more dissolved oxygen, so that the DO in the river waters would decrease (Alfatihah et al., 2022). The decrease in the DO concentrations in the river waters could then in turn decrease the population of the aquatic organisms (Haris and Yusanti, 2018).

Table 5. DO test results

River	Parameter	Unit	Quality Standard	Result	Description
Citarum Cimanggu	DO	mg/L	Minimal 6	3.66 3.64	Un-conformed with the standard

3.2. River Water Quality Based on TSS Parameter

The results of the TSS are illustrated in **Table 6**. Based on **Table 6**, all the samples met the quality standards (3.0-22.0 mg/L). This might be due to several factors, such as the low process of the soil erosion, and the results of the rock weathering around the river (Sitepu et al., 2021). Although the TSS concentrations of the six samples met the quality standards, they were still appeared. This is in accordance with Sitepu, et al., 2021 who stated that the presence of the plantations and the rice fields around the river, such as those in the midstream and the downstream of the Ciwayang River and the midstream of the Cigugur River, might lead to the runoff from the rock and the soil processes that landed on the river, hence resulted in the occurrence of the TSS in the river waters. The presence of the TSS in the water could also be resulted from the runoff of the sand from the beach, such as in the downstream part of the Citonjong River, because sand is in fact a suspended solid (Juwitanigtyas, 2020). Furthermore, the TSS in the river water could also be produced from the runoff of the inorganic materials from the settlements and the hospitals, such as in those in the upstream part of the Citonjong River and the Citarum River. These inorganic materials were generated from the remaining soapy water from the cleaning activities in those settlements and the medical wastewater from those hospitals (Alya and Haryanto, 2022).

Table 6. TSS test results

River Location	W_0		W_1		TSS Concentration (mg/L)	Quality Standard (mg/L)	Description
	gram	mg	gram	mg			
Midstream of Ciwayang River	0.1247	124.7	0.1269	126.9	22.0	40	Conformed with the standard
Downstream of Ciwayang River	0.1218	121.8	0.1239	123.9	21.0		
Midstream of Cigugur River	0.1322	132.2	0.1330	133.0	8.0		
Upstream of Citonjong River	0.1270	127.0	0.1273	127.3	3.0		
Downstream of Citonjong River	0.1269	126.9	0.1274	127.4	5.0		
Citarum River	0.1226	122.6	0.1231	123.1	5.0		

3.3. River Water Quality Based on Total Coliform Parameter

The results of the presumptive test on the upstream and the downstream of the Cibogo River samples showed a positive reaction. Meanwhile, the results of the confirmation test revealed that all the tubes of the Cibogo River samples in the upstream part reacted positively. This indicates that generally most of the tubes (10, 1, 0.1 mL) contained the coliform bacteria; only one tube of 1 mL of the downstream of the Cibogo River sample revealed a negative result. The total number of coliforms is exhibited in **Table 7**.

Based on **Table 7**, the total coliform concentration in the upstream part of the Cibogo River water sample was above the standard (> 1,600 MPN/100 mL); while in the downstream part met the quality standard (430 MPN/100 mL). The high total coliform concentration in the upstream Cibogo River water sample might be resulted from the optimum coliform growth due to the high pH, COD, and water temperature parameters, as well as the low DO concentrations (Naillah et al., 2021). The estimated sampling point in the upstream part of the Cibogo River was near the settlement sites and the fishing grounds; while the downstream part was close to the location of the schools, the fishing grounds, the restaurants, and the settlements. The high concentration of the total coliform in the upstream part of the Cibogo River water sample could be caused by the wastewater generation (Daramusseng and Syamsir, 2021) and the poor sanitation systems from/in the settlements and the fishing grounds (Afifah, 2019). On the other hand, the total coliform in the downstream Cibogo River water sample was low. This could be due to the better sanitation systems and the lower waste generation than in the upstream.

Table 7. Total coliform test results

River	Parameter	Unit	Quality Standard	Result	Description
Upstream of Cibogo River	Total coliform	MPN/100 mL	1,000	>1,600	Un-conformed with the standard
Downstream of Cibogo River				430	Conformed with the standard

3.4. Alternative Processes of River Water as Raw Water for Drinking Water

3.4.1 Aeration Unit

Based on the results, the DO in the Citarum River and the Cimanggu River water samples did not meet the quality standards. Aeration can be done to increase the DO by injecting oxygen into the water, so that the dissolved oxygen in the water will increase. Aeration can also reduce the concentration of iron, manganese, hydrogen sulfide, organic compounds, and carbon dioxide in the waters. Several types of aeration can be used to increase the DO employing a gravity aerator, a spray aerator, a diffuser aerator, and a mechanical aerator (Batara et al., 2017). The type of aerator that is often used is a cascade aerator or the gravity aerator, which can increase oxygen in the water by up to 60-80% (Diansari et al., 2022). Few PDAMs employ the “real aeration” process to treat their raw waters to enhance the DO concentrations. Most of them rely on an outdoor hydraulic free fall coagulation process to get free air to enter their raw waters.

3.4.2 Chlorination Unit

Chlorination is the process of adding chlorine to water. Chlorine act as a disinfectant that kill or inactivate bacteria that enter the distribution system of the drinking water (Yulanto and Ardhayanti, 2020). Chlorine can reduce coliforms by up to 98.55%, and can also oxidize iron, manganese, nitrites, and organic materials (Mutu and Gunungsindur, 2022). All PDAMs in Indonesia use chlorination process to treat their raw waters to kill or inactivate the pathogen bacteria.

4. Conclusions

Based on the results and the analysis of the water quality from the six rivers studied, the following results were obtained. The concentrations of the DO in the Citarum River and Cimanggu River water samples did not meet the quality standard. The concentrations of the TSS in the water sample of the Citarum River, the mid and downstream part of the Ciwayang River, the midstream part of the Cigugur River, and the up and downstream part of the Citonjong River conformed with the standards. The concentration of the total coliform in the Cibogo River water samples in the upstream part did not in line with the quality standard; while the downstream part did. The waters containing DO and total coliform that did not conform with the standards have to be chemically treated previously, so that it can be used as drinking water. To enhance the DO concentration, the raw water can be aerated first. While, to reduce the total coliform concentration, chlorine can be injected into the raw water.

Further studies need to be done to evaluate the effectivity of an outdoor hydraulic free fall coagulation process on enhancing the DO concentration in the waters; and to study the effectivity of chlorination process on removing the pathogen bacteria from the water (particularly the required chlorine dosage and the CT (concentration of residual chlorine times the contact time) value.

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