Water quality assessment of Cisadane River using pollution indicator parameters

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Abstract. The Cisadane River catchment area is approximately 1,375.43 km², and it is one of the main rivers in Banten and West Java Province, Indonesia. The Cisadane River has an important function in supporting the lives of many people with all their activities. Most of the studies related to the assessment of the water resources quality have used through several water quality indices, Those are are water quality index (WQI), water pollution index (WPI), and river habitat survey (RHS). However, the study of determining pollutant sources in the river has less done, including Cisadane River in this case. This study aimed to identify the important environmental parameters that can be used as indicators of pollution in the Cisadane River. This research was conducted in 2007 - 2014 by collecting water samples, 2 - 4 times every year. Employing the box and whisker statistical method, it can be concluded that free chlorine (Cl²), biological oxygen demand (BOD), chemical oxygen demand (COD), phenol, total coliform and E.coli were reliable indicators of contamination in The Cisadane River. As an indicator of pollution in the Cisadane River these parameters can be used as a basis for assessing the quality of Cisadane water.

1. Introduction

Cisadane River is one of the main rivers in Banten and West Java Province, Indonesia. The total area of this catchment is approximately 1,375.43 km², and covering the river length of about 140 km. The spring is originated from Mount Salak - Mount Pangrango in Bogor Regency [1-3].

As commonly occur in big river, Cisadane River is also experiencing disturbances where urbanization, industrialization, and agriculture activities are under way in the surrounding area. Those anthropogenic activities are extremely main sources of pollution to the river. Cisadane River, in fact, has a very important function as a source of raw water for the people of Bogor City and Tangerang Region. This important river crosses several administrative areas ranging from Bogor Regency to Tangerang City with high urban activities and cause the river receives a burden of high pollutant load [3-5].

The water quality data is very dynamic, prone to measurement mistakes and recording mistakes. Base on this fact, therefore systematic evaluation as regards the water quality data is needed, and the work is initiated from identifying important parameters of water quality that significantly impact the human health and river health. The significant parameter needed to be measured consistently in regular spatial monitoring base [6].

In the context of sustainable water management, many hydrological studies have been published around the world, which highlights the ecological role of water from the rivers [7-8]. Moreover, there have been more and more researches widely disseminated regarding water quality evaluation [7]. Most of the studies related to the assessment of the water resources quality use several water quality indices, and among the most important are water quality index (WQI), water pollution index (WPI), and river habitat survey (RHS) [7, 9-11]. This type of research is generally related to ordinary pollution loads
uses modelling such as the QUAL2Kw method [8]. However, integrated study designed to determine critical indicator of pollution through assessment of important parameter in the case of Cisadane river is still scarce. Based on seven year annual report [12], it is evident that 18 parameters out of 24 usually monitored parameters are fulfilled the water quality criteria value of Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control. In the mean time, 6 parameters have been observed to be exceeding the water quality criteria, and as a result this 6 parameters are considered as critical indicator of pollution to be used. In addition, data related to pollutant sources in each segment on the watershed of Cisadane River is still inadequate [8]. This study aimed to identify water quality parameters for use as key indicators of pollution in the Cisadane River.

2. Methodology
2.1. Time and Study Area
Cisadane is a 140 km long river. The upstreams of Cisadane River are coming from Gede-Pangrango and Salak Mountains and flowing into Java Sea through Naga Bay estuary [1-3-12]. The study was conducted in 2007-2014 at 15 points representing upstream to downstream of the Cisadane River (figure 1). Samples were taken in January, March, June and August [12].

2.2. Materials
Water quality parameters include pH, temperature, conductivity, TDS, TSS, DO, COD, BOD, TOC, NO$_3$-N, NO$_2$-N, NH$_3$, Cl$_2$, SO$_4$, PO$_4$, oil and grease, CN, phenol, Fe, Pb, Cd, Cu, Cr$^{6+}$, total Hg, total coliform, E. coli, and chlorophyll a were used to assess the water quality of the Cisadane River in this study.

2.3. Procedure
2.3.1. Sampling. Composite samples from each location were obtained by collecting grab samples at homogeneous point in the river as many as fifteen sampling points [13].

2.3.2. Data Analysis. The data obtained were processed by using a statistical box and whisker method to see trends based on the median. The trend value of each parameter was compared with the water quality criteria value of Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control for class I and II. Six water parameters from the 24
parameters that exceeded water quality criteria as water classes I and II for each monitoring year from 2007 to 2014, and after observing the trend of the box and wisher test, these parameters were chosen as critical indicator or indicators of pollution in the Cisadane River.

2.3.3. **Laboratory Analysis.** The following is a list of laboratory analysis methods used.

**Table 1. The list of laboratory analysis methods**

| No. | Parameters                          | Analysis Methods                                      | Manual                                      |
|-----|------------------------------------|-------------------------------------------------------|---------------------------------------------|
| 1.  | Biological Oxygen Demand (BOD)     | JIS K 0102-21-2008 (The dissolved oxygen before and after incubation method) | NN, JIS, 2008, Japan International Standard Tokyo |
| 2.  | Chemical Oxygen Demand (COD)       | APHA 5220 D-2012 (The potassium dichromic oxidizer method) | Eugene W.R SM Ed. 23th, 2017, APHA          |
| 3.  | Free Chlorine (Cl₂)                | IK 15/A/LPDL (DPD) (Reacts with N, N-diethyl-p-phenylenediamine to form red) | P3KLL, 2014                                |
| 4.  | Phenol                             | SNI 06-6989.21-2004 (The aminoantipirin at pH 7.9 ± 0.1 methods) | Eugene W.R SM Ed. 23th, 2017, APHA |
| 5.  | Total Coliform                     | AOAC petri film modified (The petrifilm method)        | Dr. William Horwitz Ed. 18th AOAC, 2005, International USA |
| 6.  | E. coli                            | AOAC petri film modified (The petrifilm method)        | Dr. William Horwitz Ed. 18th AOAC, 2005, International USA |
| 7.  | pH                                 | SNI 06-6989.11-2004 (The potentiometer method)          | Eugene W.R SM Ed. 23th, 2017, APHA |
| 8.  | Temperature                        | SNI 06.6989-2005 (The mercury thermometer method)       | Eugene W.R SM Ed. 23th, 2017, APHA |
| 9.  | Electrical Conductivity (EC)       | SNI 06-6989.1-2004 (The Electrometry using potassium chloride solution method) | Eugene W.R SM Ed. 23th, 2017, APHA |
| 10. | Total Dissolve Solid (TDS)         | SNI 06-6989.1-2004 (The conductor Sodium Chloride solution method) | Eugene W.R SM Ed. 23th, 2017, APHA |
| 11. | Total Suspended Solid (TSS)        | SNI 06-6989.3-2004 (The gravimetrically method)         | Eugene W.R SM Ed. 23th, 2017, APHA          |
| 12. | Dissolve oxygen (DO)              | JIS K 0102-2008 (The manganese and iodine ion method)  | NN, JIS, 2008, Japan International Standard Tokyo |
| No. | Parameter                  | Method/Standard                                                                 | Author/Reference                                                                 |
|-----|----------------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 13  | Total Organic Carbon (TOC) | Standard Method, APHA-5310 B-2005 (The NDIR with a temperature of 680 °C)       | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 14  | NO₃-N                     | SNI 6989.79:2011-2004 (The soroprophotometer by cadmium reduction method)        | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 15  | NO₂-N                     | SNI 06-6989.9-2004 (The sulfanilamide spectrophotometer method)                  | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 16  | SO₄₂⁻                    | SNI 06-6989.20-2004 (The Barium Chloride in turbidimetry)                        | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 17  | PO₄                        | JIS K 0102-46.31-2008 (The perocodisulfat spectrophotometer method)              | NN, JIS, 2008, Japan International Standard Tokyo                              |
| 18  | Oil and grease            | SNI 6989.10.2011 (The Gravimetrically method)                                   | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 19  | Total Metal               | Standard Method, APHA 3111B-2012 (The atom-SSA absorption spectrophotometer method) | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 20  | Cyanide (CN)              | JIS K 0102,38.1.2, 38.3-2002 (The spectrophotometer at 4-pyridine pyrazolone carboxylic acid method) | NN, JIS, 2002, Japan International Standard Tokyo                              |
| 21  | NH₃                      | SNI 06-6989.30-2005 (The phenate method)                                         | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 22  | Dissolved Metal (Fe,Pb,Cd,Cu) | Standard Method, APHA 3111B-2012/AAS-Flame (The atom-SSA absorption spectrophotometer method) | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 23  | Cr⁶⁺                     | SNI 06.6989.71-200 (The diphenyl carbaside in an acidic atmosphere method)       | Eugene W.R SM Ed. 23th, 2017, APHA                                              |
| 24  | Chlorophyll a             | Standard Method, APHA 10200H (The trichrometric spectrophotometer method)        | Eugene W.R SM Ed. 23th, 2017, APHA                                              |

### 3. Results and Discussion

Water parameters that exceed water quality criteria as water class I and II for each monitoring year were selected as critical indicators (parameters) or pollution indicators on the Cisadane River. The
pollution indicator observed include free chlorine ($\text{Cl}_2$), biological oxygen demand (BOD), chemical oxygen demand (COD), phenol, total coliform and $E. \text{coli}$ (see figure 2-7). Other parameters that still fulfill the Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control for class I and II, are not further discussed here. Hence, only the parameters exceeded the standard are discussed below.

According to Government Regulation No. 82/2001, the water quality classification in Indonesia includes four quality classes based on its designation (table 2) [14].

| Class | Designation                          | BOD | COD | $\text{Cl}_2$ | Phenol | T Coliform | $E. \text{coli}$ |
|-------|--------------------------------------|-----|-----|--------------|--------|------------|-----------------|
| I     | Drinking water                       | 2   | 10  | 0.03         | 0.001  | 1000       | 100             |
| II    | Water recreation facilities          | 3   | 25  | 0.03         | 0.001  | 5000       | 1000            |
| III   | Freshwater for fish, farming and husbandry | 6   | 50  | 0.03         | 0.001  | 10000      | 2000            |
| IV    | Crops irrigation                     | 12  | 100 | 0.03         | 0.001  | 10000      | 2000            |

The research results indicated that there are 6 out of total 24 water quality parameters that exceeded class I and II water quality criteria, and they are BOD, COD, $\text{Cl}_2$, phenol, total coliform and $E. \text{coli}$. These important parameters bearing a tendency with a value exceeding the water quality criteria as required by the Environment Minister's Regulation No. 82 of 2001, especially for class I. This is a truly intricate problem simply because the water from Cisadane River is mostly used for drinking water source by many people in the surrounding. Dissemination of this information should be delivered to the related government institutions for them to provide an early warning system in terms of drinking water quality of Cisadane River. BOD and COD values are presented in figure 2 and 3.

![Figure 2. Trend of Cisadane BOD concentration in 2007-2014](image2)

![Figure 3. Trend of Cisadane COD concentration in 2007-2014](image3)

The values of BOD from 2007 to 2014 have exceeded Class I water quality criteria, however this BOD trends seems fluctuated, and fall in to Class II criteria (figure 2). The sharp increase of BOD and COD occurred in 2012 might be influenced by the severe dry season causing the decrease debit of water in the river and hence lifting up pollution concentration [15]. Moreover, COD value also exceeds Class I water quality criteria and still meets the criteria for class II as shown in figure 3. BOD
is a measure of the oxygen required to breakdown organic compounds. High BOD levels significantly deplete the amount of dissolved oxygen (DO) in water surface. Consequently, high BOD level can have a detrimental effect on health of aquatic species that requires elevated (DO) level, such as fish [16]. In the meantime, the chemical oxygen demand (COD) is swiftly measured parameter employed to evaluate the pollution strength of domestic and industrial waste waters and showing organic pollution applied to both waste water and surface water [16-17]. The higher the COD level, the higher the oxidation state in an organic compound in the surface water, which will in due course lowerdown the dissolved oxygen (DO) levels [17]. Value of free chlorine and phenol of Cisadane River are presented in figure 4 and 5.

**Figure 4. Trend of Cisadane Cl<sub>2</sub> concentration in 2007-2014**

**Figure 5. Trend of Cisadane Fenol concentration in 2007-2014**

In the case where there is enough chlorine added, some will remain in the water after the whole possible organisms have been decomposed. The magnitude of residual chlorine is then called as free chlorine [18] . The toxicity of by-product formed during the chlorination of natural waters produce from the reaction of free chlorine used for disinfection purpose with the dissolved organic carbon (DOC) present in the water. The free chlorine concentrations recorded in this study ranging from 0.05 mg/L to 0.18 mg/L, and this situation exceeds water quality criteria class II of 0.03 mg/L, as they are presented in figure 4. Higher concentration of chlorine observed in 2008 could be due to the increase of decontamination work used by households.

Phenolic compounds are common water pollutants and include wide variety of organic chemicals. High phenol concentration causes a lot of detrimental effects to fish and of public health concern [19]. In figure 5, it is shown that the number of phenols in the Cisadane River has exceeded the established water quality criteria class I of 0.001 mg/L. The standard itself was not shown up in the figure 5 because the concentration is too low in the graph scale. Low phenol occurred in 2012 could be affected by in 2012 the BOD value was high, showing that the activity of microorganisms decomposes organic matter. Low phenol concentrations and in shape simple phenols are easily soluble in water and more easily degraded by phenol-decomposing microorganisms [20]. Trend of total coliform and *E. coli* are presented in figures 6 and 7.
This study indicates that the number of coliform bacteria is exceeded the water quality criteria as shown in figures 6 and 7. Biological beings are among the oldest health threats to drinking water quality and these organism currently responsible for most aquatic diseases. Total coliform (TC) bacteria are very common in the environment (including in soil atmosphere) and the digestive tract of animals and are commonly not harmful. Further faecal coliform (FC) and *Escherichia coli* (*E. coli*) bacteria are found in greater amount in the total coliform in animal faecal matter. If present in small quantities, they are not a threat to the health and life of humans, but in larger quantities it can be a pathogenic factor causing much discomfort [21-22]. *E. coli* is widely accepted as the better faecal indicator organism than the total coliforms, and in the water quality criteria class II is set at 1000 amounts / 100 ml. Although coliforms do not usually cause serious illness they are used to indicate the presence of more pathogenic bacteria and viruses, and in the water quality criteria class II is set at 5000 amounts / 100 ml [23]. The high concentration of total coliform and *E. coli* indicated that the sanitation level of the community is still low. This situation is probably related to education level and economic level of the people as well.

Specific pathogenic organisms present in water are not easily identified. It will be very difficult, expensive, and time consuming to monitor their present. For this reason, it is necessary to select "indicator organisms" that are easily measured, whose presence indicates that pathogenic organisms might exist. In many instances a group of bacteria, total coliform, has been chosen as an indicator of harmful organisms in drinking water [21]. There is a very significant positive correlation between the number of microorganisms and the physicochemical indicators of water quality chosen like BOD [22]. Total coliforms in the reservoirs were closely related with water physicochemical properties, while faecal coliforms were more associated with external input brought in by seasonal water movement [24]. Based on these conditions it is necessary to follow up meaningful action if there is an indication of the high amount of faecal coliforms in the water.

In this study, the 18 parameters that fulfil the water quality standard are recorded and kept for use as baseline data. This is true owing to the fact that those parameters were considered somewhat stable across years of observation, and hence grouped as constant. Therefore, evaluation of water quality and monitoring can be done based on only six critical parameters [6]. These six parameters are the minimal number of water quality parameters at Cisadane River that has to be consistently measured on predetermined time and location, and also become the key indicator of human health and environment health quality. These parameter, as a results, are often used as a river water quality parameter, and these trends have been reported by several other studies [25].
4. Conclusion
To sum up, there are six water quality parameters namely Cl\textsubscript{2}, BOD, COD, phenol, total coliform and \textit{E. coli}, which are evident from this research, to be critical indicators of pollution in the Cisadane River. Just as in several other studies in the world, these parameters are also often used as river water quality parameters. In other words, results of this study verifies and strengthens those reported by other researcher.

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